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PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XIV.

SESSION 1899-1900.

LIVERPOOL:

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"TRANSACTIONS" BY T. DOBB & Co.

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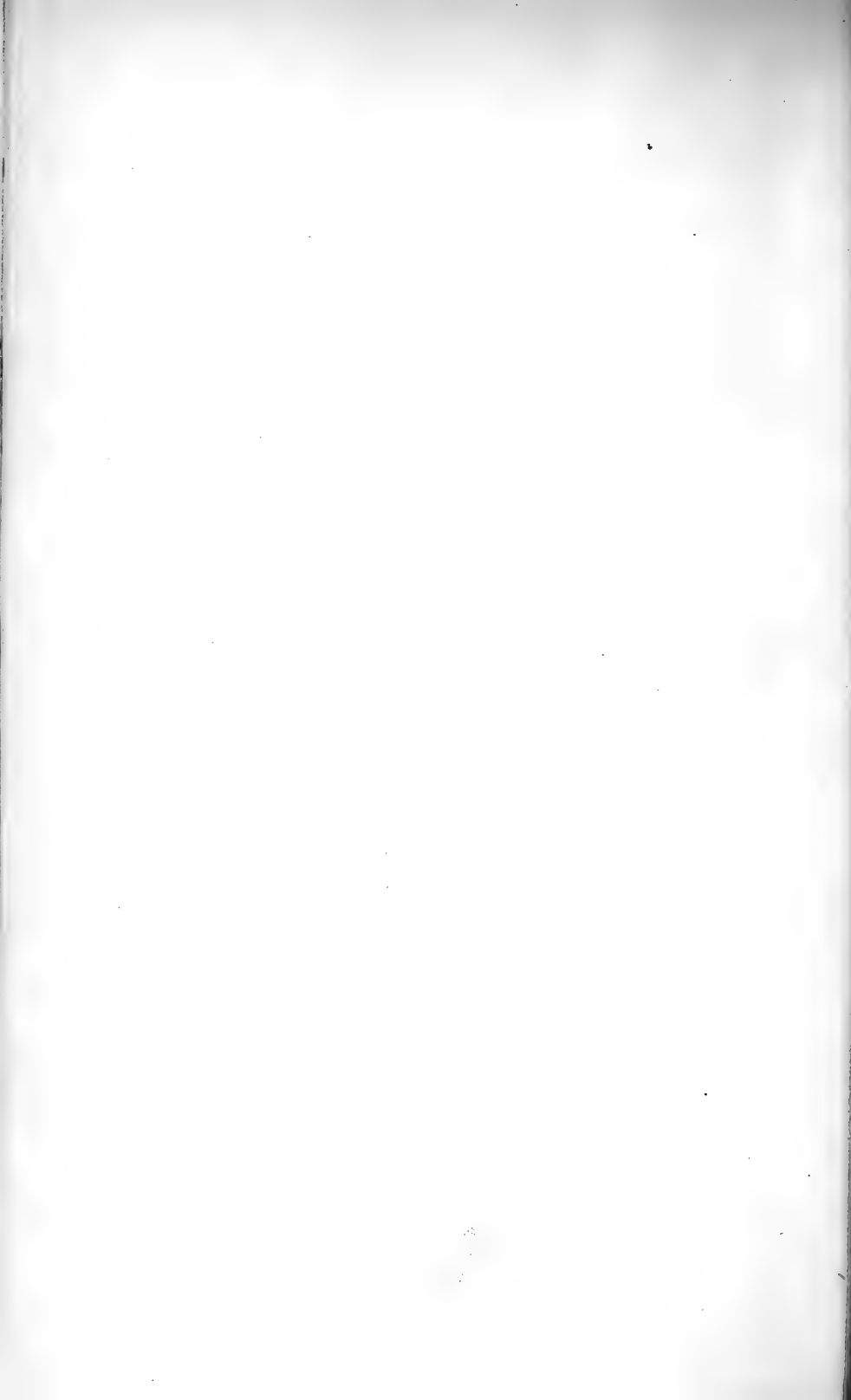
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PROCEEDINGS
OF THE
LIVERPOOL BIOLOGICAL SOCIETY



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.
-

SESSION XIV., 1899-1900.

President :

J. WIGLESWORTH, M.D., F.R.C.P.

Vice-Presidents :

PROF. W. A. HERDMAN, D.Sc., F.R.S.
REV. L. de BEAUMONT KLEIN, D.Sc.

Hon. Treasurer :

T. C. RYLEY.

Hon. Librarian :

JAMES JOHNSTONE.

Hon. Secretary :

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

Council :

H. C. BEASLEY.	G. H. MORTON, F.G.S.
W. J. HALLS.	JOHN NEWTON, M.R.C.S.
CHAS. E. JONES, B.Sc.	PROF. PATERSON, M.D.
W. S. LAVEROCK, M.A., B.Sc.	ALFRED QUAYLE.
REV. T. S. LEA, M.A.	PROF. SHERRINGTON, F.R.S.
JOSEPH LOMAS, F.G.S.	I. C. THOMPSON, F.L.S.

REPORT of the COUNCIL.

DURING the Session 1899-1900 there have been seven ordinary meetings and two field meetings of the Society. The latter were held at Cuerdley Marsh, Widnes, and at Delamere Forest, Cheshire, respectively. The second field meeting was a joint meeting with the Liverpool Geological Society.

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

On the occasion of the lecture, entitled:—"Why we wish to Explore the Antarctic, with special reference to the projected Expedition," given by Prof. Herdman, F.R.S. (Member of the National Antarctic Committee), your Council issued special invitations for the meeting, and a large audience assembled.

The Library continues to make satisfactory progress and additional important exchanges have been arranged during the year. A grant of money was voted for the purpose of binding.

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	51
Student Members.....	26

Total.....86

In accordance with a resolution of council passed several years back, that short obituary notices of deceased members who have taken a specially prominent part in the affairs of the Society, should be drawn up and inserted in the "Proceedings" for the year, the following account of our late member, Mr. G. H. Morton, is here inserted.

G. H. MORTON, F.G.S., F.R.G.S.I.

DURING the past Session the Society has had to deplore the loss of Mr. G. H. Morton, F.G.S., F.R.G.S.I., one of its pioneer members. He served on the Council from its inauguration to the time of his death, contributed to its "Transactions," and was always ready to bring his mature judgment and sound geological knowledge to bear when any subject connected with his favourite science was under discussion at the meetings.

Mr. Morton was a Liverpool man, and from the time he left school up to a few years ago was connected with a business requiring and receiving from him constant care and attention, and one in which he attained success, yet in the small amount of leisure he had, he contrived to make himself a master of geological science, bringing to bear on it those very qualities which contributed to his success in business. He began to collect rocks and fossils, it is said, when seven years old. It is certain, however, that when sixteen years old (or about 1842), having read the article on Geology in "Knight's Store of Knowledge," he determined to make a systematic study of it, and from that time until his death, he devoted the whole of his spare time to it.

He studied geology and zoology from such books as were obtainable, but his principal study was in the field. Heedless of discomfort and fatigue, walking great distances and making the most of such scant holidays as he had, he laid the foundation of those habits of accurate obser-

vation, careful record of facts and methodical arrangement of specimens which distinguished all his scientific work, and was the secret of the great amount of work he was able to do. He lectured on Geology to a class at the Queen's College in the fifties, and so fostered a love of science in others, and at the close of 1859 was able to found the Liverpool Geological Society, which at first held its meetings at his house. He was appointed hon. secretary which office he continued to hold till 1885, with the exception of two Sessions when he was President, and he was again elected President for the Sessions 1885 to 1887.

In 1860 he read his "Geology of the Neighbourhood of Shelve in Shropshire," which he shortly afterwards issued separately. In 1863 the Naturalist's Field Club published for him the first edition of his, "Geology of the country around Liverpool." In February, 1869, he read what may be considered the first of the series of papers on the Carboniferous Limestone of North Wales which have gained him a European reputation. It was entitled "Palæontological Observations on the Carboniferous Limestone of Flintshire." Then followed in November, 1873, "The Carboniferous Limestone and Millstone Grit of North Wales." He continued to communicate papers on the same until his death. The concluding paper dealing with Anglesea was left ready for publication, and only awaited a visit he proposed to pay this summer to the district to verify his list of fossils. It is with the palæontological portion of his work that this Society is primarily interested. His lists of fossils are arranged with reference to their relative numerical importance in each division of the formation and in each locality. Only those who have watched his methods of working can have any idea of the pains he took to insure accuracy. This and the re-arrangement, compiling, and re-cataloging of his unique collections were

the main employment of the last few years of his life. But in addition he produced a year or two ago a new geological map of Liverpool embodying his observations of forty years, and wrote the geological portion of the Handbook of the British Association, Liverpool Meeting, 1896.

Only a week or two before his last short illness he remarked to the writer of this notice that when he had paid his proposed visit to Anglesea he should have finished his work, and appeared rather to fear the prospect of having no further work in hand.

With regard to other work, his Presidential address to the Liverpool Geological Society in 1885 on the "Earliest Appearance of each class in the Vegetable and Animal Kingdoms," is of particular interest to this Society. He was a member of the British Association Committee on "Life Zones in the Carboniferous Formations," and he was local secretary to the Palæontographical Society.

He devoted great labour to forming his geological collections, which were models of what such collections should be, and of which the authorities of the British Museum showed their high appreciation by securing the Palæozoic portion for the nation.

In 1891 Mr. Morton issued a second enlarged edition of his "Geology of the country around Liverpool," and it was re-issued with a map and appendix, bringing it up to date in 1897.

In 1892 he was awarded the Lyell Medal by the Geological Society of London, and his correspondence with our leading geologists both here and abroad shows the high estimation in which he was held. Of what he was to his personal friends we need not speak here, but there is a large circle of younger geologists who will miss the generous friend who dispensed the results of his sixty years of geological study so freely to all who sought help and encouragement.

[H. C. B.]

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the fourteenth session was held at University College on Friday, October 13th, 1899.

The President-elect (J. Wigglesworth, M.D., F.R.C.P.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1898-99 (see "Proceedings," Vol. XIII p. viii.) was submitted and adopted.
2. The Treasurer's Balance Sheet for the session 1898-99 (see "Proceedings," Vol. XIII p. xxxiv.) was submitted and approved.
3. The Librarian's Report (see "Proceedings," Vol. XIII. p. xxiv.) 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 Rev. L. de Beaumont Klein, D.Sc.; Hon. Treasurer, T. C. Ryley; Hon. Librarian, James Johnstone; Hon. Secretary, Joseph A. Clubb, M.Sc.; Council, H. C. Beasley, W. J. Halls, Chas. E. Jones, B.Sc., Rev. T. S. Lea, M.A., W. S. Laverock, M.A. B.Sc., Joseph Lomas, F.G.S., G. H. Morton, F.G.S., John Newton, M.R.C.S., Prof. Paterson, M.D., M.R.C.S., Alfred Quayle, Prof. Sherrington, M.D., F.R.S., I. C. Thompson, F.L.S.
5. J. Wigglesworth, M.D., F.R.C.P., delivered the Presidential Address, entitled "Flightless Birds," (see "Transactions, p. 1.) A vote of thanks was proposed by Dr. de Beaumont Klein, seconded by Prof. Herdman, and carried with acclamation.

The second meeting of the fourteenth session was held at University College on Friday, November 10th, 1899. The President in the chair.

1. Mr. F. J. Cole exhibited with remarks a specimen of *Chlamydoselache anguineus*.
 2. Prof. Herdman submitted the Thirteenth Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station (see "Transactions," p. 89.)
 3. Mr. I. C. Thompson, F.L.S., gave a report on some recent additions to the Copepoda of Liverpool Bay, (see "Transactions," p. 139.)
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The third meeting of the fourteenth session was held at University College, on Friday, December 8th, 1899. The Vice-President (Prof. Herdman) in the chair

1. Mr. C. E. Jones B.Sc., exhibited with remarks specimens of a species of *Podostemon* from India.
2. Prof. Herdman exhibited some interesting photographs of sea-anemones, and of elephant seals on the Falkland Islands.
3. Mr. E. Dukinfield Jones exhibited normal and abnormal larvæ and the perfect insect of *Molippa sabina*, Wlk., from Brazil. The normal larva is grey and black, with rather short spines from long central protuberances. The abnormal larva is bright yellow and black with much larger and more bushy spines. Both forms occur at the same time on *Mimosa*. The abnormal form takes place after the third (?) change of skin, the two last stages being yellow and black. Before the third (?) change the larvæ are of the normal form and colour. Specimens were seen

before and after the change. There is a short and a long period of pupal stage in this moth and the abnormal larva belongs to the long period. Pupation takes place in February and the perfect insect appears in November. The short period is five or six months. There is apparently no difference in the adult insect from the two forms of caterpillar.

4. Mr. H. C. Robinson exhibited with remarks certain variations in species of birds from Eastern Australia.
5. Mr. I. C. Thompson gave a report on two collections of Tropical and more Northern Plankton, (see Transactions, p. 242.)
6. Dr. Henry O. Forbes gave a lecture on "A collection of Flint Implements from recently discovered mines in Ancient Egypt," illustrated by lantern slides and specimens.

The fourth meeting of the fourteenth session was held at University College, on Friday, January 12th, 1900. The President in the chair.

1. Prof. Herdman exhibited with remarks a series of microscopical preparations of larval Crustacea.
2. Mr. H. C. Robinson exhibited a series of birds and mammals from North Queensland.
3. Rev. T. S. Lea, M.A., communicated some notes on the Botany of Widnes (see "Transactions," p. 295.)
4. Prof. Sherrington, F.R.S. gave an account of some recent experiments in the laboratory on Touch Spots.
5. The Annual Report of the Sea-Fisheries Laboratory for 1899 by Prof. Herdman, A. Scott, and J. Johnstone was submitted (see "Transactions," p. 145.)
6. Mr. H. C. Beasley exhibited a supposed fossil found in the Trias.

The fifth meeting of the fourteenth session was held at University College on Friday, February 19th, 1900. The President in the Chair.

1. Exhibition of microscopic preparations illustrative of Mr. J. Johnstone's communication on *Cardium edule*.
 2. Mr. J. Johnstone gave an account of the Cockle Fishing of Lancashire including a description of the structure and minute Anatomy of the common cockle (*Cardium edule*.) (see "Transactions," under "Report on the Investigations carried on in 1899 in connection with the Lancashire Sea-Fisheries Laboratory, University College, Liverpool," p. 145.)
 3. Mr. Laverock exhibited and described an abnormal pear.
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The sixth meeting of the fourteenth session was held at University College on Friday, March 19th, 1900. The President in the chair.

1. Prof. Harvey Gibson exhibited plans and gave a description of the proposed new Botanical Laboratories, shortly to be erected in connection with University College.
 2. Mr. H. C. Robinson exhibited with remarks a collection of Australian Birds with nests and eggs.
 3. Prof. Harvey Gibson laid before the Society the memoir on "*Codium tomentosum*," by Miss Helen P. Auld and himself, (see "Transactions," p. 326).
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The seventh meeting of the fourteenth session was held at University College on Friday, May 11th, 1900. Mr. I. C. Thompson in the chair.

1. Sympathetic reference was made from the chair to the loss the Society and science generally had sustained

by the death of Mr. G. H. Morton, F.G.S., who had been a member of council of the Society since its inauguration.

2. Prof. Herdman, F.R.S., as a Member of the National Antarctic Expedition Committee, gave a lecture on "Why we wish to explore the Antarctic, with special reference to the projected Expedition." At the outset it was explained that a great Antarctic expedition was expected to start from England in the latter half of 1901, which would act in concert with an expedition now being promoted in Germany, and a smaller one—of a rather more private character—which was being organised in Scotland. The object was to explore in three years certain portions of the Antarctic Circle as thoroughly as possible, and not merely to discover the South Pole, as was popularly supposed. The projected expeditions were the result of a very great deal of work on the part of scientific men during the past ten years, and great credit was due amongst others to Sir John Murray, the eminent oceanographer, who had helped most materially to inaugurate the arrangements. The leadership has been given to Professor Gregory, a distinguished geologist who had been recently appointed Professor of Geology at Melbourne. The world of science was expecting to receive great advantages from the expedition, and every department of natural knowledge would be enriched by a systematic exploration of the regions under consideration. Hence the great interest which scientific men, apart from Geographers, were evincing in the forthcoming expedition. It was on this account, too, that the Royal Society had taken the matter up, and, along with the Royal Geographical Society, had been instru-

mental in securing the assistance of the Government. In concluding, Professor Herdman said there was scarcely a branch of scientific knowledge that would not receive some benefit from this expedition. The great winds which seem to have their origin on the Antarctic lands would be investigated, and the tides, currents, and ocean circulation would come under the observation of the explorers. Although the two Polar areas differ in so far as the South Pole is surrounded by continental land, whilst the North Pole is surrounded by an ocean, still there is said to be a certain similarity between the two Polar faunas; but he said that he was one who did not believe in the Bi-Polar theory, supported by Sir John Murray, which held that the organisms existing at the South Pole were similar to, and of common origin with, those at the North Pole. There was a layer of ice-cold water lying at the bottom of the sea from north to south, however, and it was possible that certain marine animals might migrate from one pole of the world to the other by this means. Fossils belonging to the Tertiary Period and also Palæozoic rocks had been discovered in Antarctic regions, which indicated that the continent was of ancient origin, and there was reason to suppose that there had been more land there formerly than now. Therefore, deposits of Geological value would come under the observation of the land party, and the results would, no doubt, form a magnificent contribution to the history of science.

The eighth meeting of the fourteenth session was a Field Meeting held at Cuedly Marsh, near Widnes on Saturday, June 9th, 1900. After tea (to which the party was kindly

entertained at St. Ambrose Vicarage by Mrs. Lea), a short business meeting was held. On the motion of Prof. Herdman from the chair, seconded by Mr. I. C. Thompson, Prof. Paterson was unaminously elected President for the ensuing session.

The ninth meeting of the fourteenth session was a Field Meeting, held, jointly with the Liverpool Geological Society at Delamere Forest, Cheshire, on Saturday June 30th, 1900.

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 formerly to submit to the Society, for election at the Annual Meeting, the names so suggested. The Secretary shall make out and send to each Member of the Society, with the circular convening the Annual Meeting, a printed list of the retiring Council, stating the date of the election of each Member, and the number of his attendances at the Council Meetings during the past session; and another containing the names of the Members suggested for election, by which lists, and no others, the votes shall be taken. It shall, however, be open to any Member to substitute any other names in place of those upon the lists sufficient space being left for that purpose. Should any list when delivered to the President contain other than the proper number of names, that list and the votes thereby given shall be absolutely void. Every list must be handed in personally by the Member at the time of voting. Vacancies occurring otherwise than by regular annual retirement shall be filled by the Council.

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

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

IX.—Every person so elected shall within one calendar month after the date of such election pay an Entrance Fee of Half a Guinea and an Annual Subscription of One Guinea (except in the case of Student Members); but the

Council shall have the power, in exceptional cases, of extending the period for such payment. No Entrance Fee shall be paid on re-election by any Member who has paid such fee.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

XXIV.—No alteration shall be made in these Laws, except at an Annual Meeting, or a Special Meeting called for that purpose; and notice in writing of any proposed

alteration shall be given to the Council, and read at the Ordinary Meeting, at least a month previous to the meeting at which such alteration is to be considered, and the proposed alteration shall also be printed in the circular convening such meeting ; but the Council shall have the power of enacting such Bye-Laws, as may be deemed necessary, which Bye-Laws shall have the full power of Laws until the ensuing Annual Meeting, or a Special Meeting convened for their consideration.

BYE-LAWS.

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

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

LIST of MEMBERS of the LIVERPOOL
BIOLOGICAL SOCIETY.

SESSION 1899-1900.

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
1897 Dutton, Dr. J. Everett, 502, New Chester-road,
Rock Ferry
1894 Forbes, H. O., LL.D., F.Z.S., Free Public Museums,
Liverpool
1891 Garstang, W., M.A., Lincoln College, Oxford
1886 Gibson, Prof. R. J. Harvey, M.A., F.L.S., University
College
1898 Grünbaum, Dr. A. S., 67, Rodney Street
1886 Halls, W. J., 35, Lord-street
1896 Haydon, W. H., 24, Upper Parliament-street

- 1886 Herdman, Prof. W. A., D.Sc., F.R.S., VICE-PRESIDENT,
University College
- 1893 Herdman, Mrs., B.Sc., Croxteth Lodge, Ullet-road,
Liverpool
- 1894 Hickson, Prof. S. J., F.R.S., Owens College,
Manchester
- 1897 Holt, Alfred, Crofton, Aigburth
- 1898 Johnstone, James, 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., VICE-
PRESIDENT, 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 Melly, W. R., Ph.D., 90, Chatham-street
- 1886 Morton, G. H., F.G.S., Edge Lane, Liverpool
- 1888 Newton, John, M.R.C.S., 44, Rodney-street
- 1894 Paterson, Prof., M.D., M.R.C.S. University College,
Liverpool
- 1894 Paul, Prof. F. T., Rodney-street, Liverpool
- 1892 Philips, 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., University College,
Liverpool

- 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., Jun., 5, Hargreaves-rd., Sefton Park
- 1895 Smith, J., F.L.S., Rose Villa, Latchford, Warrington
- 1886 Thompson, Isaac C., F.L.S., F.R.M.S., 53, Croxteth-road
- 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., PRESIDENT, County Asylum, Rainhill
- 1896 Willmer, Miss J. H., 20 Lorne-rd., Oxtton, B'head

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- Carstairs, Miss, Lily-road, Fairfield
- Crompton, Miss C. A., University College, Liverpool
- Dickenson, T., 3, Clark-street, Princes Park
- Drinkwater, E. H., Rydal Mount, Marlboro'-road, Tuebrook
- Elder, D., 49, Richmond Park, Liverpool
- Gill, E. S. H., Shaftesbury House, Formby
- Hannah, J. H. W., 55, Avondale-road, Sefton Park
- Harrison, Oulton, Denehurst, Victoria Park, Wavertree
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- Hick, P., 3, Victoria Drive, Rock Ferry
- Hunter, S. F., Westminster Park, Chester

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REPORT of the LIBRARIAN.

DURING the past year, exchanges, in most cases retrospective, have been arranged with the following Societies and Institutions:—

Société Linnéenne de Normandie, Caen.

The Field Columbian Museum, Chicago (U.S.A.)

The Botanical Gazette, University of Chicago (U.S.A.)

Société de Biologie, Paris.

The Essex Institute, Salem (U.S.A.)

The Johns Hopkins University, Chicago (U.S.A.)

At the beginning of last session the Council voted £12 to be spent in binding the books in the Library. This sum has proved insufficient, and as it is very desirable that this work should be completed with as little delay as possible, it is hoped that a similar grant will be made during the forthcoming session.

Lists are given below of the publications which have been added to the Library, by exchange and otherwise, since the end of the Thirteenth Session, and of the Societies and Institutions with which publications are exchanged.

Batavia, *Natuurkundig Tijdschrift v. Nederlandsch-Indie*. Deel LVIII.

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

- AMSTERDAM—Koninklijke Akadämie van Wetenschappen
Koninklijke Zoölogisch Genootschap Natura Artis Magistra
- BALTIMORE—Johns Hopkins University
- BATAVIA—Koninklijke Naturkundig Vereeniging in Ned. Indie.
- BERGEN—Museum
- BERLIN—Konigl, Akadämie der Wissenschaften
Duetscher Fisherei-Vereins
- BIRMINGHAM—Philosophical Society
- BOLONGA—Accademia della Scienze
- BONN—Naturhistorischer Verein des Preussichen Rheinlande und Westfalens
- BORDEAUX—Société Linnéenne
- BOSTON—Society of Natural History
- BRUSSELS—Académie Royal des Sciences, etc., de Belgique
- BUENOS AIRES—Museo Nacional
Museo de la Plata
- *CAEN—Société Linnéenne de Normandie
- CAMBRIDGE—Morphological Laboratories

CAMBRIDGE, MASS.—Museum of Comparative Zoology of Harvard College

*CHICAGO, U.S.A.—The Field Columbian Museum

The Botanical Gazette, Chicago University

The Johns Hopkins University

CHRISTIANIA—Videnskabs-Selskabet

DUBLIN—Royal Dublin Society

EDINBURGH—Royal Society

Royal Physical Society

Royal College of Physicians

Fishery Board for Scotland

FRANKFURT—Senckenbergische Naturforschende Gesellschaft

FREIBURG—Naturforschende Gesellschaft

GENEVE—Société de Physique et d'Histoire Naturelle

GIESSEN—Obeshessische Gesellschaft für Natur und Heilkunde

GLASGOW—Natural History Society

GOTTINGEN—Konigl. Gesellschaft der Wissenschaften

HALIFAX—Nova Scotian Institute of Natural Science

HAARLEM—Musée Teyler

Société Hollandaise des Sciences

HELIGOLAND—Königliche Biologische Anstalt

ILLINOIS, U.S.A.—Reports of the State Laboratory of Natural History.

KIEL—Naturwissenschaftlichen Vereins für Schleswig—Holstein

Kommission für der Untersuchung der Duetschen meere

KJOBENHAVN—Naturhistorike Forening

Danish Biological Station (C. G. John Patersen)

Kongelige Danske Videnskabernes Selskab

LAWRENCE, U.S.A.—The Kansas University Quarterly

LEEDS—Yorkshire Naturalists Union

LEIPZIG—Konigl. Sachs. Gesellschaft der Wissenschaften

LILLE—Revue Biologique du Nord de la France

LIVERPOOL—Geological Society

Bulletin of the Liverpool Museums

LONDON—Royal Microscopical Society

British Museum (Natural History Department)

MANCHESTER—Microscopical Society

Owens College

MARSEILLES—Station Zoologique d'Endoume

Musée d'Histoire Naturelle

MASSACHUSETTS—Tufts College Library

MECKLENBURG—Vereins der Freunde der Naturgeschichte

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
 Société Zoologique de France
 Bulletin Scientifique de la France et de la Belgique
 *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 Scientifique du Chili
 STAVANGER—Stavanger Museum
 *SALEM, U.S.A.—The Essex Institute
 STOCKHOLM—Académie Royale des Sciences
 SYDNEY—Australian Museum
 TOKIO—Imperial University
 Zoological Society of Tokyo
 TORINO—Musei de Zoologia ed Anatomia Comparata della R. Università
 TORONTO—Canadian Institute
 TRIESTE—Società Adriatica de Scienze Naturali
 UPSALA—Upsala Universitet
 Société Royale des Sciences
 WASHINGTON—Smithsonian Institution
 United States National Museum
 United States Commission of Fish and Fisheries
 WELLINGTON, N. Z.—New Zealand Institute
 WIEN—K. K. Naturhistorischen Hofmuseums
 K. K. Zoologisch—Botanischen Gesellschaft
 ZURICH—Zürcher Naturforschende Gesellschaft

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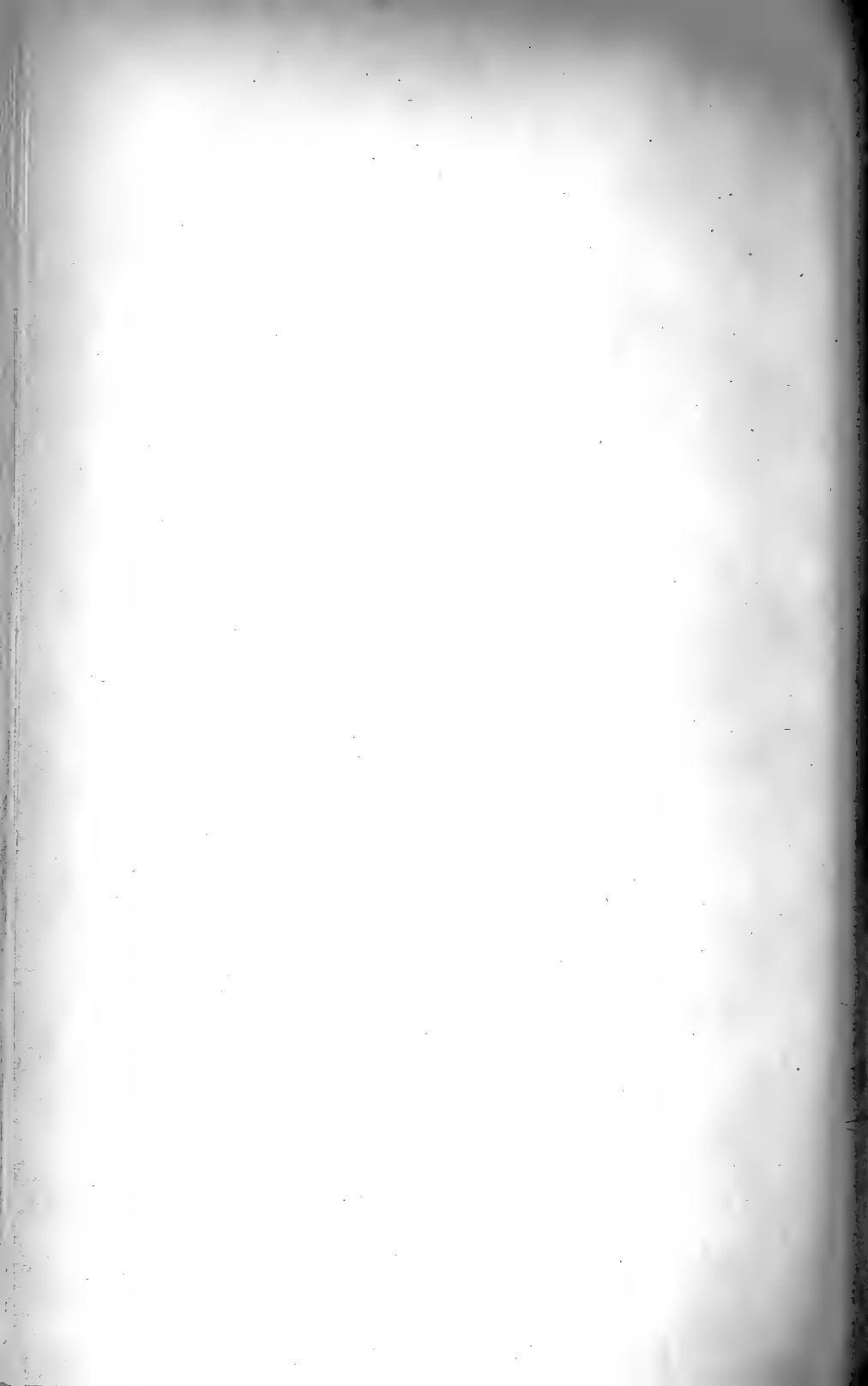
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TRANSACTIONS
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INAUGURAL ADDRESS ON FLIGHTLESS BIRDS.

By J. WIGLESWORTH, M.D., PRESIDENT.

[Read Oct. 13th, 1899.]

It is my first duty, as it is my first pleasure, to thank you very cordially for the honour you have done me in placing me in this chair, an honour which I fear I have done very little to deserve; but as you have put me here I will do my best to serve you during the coming session.

The subject which I have chosen for my address this evening, that, namely of "Flightless Birds," opens up an attractive field in Biology, and one which I cannot hope to do justice to in the short time at my disposal; but I have thought that a review of some of the more striking examples of this singular group of birds would afford material for discussion, and could not fail to be of some interest.

We are so accustomed to regard the power of flight as the most essential attribute of birds, that the term "flightless birds" sounds almost an anomaly, and it would indeed appear much more so than it does, had we not in the Ostrich and its congeners been familiarized from our youth with one class of birds that is quite incapable of flight.

Now birds have lost their powers of flight, or have never acquired them, from very different causes, and they belong to widely separated families, and I purpose grouping these together, under different heads, and singling out one or two members of each group for more detailed consideration, by which means an opportunity will be afforded of touching upon some of the affinities of each class.

Looked at from the physiological standpoint, and regarding merely the different ways in which birds have lost the faculty of flight, and the conditions appertaining thereto, all birds so circumstanced may be divided into three groups.

(1) Birds which have lost the use of their wings (or, according to some authorities, which have never acquired them) because the great development of their posterior extremities, whether for the obtaining of food or the avoidance of enemies, has rendered the use of their anterior extremities unnecessary to them. This group may be sub-divided into two, according as the posterior extremities have been developed for progression, (a) in water, (b) on land. The first sub-division of this group (that developed for aquatic purposes) contains one bird only—the gigantic extinct *Hesperornis*; whilst the second sub-division comprises the Ostrich and its congeners, indeed, all birds belonging to the Ratite sub-class.

(2) My second group comprises birds in which the anterior limbs are perfectly useless for flight, but which have, nevertheless, had these organs specially developed for progression in another medium, to wit, water, for all birds of this group are aquatic. Under this head fall all the Penguins, and probably the extinct Great Auk.

(3) Yet another group comprises birds from very different families, in which the anterior extremities or wings are perfectly functionless, but which have, nevertheless, not acquired any compensatory advantages in other directions. This includes degenerate birds, such as *Didus*, *Stringops*, &c.

I need scarcely remind you of the customary classification by which the great class AVES is divided into two main sub-classes—the CARINATÆ and the RATITÆ, according as the sternum possesses a keel or the reverse; the

keel being a projection on the anterior surface of the sternum to which are attached the great pectoral muscles, the chief agents in the movements of the wings, and hence, being very definitely associated with the power of flight, is characteristic of the great majority of birds; whilst in birds like the Ostrich there is no keel, the sternum being smooth and free from projections in harmony with the absence of need for large pectoral muscles. Now it is a belief, held by many systematists, that these two divisions represent two fundamentally different types of birds—that the great contrasts which exist between these two great sub-classes of birds at the present time have existed from the earliest times, and that the common ancestor must be sought, not in a flying bird originally common to both, but in a pre-avian or reptilian form; that, in fact, the divergence between the two commenced in the reptilian and not in the avian condition.

Others, again, see in the Ratitæ the primitive type of birds—a stage through which all Carinate birds have passed in the course of their development.

To neither of these two opinions can I subscribe, as I agree with those who hold the view that both Carinate and Ratite birds are descended from a common avian ancestor which possessed the powers of flight; and in briefly reviewing the different groups of flightless birds already sketched out, we shall, at the same time, consider some of the evidence upon which this opinion rests.

To begin with the first group into which I divided flightless birds, that, namely, in which compensation has been obtained for the loss of function of the wings by the great development of the posterior extremities, we have, as already indicated, an aquatic and a land section; and to take the former section first, we have included in it only a single genus, but one of great interest, the gigantic

extinct toothed bird *Hesperornis*, from the Cretaceous deposits of North America, for the elucidation of which we are indebted to the labours of Prof. Marsh. In this, as in the other types to be considered, attention will be chiefly concentrated on the fore-limb, pectoral-girdle, and sternum.

Hesperornis regalis, the type of the genus, was a huge bird, measuring from the point of the bill to the end of the toes about 6 feet, and was eminently adapted by the manner of development of its posterior extremities for an aquatic life. It had a long beak, and teeth of a definitely reptilian form inserted in continuous grooves. In general form it resembled a Diver (*Colymbus*), and it agreed with that bird and the Grebes in its long, narrow pelvis, large cnemial crest of the tibia, and relatively enormous patella; and it is now generally considered to have had its nearest allies in these birds. On the other hand, it has many points of contact with the Struthious birds, with which it was classed by its discoverer, and described by him as "A swimming Ostrich." There are characters in the skull, such as the fact that the upper articular head of the quadrate bone is not divided into two distinct facets, which point in this direction, but the most striking resemblances are, perhaps, to be found in the sternum and shoulder-girdle. The sternum was completely smooth, and devoid of all trace of a keel. The coracoid was short and wide, and it and the scapula were nearly in the same straight line, thus much resembling the condition found in the Ratites; but these two bones were not ankylosed together as they are in the group of birds just named, and, moreover, there were two separate clavicles. The fore-limb indicates almost the greatest amount of degeneration of any known bird, as it is represented by the humerus only. The remaining bones of the

fore-arm are presumed to have been non-existent, as no trace of them has been found, and the humerus, at its distal extremity, presents no trace of articular facets. It is possible, however, that they may have existed, although in a very rudimentary form. As before mentioned, *Hesperornis* is now usually classed with the Divers, but it is quite possible that the characters, such as the long, narrow pelvis, &c., upon which reliance is placed, may be purely adaptive in nature, and acquired owing to similar habits of life. It is not by any means always easy to distinguish between characters which are simply adaptive and those which indicate community of origin; and a small character, such as the single upper articular head of the quadrate bone, which is characteristic of almost all the Ratitæ, may really be of more importance as indicating blood relationship, than the more striking features of the pelvis, &c.

Lately, indeed, a remarkably perfect specimen of *Hesperornis* has been discovered, with the feathers in place, and these are stated by Marsh to resemble the typical plumage of the Ostrich. So that, possibly, the earlier view, that of the discoverer, may yet prove to be the more correct, and *Hesperornis* may find its nearest allies in the Ratitæ.

The fact that this bird presents us with an example of a smooth sternum and functionless wing, occurring as far back as Mesozoic times, has been held by some to support the view that the Carinate birds passed through a Struthious stage prior to attaining their present development. Unfortunately for this view, however, in so far as it rests upon *Hesperornis*, there are found side by side with this bird, in the same Cretaceous beds, fossil remains of a bird, *Ichthyornis*, resembling a Tern, which, from the great development of the keel of the sternum and the strongly-

marked humeral crest, evidently possessed great powers of flight, equal at least to the great majority of birds at the present day. So that, even in the Cretaceous period, fully developed flying and flightless birds existed side by side, and the problem is simply thrown further back. The earliest known fossil bird, I may say, the *Archeopteryx*, from the Triassic deposits of Bavaria, although presenting many reptilian features, was nevertheless a true bird, possessing well-formed feathers; so that birds have clearly a greater antiquity than used to be thought, and we must go back to Triassic, and probably even to Palæozoic, times in order to get at the original avian ancestor from which all other birds have been derived.

Before leaving *Hesperornis*, it is very interesting to observe the small size of the brain of this bird. Comparing it, as Marsh has done, with the brain of a modern Diver, the superiority in size and complexity of the latter is very marked. Precisely similar results were obtained, by the same investigator, in comparing the brain cavity of *Ichthyornis* with that of a modern Tern, to which bird *Ichthyornis* is considered to be most nearly allied.

I think that hardly sufficient importance has been attached to this highly pregnant fact, namely, the steadily increasing size and complexity of the brain in birds, as we pass from Mesozoic to modern times, without, so far as we can judge, a corresponding increase in the complexity of other parts of the body; for, to my mind, the gradual increase of brain power which has been going on for past ages accounts for not a little of the silent extinction of species which is written large on every page of the geological record.

With this digression, I pass to the second section of my first group of flightless birds, which comprises birds in which the lower extremities have been specially developed

for progression on land. This includes all the true Ratite birds, and hence comprises, amongst existing birds, the Ostrich (*Struthio*), the South American Ostrich (*Rhea*), the Cassowary (*Casuarius*), and the Emeu (*Dromæus*) from the Australian region, and the little *Apteryx* of New Zealand; whilst, amongst extinct birds, must here be classed the various species of Moa, included in the family Dinornithidæ of New Zealand, and the *Æpyornithidæ* of Madagascar. It is possible that the Stereornithes, a group of gigantic flightless birds, discovered in recent years in the Tertiary deposits of Patagonia, should here be included. They were originally so classed by their discoverer, Ameghino, but later researches have thrown great doubt upon them being true Ratites. Their affinities are not, indeed, sufficiently known to render it profitable to discuss them, and I will merely remark that the most striking thing about them was the enormous size of the skull, which, in one species, measured 2 feet in length; they possessed also well-formed wings, but these were apparently quite useless for the purpose of flight. Other fossil forms also occur, which are less equivocally Ratite, such as *Gastornis*, *Dasornis*, &c., but these I shall not allude to further.

To examine in detail the fore-limb girdle in all the above birds would, of course, take one far beyond one's limits, and it must suffice to take one or two examples as types of the rest.

The Ostrich (*Struthio*) differs from other members of the Ratitæ in certain important particulars, such, for instance, as the structure of the skull and the presence of only two toes, but the likenesses considerably outweigh the differences, and point definitely to a common origin for the class. If, therefore, the Ostrich were descended from a totally different stock to that which produced the

Carinate birds, we should expect to find the fore-limb developed on a different pattern to the wings of flying birds, but this, as we shall see, is far from being the case; and if a quite definite relationship to a Carinate wing can be made out in the Ostrich, we may probably infer the same of the other Ratites. The sternum of the Ostrich, as of all other birds of this class, differs of course greatly from that of the vast majority of Carinate birds in its flat raft-like character, with absence of all trace of a keel; but I submit, and this truth will become more apparent later on, that the absence of a keel is simply the anatomical expression of the loss of flight, and too much importance has been attached to it as pointing to an entirely different origin for the birds which have it not from those which have it; that the keel is not there now does not, to my mind, prove that it has never been there. The coracoid is broad, and it and the scapula are fused together into one bone at a very open angle—another character common to all the Ratites as distinguished from the Carinates. *Struthio* also has no clavicles, though certain of the Ratites, such as the Emeu and Cassowary, possess rudimentary ones. Turning now to the fore-limb proper, we shall see that this is simply a reproduction in almost every character, except that of relative size, of the type presented by every Carinate bird of the present day.

Take an illustration of the bones of the right wing of a Duck, and side by side with it place a figure of the corresponding manus of the Ostrich, and let me direct your special attention to the bones of the pinion or manus. The single metacarpal bone consists of three bones fused into one (it contains also some elements of the carpus, but these are indistinguishable in the adult state), corresponding with the three digits or fingers of birds; the first bone being very short, and indicated merely by a prominence at

the head of the compound bone, considered to be the metacarpal bone of the thumb or pollex; the second bone being much the largest and broadest of the three component parts, corresponding to the index finger; whilst the third segment is nearly as long as the second, but is a much slenderer bone than this, with which it is fused at its two extremities, corresponding with the third digit. At the end of this triply-compound metacarpal bone come the phalanges forming the digits, represented in the Duck, as in most birds, by two for the first metacarpal, two for the second, the proximal phalanx of the second digit being much the largest and broadest in correspondence with the large metacarpal from which it arises, and one for the third. Though this triply-compound metacarpal bone, with the three digits at the end, is supposed to correspond with the thumb and first two digits of the generalised vertebrate type, some authorities consider that it is more correct to regard them as the second, third, and fourth digits, the thumb being suppressed altogether.

Now this peculiar arrangement of metacarpals and phalanges is remarkably constant and characteristic of all modern flying birds, and it may be seen equally well-developed in the strong flying *Ichthyornis* of the Cretaceous period. It is a type specially developed, so as to allow little individual motion in the digits, and, as such, it is highly characteristic of flying birds, where compactness and immobility in these parts are required. It would be very unlikely that such a highly specialised type of manus would be developed independently for a different purpose, and if the wing of the Ostrich had never been used for the purpose of flight, we should not expect to find in its manus the type characteristic of flying birds. Yet this is just what occurs. We find the same triply-compound metacarpal bone, and the same arrangement of the

phalanges, which we meet with in modern Carinate birds, and, so far as the actual arrangement of the bones is concerned, there is little in the wing bones of the Ostrich, taken by themselves, and without reference to the size of the bird from whence they came, which would lead one to suppose that they did not belong to a bird which possessed the power of flight. Surely such a fact can only be satisfactorily explained by supposing that the manus of the Ostrich, like the bones of the rest of the wing, was originally developed in the way described for the same reason that the bones of the wing of all modern Carinate birds have been developed, namely, to facilitate the process of flight, and that the reduced condition in which we find the wing bones of this bird is simply the result of atrophy from disuse. Furthermore, the wing of the Ostrich contains definite though reduced remiges or flight feathers, which is, of course, a fact pointing strongly in the same direction.

But of all the Ratitæ, *Struthio* is the genus in which we find the wings best developed, and it might be argued that this and other characters formerly alluded to might indicate a different origin for this bird than for the other members of this sub-class. It is a fact, indeed, that in other Ratites we find the wings in a more degenerate condition than in the Ostrich. In *Dromæus*, *Casuaricus*, and *Apteryx*, for instance, the wing is much more reduced, and there is but a single digit to the manus. Of all living birds, indeed, *Apteryx* presents us with about the most extreme type of reduction of wing, so that if in this bird we can find evidence in favour of its having passed through a previous flying condition, the case in favour of all the other Ratites having passed through a similar stage will be much strengthened. Through the kindness of Dr. Forbes I am able to show you a specimen of this unique bird, together

with its skeleton, as well as several other beautiful specimens illustrating the subject before us. There are few more interesting birds than this little *Apteryx*, which was at one time abundant in some of the mountainous parts of New Zealand, but is now fast dying out before the advance of civilization, and its attendant pests of dogs and cats run wild, and other vermin which now over-run the islands. About four species are known, two of them *Apteryx bulleri* (*Mantelli*) and *A. australis*, from the north and south islands respectively, well illustrating what is seen in many other New Zealand birds, as well as in other similar districts, the fact of two distinct, but closely allied, species inhabiting contiguous but dissociated areas. *Apteryx* is about as large as a domestic fowl, and differs, amongst other things from other Struthious birds, in having a back toe, and it presents the remarkable peculiarity of its nostrils being placed at the extremity of its long bill; it is clothed with a soft, loose plumage, resembling that of other Struthious birds, but the feathers lack an aftershaft. It has powerful legs and claws, and it can run with considerable swiftness. It is strictly nocturnal in its habits, and it feeds mainly upon large earthworms, to obtain which it plunges its long flexible bill deep into the soft ground which it frequents. It lays two white eggs, of a relatively enormous size (one egg obtained by Buller measured 5·30 by 3·30 inches, and weighed $15\frac{1}{2}$ ounces), in burrows dug out or adapted by the bird, the work of excavation being apparently performed by the female only. This was amusingly illustrated by an incident which occurred to Sir W. Buller when once out Kiwi hunting, "Kiwi" being the native name for the *Apteryx*, which is hunted by dogs specially trained for the purpose, which track the birds to their holes by scent. Seven specimens having been captured, four females and three males, they were

placed in a cage outside for the night, but in the morning it was found that all the females had disappeared, they having made a tunnel through the floor of their prison, and having thus got away, whilst the three males remained in the cage. In the breeding season, also, the adult females were all found to have their claws blunted as the result of their digging operations, whilst the claws of the males were perfectly sharp. On the other hand, the males, as in other Struthious birds, appear to do all the duty of incubation, and also take entire charge of the young till they are able to shift for themselves. So that the two sexes of this bird appear to have established a well-defined division of labour with regard to their nesting operations. It is said, indeed, by the natives, that after laying her two eggs in the nesting cavity prepared by herself, the female goes off and pairs with another male, forming a new nest elsewhere.

The wings are extremely aborted, and the condition of these and the parts of the skeleton connected with them, is of great interest.

To begin with, a distinct alar membrane is present. In the wing of *A. bulleri* there is clearly manifest a definite fold of skin or pre-patagium passing between the upper-arm and the fore-arm, and an equally well-marked fold or post-patagium between the upper-arm and the trunk; this is precisely what we meet with in typical flying birds, and it is very suggestive. Furthermore, there are clear remains of remiges or flight feathers in the wings. Thus, T. J. Parker found 3 to 4 metacarpo-digitals and 9 to 10 cubitals in the fresh wing of *A. bulleri*, and on the outer side of the wing there was a distinct row of tectrices majores, or greater wing coverts. Though so small and reduced, these remains of flight feathers point definitely to a time when they served the purpose for which flight

feathers were originally developed, without which purpose they have no meaning.

The sternum of *Apteryx* is a small quadrate bone with wide anterior emargination, and rather deep notches posteriorly, caused by the projection of the posterior lateral processes. It is usually quite smooth on the anterior surface, like that of *Ratites* generally, but in two or three cases, T. J. Parker found a distinct median longitudinal thickening along the anterior half of the front of the sternum, which formed in fact a low keel. This is very significant, as it probably indicates reversion to a time when the bird possessed a keel to its sternum, and therefore the power of flight. The coracoid and scapula are ankylosed together at an open angle, after the manner of *Ratites* generally, and there is no furcula.

With respect to the fore-limb the only thing that need be noted with reference to the humerus, radius, and ulna, is their very small size.

As regards the manus, in a specimen of *A. australis*, figured by Parker, there is no separate carpus, the bones of the fore-limb being succeeded by a single irregularly-flattened bone, the carpo-metacarpus, to the distal end of which is attached a single digit consisting of three phalanges. There is, however, some variety in these respects, both in different species of *Apteryx* and in different specimens of the same species, some showing remnants of a carpus in the shape of a single small bone and the metacarpus giving indications of a separation into component parts. In no case is there more than one digit. During development, however, there are always definite indications of a carpus and of a division of the single metacarpal bone of the adult into three segments; so that, in development, the skeleton of the fore-limb follows the same lines as those of a true wing.

As in the bones of the fore-limb, so in the muscles, there is distinct evidence of degeneration, but the wing has the usual flexors and extensors, and also a good development of muscles acting as pronators and supinators.

To these facts, all pointing unmistakably to this bird having passed through a flying stage others might be added, but I think I have pointed out enough to indicate at any rate the strong probability that the ancestor of *Apteryx*, in remote time, was a bird which possessed the power of flight. And if this can be considered proved of *Apteryx*, it may, I think, be safely asserted of the remainder of the existing Ratites. If, however, we turn to the gigantic extinct Ratite birds of New Zealand, comprised under the general term "Moas," we find a still further degradation of the wing, to such an extent indeed that it is doubtful if it existed at all.

Dinornis may be taken as the type genus of this group of birds, which were very numerous, and the remains of which have been divided up into five genera, and about twenty-five species. One of the most striking features of the group is the immense size reached by some of the species; *Dinornis maximus*, for instance, had a tibia measuring 39 inches in length, and this bird probably attained a height of 12 feet. Their great numbers indicate that the conditions under which they flourished must have been very favourable to their existence. With the advent of man upon the scene, however, the balance of nature was upset, and they were exterminated for food by the native Maoris long before any Europeans set foot in the country.

But the condition of the shoulder-girdle and its connections is what has most interest for our present enquiry. The sternum was a smooth, sub-quadrate, more or less flattened bone, with a pair of deep and wide posterior

notches caused by the divergent posterior lateral processes, whilst the coracoid and scapula were confluent, as in the other Ratites.

No wing bones, however, have been discovered, not even a trace of a humerus has been found in, at any rate, the majority of species, and it has been assumed, therefore, that these birds were unique in possessing but a single pair of limbs. This opinion was held by Sir R. Owen, who came to that conclusion, not merely from the circumstance that no wing bones were present in the numerous specimens he examined, but from the fact that in the confluent coraco-scapula in species of *Dinornis* he could find no trace of a glenoid cavity.* The fact that no bones of the fore-limb have been discovered does not, of course, by itself prove that they did not exist; but when we consider the enormous number of bones of these birds which have been unearthed, it is certainly remarkable that no unequivocal evidence of the existence of these bones should have been forthcoming had they been in existence. Indeed, it is thought that the pectoral-girdle itself was absent in some of the species, as in some cases, *e.g.*, the genus *Pachyornis* (Lydekker), the sternum presents no facets for the coracoids. That the remote ancestors of the Moas did possess a fore-limb is, of course, certain, but whether this was formed on the type of a wing cannot be definitely affirmed for lack of material.

Looking, however, to the numerous points of resemblance between the Dinornithidæ and the other Ratites, it seems

* Since this Address was delivered Dr. Forbes has kindly called my attention to the fact that he has described and figured (*Nature*, Jan. 14th, 1892) the scapulo-coracoid of a species of *Dinornis*, showing a distinct glenoid cavity. The bone presented "a deep, well-marked depression, with a beautifully smooth and polished concavity, which leaves no room for doubt that it has been a functional glenoid cavity for a humerus, possessing a head not less substantial at least than that in the Cassowaries."

to be a fair inference that their origin was substantially the same, and therefore that they at one time possessed functional wings, even if they subsequently lost them altogether. It is an interesting fact that the gigantic extinct *Æpyornis* of Madagascar, which presented many resemblances to the Dinornithidæ, possessed a distinct, though rudimentary, humerus. The combined coraco-scapula of this bird is typically Ratite, the angle between the two bones being very slight, and there is a distinct glenoid cavity. The sternum also was truly Ratite, the most striking peculiarity about it being its great shortness as compared with its width.

With this brief survey I must take leave of the Ratites, and with them, of my first division of flightless birds. Though possessing only functionless wings, and, therefore, in that sense showing inferiority, they cannot be looked upon exactly as degenerate birds. They have been compensated in great measure for their loss of flight by their swiftness of foot, and have thus, as it were, competed with the mammals on their own ground, and have held, and still hold, their own over wide areas—as in the case of the African Ostrich—in the presence of numerous and powerful enemies, and they have survived by virtue of their capacity to cope with these. That all these birds were descended from an ancestor which possessed the power of flight, I have given reasons for believing, but it is not to be supposed that that ancestor is to be found in any of the types of flying birds of the present day. The differentiation between the existing Ratites and Carinates is too great for that. Rather is the ancestor to be looked for in an ancient flying type, from which the Ratite and Carinate birds have alike diverged. That this ancestor was a true bird, possessing feathers and the power of flight, is all that I contend for.

I now turn to the second of my three groups of flightless birds, those, namely, in which the anterior limbs, though perfectly useless for the purpose of flight, are, nevertheless, functionally active, having been developed in a special direction for progression under water. This group is practically made up of the Spheniscidæ or Penguins, a very interesting family, but one which the ornithologist of northern climes has, unfortunately, no opportunity of studying in the wild state, as all the species, of which there are about a dozen, distributed amongst three or four genera, are confined to the Southern Ocean, not a single species being found north of the equator. Penguins have their bodies entirely covered with short, scale-like feathers, and there is an entire absence of remiges in the wings.

If we look at the uncouth, clumsy figure of the Penguin on land, we should be apt to conclude that we had a very degenerate creature before us. But in reality the bird is a beautiful example of adaptation to special conditions, and is as well fitted for progression in its chosen medium, the water, as any flying bird is for progression in *its* medium, the air. It is essentially an inhabitant of the ocean, and comes to land only for the purpose of rearing its young, which it does in large colonies, when its helpless condition causes it to incur much danger from that most destructive of all animals—Man. The wing of the Penguin has been converted into a veritable paddle so perfectly adapted to progression under water, that when the bird is diving it makes use of its paddle-like wings only, the legs being stretched out behind as in the case of ordinary birds when flying, so that the mode of progression of this bird may be truly described as a sub-aqueous flight, and all observers testify to the grace and ease of its movements when so engaged. The wing is much compressed and, when in use, it is carried forwards so that its sharp anterior edge offers the

least amount of resistance to the water, while in the backward or effective stroke, a broad surface is presented. The bones of the shoulder-girdle and wing present exactly the same number and arrangement as obtains in the wing of a flying bird, with the single exception that the first phalanx of the first metacarpal is wanting, so that the Penguin has no thumb. The sternum has a deep keel, and thus resembles that of an ordinary flying bird, the muscles attached to it, however, being used for sub-aqueous instead of aerial flight. The scapula is very broad, and relatively to the size of the bird is larger than in any other group of birds. This is correlated in a very interesting way with the very great and quite exceptional development of the muscles which act on the shoulder joint, as it is chiefly from the shoulder that the movement of the paddle-like wing is effected. On the other hand, there is atrophy of the muscles of the fore-arm and hand, consequent on the comparative fixity of the joints below the elbow, the movements of these joints taking on a somewhat rotatory screw-like character.

The most striking point about all the bones of the fore-limb is their remarkably compressed flattened character, developed thus in harmony with the needs of the paddle-like wing. But from the developmental point of view, the most interesting bone the bird possesses is the tarso-metatarsal, the different segments of which, instead of being fused into one uniform bone, as is universal in all other known birds, show a definite tendency to a division into three parts by means of two deep longitudinal grooves, the upper end of each groove being perforated by a foramen.

This fact alone points to a great antiquity for these birds, for it clearly indicates that the ancestral Penguin must have branched off from the primitive avian stem

before the metatarsal bones, which were, of course, originally separate, had become completely fused into the single bone, so characteristic of modern birds, a fusion which was, indeed, as complete in the toothed birds of the Cretaceous period as in the birds of the present day. So that the despised Penguin is of ancient lineage, and has very blue blood in his veins.

But that the ancestral Penguin was a flying bird appears to be proved by the researches of Prof. Watson. That investigator found, on dissection of the wing of the Penguin, that every muscle characteristic of the wing of an ordinary flying bird was represented there, but represented not by muscular but by tendinous bands, which had attachments similar to those of the muscles in question. These tendons being functionally useless, could only have been derived through a process of structural degeneration from muscle bands, which had at one time been functionally active, but the need for which had disappeared in the different mode of life adopted by the bird, the paddle-like wing of the Penguin being moved, as before indicated, in a manner different to that required for aerial flight.

Penguins are in places so numerous that they become of economic value. Thus, at Dassen Island and adjoining islands off the coast of South Africa, the Jackass Penguin, *Spheniscus demersus*, is so abundant that it is actually farmed by the Cape Government, the eggs being regularly collected and sold for food. Some 300,000 to 400,000 eggs are annually taken, and the net profit resulting therefrom amounts to upwards of £700 a year.

The only other bird, besides the Penguin, which can reasonably be included in this second group of flightless birds, is the extinct Great Auk—*Alca impennis*. Though presenting a superficial resemblance to the Penguin, it is

in reality widely different, being, in fact, a near relative of the Razor-bills and Guillemots of our own seas. These latter birds, like other members of the Alcidæ, make active use of their wings in diving, as anyone may have noticed who has watched these birds diving in an aquarium; but their use in this direction has not prevented them retaining the power of flight, though they are, comparatively speaking, rather feeble fliers. In the Great Auk, however, the specialization of the wing as a diving organ had advanced so far that it had wholly lost its capacity for aerial progression, but there seems no doubt that it formed an efficient paddle, though one framed on a different pattern to that of the Penguin. The anterior limbs were therefore truly functional, although functional in the medium water only, and in harmony with this fact the well-developed keel to the sternum is noteworthy. The extinction of this interesting bird, which appears to have been completed shortly before the middle of the present century, was wholly accomplished by the destructive propensities of the genus *Homo*, the helplessness of this bird at its breeding stations causing it to fall an easy prey to the destroyer.

I now come to the third and last division of my subject, that, namely, which deals with those flightless birds which have lost the use of their wings without having obtained any compensating advantages in other directions. The birds in this group belong to very different families, all however, included in the Carinate sub-class, and they are all strictly degenerates. When speaking of the members of the first group—*Hesperornis* and the Ratites—I remarked that these birds, many of them, had survived to the present day by virtue of their capacity to cope with the enemies with which they came into contact. The members of the present group, however, may be said to

have survived (for such time as they did survive) by virtue of the fact that they had no enemies to cope with. Almost without exception birds of this class have been met with on islands where the surrounding conditions have been particularly favourable to their existence, and where there has been an absence of enemies in the shape of predatory mammals to cause them discomfort. Such birds have been more numerous than might have been anticipated, and some few still survive. The Mauritian group of islands in the Indian Ocean, to the east of Madagascar, have furnished some of the best-known examples. Mauritius itself supplied the celebrated Dodo, *Didus ineptus*; the sister island, Rodriguez, gave birth to another Didine bird—the Solitaire, *Pezophaps solitarius*; whilst it is known that another island of this group, Bourbon, was at one time inhabited by a flightless bird, allied to the above two, but no trace of this is now known to exist. Other flightless birds, however, besides the Didine group, at one time inhabited these islands, such as the flightless rail, *Aphanapteryx*, from Mauritius; and there were brevipennate birds, such as the large Heron, *Ardea megacephala*, from Rodriguez. But the New Zealand region has probably been more prolific of birds of this kind than any other portion of the world. Thus, amongst birds still existing, we have the different species of Woodhen—*Ocydromus*, the large ralline bird *Notornis*, the Owl Parrot *Stringops*, from New Zealand proper; and the small Duck, *Nesonetta aucklandica*, from the Auckland Islands. Whilst amongst extinct forms from the same zoological region may be mentioned the giant Woodhen, *Aptornis*, and a huge anserine bird, *Cnemiornis*. The Chatham Islands, again, have furnished other instances of flightless rails, such as *Palæolimnas*, *Nesolimnas*, and *Diaphorapteryx*, though the first named of these may possibly still have

been capable of limited flight. Other examples might be named; and if we were to include brevipennate birds with very limited powers of flight, such as *Geopsittacus*, the Ground Parrot of Australia, which are, as it were, on the highroad to becoming flightless, the list might be considerably extended. It would be possible, indeed, with the aid of intermediate forms, to construct a complete series from strong flying to completely flightless birds. Doubtless, also, many more forms have disappeared altogether without, alas! the opportunity having been afforded to any naturalist of observing and studying them. To attempt to examine all these species in detail is, of course, impracticable here, and it must suffice very briefly to review the three typical examples furnished by *Didus*, *Notornis*, and *Stringops*.

Here is the familiar figure of the Dodo, a large uncouth bird about the size of a Turkey, with a huge raptorial looking beak, stout and strong legs and feet, mere apologies for wings, and a few curled feathers by way of a tail. When Strickland and Melville wrote (in 1848) their well-known monograph on this bird, comparatively little was known of it, and but few remains of it were extant—a foot in the British Museum, a head and foot at Oxford, and a head at Copenhagen being all the fragments in existence. Much difference of opinion has existed as to its affinities. It has been referred by some to the Struthious family, by others to the Gallinaceous birds, and by others again to the Raptores. But Prof. Reinhardt of Copenhagen, as far back as 1845, from an examination of the skull of this bird, existing in the museum of that city, gave it as his opinion that the Dodo was a greatly modified pigeon, and should, therefore, be classified amongst the Columbæ, an opinion which was adopted and emphasised by Strickland. The acumen of the Danish professor has been abundantly

confirmed by the subsequent discoveries of great numbers of the bones of this bird in the island of Mauritius, which have enabled its skeleton to be almost entirely reconstructed, thereby placing its Columbine nature beyond doubt, a fact which is now admitted by all naturalists. And as showing the accuracy of the old paintings of the Dodo, some of which it can hardly be doubted were painted from living specimens, it may be pointed out that the outline of the reconstructed skeleton strikingly harmonises in form and size with the figure of the Dodo, as represented in these pictures.

Clumsy, flightless, and uncouth, the Dodo may well be regarded as a very degenerate descendant of the Columbine stock, and the causes which led to its passing into such a helpless condition are of much interest. It was a ground feeder, and its principal food is supposed to have been the fruits of palm and other trees with which the island of Mauritius was formerly covered, the fruits of which doubtless strewed the ground in profusion, and its powerful beak was developed for the purpose of tearing open these fruits to get at the kernel. A superabundance of food increased the size and weight of the body, and, at the same time, induced a certain amount of inertia, so that a diminishing desire to use its wings went, *pari passu*, with a diminishing capacity for doing so. The increase in size was further aided by the diversion of nerve force from the wings to the requirements of general body growth, until, with increasing weight, there came a time when the wings could no longer raise the bird from the ground, and henceforward their complete functional disuse and subsequent atrophy was only a matter of time. Had the ancestors of this bird been exposed to the attacks of enemies in their island home, such a type as the Dodo could never have arisen, for any birds which varied in that

direction would have been quickly cut off and wiped out of existence.

But the conditions of life were altogether too easy for it; a superabundance of food, to be had for the picking of it up, and an absence of any enemies to interfere with it, produced their usual result, and degeneration set in—a result, I may remark, by no means confined to the Dodo, but one of which, under similar circumstances, proud Man himself furnishes conspicuous examples. As long as the conditions of life remained uniform, the Dodo thrived luxuriantly, but with the advent of man upon the scene, the balance was upset, and the helpless, defenceless condition of the birds rendered them an easy prey, whilst the hogs and cats turned loose in the island by its early discoverers completed the work of destruction.

The extermination of the bird appears to have been complete by the end of the 17th century, less than 100 years from the earliest notice of it by the first Dutch occupiers of the island.

The sternum of the Dodo is very interesting, for it shows that the keel—that special characteristic of flying birds—has become greatly reduced in depth, measuring, in fact, not more than $\frac{3}{4}$ inch in a sternum about 7 inches in length. The keel is, however, there, a plain record of a time when the wings were functional, and required a keel for the attachment of the muscles which moved them. The scapula and coracoid were ankylosed together at a wide angle, in this respect resembling the condition found in the Ratitæ.

Turning now to a bird of a very different character, *Notornis mantelli* from New Zealand, presents us with the very interesting case of a bird first described from fossil specimens undoubtedly contemporaneous with the Moa, and supposed to be extinct, but of which living

examples subsequently came to light. The *Notornis* is a huge ralline bird, in many respects resembling a giant Swamp-hen (*Porphyrio*), but with feet more adapted for terrestrial habits. Its wings are very abbreviated, so that it is quite incapable of flight, but it appears to be able to run with some rapidity. Its most striking external feature is its large, much arched, bill, strongly compressed laterally. It inhabits swampy districts, where the vegetation is very dense, and where the thickness of cover and difficulty of access combine to give it the security which its comparatively helpless condition necessitates. For many years only three specimens were known, two of which are in the British Museum, and the third in Dresden, but quite recently a fourth specimen has been secured.

It does not happen every day when one is strolling along the shore of a lake for one's dog to disappear into the scrub and come back with a bird in its mouth worth £300. Yet this is what occurred near the shore of Lake Te Anau, in New Zealand, in August of last year, and the above sum is what was offered for it. This specimen remains in the colony, which is undoubtedly the fittest place for it. As this is only the fourth specimen of this bird obtained in 50 years, although it has been much sought for, it looks as if it were on the verge of extinction, but considering how dense and difficult of access is the ground it inhabits, there is reason to hope that it may continue to survive.

The sternum of *Notornis* is broad and flat, and is devoid of all trace of a rostrum; its lateral curvature is very slight, the transverse sternal angle being very open. The keel is feebly developed, measuring, in a specimen examined by Jeffrey Parker, only .9 cm. in depth. The coraco-scapular angle is also more open than it is in the allied

genus *Porphyrio* (a good flier). All these points indicate an approach to Ratite characteristics.

The loss of the power of flight in a member of the Rallidæ does not appear so extraordinary as in the case of some other birds, when we call to mind the skulking habits of most members of the family, and how they habitually trust, for security from their enemies, much more to the concealment which their haunts afford than to their powers of flight. We know how difficult it is to flush a Water-rail or a Corncrake from its cover, and it is not difficult to understand how the comparative disuse of the wings, which these birds exemplify, might, under favourable circumstances, be carried still further, until loss of flight became permanently established.

As a matter of fact, taking extinct and recent forms together, flightless species amongst the rails are comparatively common.

One final example let me bring under your notice. Here is a figure of *Stringops habroptilus*, the Owl-Parrot of New Zealand, so-called because its face with its peculiar disk causes it to present a superficial likeness to an Owl, whilst in all essential characteristics of structure it is a true Parrot. This bird was formerly very abundant in many of the wooded hills of New Zealand, but, like other members of this group, it is rapidly vanishing in presence of the new forms of enemies, such as wild dogs and cats, which civilization has carried in its train. It lives in holes under roots of trees and rocks, and is strictly nocturnal in its habits, lying concealed all day in its burrows and only coming out at night to feed. It is a vegetable feeder, subsisting on mosses, grasses, and ferns, the leaves and tender shoots of various plants and also berries. It is more or less gregarious in its habits, and in places where it was formerly abundant, well marked tracks could be seen on

the mountain sides caused by the birds in their nocturnal rambles, marching in line one after the other. Its plumage of mixed green and brown wonderfully assimilates to the vegetation amongst which it lives, so that at a little distance it is almost impossible to distinguish it. It is said to be a clever, intelligent bird, of a playful disposition, and, in captivity, to contract a strong affection to those who are kind to it. It has ample wings, but all observers testify to its complete inability to fly, at most merely using its wings to break its fall when dropping from a height to the ground, and not always even on those occasions. This inability to fly is correlated in a very interesting way with the practical loss of the carina sterni. The sternum, as is well seen in the skeleton before you, is almost flat, and probably in this respect approaches the Ratitæ more nearly than any other Carinate bird; the keel is indeed there, but it is reduced to a very low median ridge and is clearly almost obsolete. Such a case as this shows us that too much importance may easily be attached to the absence of a keel to the sternum in the Ratite birds in discussing their phylogeny. If in *Stringops*, an undoubted member of a tribe of strong flying Carinate birds, the keel of the sternum can be reduced by disuse of the wings to the low ridge seen in the specimen, it is not in the least to be wondered at that in the Ratite birds, a much more ancient type than that of the Psittaci, it should have disappeared altogether from the same cause; and hence, as before argued, the absence of a keel in the Ratite birds by no means negatives their descent from a Carinate stock. The causes which have led to the loss of the faculty of flight in *Stringops* are not difficult to trace, and run on parallel lines to the similar instance of the Dodo, but we have, in the case of *Stringops*, the great advantage of a definite knowledge of the habits of the bird.

Having become a ground feeder, a habit doubtless very gradually acquired, it began less and less to use its wings, whilst the superabundance of its food alike tended to induce indolent habits, and rendered unnecessary the use of flight to take the bird to pastures new. The conditions of existence became too easy for it, with the usual result of degeneration setting in. Under the usual conditions of life, nature would have stepped in and silently quenched the tendency towards too indolent a habit of life, by cutting off those individuals which, by showing a definite leaning thereto, rendered themselves thereby a more easy prey to the attacks of enemies. But New Zealand, as is well known, prior to the advent of the white man, possessed no predatory mammals—no mammals at all, indeed, except a rat, which was frugivorous in its habits—and consequently there were no enemies of this class to check the tendency to degeneration; whilst from diurnal birds of prey, of which indeed, New Zealand does not possess many, the nocturnal habits of *Stringops* sufficiently protected it. Hence, having no inducement to fly either to obtain food or to escape from enemies, the disuse of its wings became a permanent habit, and along with this went atrophy of the structures, which rendered flight possible. That *Stringops* was, however, well adapted to its particular environment is evidenced by its former great abundance, whilst its scarcity now is owing to a change in that environment and the complete incapacity of the poor bird to adjust itself to its new conditions. Ere long its destruction will be completely accomplished, and one of the most interesting forms of bird-life will have passed from us for ever.

This and other similar examples serve to indicate that the power of flight is no essential and necessary attribute of birds; it is a function acquired solely for the purpose of

obtaining food or for the avoidance of enemies, and as such, under the usual conditions of life, it has given its possessors an enormous advantage in the struggle for existence; but in the comparatively rare cases, where the above conditions of existence are satisfied without calling in the aid of flight, then we find this function dispensed with, as involving an expenditure of nerve force no longer required.

We need not, however, go to New Zealand for an example of a flightless bird. The domestic Duck of our farm yards furnishes us with an instance in which similar causes have produced similar results, though, of course, the favouring conditions, such as the protection from enemies, have here been artificially produced. The excess of food and the consequent increase of body weight, associated with an absence of any need for the use of the wings, have produced the same results, as we see in the birds just described, though doubtless, in the case of the Duck, a certain amount of artificial selection of the larger and heavier birds for breeding from, as being the more valuable, has operated in favour of increased weight of body. We do not, indeed, see in the domestic Duck the skeletal changes observed in *Stringops*, for instance, but this is probably mainly due to the fact that the factors have been in operation for a much shorter period of time, for, as a matter of fact, a tendency in the same direction can be traced.

Darwin, as is well known, found that the bones of the wing of the domestic Duck weigh less and the bones of the leg more, in proportion to the whole skeleton, than do the same bones in the wild Duck; but so far as I know the condition of the carina sterni in this bird has not received attention.

It occurred to me, however, that the flightless condition

to which the domestic Duck is now reduced might quite possibly have been in operation sufficiently long (though for how long we have no definite data) to have resulted in some reduction of the keel of the sternum as compared with that of the wild bird. I therefore obtained specimens of the sterna of *Anas boschas*, and of the domesticated species, and from these specimens, which I show you, both taken, I may say, from adult, full-sized birds, it seems clear that a reduction in the carina sterni of the domesticated bird is in course of progress. As domesticated Ducks vary not a little in bulk, the size of the sternum, as of other parts of the skeleton, will be liable to corresponding variations, and a considerably larger number of measurements than I have been able to make would be desirable, but the specimens before you probably represent a fair average. The sternum of the domestic Duck is, of course, larger than that of the wild bird, in harmony with the larger size of the bird itself, the specimen I have chosen measuring 10 cm. in length and 5.2 cm. in breadth, as compared with a length of 9.2 cm. and a breadth of 4.8 cm. in the specimen of the sternum of the wild bird. Other things being equal, we might expect a deeper keel to go with the larger sternum; but, as a matter of fact, I find that the reverse is the case. The carina sterni of the domestic bird is not only of less depth than that of the wild bird, but its shape is different, for, instead of describing a definite convex curve from its anterior to its posterior extremity, as that of the wild bird does, it runs from before backward as a nearly straight ridge, the curve it does describe being very slight, diminishing in depth, of course, as it proceeds backwards. At the extreme anterior ends the sternal keels of the two birds are alike in depth, measuring 2.5 cm. each, but from this point backwards the keel of the wild bird is everywhere deeper than that of

its domestic congener, the actual measurements taken at intervals of one-fourth of the length of the sterna from before backwards, being for the wild bird 2.4, 2.1, and 1.4 cm., and for the domestic bird in the corresponding positions, 2, 1.8, and 1.2 cm.

This is an interesting comparison, for assuming the domestic Duck to be descended from *Anas boschas*, it shows clearly that the keel of the sternum is undergoing atrophy in association with the loss of the faculty of flight, and we thus have a comparison between a flying bird and the same bird in a flightless condition, and are able, as it were, to see the process actually at work.

And now I must bring these somewhat fragmentary remarks to a close. I should have been glad to have dilated more fully upon certain questions, but the subject is a large one, and the time at my disposal has been short. Nor can some of the questions raised be considered finally set at rest.

We want many more observations and many more workers in the field, particularly in new countries which, on being opened out and colonized, quickly lose their special faunal characteristics, and opportunities for observation, unless promptly seized, are apt to disappear for ever. I have often thought how favourably placed many of the officers in our army and navy are, when located on foreign stations, for making observations on the fauna of their districts, and yet, with some notable exceptions, how comparatively seldom are these opportunities taken advantage of. Doubtless many men when thus circumstanced would be only too glad to occupy themselves in this way, and find therein a welcome relief from what must often be a monotonous existence; but not having had any biological training, they are ignorant of the very rudiments of the subject, and know not how to begin.

Well, these are the main objects for which this Society was founded—to foster the study of Biology, and to ever enlarge the circle of interested workers—and I think I may say that they have met with no small measure of success. Happily we have still with us the indefatigable founder of our Society, and under his fostering care, there is no reason to doubt that our success will be at least as great in the future as it has been in the past.

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L.M.B.C. MEMOIRS

No. I. ASCIDIA

[Reprinted by arrangement with L.M.B.C.]

EDITOR'S PREFACE.

THE Liverpool Marine Biology Committee was constituted in 1886, with the object of investigating the Fauna and Flora of the Irish Sea.

The dredging, trawling, and other collecting expeditions organised by the Committee have been carried on intermittently since that time, and a considerable amount of material, both published and unpublished, has been accumulated. Thirteen Annual Reports of the Committee and four volumes dealing with the "Fauna and Flora" have been issued. At an early stage of the investigations it became evident that a Biological Station or Laboratory on the sea-shore nearer the usual collecting grounds than Liverpool would be a material assistance in the work. Consequently the Committee, in 1887, established the Puffin Island Biological Station on the North Coast of Anglesey, and later on, in 1892, moved to the more commodious and convenient Station at Port Erin in the centre of the rich collecting grounds of the south end of the Isle of Man.

In our twelve years experience of a Biological Station (five years at Puffin Island and seven at Port Erin), where College students and young amateurs formed a large proportion of the workers, the want has been constantly felt of a series of detailed descriptions of the structure of certain common typical animals and plants, chosen as representatives of their groups, and dealt with by specialists. The same want has probably been felt in other similar institutions and in many College laboratories,

The objects of our Committee and of the workers at our Biological Station have hitherto been chiefly faunistic and speciographic. The work must necessarily be so at first when opening up a new district. Some of our workers have published papers on morphological points, or on embryology and observations on life-histories and habits; but the majority of the papers in our volumes on the "Fauna and Flora of Liverpool Bay" have been, as was intended from the first, occupied with the names and characteristics and distribution of the many different kinds of marine plants and animals in our district. And this faunistic work will still go on. It is far from finished, and the Committee hope in the future to add greatly to the records of the Fauna and Flora. But the papers in the present series are quite distinct from these previous publications in name, in treatment, and in purpose. They will be called the "L.M.B.C. Memoirs," each will treat of one type, and they will be issued separately as they are ready, and will be obtainable Memoir by Memoir as they appear, or later bound up in convenient volumes. It is hoped that such a series of special studies, written by those who are thoroughly familiar with the forms of which they treat, will be found of value by students of Biology in our laboratories and in Marine Stations, and will be welcomed by many others working privately at Marine Natural History.

It is proposed that the forms selected should, as far as possible, be common L.M.B.C. (Irish Sea) animals and plants, of which no adequate account already exists in any text-book. Probably most of the specialists who have taken part in the L.M.B.C. work in the past, will prepare accounts of one or more representatives of their groups. The following have already promised their services, and in some cases the Memoir is already far advanced. The

first three Memoirs will be issued before the end of 1899, and others will follow it is hoped in rapid succession.

- Memoir I. ASCIDIA, W. A. Herdman.
 II. COCKLE, J. Johnstone.
 III. ECHINUS, H. C. Chadwick.
 DENDRONOTUS, J. A. Clubb.
 ZOSTERA, R. J. Harvey Gibson.
 HALIDRYS, C. E. Jones.
 CODIUM, R. J. H. Gibson and Helen Auld.
 DIATOMS, F. E. Weiss.
 GIGARTINA, O. V. Darbishire.
 ALCYONIUM, S. J. Hickson.
 PLAICE, F. J. Cole and J. Johnstone.
 BOTRYLLOIDES, W. A. Herdman.
 CUTTLE-FISH, W. E. Hoyle.
 OSTRACOD, Andrew Scott.
 PATELLA, J. R. Ainsworth Davis.
 CALANUS, I. C. Thompson.
 ACTINIA, J. A. Clubb.
 POLYZOON, Laura R. Thornely.
 CALCAREOUS SPONGE, R. Hanitsch.
 PORPOISE, A. M. Paterson.
 ARENICOLA, J. H. Ashworth.
 OYSTER, W. A. Herdman.

Finally, I desire to acknowledge that a welcome donation of £100 from Mr. F. H. Gossage of Woolton has met the expense of preparing the plates in illustration of the first few Memoirs, and so has enabled the Committee to commence the publication of the series sooner than would otherwise have been possible.

W. A. HERDMAN.

L.M.B.C. MEMOIRS.

No. I. ASCIDIA.

BY

Professor W. A. HERDMAN, D.Sc., F.R.S.

ALTHOUGH the Ascidian has been much talked of and written about during the last quarter of a century, comparatively few people, beyond the circle of professional biologists, have an accurate idea of what the animal is like in appearance and structure, or have more than a vague notion as to what the popular impression of its relationship to higher animals is based upon.

The adult or fully-developed Ascidian is a very remarkable animal, and presents numerous interesting problems for the biologist to investigate; but its reputation is due, not to any of these, but to certain changes which the young animal undergoes in its development from the egg; changes so remarkable and interesting that when the more important of them were discovered by Kowalevsky, some thirty years ago, they gave rise to the belief that Ascidiæ were a group of animals holding a position between the Vertebrata and the Invertebrata, and indicated a possible line along which the former might have been evolved from the latter. The opinions of scientific men on this point have undergone a certain amount of modification during

late years, and Ascidians are now regarded as the degenerate descendants of a very lowly-developed group of the early Vertebrata (or more correctly, Chordata).

But before we are in a position to understand this important matter, it is well to have some knowledge of the ascidian structure at several different stages in the life-history, and we shall commence with the last stage of all—the full-grown, or adult condition.

MODE OF OCCURRENCE.

Ascidians are all marine, and they have been found in all seas, from tropical to polar regions, and at depths varying from near high-water mark down to three and a quarter miles or so. Round most of our own coasts they are common, and some kinds are familiar enough, under the name of “sea-squirts,” to many sea-side visitors, as being amongst the inhabitants of rock-pools which can be collected and kept in aquaria. Such forms are usually found as dome-shaped bodies of a dull red colour, adhering to the rock or sea-weed, and having two small openings on their upper surface from which, when touched, they emit delicate jets of sea-water with considerable force—thus establishing their claim to the title of “sea-squirts”; and their resemblance to double-necked leather bottles, whence the name Ascidian (from the Greek ἀσκήδης).

Others again form flat gelatinous expansions attached to sea-weeds or stones, and symmetrically marked with bright spots of colour in the form of circles, meandering lines, or starlike patterns. These are really colonies in which each spot of colour or ray of the star represents an ascidiozoid or member of the colony equivalent to the whole animal in the case of the solitary Ascidian.

By dredging around the coast, outside low-water mark, many other kinds of Ascidians are found, of diverse forms

and often most gorgeous colouring. One of the commonest species of our seas, *Ascidia virginea*, O. F. Müller, has the form of a short and somewhat irregular cylinder, with rounded ends, one of which is attached to a stone or dead shell, or some other object at the bottom, while the other end is directed upwards into the water, and bears two short projections, each terminated by an opening (see fig. 1, Pl. II.). This species is of a dull grey colour; it is usually found in from five to twenty fathoms of water, and is in some places so abundant that the naturalist's dredge may come up absolutely filled with it. An average size is an inch and a half in length, an inch in breadth, and half an inch in thickness; but in a dredgeful one usually finds all sizes, from a quarter of an inch to two inches in length. Our largest British species, *Ascidia mentula*, O. F. Müller (see Pl. I.), measures from three to six inches in length, and is usually found on a muddy bottom in from ten to fifty fathoms. Either of these two species of *Ascidia* will serve very well as the type of a simple ascidian, and the following description in nearly all details applies to both.

EXTERNAL APPEARANCE.

The two openings at the upper end, although they appear very similar at first sight, are really different, and can readily be distinguished with a little practice. One of them (*Br.* in fig. 1, Pl. II.), is higher, or more nearly terminal in position than the other (*At.*), which may be placed some way down one edge; the former is the Branchial, and the latter the Atrial aperture. A close examination will show that the margin of the branchial aperture is cleft into eight small projections, or lobes; while the atrial aperture is bounded by six lobes only (see also Pl. I.—as an individual peculiarity this specimen has a seventh small lobe at its atrial aperture). Conse-

quently, we can distinguish the apertures both by their position and by the number of their lobes; and this is a very important matter, since it enables us to recognise the different regions in the body of the Ascidian; and also because the exact number of lobes is a characteristic of certain families and genera of Ascidiæ, *e.g.*, *Molgula* has six branchial and four atrial lobes, while *Ascidia* has eight branchial and six atrial. Plate I. shows the exact shape of the lobes and the apertures in *Ascidia mentula*.

The branchial aperture (*Br.*) indicates the anterior end of the body, the region which corresponds to the head end of a man, a dog, or a fish; and, consequently, the opposite part, which is attached to the stone, is the posterior end. Then, the atrial aperture (*At.*) is invariably placed to the dorsal side of the branchial; hence, that side of the body near which the atrial aperture is situated corresponds to the back of the man, dog, or fish; while the opposite side is, of course, ventral.

Now that it is known which is the anterior end, and which is the dorsal surface, or back, it is easy, by placing the Ascidian alongside oneself, and comparing the parts, to determine which is the right-hand side and which is the left. In Pl. I. and in Pl. II., figs. 1 and 4, it is the right side of the specimens which is shown. The area of attachment at the posterior end frequently involves a certain amount of the left side.

THE TEST.

The outside of the Ascidian—all that is visible, unless one looks into the expanded apertures—is formed by a stout, gristly, translucent layer called the Test or Tunic (hence “Tunicata,” the name of the group), which is notable amongst animal structures for containing

“tunicine,” a substance which appears to be identical in composition, and in behaviour under various treatments, with “cellulose”—a characteristically vegetable substance, entering largely into the composition of plants. The test is a protective layer, usually about a quarter of an inch in thickness, and may be considered as an exo-skeleton. It is the only tissue of a skeletal nature which the adult Ascidian possesses.

In shape the test is an oblong sac, pierced only by the branchial and atrial apertures, and forming, at its posterior end and left side, the place of attachment by which the Ascidian adheres to the rock (Pl. II., figs. 1 and 4). At this point it may become greatly thickened and expanded to form a margin, or may even grow out in the form of a short stalk, raising the body above the surrounding surface. Stones, sea-weeds, dead shells, and remains of other animals may be overgrown by the test and incorporated in its substance; many sessile animals and various kinds of sea-weeds may become attached to its outside; and some parasitic Amphipod Crustaceans (*Tritæta gibbosa*) and Lamellibranch Molluscs (*Modiolaria marmorata*) may inhabit cavities excavated in its thickness. Microscopic parasitic Algæ may also be present amongst the cells in the interior of the test, and help in giving the animal its colour.

The test is cartilaginous in appearance and consistence, and to some extent in structure, as it consists of a clear or slightly fibrillated matrix in which are imbedded many cells. As the test is morphologically a cuticle, being at first a secretion on the outer surface of the ectoderm (Pl. II., fig. 5, *ec.*), the cells it contains have immigrated to it from the body; and it has been shown by Kowalevsky and others that many of these are mesodermal cells or wandering amoebocytes which have passed through the

ectoderm. In the test they reproduce freely and secrete large quantities of the tunicine matrix.

Many of the cells in the test remain small and simple, as the rounded, fusiform, or stellate test cells (fig. 5, *t.c.*). Some become larger, much branched, elongate into fibres, or degenerate into globular pigment cells; others may store up reserve products; while others again are converted into the large vacuolated "bladder-cells" which, in the outer part of the test of *Ascidia mentula*, form a well-marked vesicular layer (Pl. III., fig. 9, *bl.*). In this the structureless matrix contains innumerable closely packed spherical vacuoles, each with a thin peripheral film of protoplasm and a parietal nucleus. These bladder cells measure from 0.10 to 0.15 mm. in diameter. Some of them show more than one nucleus, and may be formed by the fusion of several cells. Some of them at least appear to be derived from the "testa-cells" of the embryo, and are thus descendants of cells belonging to the follicle which surrounds the ovum.

The test also becomes organised by the growth into it of the so-called "vessels." These are out-growths of the mesodermal body-wall, covered by ectoderm, and containing prolongations of blood channels from the connective tissue of the body-wall. Plate II., fig. 5, shows such an out-growth, and exhibits the general relations of test (cuticle) ectoderm, and mesoderm. It also explains how it is that the blood channel being pushed out as a loop gives rise to the double or paired vessels seen branching through the test (Pl. III., fig. 9). The two vessels of a pair are one blood channel imperfectly divided by a connective tissue septum. The blood courses out along one side, round the communication in a terminal knob at the end and back down the other side. The terminal knobs are very numerous and form a marked feature in the outer

layer of the test (fig. 9, *t.k.*); in some Ascidians they probably form an accessory organ of respiration. In the adult *Ascidia* the vessels enter the test by a double trunk ventrally, near the posterior end of the left side (see Pl. III., fig. 10).

ECTODERM AND BODY-WALL.

Inside the test, and lying between its inner surface and the muscular body-wall ("mantle"), is a very delicate membrane, formed entirely of small cubical or more flattened cells (Pl. II., fig. 5, *ec.*), with delicate "secreting processes" projecting into the test. This is the Ectoderm, the outermost complete layer of cells in the body; and the test lying over it has been produced as a sort of gelatinous exudation upon the surface of the ectodermal cells, aided by the numerous mesoderm cells which have migrated into it, and which give it the appearance of a connective tissue. Besides the ordinary epithelial cells, a few gland cells and pigment cells may be found in the ectoderm. The ectoderm is turned in for a short distance at the branchial aperture (mouth) and atrial aperture (cloacal), as a short stomodæum and proctodæum, lined in each case by a delicate prolongation of the test (Pl. II., fig. 4, *Br.* and *At.*).

Inside the ectoderm lies a thicker layer, the so-called "Mantle" or body-wall (parietal mesoderm), containing a large number of muscles, which run some along the length of the body, and others across it, so that they form a rude interlacing net-work (Pl. II., fig. 4, *m.*), which is much more strongly developed on the right than on the left side of the body. The shape of the body can be changed, to a slight extent, by means of these muscles in the body-wall. When the Ascidian is killed by re-agents it is generally found that the muscles have contracted and drawn the

mantle away from the test, so that these layers are no longer in continuity except on the branchial and atrial siphons, and at the posterior end where the vessels enter the test.

The body-wall (Pl. II., fig. 5) is largely formed of connective tissues, both homogeneous and fibrous, with cells, blood sinuses or lacunæ, nerves, and the many muscle bundles, large and small, formed of long, fusiform, non-striped fibres. The largest muscle bundles are found about the centre of the right side, where they may be 0.5 mm. in thickness. This part in the living *Ascidia* is often brilliantly pigmented—red, yellow, and opaque white—the coloured cells being exactly like those found in the blood. The connective tissue cells or corpuscles are fusiform, stellate, or amoeboid, and may become pigmented or vacuolated, like the similar cells of the test.

At the anterior end the body-wall is prolonged outwards to form the two well-marked siphons, or short wide tubes, which lead in from the branchial and atrial apertures. These are surrounded by strong sphincter muscles (Pl. II., figs. 2, 6, and 7, *sph.*). Inside the body-wall lies the large cavity called the Atrium, or the peribranchial cavity, which communicates with the exterior through the atrial aperture, and serves to convey away the water which has been used in respiration (see Pl. II., figs. 2 and 4, *p.br.*).

The ectodermal lining of the atrial or peribranchial cavity has been called by some French writers the third tunic—the first being the test and the second the mantle. The cavity of the atrium is traversed by numerous vascular strands of mesoderm, called connectives (Pl. II., fig. 2, *con.*), passing from the body-wall inwards to the branchial sac.

Figure 6 on Pl. II. shows the relations of ectoderm (with test over it), mesoderm, and endoderm in a section through

the antero-dorsal part of the body, where *t.* indicates the test, and *sph.* the sphincter of the branchial aperture. The cavity marked *p. br.* is a portion of the atrial cavity lined by ectoderm, and not to be confounded with a coelom or body-cavity. The absence of a true coelom in the mesoderm will be noticed in this and the other figures (*e.g.* fig. 4); and yet the Tunicata are Cœlomata—although it is very doubtful whether an enterocœle is ever formed, as has been described by E. van Beneden and Julin in the development of some. The primitive coelom is, however, largely suppressed during development, and is only represented in the adult by the pericardium and small cavities in the renal and reproductive organs and ducts, as will be shown further on.

CAVITIES OF THE BODY.

The following list of the cavities present in the body of the adult *Ascidia* may be useful at this point:—

1. The alimentary canal, including the branchial sac. This is derived from the archenteron of the embryo, is lined throughout by endoderm, and the system of cavities of the intestinal gland is to be regarded merely as an outgrowth from the alimentary canal.

2. The peribranchial (atrial) cavity, derived from two lateral ectodermal invaginations which join dorsally to form the cloaca and open to the exterior by the atrial aperture.

3. The original embryonic segmentation cavity (blastocœle) remains, where not obliterated by the development of the mesodermal connective tissue, as the irregular system of blood spaces, with its outgrowths in test and branchial sac. The heart is only a special part of this cavity which has differentiated muscular walls.

4. The pericardium and epicardium originate as outgrowths from the archenteron. They may therefore be regarded as cœlomic spaces. The pericardium becomes completely closed off and separated from the alimentary canal. The epicardium may form paired tubes of great length, and may remain permanently connected with the branchial sac in some Tunicata.

5. The cavities of the renal vesicles and of the gonads and ducts are spaces formed in the mesoblast. They have been variously interpreted:—

(a) As of the same nature as the blood spaces (blastocœlic), or

(b) As formed by a splitting of the mesoblast (cœlomic).

6. The cavity of the neural gland and its duct opening at the dorsal tubercle is derived from the primitive dorsal neural tube of the embryo, and so may be regarded as a part of the lumen of the cerebro-spinal nervous system.

BRANCHIAL SIPHON AND TENTACLES.

The branchial aperture opens into a large cavity, the Branchial Sac (Pl. II., fig. 4, *br.s.*), which is merely the anterior portion of the alimentary canal, corresponding to the pharynx or back of the mouth in man, enlarged and greatly modified so as to act as a breathing organ, or branchia—whence its name—in addition to performing other important functions.

The branchial aperture itself (*Br.*) is thus the mouth of the Ascidian, and the siphon is therefore the commencement of the alimentary canal. Its inner surface is lined for a short distance by a prolongation of the test, and where this stops, at about the line of junction of the ectoderm of the stomodœum with the endoderm of the mesenteron, a circle of delicate hair-like Tentacles (Pl. II.,

fig. 4, *tn.*) projects into the mouth cavity and forms a sensitive sieve or strainer, through which all the sea-water, and its contents, drawn into the branchial sac has to pass.

The tentacles are simple and tapering in *Ascidia*, but in many other Ascidiæ they are compound and may be very elaborately branched (*e.g.*, in *Cynthia* and *Molgula*). They are in many cases of different sizes arranged alternately or with some marked symmetry. In *Ascidia mentula* there are usually from 70 to nearly 100 tentacles, of which one-third, say 20 to 30, are much larger than the rest. The rule is for two, occasionally three, much smaller tentacles to be placed between each pair of larger ones visible to the eye. Fig. 7 on Pl. II. shows, what is sometimes found, three orders of tentacles placed symmetrically, the middle one of each group of three smaller ones being longer than its two neighbours. In *Ascidia virginea* also the tentacles are very numerous, nearly 100, and are of two sizes placed alternately.

Each tentacle is practically an ingrowth of the connective tissue of the body-wall, covered by the epithelial lining of the front of the alimentary canal. It has consequently a connective tissue core containing muscle fibres and nerves, and one or more blood lacunæ continuous with those of the body-wall. The delicate epithelium with which it is covered contains some simple sensory cells. These tentacles not only act mechanically in preventing large objects from entering, but are also sensitive like the lobes of the apertures, although only scattered sensory cells and no specially differentiated sense-organs are present.

Behind the tentacles lies the plain or papillated pre-branchial zone (Pl. II., fig. 7, *p.br.z.*) bounded behind by a pair of parallel and closely placed ciliated ridges with a groove between—the peripharyngeal bands (*p.p.b.*)—

which encircle the anterior end of the branchial sac. The anterior band forms a complete ciliated ring, but the posterior is interrupted in the ventral and dorsal median lines: its ends becoming continuous respectively with the marginal folds of the endostyle (ventrally), and with the front of the dorsal lamina, where before joining, they bound a narrow triangular cavity lined by ciliated epithelium, the epibranchial groove (see Pl. II., fig. 7, above *d.l.*). Behind the peribranchial bands the proper wall of the branchial sac commences.

BRANCHIAL SAC AND ATRIUM.

The wall of the branchial sac is penetrated by a large number of channels, through which blood flows. Some of these run in one direction and some in another, so as to form complicated but perfectly definite networks, which differ in their arrangement in different kinds of Ascidians. Between these blood channels there are clefts (the secondary gill-slits or "stigmata") in the wall of the branchial sac, by means of which the water from the interior passes into the large external or peribranchial cavity—the atrium.

The transverse section (Pl. II., fig. 2) shows how this atrium surrounds the branchial sac on all sides except the ventral, where the wall of the branchial sac becomes continuous with the body-wall. The right and left halves of the atrium may be called the right and left peribranchial cavities (*p.br.*). They unite along the dorsal edge to form the cloaca, and there open to the exterior. The cavity of the branchial sac communicates with the surrounding atrium by means of the stigmata, as shown on the upper half (left side) of fig. 2 (Pl. II.). The section on the right side is shown passing along a transverse vessel between two of the rows of stigmata.

If an Ascidian expanded in sea-water, in a healthy condition, be closely watched, it will soon be noticed that there is a constant stream of water pouring in through the branchial aperture, and another flowing out from the atrial (as represented in fig. 1, Pl. II.); and if some fine and insoluble coloured powder be dropped into the water near the branchial aperture, it will rapidly be drawn in with the current, and after a short time some of the powder will make its appearance in the water ejected from the atrial aperture.

Hence, it is obvious that there is a current of sea-water flowing through the body of the Ascidian. This current has four distinct uses or functions: (1) it enables the animal to breathe, by bringing in fresh supplies of oxygen; (2) in the first part of its course it carries the microscopic food particles into the Ascidian's body; (3) in the last part of its course it carries out of the body various waste materials, which must be got rid of; and (4) it ejects the mature ova and spermatozoa from the body. The course which this water-current takes is:—in through the branchial aperture to the branchial sac, then through the clefts in the wall of that organ into the surrounding atrium, and lastly out through the atrial aperture to the exterior. The direction of this current may occasionally be temporarily reversed; and, when the muscular body-wall contracts, a sudden current may be ejected through both apertures simultaneously.

All the clefts or stigmata in the wall of the branchial sac (shown in fig. 3, Pl. II.) are bounded by cells which bear a number of cilia (Pl. IV., fig. 3) projecting across the cleft. These cilia, so long as the animal is alive, are in constant motion, lashing rapidly from the branchial sac towards the atrium, so as to drive the water in the cleft outwards; and it is this constant action of these very

minute cilia which causes the regular current of water to flow in at the branchial aperture and out at the atrial.

The branchial sac is very large, much the largest organ of the body (it may be 15 cm. in length), and extends almost to the posterior end of the body, while the rest of the alimentary canal lies upon its left side imbedded in the body-wall. The food particles, consisting of very minute plants and animals, are carried in through the branchial aperture by the current of water, but most of them do not pass out into the atrium, being caught by the ciliary action of the peripharyngeal bands, and entangled in the viscid substance which fills the groove between them near the anterior end of the branchial sac. This viscid substance, or mucus, is formed in a long canal-shaped gland called the Endostyle or hypobranchial groove (Pl. II., figs. 2 and 4, *end.*), which lies along the ventral edge of the branchial sac, and terminates both anteriorly and posteriorly in a short *cul-de-sac*.

THE ENDOSTYLE.

On the floor of the endostylar groove is found a tract of cells with very long cilia (Pl. II., fig. 2). On each side are at least two (in some Ascidians three) laterally placed clumps of gland cells (Pl. IV., fig. 5), each clump separated from its neighbours by an area of closely packed fusiform cells with short cilia, amongst which are found some sensory bipolar cells. The lips of the endostyle are formed of ciliated cubical epithelium.

This organ, on account of its thick glandular walls, has an opaque appearance, and seems, in side view, to run like a conspicuous solid rod in the more transparent walls of the branchial sac—hence its name endostyle. It is, however, really a gland, and corresponds to the hypopharyngeal groove of *Amphioxus* and the median part of

the thyroid gland of Vertebrata. It is interesting to notice that the four (at least) longitudinal tracts of gland cells are of remarkable constancy, being found not only in all groups of Tunicata (often six tracts) including even the pelagic, tailed, Appendicularians, but also in *Amphioxus* and in the young thyroid gland of the Ammocoete.

The posterior *cul-de-sac* of the endostyle is quite short in *Ascidia*, but in some other Tunicata it is longer and becomes of great importance as an organ for the production of buds. Behind the *cul-de-sac* the marginal folds of the endostyle unite to form a slight ridge, the posterior fold, which runs round the posterior end of the branchial sac to join the end of the dorsal lamina behind the œsophageal opening. The endostyle, in addition to its glandular function, shares in the sensory functions of the peripharyngeal band, the tentacles, and the dorsal tubercle, in all of which similar sensory cells and nerve endings have been found.

DORSAL LAMINA.

The mucus formed by the glands in the lateral walls of the endostyle is carried forwards by the lashing action of the long cilia placed on the floor of the organ, and so reaches the front of the branchial sac; here it changes its direction of flow, and bends round to the right and left, in the groove between the peripharyngeal bands, so as to gain the dorsal edge of the sac, where it encounters a projecting membranous fold, the dorsal lamina or epi-branchial ridge, along which it is carried backwards—still by ciliary action—to the opening of the œsophagus, the next region of the alimentary canal after the pharynx. The food particles become entangled in this train of mucus chiefly in its course round the right and left sides of the anterior end of the sac, and from this point are carried

back along the right side of the dorsal lamina to the œsophagus.

The dorsal lamina is at its widest round the œsophageal aperture (Pl. II., fig. 4, *oes.*). It is more or less ridged transversely, especially on its convex left side, and may have marginal tags or teeth (Pl. IV., fig. 4), which in some Ascidians become long processes, the languets. In the living animal, the lamina has its free edge curved to the right hand side in such a manner as to constitute a fairly perfect tube along which the train of food passes.

WALL OF BRANCHIAL SAC.

Fig. 3, Pl. II. shows a small part of the wall of the branchial sac of *Ascidia* in which it may be seen that the bars containing the blood channels are arranged in three regular series:—

(1) The “transverse vessels” (*tr.*) which run horizontally round the wall and open at their dorsal and ventral ends into large median longitudinally running tubes, the dorsal blood sinus behind the dorsal lamina and the ventral blood sinus below the endostyle (see also Pl. III., fig. 10).

(2) The fine longitudinal or “interstigmatic vessels” (*l.v.*) which run vertically between adjacent transverse vessels and open into them, and which therefore bound the stigmata.

(3) The “internal longitudinal bars” (*i.l.*) which run vertically in a plane internal to that of the transverse and fine longitudinal vessels. These bars (see Pl. II., fig. 3, *B.*) communicate with the transverse vessels by short side branches (*c.d.*) where they cross, and at these points are prolonged into the cavity of the sac in the form of hollow papillæ (*p.*).

In some Ascidians (*e.g.* *Corella parallelogramma* and most of the Molgulidæ) the interstigmatic vessels are curved

so that the stigmata form more or less complete spirals. In some species of *Ascidia*, and other Ascidiæ, the interstigmatic vessels are inserted into the transverse ones in undulating in place of straight lines, the result being that the stigmatic part of the wall of the branchial sac seems to be folded or thrown into microscopic crests and troughs. This device for increasing the surface is known as "minute plication," and is seen well in *Ascidia mentula* (Pl. IV., figs. 1 and 2). In some cases, again (Cynthiidæ), the whole wall of the sac is pushed inwards at intervals to form large folds visible to the eye.

The intersections of the internal longitudinal bars with the transverse vessels divide up the inner surface of the branchial sac into rectangular areas called "meshes" (Pl. IV., fig. 2). One such mesh, containing eight stigmata in a row, is seen in fig. 3, Pl. II. The internal longitudinal bars bear hollow papillæ at the angles of the meshes, and occasionally in intermediate positions. There are frequently horizontal membranes (fig. 3, B. *h.m.*) attached to the transverse vessels between the papillæ, and the transverse vessels may be of two or more sizes arranged symmetrically. There are many "connectives" running from the outer wall of the branchial sac to the body-wall, and allowing the blood in the transverse vessels to communicate with that in the sinuses outside (Pl. II., fig. 2, *con.*).

In an adult medium-sized *Ascidia mentula* there are about 150 transverse vessels on each side of the branchial sac, and at least 80 internal longitudinal bars, making by their intersection 12,000 meshes. The average number of stigmata in a mesh is, in this species, six to eight. So there may be as many as 96,000 stigmata present on each side of the sac, nearly 200,000 in all. Probably these numbers are greatly exceeded in large specimens, such as that shown on Pl. I. These stigmata are to be regarded as

secondary openings due to the breaking up or subdivision of the primary Chordate gill-clefts.

In addition to the stigmata there are generally one or two pairs of much larger (up to 15 mm. in length), narrow, elongated slits placed near the posterior end of the sac and close to the dorsal lamina, so as to be underneath the atrial aperture, by which water can escape into the cloacal part of the peribranchial cavity. These pharyngo-cloacal slits have well-marked edges which bear much finer cilia than those of the stigmata.

The lining of the branchial sac is the pharyngeal epithelium (endoderm) while the outer surface is covered by the lining membrane of the peribranchial cavity in free communication with the outer surface of the body through the atrial aperture (see Pl. II., fig. 2). Both of these epithelial surfaces are formed of squamous cells. Round the sides of the stigmata (Pl. IV., fig. 3) the cells on the longitudinal vessels become more nearly cubical in shape and bear the cilia, while at the ends of the stigmata, near the transverse vessels, the cells approach a columnar form (Pl. IV., fig. 3). The epithelium along the internal edge of the longitudinal bars, and on the apices of the papillæ, is also cubical or almost columnar in form.

Between the outer and the inner epithelium the wall of the branchial sac is formed of connective tissue in which the blood lacunæ, known as "vessels," are excavated. These vessels are very regular in size and arrangement, and are so large that comparatively little connective tissue is left, and so the blood is in close proximity with the epithelial surface. In some branchial sacs a few non-striped muscle fibres are found running longitudinally in the connective tissue around the chief vessels (see Pl. IV., fig. 1).

ALIMENTARY CANAL.

The œsophagus is a short, narrow, curved tube which leads ventrally to the stomach—a large, thick-walled organ, lying on the left-hand side of the branchial sac, imbedded in the body-wall and projecting into the atrium, (as shown in fig. 4, Pl. II.). From the other (ventral) end of the fusiform smooth-walled stomach arises the intestine, a long serpentine tube which ends by opening into the dorsal or cloacal part of the atrium, from which the undigested portions of the food are carried to the exterior through the atrial aperture, by the water current.

The intestine is curved so as to form two loops (Pl. II., fig. 4), a first between the stomach and intestine, open posteriorly, and in which the ovary lies; and a second between the intestine and rectum, open anteriorly, and in which the renal vesicles lie. The external convex edge of the intestine is thickened internally to form the “typhlosole,” a large pad which runs along its entire length (Pl. II., figs. 2 and 4, *ty.*), reducing the lumen to a crescentic slit.

The walls of the stomach are glandular; and, in addition, a system of delicate hyaline microscopic branched tubules with dilated ends (the “refringent organ”), which ramifies over the outer wall of the intestine and communicates with the cavity of the stomach at the pyloric end by means of a duct, is possibly a digestive gland. There is in *Ascidia* no separate large gland to which the name “liver” can be applied as in some other Tunicata (*e.g.*, *Molgula*). Over these viscera, on the left side of the body, the body-wall is thin and gelatinous, and has usually no muscle fibres visible.

The wall of the alimentary canal, throughout its length, consists of an epithelial lining (endoderm), a thick layer of highly vascular connective tissue, and, over that, the flattened epithelium lining the peribranchial cavity. The

only notable regional differences lie in the epithelium. The connective tissue is much the same throughout, and is continuous with that of the body-wall in which the digestive viscera are imbedded. The blood lacunæ are very numerous and communicate on the one hand with the cardio-visceral, and on the other hand with the branchio-visceral main blood vessels.

The connective tissue is also penetrated by (*a*) the cæca of the gonads, especially the spermatic tubules, and (*b*) the delicate branched clear tubules of the enigmatical refringent organ or pyloric gland (Pl. IV., fig. 7). The tubules of this organ are lined by low cubical cells, usually non-ciliated, containing no concretions or granules, and having no great resemblance to gland cells. They have been called "chylific" and absorptive, but the function is still undetermined. There are few, if any, muscle fibres in the connective tissue of the alimentary canal until the rectum is reached.

The lining epithelium is for the most part ciliated, especially in the œsophagus and intestine. The œsophagus has slight longitudinal ridges and grooves, one of which seems to continue the canal of the dorsal lamina onwards to the stomach, while another is in relation with the posterior fold coming from the lower end of the endostyle. There are a few glandular (mucous) cells scattered amongst the ciliated columnar cells of the œsophageal wall.

The stomach has projecting folds in its interior which unite at its pyloric end to form the intestinal typhlosole, and, in addition to some ciliated and mucous cells, it has large masses of highly coloured markedly glandular cells packed with yellow granules. The intestine, again, has ciliated and gland cells, and in the rectum the gland cells become fewer and die out. The termination of the

rectum, close to the atrial aperture, is very thin-walled, with a slight thickened edge at the anus, but no sphincter.

HEART AND CIRCULATION.

The soluble product of the food which has been digested passes through the wall of the alimentary canal, and enters the numerous small blood spaces in the connective tissue on both sides of the stomach and intestine. These lead, by the cardio-visceral vessels, to the dorsal end of the heart (see Pl. III., fig. 10), which is merely a delicate tube, irregularly swollen in the middle, placed behind the stomach, and projecting into a space, the pericardium (Pl. IV., fig. 9, *p.c.*), which is a part of the original cœlom.

The wall of the heart is continuous along one edge (that next the stomach) with that of the pericardium, and the heart is to be regarded as a tubular invagination of the pericardial wall (see Pl. IV., fig. 10), shutting in a portion of the external space (the blastocœle of the embryo) and having open ends which communicate with the large blood sinuses leading to the branchial sac, to the viscera, and to the body-wall and test. The cavity of the heart is not divided and has no valves. Its wall is formed of a single layer of epithelio-muscular cells, the inner (muscular) ends of which are cross-striated fibres running round the heart—the only striated muscle found in the body of the Ascidian. The larger channels through which the blood flows are lined by a delicate endothelium, the smaller are merely spaces in the connective tissue. All the blood spaces and lacunæ are probably derived, like the cavity of the heart, from the blastocœle of the embryo, and are not (like the pericardium) a derivative of the cœlom. The wall of the pericardium is simple squamous epithelium.

From the ventral end of the heart the blood is conveyed by the branchio-cardiac vessel and the great ventral vessel

lying underneath the endostyle (Pl. III., fig. 10, *br. ao.*) to the walls of the branchial sac, where, in passing along the transverse and interstigmatic vessels, it is purified, and receives a supply of oxygen from the water passing through the stigmata. It is then conveyed, by the great dorsal vessel and the branchio-visceral vessel and its branches, to different parts of the viscera and body-wall, so that all the organs may receive food and oxygen, and have their waste materials carried away. Some of these branchio-visceral vessels from the branchial sac lead to the walls of the stomach and intestine (see Pl. III., fig. 10), and thus bring us back to the point from which we started.

The great dorsal and ventral vessels of the branchial sac are connected (Pl. III., fig. 10), not only by the transverse vessels, which run like hoops round the walls, but also at their anterior extremities, by a circular vessel which surrounds the front of the branchial sac, underneath the peripharyngeal bands. A short branch runs from near the front of the dorsal vessel to the sinuses which surround the nerve ganglion.

From each end of the heart "vessels" are also given off to supply the body-wall and test. Moreover, "connectives" run from the transverse vessels of the branchial sac directly outwards, on each side, to the body-wall and viscera. On the left side there are three especially large blood tubes amongst the connectives, which cross to the alimentary canal and ovary, and branch through these viscera.

But the course of this circulation of the blood is not always the same; sometimes it is exactly reversed, the blood flowing from the branchial sac to the heart, and from that organ to the viscera, and then back to the branchial sac again. This curious state of affairs is caused by the remarkable manner in which the Ascidian heart

beats. If a young individual of a small transparent species, such as *Ascidia virginea*, be placed alive, left-side uppermost, in a watch-glass of sea-water, and examined with a low power of the microscope, the heart will be readily seen near the posterior end of the transparent body. It will then be noticed that the "beating" looks like successive waves of blood, which are pressed through the tubular heart from one end to the other by the contractions of the muscle fibres. After watching the waves passing, let us suppose, from the dorsal end of the heart to the ventral, for about a minute and-a-half or two minutes, it will be seen that they gradually become slower and then stop altogether. But now, after several seconds, a faint wave will start from the *ventral* end of the heart and pass over it to the dorsal; and this will be followed by larger ones for perhaps a minute or two, and then again a pause will occur and the direction change. So that we may say, the heart of the Ascidian beats first in one direction and then in the other; and the reversal of the blood current takes place every minute or two. There are generally rather more beats in the dorso-ventral than in the opposite direction, but there is considerable irregularity. The numbers are usually between 60 and 80.

The cause of this remarkable reversal may possibly be that the heart being on the ventral vessel, which is wider than the corresponding dorsal trunk, it pumps the blood into either the lacunæ of the branchial sac or those of the viscera in greater volume than can possibly get out through the smaller branchio-visceral vessel in the same time, the result being that the lacunæ in question will soon become engorged, and by back pressure cause the stoppage, and then reversal of the beat. The absence of any valves in the heart to regulate the direction of flow obviously facilitates this alternation of the current.

When the heart is contracting ventro-dorsally it receives oxygenated blood from the branchial sac by the branchio-cardiac vessel (now a vein), and propels it by the cardio-visceral trunk (now an artery) to both sides of the viscera and body-wall. This blood, after circulating through the system, is collected as impure blood by the branchio-visceral vessel and conveyed to the dorsal sinus of the branchial sac to be re-oxygenated. The heart is then a systemic heart and contains pure blood. But after the reversal, when the heart contracts dorso-ventrally the veins and arteries exchange functions, the oxygenated blood passes from the branchial sac to the viscera, the heart receives impure blood from the system and propels it to the ventral edge of the branchial sac, and so what was a minute before a "systemic," is now a "respiratory" heart. This is a phenomenon without parallel in the animal kingdom.

The blood of Ascidians is in the main transparent, but contains usually certain pigmented corpuscles in addition to many ordinary leucocytes or colourless amoeboid nucleated cells (Pl. IV., fig. 6). The pigment in the coloured cells may be red, yellow, brown, or in some cases blue or opaque white, and these are the result of deposition of pigment granules in the older leucocytes. In *Ascidia mentula* a large number of blood corpuscles are usually brown. The unaltered leucocytes may be actively amoeboid, and can proliferate. As we have seen, the blood may reach the branchial sac either from the dorsal or from the ventral median sinus, according to the direction in which the heart is beating at the moment; and it is a most interesting and beautiful sight to watch the alternating circulation of the variously coloured corpuscles through the transparent vessels, and the lashing of the cilia along the edges of the

neighbouring stigmata, as shown in a small Ascidian under the microscope.

NERVOUS SYSTEM AND SENSE ORGANS.

The nervous system of the Ascidian consists of a single elongated Ganglion or "brain," placed near the front end of the body, in the dorsal median line, between the branchial and atrial apertures (Pl. II., fig. 4, *n.g.*) It gives off several large nerves at each end, which break up into the fibres that go to the different parts of the body, and especially to the lobes and the muscles surrounding the branchial and atrial apertures (Pl. II., fig. 6). In *Ascidia mentula* there are four chief nerves from the anterior end of the ganglion, one to the surface of the body and the other three to the branchial siphon; while three nerves run from the posterior end to the atrial aperture and wall of cloaca. There are also one or two smaller lateral nerves that leave the sides of the ganglion.

This ganglion is the degenerate remains of the anterior part of the cerebro-spinal nervous system of the tailed larval Ascidian. The posterior or spinal part has almost entirely disappeared in most adult Tunicata; but its remains may be traced in a tract of degenerate nerve tissue (the dorsal nerve cord) which runs posteriorly from the ganglion (Pl. II., fig. 6, *d.n.*) above the base of the dorsal lamina towards the viscera. The ganglion has small rounded nerve cells on its surface, while the centre is a mass of interlacing nerve fibres. Small cells are also found scattered along the course of the dorsal nerve cord. The nerve cells in *Ascidia mentula* are mostly pyriform or triangular in form, and are bi-polar or multi-polar, and finely granular.

The Ascidian has little papillæ containing sensory cells in its ectoderm, especially round the apertures, and has

isolated sense-cells and nerve-endings in various parts of its internal epithelium; but is very badly provided with more definite "sense organs." It has no true eyes—for the little brightly-coloured dots or "ocelli" placed along the margins of the apertures (Pl. I.), and formed of a group of modified ectoderm cells, supplied by a nerve and imbedded in a mass of red and yellow pigment (Pl. IV., fig. 8), can scarcely be called such; and it certainly has no ears or otocysts. The tentacles are not very efficient tactile organs, and the thin expanded margins of the branchial and atrial siphons are apparently the most sensitive parts of the body.

But there is a curiously-curved projection, the Dorsal Tubercle (Pl. II., fig. 7, *d.t.*), placed at the front of the dorsal lamina, in the prebranchial zone, near the entrance to the branchial sac, which may possibly be an organ for testing, by smell or taste, the quality of the water drawn in through the branchial aperture. This organ has a narrow slit which leads by means of a ciliated funnel into a delicate non-ciliated tube, and this can be traced back for a distance of several centimetres to a glandular mass, the neural gland, formed of tubules lined by small cubical cells, lying imbedded in the connective tissue immediately underneath the brain (see *n. gl.*, fig. 6, Pl. II.).

Hence, it has been suggested that the supposed olfactory organ is merely the complicated opening of the duct from the neural gland, and that this gland probably corresponds to the hypophysis cerebri or pituitary body, which is found in all Vertebrata, from fishes up to man, attached to the infundibulum on the lower surface of the brain. It is probable that both views are partly right, and that therefore the duct of the pituitary gland in the Ascidian, opens into a sense organ placed on the roof of the mouth.

Sensory cells have been found amongst the ciliated

epithelium of the dorsal tubercle, as well as in the tentacles, the peripharyngeal bands, the endostyle, and neighbouring parts.

As to the function of the neural gland—apart from the dorsal tubercle—it is still somewhat mysterious. It may be merely to secrete viscid matter which is poured like that from the endostyle into the peripharyngeal groove, or it may possibly be that the function is renal—for the removal of nitrogenous waste matters in the neighbourhood of the nervous system.

RENAL ORGAN.

A mass of large clear-walled vesicles, which occupies the rectal loop and the adjacent walls of the intestine, and may extend over the whole left side, is undoubtedly a renal organ without a duct. Each vesicle (Pl. IV., fig. 11) is apparently a little closed sack formed of modified mesoblast cells which eliminate nitrogenous waste matters from the blood in the neighbouring lacunæ and deposit them in the cavity, where they form one or more constantly increasing concentrically laminated concretions of a yellowish or brown colour, sometimes coated with a chalky deposit. These concretions (Pl. IV., fig. 14) contain uric acid, and in a large Ascidian are very numerous and of considerable size. The nitrogenous waste products are thus deposited and stored up throughout life in the renal vesicles in place of being excreted from the body.

The cells forming the walls of the renal vesicles have a curiously wavy outline (Pl. IV., figs. 11, 12, and 13), which gives them a characteristic appearance. The contents of these cells seem to differ considerably (Pl. IV., fig. 13) in different cases, probably as a result of their functional activity.

REPRODUCTIVE ORGANS.

Ascidians are not divided into two sexes, and consequently each individual is hermaphrodite, or possesses both male and female reproductive organs (gonads), although cross-fertilization is probably the rule as a protogynous condition is very general—the female organs maturing before the male. In *Ascidia mentula*, however, self-fertilization does sometimes take place. The gonads in *Ascidia* lie close together on the left side of the body, alongside the stomach and intestine (Pl. II., fig. 4, *gon.*), and are provided with delicate ducts (*gd.*), which open like the intestine into the atrium; so that the mature ova and spermatozoa are carried out of the Ascidian's body by the current of water flowing from the atrial aperture. In many Ascidians fertilisation and development take place in the atrium, a part of which may be set aside as an incubatory pouch. In some Ascidians (certain Molgulidæ and Cynthiidæ) reproductive organs are present on both sides of the body, and in others (*Polycarpa*) there are many complete sets of both male and female systems attached to the inner surface of the body-wall, on both sides, and projecting into the peribranchial cavity.

The ovary in *Ascidia mentula* is a slightly ramified gland which occupies the greater part of the intestinal loop (Pl. II., fig. 4, *gon.*). It contains a cavity which, along with the cavities of the testis, is derived from an embryonic mesodermal space which has been compared with a cœlom but may be merely blastocœlic, and the ova are formed on its walls and fall when mature into this cavity. The oviduct is directly continuous with the cavity of the ovary, and leads forward alongside the rectum, and external to the vas deferens to open into the atrium.

The testis is composed of a great number of delicate branched white tubules, which ramify over the much

coarser tubules of the ovary and the adjacent parts of the intestinal wall. These spermatid tubules terminate in ovate swellings, usually grouped in bunches (Pl. IV., fig. 15). Near the commencement of the rectum the larger tubules unite to form the vas deferens, a tube of considerable size which runs forward alongside the rectum, and, like the oviduct, terminates by opening into the peribranchial cavity close to the anus. The lumen of the tubules of the testis, like the cavity of the ovary, is a mesoblastic space in the embryo, and the spermatozoa are formed from the cells lining the wall, and are set free into the cavity.

The mature ovum is of small size (about 0.12 mm. in diam.), colourless, and with little or no food yolk in the case of *Ascidia*. It is only some of the germinal cells in the ovary that are destined to become ova. Of the rest, some form a protecting layer, the follicle, around the young ova. Certain of these primary follicle cells migrate inwards and give rise, by proliferation, to a layer of cells in the superficial part of the ovum (Pl. V., fig. 1, *t.c.*). These are the so-called "testa-cells" or kalymmocytes. These later on produce a thin gelatinous layer over the surface of the ovum and between it and the follicle, which looks like the beginning of the test—hence the name given to the cells, which, although so different in origin from the mesodermal test cells of the adult, probably to some extent give rise to "bladder cells" in the test. The rest of the follicular "testa-cells" eventually disappear.

The follicle cells proper produce two layers, the outer of which remains in the wall of the ovary when the ovum is set free; while the inner layer adheres to the surface (Pl. V., fig. 1, *fol.*), and its cells become large and much vacuolated, some of them growing out to form long papillæ, which help to sustain the floating egg in the sea-water.

Altogether there may be as many as seven distinct layers around the mature egg, but they are all produced by the differentiation or activity of the follicle cells.

Polar bodies are formed from the maturing ovum in the usual manner, and effect the usual reduction in the number of chromosomes in the nucleus. In the common *Styelopsis grossularia* there are two chromosomes left in the ovum, while in some species of *Ascidia* there are eight.

The spermatozoa of *Ascidia* are of typical form (see Pl. V., fig. 1, s.).

EMBRYOLOGY AND LIFE-HISTORY.

The egg (Pl. V., fig. 1) after being fertilised (probably in most cases by a spermatozoon carried by the current of water from *another* Ascidian somewhere in the neighbourhood), proceeds to segment or divide into a number of small pieces or young cells, thus becoming an embryo Ascidian (Pl. V., fig. 2, &c.). The cells of the embryonic body gradually come to be arranged (in a manner the details of which will be described below) so as to form—(1) a skin or layer of cells—the ectoderm of the adult—covering the outside; (2) a tubular nervous system running along the middle of the dorsal surface, underneath the ectoderm; (3) a short wide tube, placed ventrally, which is the beginning of the branchial sac and the remainder of the alimentary canal; and (4) a cellular rod—the notochord—which lies in the posterior part of the body, between the dorsal nerve tube and the ventral alimentary canal, and is a rudimentary or very simple back-bone, similar to that found in the embryos of vertebrate animals (fig. 6, Pl. V.). In fact, the embryo Ascidian at this stage is comparable with an embryo fish or frog, and is found to have the same chief organs or parts similarly arranged; and, moreover,

these parts have been formed in essentially the same manner in both cases; so that if similarity in structure and development indicate relationship, it is evident that the young Ascidian is related to the fish and the frog and other Vertebrata, and is to be regarded as one of the Chordata (animals which at some time of their life have a notochord).

Turning now to the details of the development,* the segmentation is complete, and bilateral, and nearly equal, and results in the formation of a spherical blastula with a small segmentation cavity (Pl. V., fig. 2).

The blastula then grows larger and begins to differentiate. There are slightly smaller cells which divide more rapidly at one end of this embryo, the future ectoderm, and slightly larger and more granular cells at the other, which become chiefly endoderm (hypoblast). Invagination of the larger cells then takes place (fig. 3), resulting in the formation of a gastrula with an archenteron. The hypoblast cells lining the archenteron become columnar (*hy.*). The curving and more rapid growth at the anterior end of the embryo narrow the primitively wide open blastopore, and carry it to the posterior end of the future dorsal surface (Pl. V., fig. 4, *b.p.*). The directions of the body are now clear. The embryo is elongated antero-posteriorly, the dorsal surface is flattened and the blastopore indicates its posterior end. Around the blastopore certain of the ectoderm cells form a medullary plate along which a groove (the medullary groove) runs forwards, bounded at the sides by laminæ dorsales which meet behind the blastopore. Underneath the posterior part of the medullary groove certain of the hypoblast cells from the dorsal wall of the archenteron in the median line form a band

* The early stages of *Ciona*, of which Castle has given a very complete account, differ in some points from those of *Ascidia* described here.

extending forward (fig. 4, *ch.*). This band separates off from the hypoblast, which closes in beneath it, and thus the notochord is formed (fig. 5, *ch.*). The same cells further laterally and posteriorly become mesoblast, and separate off as lateral plates which show no trace of metameric segmentation (fig. 7a, *m.b.*). The remainder of the archenteron will become the branchial sac, and by further growth bud off the rest of the alimentary canal.

The medullary groove now becomes converted into the closed neural canal by the growing up and arching inwards (fig. 7a, *n.c.*) of the laminae dorsales, which unite with one another from behind forwards in such a way that the blastopore now opens from the enteron into the floor of the neural canal, forming the neurenteric passage (fig. 5, *n.e.c.*). For a time the anterior end of the neural canal remains open as a neuropore. The posterior end of the body is now elongating to form a tail, and the embryo is rapidly acquiring the tadpole shape (fig. 6) characteristic of the free larva.

The tail grows rapidly, curves round the body, and also undergoes torsion so that its dorsal surface comes to lie on the left side. It contains ectoderm cells on its surface, notochordal cells (in single file) up the centre (see fig. 7, *n.ch.*), a neural canal dorsally, and a row of endoderm cells (*hy.*) representing the enteron ventrally to the notochord. Later on the mesoblast also is prolonged into the tail where it forms a band of striated muscle-cells at each side of the notochord. When the ectoderm cells begin to secrete the cuticular test it forms two delicate transparent longitudinal (dorsal and ventral) fins in the tail (fig. 7), and especially at its extremity where radial thickenings form striæ resembling fin rays. The ectoderm on the anterior end of the body grows out into three adhering papillæ (figs. 8 and 9).

The neural canal now differentiates into a tubular dorsal nervous system. The anterior end dilates to form the thin-walled cerebral vesicle (figs. 8 and 9, *n.v.*), containing later the intra-cerebral, dorsal, pigmented eye (*oc.*) and the ventral otolith (*au.*) of the larva. The next part of the canal thickens to form the trunk ganglion, and behind that is the more slender spinal cord (*n.c.*), which runs to the extremity of the tail. A ciliated diverticulum of the anterior end of the enteric cavity (future pharynx), which enters into close relations with the front of the cerebral vesicle, and later opens into the ectodermic invagination which forms the mouth at that spot, is evidently the rudiment of the neural or hypophysial gland and canal.

The future branchial sac (fig. 9, *mes.*), with a ventral median thickening which will be the endostyle, is by this time clearly distinguishable, by its large size, from the much narrower posterior part of the enteron which grows out to become the œsophagus, stomach, and intestine.

The notochord does not extend forward into the branchial region, but is confined to the posterior or caudal part of the embryo. It now shows lenticular pieces of a gelatinous intercellular substance secreted by the cells and lying between them (fig. 8). The mouth forms as a stomodæum or ectodermal invagination anterodorsally, in the region where the neuropore had closed up; and, about the same time, two lateral ectodermal involutions appear (fig. 9, *at.*) which become the atrial or peribranchial pouches, at first distinct, afterwards united in the mid-dorsal line to form the adult cloaca and atrial aperture.

In-growths from the atrial pouches and out-growths from the wall of the pharynx coalesce to form the proto-stigmata (primary gill slits) by which the cavity of the branchial sac is first placed in communication with the

exterior through the atrial apertures. Opinions differ as to whether only one or a few pairs of true gill clefts are represented in the young Ascidian, and the actual details of their formation and sub-division differ greatly in different forms. To what precise extent the walls of the atrial or peribranchial cavities are formed of ectoderm or endoderm, is also still doubtful.

The embryo is hatched, about two or three days after fertilisation, as a larva or Ascidian tadpole (fig. 9) which leads a free-swimming existence for a short time during which it develops its nervous system and cerebral sense organs, and the powerful mesoblastic muscle bands lying at the sides of the notochord (now a cylindrical rod of gelatinous nature surrounded by the remains of the original cells) in the tail, and forming the locomotory apparatus. Figure 9 shows this stage, the highest in its chordate organisation, when the larva swims actively through the sea by vibrating its long tail provided with dorsal and ventral fins.

In addition to the structures already mentioned, the mesoderm has formed the beginning of the muscular body-wall and the connective tissue around the organs, and has given rise to the blood, the endostyle has developed as a thick-walled groove along the ventral edge of the pharynx, which now becomes the branchial sac, and the pericardial sac and its invagination the heart have formed in the mesoblast between the endostyle and stomach. The unpaired optic organ in the cerebral vesicle, when fully formed, has a retina, pigment layer, lens and cornea; while the ventral median sense-organ is a large spherical, partially pigmented otolith, supported by delicate hair-like processes on the summit of a hollow "crista acustica" (fig. 9). Both the otolith and the retina and lens of the eye are formed originally by the differentiation of a group of cells

in the epithelium lining the cerebral vesicle—they are myelonic sense-organs.

After a few hours, or at most a day or so, the larva attaches itself by one or more of the three anterior ectodermal glandular papillæ (one dorsal and two lateral) to some foreign body, and commences the retrogressive metamorphosis which leads to the adult state. The adhering papillæ having performed their function begin to atrophy, and their place is taken by the rapidly increasing test. The tail, which at first vibrates rapidly, is partly withdrawn from the test and absorbed and partly cast off in shreds (figs. 10 to 12). The notochord, nerve tube, muscles, &c., are withdrawn into the body, where they break down and are absorbed by phagocytes, or dissolved in the fluid of the body-cavity. The posterior part of the nerve tube and its anterior vesicle with the large sense organs disappear, and the middle part undergoes proliferation dorsally to form the relatively small ganglion of the adult, underneath which the neural tube gives rise to the hypophysial gland. While the locomotory, nervous, and sensory organs are thus disappearing or being reduced, the alimentary canal and reproductive viscera are growing larger. The branchial sac enlarges, its walls become penetrated by blood channels and grow out to form bars and papillæ, and the number of openings greatly increases by the primary gill slits becoming broken up into the transverse rows of stigmata.

The stomach and intestine, which developed as an out-growth from the back of the branchial sac at the dorsal edge, become longer and curve so that the end of the intestine acquires an opening into at first the left-hand side, and eventually the cloacal or median part of the atrial cavity. The adhering papillæ have now disappeared, and are replaced functionally by a growth of the test over

neighbouring objects; and, at the same time, the region of the body between the point of fixation and the mouth (branchial aperture) increases rapidly in extent so as to cause the body of the Ascidian to rotate through about 180° , and so carry the branchial siphon to the opposite end from the area of attachment (see figs. 10, 11, 12, and 13 on Pl. V.).

Finally, the gonads and their ducts form in the mesoderm between stomach and intestine, and so bring us to the sedentary degenerate fixed adult Ascidian with little or no trace of the Chordate characteristics so marked in the earlier larval stage (compare figs. 13 and 9). The free-swimming tailed larva shows the Ascidian at the highest level of its organisation, and is the stage that indicates the genetic relationship of the Tunicata with the Vertebrata. In some Ascidians with more food-yolk in the egg, or in which the development takes place within the body of the parent, the life-history as given above is more or less modified and abbreviated, and in some few forms the tailed larval stage is missing.

The remarkable life-history of the typical Ascidian, of which the outlines are given above, is of importance from two points of view:—

1st. It is an excellent example of degeneration. The free-swimming larva is a more highly developed animal than the adult Ascidian. The larva is, as we have seen, comparable with a larval fish or a young tadpole, and so is a chordate animal showing evident relationship to the Vertebrata; while the adult is in its structure non-chordate, and may be regarded as being *on a level* with some of the worms, or with the lower Mollusca, in its organisation—although of an entirely different type.

2nd. It shows us the true position of the Ascidiæ (Tunicata) in the animal series. If we knew only the adult forms we might regard them as being an aberrant group of the Vermes, or possibly as occupying a position between worms and the lower Mollusca, or we might place them as an independent group; but we should certainly have to class them as Invertebrate animals. But when we know the whole life-history, and consider it in the light of "recapitulation" and "evolutionary" views, we recognise that the Ascidiæ are evidently related to the Vertebrata, and were at one time free-swimming Chordata occupying a position somewhere below the lowest Fishes.

N.B.—In an account of this nature, in which I have obviously made the fullest use of the published works of my predecessors, I have not considered it necessary to burden the text with frequent references to original memoirs. While accepting, then, full responsibility for my statements—nearly all of which I have taken occasion to verify by personal observation—I do not, of course, claim any originality in regard to them. Several excellent bibliographies of the Tunicata have already been published: another seems superfluous.

APPENDIX.

It may be useful to add here a brief statement of the classification and characters of the TUNICATA, in order to indicate the position of *Ascidia* as a type of the group, and its relations to the other British Ascidiæ.*

TUNICATA.

The Tunicata (or Urochorda) are hermaphrodite marine chordate animals, which show in their development the essential vertebrate characters, but in which the notochord is restricted to the posterior part of the body, and is in most cases present only during the free-swimming larval stage. The adult animals are usually sessile and degenerate, and may be either solitary or colonies, fixed or free. The nervous system is in the larva of the elongated, tubular, dorsal vertebrate type, but in most cases degenerates in the adult to form a small ganglion placed above the pharynx. The body is completely covered with a thick cuticular test ("tunic"), which contains a substance similar to cellulose. The alimentary canal has a greatly enlarged respiratory pharynx (the branchial sac), which is perforated by two, or many, more or less modified gill slits, opening into a peribranchial or atrial cavity, which communicates with the exterior by a single dorsal exhalent aperture, rarely two ventral apertures. The ventral heart is simple and tubular, and periodically reverses the direction of the blood current.

* For a more detailed classification, with definitions of all the groups and analytical keys to the species, see Herdman's Revised Classification of the Tunicata. Journ. Linn. Soc.—Zool., vol. XXIII., p. 558, 1891.

The leading vertebrate characteristics of the Tunicata are the notochord, the dorsal nervous system, the ventral heart, and the respiratory pharynx with gill clefts, but these all disappear or undergo modification to such an extent, during the metamorphosis, that the degenerate adults would not, in most cases, be recognised as belonging to the chordata were it not for our knowledge of the life-history.

The class Tunicata may be divided into three orders:—

Order I. LARVACEA.

This comprises the free-swimming, permanently-tailed, larva-like, mostly minute Appendicularians. A relatively large test or "House" is formed with great rapidity as a secretion from the surface of a special part of the ectoderm; it is, however, merely a temporary structure, which may be cast off and afterwards replaced by another "House." The branchial sac is simply an enlarged pharynx, with two ventral ciliated openings (stigmata) leading to the exterior. These open independently on the ventral surface, and there is no separate peribranchial cavity. The tail is a large locomotor appendage, in which there is a skeletal axis, the urochord, comparable with the notochord of Vertebrata. The nervous system consists of a large anterior and dorsally-placed ganglion, and a long nerve cord with smaller ganglia stretching backwards from it over the alimentary canal to reach the tail, along which it runs on the left side of the urochord. The alimentary canal lies behind the branchial sac, and the anus opens ventrally on the surface of the body in front of the stigmata (or atriopores). The gonads are placed at the posterior end of the body. Gemmation does not take place, and alternation of generations and metamorphosis do not occur in the life-history.

This group contains a single family, the Appendiculariidae, all minute (about 5 mm. long), tailed, free-swimming forms which have undergone comparatively little degeneration, and, consequently, correspond more nearly to the tailed larval condition than to the adult forms of the other groups of Tunicata. There are nearly a dozen genera known, of which at least two, probably more, inhabit British seas. In the genus *Oikopleura*, to which our commonest Appendicularians belong, the body is short and ovoid, and no anterior fold or "hood" is present. The tail is three or four times the length of the body, and four to six times as long as it is broad. In *Fritillaria*, on the other hand, the body is elongated, and somewhat constricted in the middle where the tail is attached. A fold of integument on the front of the body forms a "hood." The tail is short and wide, not twice as long as the body.

The British species of Larvacea are still insufficiently known.

Order II. THALIACEA.

Free-swimming pelagic forms of moderate size, which may be either Simple or Compound, and in which the adult is never provided with a tail or notochord. Consequently the whole body here corresponds to the trunk only of the Appendicularian, without the tail. The test is permanent, and may be either well-developed or very slight. In all cases it is clear and transparent. The musculature of the body-wall is in the form of more or less complete circular bands, by the contraction of which water is ejected from the body, and so locomotion is effected. The branchial sac has either two large or many small apertures (stigmata), leading to a single peribranchial cavity, into which the anus also opens. Alternation of

generations occurs in the life-history, and may be complicated by polymorphism. The order Thaliacea comprises two groups, CYCLOMYARIA and HEMIMYARIA.

Sub-order I. CYCLOMYARIA.

Free-swimming pelagic forms, which exhibit alternation of generations in their life-history, but never form permanent colonies. The body is cask-shaped, with the branchial and atrial apertures at the opposite ends. The test is moderately well developed. The musculature is mostly in the form of complete circular bands surrounding the body. The branchial sac is fairly large, occupying the anterior half or more of the body. Stigmata are usually present in its posterior part only. The peribranchial cavity is mainly posterior to the branchial sac. The alimentary canal is placed ventrally close to the posterior end of the branchial sac. Hermaphrodite reproductive organs are placed ventrally near the intestine.

This group contains only one British genus, *Doliolum*, and even that is probably only an occasional visitant. It has a cask-shaped body, from 1 to 2 cm. in length, with lobed terminal branchial and atrial apertures. The body-wall contains eight or nine circular muscle bands, by the contraction of which the animal swims.

The best-known British form, *Doliolum tritonis*, has been captured on occasions in thousands off our N.W. coast, between the Hebrides and the Färoes. This species, and the closely allied *D. nationalis*, have also been found in the English Channel and off the S.W. coast of Ireland.

Sub-order II. HEMIMYARIA.

Free-swimming pelagic forms, which exhibit alternation of generations in their life-history, and in the sexual condition form colonies. The body is more or less fusiform,

with the long axis antero-posterior, and the branchial and atrial apertures nearly terminal. The test is well developed. The musculature of the body-wall is in the form of a series of transversely-running bands, which do not form complete independent rings, as in the CYCLOMYARIA. The branchial and peribranchial cavities form a continuous space in the interior of the body, opening externally by the branchial and atrial apertures, and traversed obliquely from the dorsal and anterior end to the ventral and posterior by a long, narrow, vascular band, which represents the dorsal lamina, the dorsal blood sinus, and the neighbouring part of the dorsal edge of the branchial sac of an ordinary Ascidian. The alimentary canal is placed ventrally. The embryonic development is direct, no tailed larva being formed.

The Salpidæ, the chief family in this sub-order, includes the single genus *Salpa*, which, however, may be divided into two well-marked groups of species—(1) those, such as *S. pinnata*, in which the alimentary canal is stretched out along the ventral surface of the body, and (2) those, such as *S. fusiformis*, in which the alimentary canal forms a compact globular mass, the “nucleus,” near the posterior end of the body. About fifteen species altogether are known; they are all pelagic forms, and are found in many seas. Each species occurs in two forms—the solitary asexual (*proles solitaria*) and the aggregated sexual (*proles gregaria*)—which are usually quite unlike one another. The solitary form gives rise, by internal gemmation, to a complex tubular stolon, which contains processes from all the more important organs of the parent body, and which becomes segmented into a series of buds. As the stolon elongates, the buds near the free end, which have become advanced in their development, are set free in groups, the members in which remain attached together

by processes of the test, each enclosing a diverticulum from the body-wall, so as to form "chains." Each member of the chain is a *Salpa* of the sexual or aggregated form, and when mature may—either still attached to its neighbours or separated from them—produce one or several embryos, which develop into the solitary *Salpa*. Thus the two forms alternate regularly.

Salpa, like *Doliolum*, is probably only an occasional visitor in our seas, but several species of the genus—*Salpa democratica-mucronata*, *S. runcinata-fusifformis*, and *S. zonaria*—have been found on occasions in the seas of the Hebrides, or cast ashore on our southern and western coasts.

Order III. ASCIDIACEA.

Fixed or free-swimming Simple or Compound Ascidiæ, which, in the adult, are never provided with a tail, and have no trace of a notochord. The free-swimming forms are colonies, the Simple Ascidiæ being always fixed. The test is permanent and well developed; as a rule, it increases with the age of the individual. The branchial sac is large and well developed. Its walls are perforated by numerous slits (stigmata) opening into the peribranchial cavity, which communicates with the exterior by the atrial aperture. Many of the forms reproduce by gemmation, and in most of them the sexually produced embryo develops into a tailed larva.

The Ascidiacea includes three groups—the Simple Ascidiæ, the Compound Ascidiæ, and the free-swimming colonial *Pyrosoma*.

Sub-order I. ASCIDIÆ SIMPLICES.

Fixed Ascidiæ which are solitary and very rarely reproduce by gemmation; if colonies are formed, the

members are not buried in a common investing mass, but each has a distinct test of its own. No strict line of demarcation can be drawn between the Simple and Compound Ascidiæ, and one of the families of the former group, the Clavelinidæ (the Social Ascidiæ), forms a transition from the typical Simple forms, which never reproduce by gemmation to the Compound forms, which always do.

The Ascidiæ Simplicæ may be divided into the following families:—

Family I. CLAVELINIDÆ:—Simple Ascidiæ which reproduce by gemmation to form small colonies, in which each Ascidiozoid has a distinct test, but all are connected by a common blood-system. Buds formed on stolons, which are vascular out-growths from the posterior end of the body containing prolongations from the ectoderm, mesoderm, and endoderm of the Ascidiozoid. Branchial sac not folded; internal longitudinal bars usually absent; stigmata straight; tentacles simple.

This family contains three chief genera—*Ecteinascidia*, with internal longitudinal bars in branchial sac; *Clavelina*, with intestine extending behind branchial sac; and *Perophora*, with intestine alongside branchial sac. *Clavelina lepadiformis* and *Perophora listeri* are common British species found at a few fathoms depth off various parts of our coast. Both occur round the south end of the Isle of Man.

Family II. ASCIDIIDÆ:—Solitary fixed Ascidiæ with gelatinous test; branchial aperture usually 8-lobed, atrial aperture usually 6-lobed. Branchial sac not folded; internal longitudinal bars usually present; stigmata straight or curved; tentacles simple.

This family contains, along with several other genera,

our typical form *Ascidia*, of which there are many species in British seas, widely distributed round our coasts. Two other common British forms, belonging to this family, are *Ciona intestinalis*, with a very soft, pale-green test and languets in place of a dorsal lamina, and *Corella parallelogramma*, in which the stigmata of the branchial sac are curved to form beautiful spirals.

Family III. CYNTHIIDÆ:—Solitary fixed Ascidiæ, usually with leathery test; branchial and atrial apertures both 4-lobed. Branchial sac longitudinally folded; stigmata straight; tentacles simple or compound.

This is the largest family of Simple Ascidiæ, and contains a number of genera, about six of which are British. *Styela* has simple tentacles, and not more than 4-folds on each side of the branchial sac. A very common species all round our coasts, between tide marks, is the little red *Styela* (or *Styelopsis*) *grossularia*. In *Cynthia* the tentacles are compound, and there are more than 4 folds, usually 7 or 8, on each side of the branchial sac. The curious little *Forbesella tessellata*, from deep water in the Irish Sea, is in some respects intermediate between *Styela* and *Cynthia*.

Family IV. MOLGULIDÆ:—Solitary Ascidiæ, often not fixed; branchial aperture 6-lobed, atrial 4-lobed. Test usually encrusted with sand. Branchial sac longitudinally folded; stigmata more or less curved, usually arranged in spirals; tentacles compound.

Several species of *Molgula*, all looking when dredged like little sandy balls, and one of *Eugyra* (*E. glutinans*), are common at a few fathoms depth round most parts of our coasts.

Sub-order II. ASCIDIÆ COMPOSITÆ.

Fixed Ascidians which reproduce by gemmation, so as to form colonies, in which the Ascidiozooids are buried in a common investing mass, and have no separate tests. This is probably a somewhat artificial assemblage, formed of two or three groups of Ascidians which produce colonies in which the Ascidiozooids are so intimately united that they possess a common test or investing mass. This is the only character which distinguishes them from the Clavelinidæ, but the property of reproducing by gemmation separates them from the rest of the Ascidiæ Simplices. The Ascidiæ Compositæ may be divided into the following families:—

Family I. DISTOMIDÆ:—Ascidiozooids divided into two regions, thorax and abdomen; testes numerous; vas deferens not spirally coiled. The chief genera are—*Distoma*, *Distaplia*, *Colella*, the last forming a pedunculated colony, in which the Ascidiozooids develop incubatory pouches, opening from the peribranchial cavity, in which the embryos undergo their development.

Family II. CÆLOCORMIDÆ:—Colony not fixed, having a large axial cavity with a terminal aperture. Branchial apertures 5-lobed. This includes one species, *Cælocormus huxleyi*, which is a transition form between the ordinary Compound Ascidians (e.g., Distomidæ) and the Ascidiæ Lucidæ (*Pyrosoma*).

Family III. DIDEMNIDÆ:—Colony usually thin and incrusting. Test containing stellate calcareous spicules. Testis single, large; vas deferens spirally coiled. The chief genera are—*Didemnum*, in which the colony is thick and fleshy, and there are only three rows of stigmata on each side of the branchial sac; and *Leptoclinum*, in which the colony is thin and incrusting, and there are four rows

of stigmata on each side of the branchial sac. Colonies of *Leptoclinum*, forming thin, white, grey, or yellow crusts, under stones at low water, are amongst the commonest of British Compound Ascidiæ.

Family IV. DIPLOSOMIDÆ:—Test reduced in amount, rarely containing spicules. Vas deferens not spirally coiled. In *Diplosoma*, the most important genus, the larva is gemmiparous. This is a common British form, especially on *Zostera* beds, and amongst sea-weeds.

Family V. POLYCLINIDÆ:—Ascidiozooids divided into three regions, thorax, abdomen, and post-abdomen. Testes numerous; vas deferens not spirally coiled. The chief genera are—*Pharyngodictyon*, with stigmata absent or modified, one species: the only Compound Ascidian known from a depth of 1000 fathoms; *Polyclinum*, with a smooth-walled stomach; *Aplidium*, with the stomach-wall longitudinally folded; and *Amaroucium*, in which the Ascidiozooid has a long post-abdomen and a large atrial languet. The last three genera contain many common British species.

Family VI. BOTRYLLIDÆ:—Ascidiozooids having the intestine and reproductive organs alongside the branchial sac. Dorsal lamina present; internal longitudinal bars present in branchial sac. The chief genera are—*Botryllus*, with simple stellate systems, and *Botrylloides*,* with elongated or ramified systems. There are many species of both these genera, which form brilliantly coloured fleshy crusts under stones and on sea-weed at low tide. They are amongst the commonest and the most beautiful of British Ascidiæ.

* It is intended that a future L.M.B.C. Memoir will deal with *Botrylloides* as a type of the Compound Ascidiæ.

Family VII. POLYSTYELIDÆ:— Ascidiozooids not grouped in systems. Branchial and atrial apertures 4-lobed. Branchial sac may be folded; internal longitudinal bars present. The chief genera are—*Thylacium*, with ascidiozooids projecting above general surface of colony; *Goodsiria*, with ascidiozooids completely imbedded in investing mass; and *Chorizocormus*, with ascidiozooids united in little groups, which are connected by stolons. The last genus contains one species, *Ch. reticulatus*, a transition form between the other Polystyelidæ and the Cynthiidæ among Simple Ascidians. *Thylacium* is the only British form.

Sub-order III. ASCIDIÆ LUCIÆ.

Free-swimming pelagic colonies having the form of a hollow cylinder closed at one end. The ascidiozooids forming the colony are imbedded in the common test in such a manner that the branchial apertures open on the outer surface, and the atrial apertures on the inner surface next to the central cavity of the colony. The ascidiozooids are produced by gemmation from a rudimentary larva (the cyathozoid) developed sexually.

This sub-order includes a single family, the PYROSOMIDÆ, containing one well-marked genus, *Pyrosoma*, with several species. They are found swimming near the surface of the sea, chiefly in tropical latitudes, and are brilliantly phosphorescent. A fully developed colony may be from an inch or two to upwards of four feet in length. *Pyrosoma* does not occur in British seas.

EXPLANATION OF PLATES.

PLATE I.

Large specimen of *Ascidia mentula*, from the right side, natural size, from life.

Length 11.5 cm. Breadth 6 cm. Thickness 3 cm.

A, shows the sensory edge of the branchial aperture with lobes and coloured lines (the "ocelli"), enlarged.

PLATE II.

Reference Letters in Plates II., III., and IV.

<i>a.</i> anus.	<i>g.d.</i> genital ducts.
<i>At.</i> atrial aperture.	<i>gl.</i> pyloric gland.
<i>at.l.</i> atrial lobe.	<i>gl.d.</i> duct of neural gland.
<i>bl.c.</i> bladder cell.	<i>gon.</i> gonads.
<i>bl.s.</i> blood sinus.	<i>h.</i> heart.
<i>Br.</i> branchial aperture.	<i>h.m.</i> horizontal membrane.
<i>br.car.</i> branchio-cardiac vessel.	<i>hyp.</i> hypophysial (neural) gland
<i>br.ao.</i> branchial (ventral) vessel.	<i>hyp.d.</i> hypophysial duct.
<i>Br.s.</i> branchial sac.	<i>i.i'.</i> intestine.
<i>br.visc.</i> branchio-visceral vessel.	<i>i.l.</i> internal longitudinal bars.
<i>card.visc.</i> cardio-visceral vessel.	<i>l.v.</i> interstigmatic vessels.
<i>c.c.</i> common cloaca.	<i>m.</i> body-wall, or mantle.
<i>c.d.</i> connecting duct.	<i>m.b.</i> muscle bands.
<i>cl.</i> cloaca.	<i>mes.c.</i> mesoblast cell.
<i>con.</i> connective.	<i>m.f.</i> muscle fibres.
<i>c.t.c.</i> connective tissue cell.	<i>n.</i> nerves.
<i>d.ao.</i> dorsal vessel.	<i>n.g.</i> nerve ganglion.
<i>d.bl.s.</i> dorsal blood sinus.	<i>n.gl.</i> neural gland.
<i>d.l.</i> dorsal lamina.	<i>æs.</i> œsophagus.
<i>d.n.</i> dorsal nerve cord.	<i>ov.</i> ovary.
<i>d.t.</i> dorsal tubercle.	<i>p.br.</i> peribranchial cavity.
<i>ec.</i> ectoderm.	<i>p.br.z.</i> prebranchial zone.
<i>en.</i> endoderm.	<i>p.c.</i> pericardium.
<i>end.</i> endostyle.	<i>p.p'.</i> papillæ.
<i>ep.c.</i> epicardial tube.	<i>pp.b.</i> peripharyngeal bands.

<i>r.</i> rectum.	<i>tn.</i> tentacle.
<i>ren.</i> renal vesicles.	<i>t.k.</i> terminal knobs on vessels.
<i>sg.</i> stigmata.	<i>tr.</i> transverse vessels.
<i>sp.</i> testis.	<i>t.v.</i> test vessel.
<i>sph.</i> sphincter.	<i>ty.</i> typhlosole.
<i>st.</i> stomach.	<i>v.</i> vessel.
<i>t.</i> test.	<i>v.app.</i> vascular appendage.
<i>t.c.</i> test cells.	<i>v.bl.s.</i> ventral blood sinus.

- Fig. 1. Diagram of the outside of *Ascidia*, from right side.
- Fig. 2. Transverse section through the atrial aperture to show arrangement of internal cavities and organs. (To avoid complication the internal longitudinal bars are not represented in the branchial sac.)
- Fig. 3. A mesh of the branchial sac, diagrammatic.
A. From the inner surface. B. In section.
- Fig. 4. Diagrammatic dissection to show the structure of *Ascidia* (compare with fig. 2).
- Fig. 5. Section through test and mantle (body-wall) to show the relations of the ectoderm and mesoderm to the test.
- Fig. 6. Sagittal section through antero-dorsal part of body to show relations of nerve ganglion, neural gland, &c.
- Fig. 7. Dorsal front of pharynx from inside, to show dorsal tubercle, tentacles, and neighbouring parts. $\times 50$.

PLATE III.

Figs. 1 to 4 show typical examples of four important families of Compound Ascidiæ, natural size.

Fig. 1 is a Distomid colony (*Colella*).

Fig. 2 is a Didemnid colony (*Leptoclinum*).

Fig. 3 is a Polyclinid colony (*Pharyngodictyon*).

- Fig. 4 is a Botryllid colony (*Botryllus*).
- Fig. 5 shows the union of two Ascidiozooids, in a Compound Ascidian colony, to form a common cloaca (*c.c.*) in the common test.
- Figs. 6 to 8 show the three forms of body found amongst the Ascidiozooids of Compound Ascidians.
- Fig. 6 is from a Botryllid colony.
- Fig. 7 is from a Distomid colony.
- Fig. 8 is from a Polyclinid colony (all from right side, magnified).
- Fig. 9. Section through outer part of test of *Ascidia* to show "vessels" and "bladder" cells. $\times 50$.
- Fig. 10. Diagram of *Ascidia* to show the arrangement of the blood system, from left side, in correct morphological position for comparison with Vertebrates.

PLATE IV.

- Fig. 1. Part of branchial sac of *Ascidia mentula*, from the outside. $\times 50$.
- Fig. 2. Part of branchial sac of *Ascidia mentula* from the inside. $\times 50$.
- Fig. 3. Small part of last. $\times 300$.
- Fig. 4. Part of the dorsal lamina. $\times 40$.
- Fig. 5. Transverse section of the endostyle. $\times 200$.
- Fig. 6. Blood corpuscles of *Ascidia*.
- Fig. 7. Part of section of wall of intestine showing refringent organ, spermatid tubules, &c.
- Fig. 8. Ocellus from the branchial aperture, in section.
- Fig. 9. The heart and pericardium, in side view.
- Fig. 10. The heart and pericardium, in section.
- Fig. 11. Group of renal vesicles. $\times 50$.
- Fig. 12. Part of a renal vesicle, more highly magnified.
- Fig. 13. Two cells from wall of renal vesicle.

Fig. 14. Concretions from renal vesicles. $\times 200$.

Fig. 15. Bunch of spermatie tubules from testis. $\times 50$.

PLATE V.

REFERENCE LETTERS.—*ar.* archenteron, *at.* atrial involution, *au.* otolith, *bc.* blastocoele, *bp.* blastopore, *ch.* notochord, *ep.* epiblast, *f.* tail fin, *foll.* follicle cell, *hy.* hypoblast, *i.* intestine, *m.* mouth, *mes.* mesoblast, *musc.* muscle cells, *mb.* mesoblast layer, *mc.* mesoblast cell, *n.* nucleus of ovum, *nc.* neural canal. *n.e.c.* neurenteric canal, *n.ch.* notochord, *n.v.* cerebral vesicle, *oc.* cerebral eye, *p.* protoplasm of ovum, *s.* spermatozoon, *t.c.* "testa" cells of ovum.

Fig. 1. Mature ovum and spermatozoon of *Ascidia*.

Fig. 2. A segmentation stage, in section, to show blastula.

Fig. 3. Early gastrula stage.

Fig. 4. Later gastrula stage.

In these and some of the other figures, the clear cells indicate the notochord, the hypoblast cells have small circles, and the nerve cells are marked with oblique lines, while the mesoblast cells are cross hatched.

Fig. 5. A later embryo, showing rudiments of notochord and nervous system.

Fig. 6. Embryo showing body and tail, &c.

Fig. 7. Transverse section of the tail of larva.

Fig. 7a. Transverse section of the body of embryo.

Fig. 8. Embryo ready to be hatched.

Fig. 9. Free-swimming tailed larva.

Fig. 10. The metamorphosis—larva attached to a stone.

Fig. 11. Tail and nervous system of larva degenerating.

Fig. 12. Further degeneration and metamorphosis of larva into

Fig. 13. the young fixed Ascidian.

PLATE I.



W.A.H. del.

ASCIDIA.

S.B. lith.

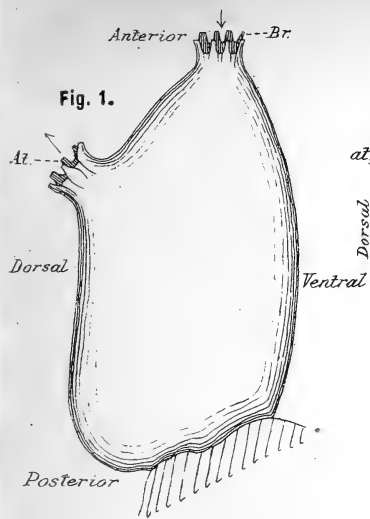


Fig. 1.

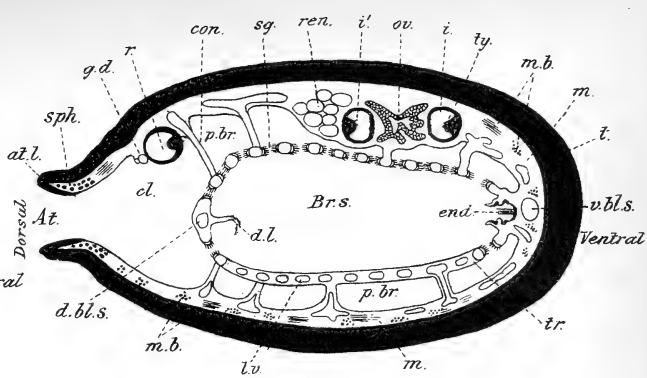


Fig. 2.

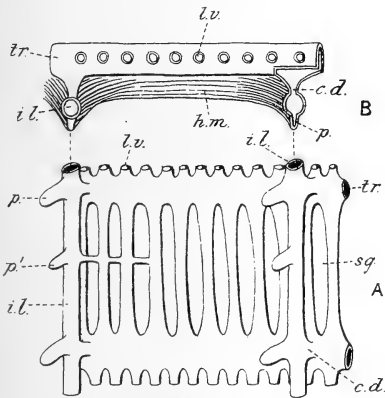


Fig. 3.

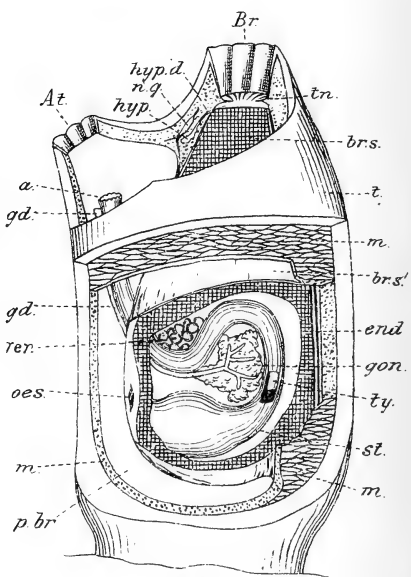


Fig. 4.

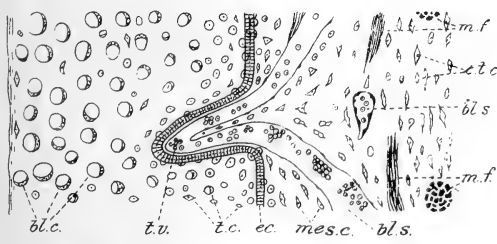


Fig. 5.

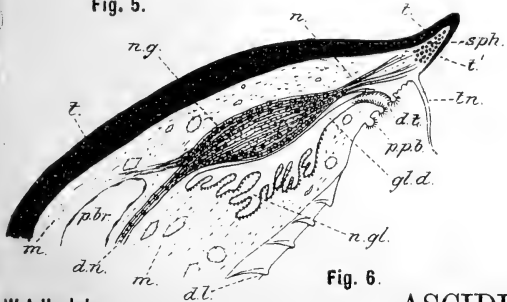


Fig. 6.

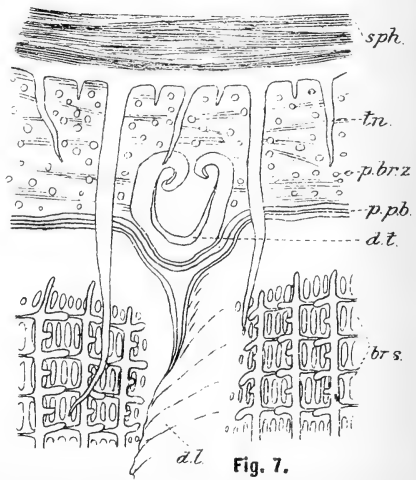
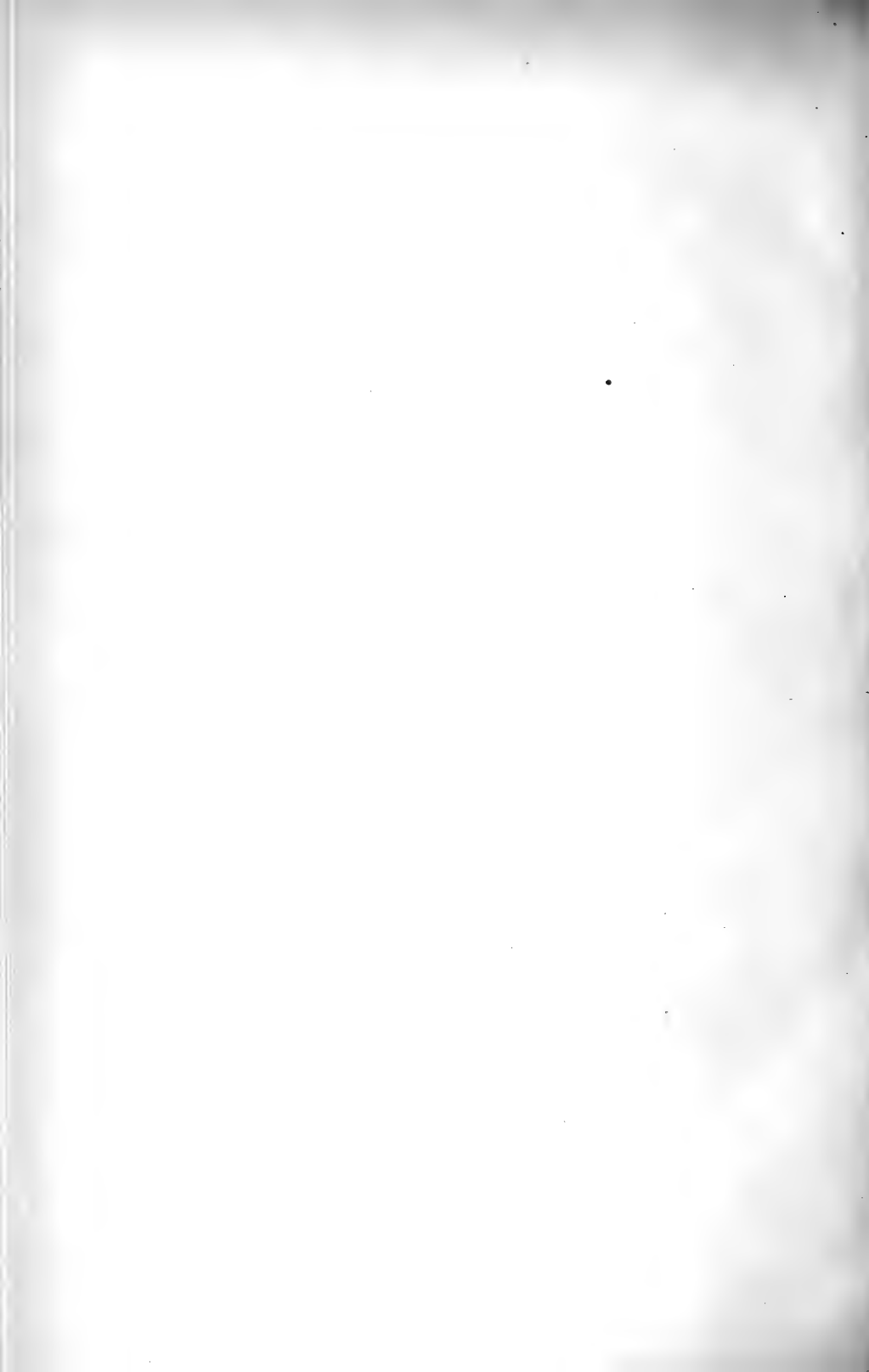


Fig. 7.



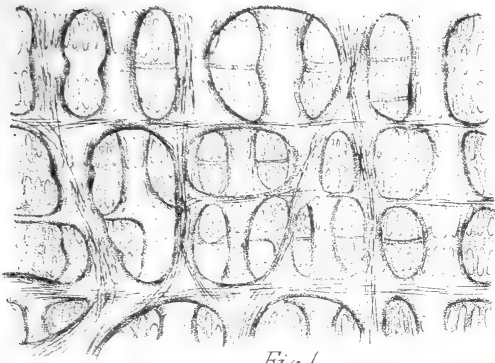


Fig. 1.

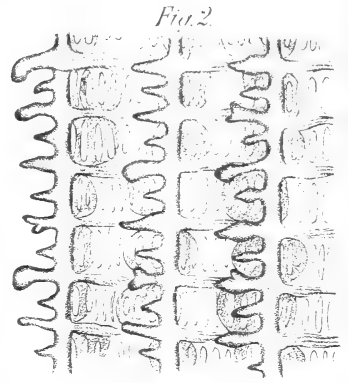


Fig. 2.

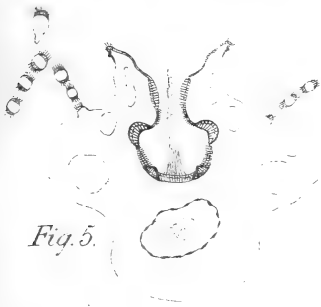


Fig. 5.

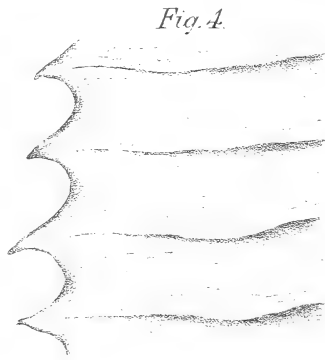


Fig. 4.

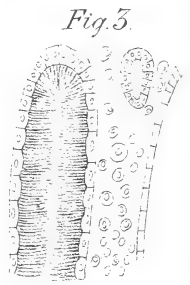


Fig. 3.



Fig. 6.

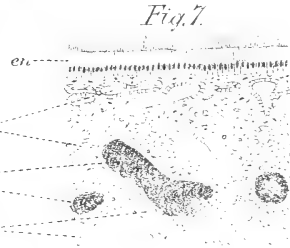


Fig. 7.

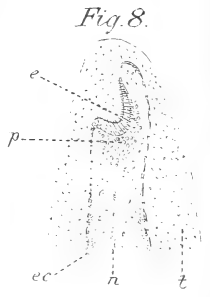


Fig. 8.

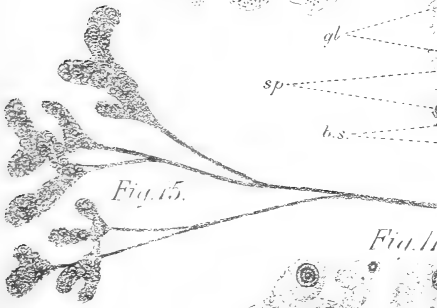


Fig. 15.



Fig. 11.

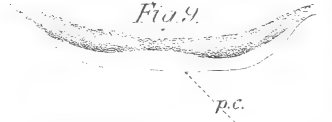


Fig. 9.



Fig. 14.



Fig. 13.



Fig. 12.



Fig. 10.

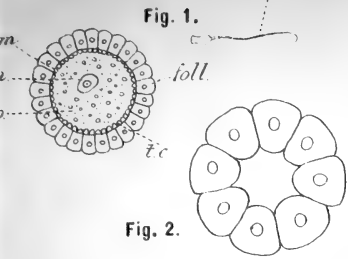


Fig. 2.

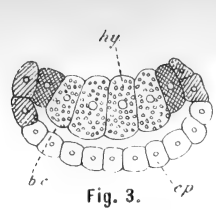


Fig. 3.

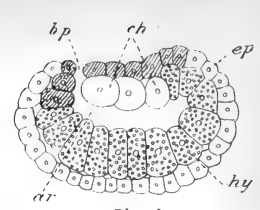


Fig. 4.

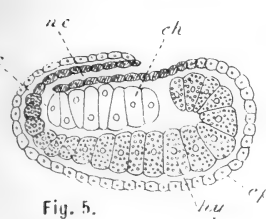


Fig. 5.

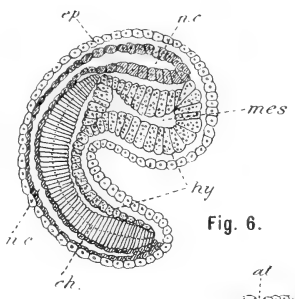


Fig. 6.

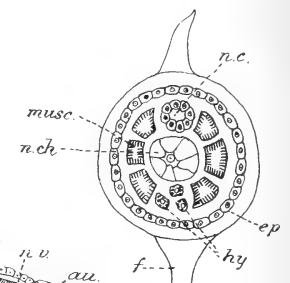


Fig. 7.

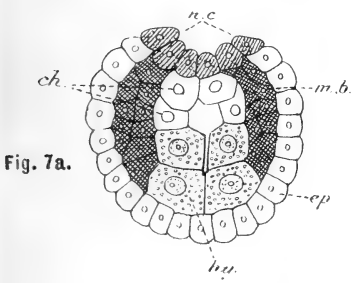


Fig. 7a.

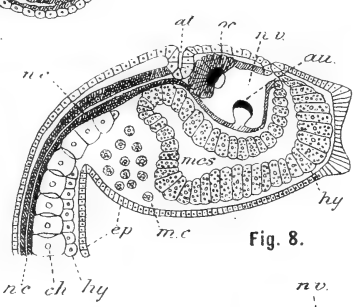


Fig. 8.

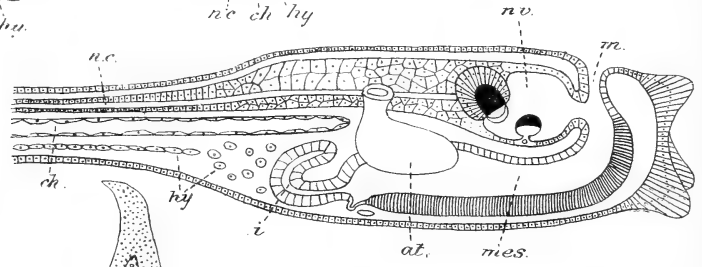


Fig. 9.



Fig. 10.

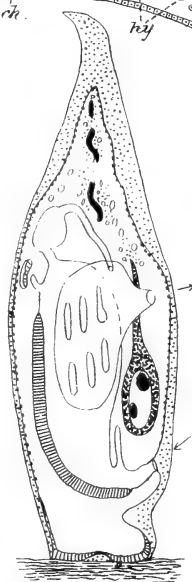


Fig. 11.

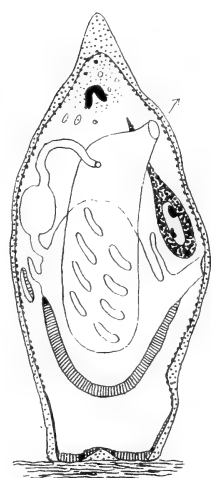


Fig. 12.

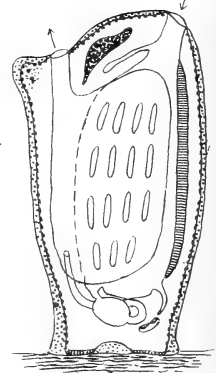


Fig. 13.



THIRTEENTH ANNUAL REPORT of the LIVER-
POOL MARINE BIOLOGY COMMITTEE and
their BIOLOGICAL STATION at PORT ERIN.

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

THE past year has been notable in several respects. In the amount and quality of the students' work at the Biological Station it is, I consider, the best year we have ever had; several new lines of investigation have been started; a new set of publications—the L.M.B.C. Memoirs—has been successfully launched, and we have renewed our tenancy of the buildings at Port Erin under new landlords. All these and other matters will be dealt with in order in the following pages. We may begin, as usual, with the formal statistics as to the occupation of the work tables at the Laboratory, and then pass to the Curator's report upon the events of the year at Port Erin. Work at Liverpool, the publications of the Committee, and wider considerations, such as the result of the Stockholm Conference on Marine Exploration, will close the Report.

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.
<i>January.</i>	Prof. W. A. Herdman	General.
—	Mr. I. C. Thompson	Copepoda.
<i>March.</i>	Miss Sollas, Newnham Coll., Cambridge	General.
—	Mr. H. S. Harrison, Univ. Coll., Cardiff	Hydrozoa.

DATE.	NAME.	WORK.
<i>March.</i>	Mr. E. T. Townsend, Owens Coll. ...	General.
—	Prof. W. A. Herdman	General.
—	Mr. I. C. Thompson	Copepoda.
—	Mr. R. L. Ascroft	Fishes.
—	Mr. E. J. W. Harvey, Liverpool...	General.
<i>April.</i>	Mr. A. R. Jackson, Univ. Coll., Liverpool	Arachnida.
—	Mr. J. C. Mann, Univ. Coll.	General.
—	Mr. R. Kelly, Univ. Coll.... ..	General.
—	Mr. F. J. Cole, Univ. Coll.	Comp. Ascidiæ.
<i>May.</i>	Mr. C. E. Jones, Univ. Coll.	Marine Algæ.
—	Mr. H. Yates, Manchester	Polychæta, &c.
<i>June.</i>	Mr. E. Schuster, New Coll., Oxford ...	Polychæta.
<i>July.</i>	Prof. W. A. Herdman	General.
—	Mr. I. C. Thompson	Copepoda.
—	Mr. E. Schuster	Polychæta.
—	Mr. J. T. Jenkins, Univ. Coll., Aberystwyth and Liverpool	Mollusca, Fishes, and Plankton.
<i>August.</i>	Mr. C. Crossland, Clare Coll., Cambridge	General.
—	Mr. J. T. Jenkins, Univ. Coll., Liverpool	Mollusca, Fishes, &c.
—	Mr. R. Simon, Manchester	General.
—	Mr. J. Corker, Manchester	General.
—	Mr. Buckley, Manchester	General.
—	Mr. D. R. Mackay, Manchester	Hydroida.
<i>September.</i>	Mr. J. T. Jenkins, Univ. Coll.	Mollusca, Fishes, &c.
—	Mr. C. Crossland, Clare Coll., Cambridge	General.
—	Mr. H. Yates, Manchester	Polychæta, &c.
<i>October.</i>	Mr. I. C. Thompson	Copepoda.
—	Mr. P. M. C. Kermode	General.
—	Prof. W. A. Herdman	General.
<i>December.</i>	Mr. I. C. Thompson	Official.
—	Prof. W. A. Herdman	Official.

This record shows an increase not merely in the number of individuals, but what is more important, in the length of time that each worker stayed, and, therefore, in the seriousness and extent of his work. The list, it will be noticed, includes students from Oxford, Cambridge, and the Welsh Colleges, in addition to those from the Colleges at Manchester and Liverpool which have secured work-tables at the Station.

THE CURATOR'S REPORT.

Mr. CHADWICK reports as follows :—

“The dissecting and compound microscopes provided early in the year have proved most useful. All the instruments and apparatus required by workers have been carefully used, and, with the exception of certain of the dredges, are in good condition. The small iron trawl, provided last year, has been frequently used, and its loss, together with the rope, towards the close of the season, was most unfortunate. The nets attached to the ‘Agassiz’ and shrimp trawls were repaired after the last steamboat dredging excursion, but renewal of both will probably be necessary ere long. All the smaller dredges are in serviceable condition. Mr. H. Yates, of Manchester, has kindly lent, for an indefinite period, a sliding microtome by Reichert, specially adapted for cutting sections of material imbedded in celloidin.

“The Shellbend boats, though in need of slight repair, are little the worse for the frequent use to which they have been put.

“The Library has been well used, and the additions to the stock of books, including a nearly complete set of the Journal of the Marine Biological Association, have considerably enhanced its value. Several zoologists have kindly continued to contribute copies of their papers, for the reception of which, and other additions, a third bookcase has been provided. Further donations from authors, and others, will be very welcome.

“A small beginning has been made with the formation of a collection of microscope slides, illustrating the local fauna, which it is hoped will be of constantly increasing value to future workers at the Station.

“The sale of living and preserved specimens has not assumed noteworthy proportions, but orders from various

sources keep coming in, and a number of carefully preserved specimens have been supplied to colleges and private workers.

“The record of meteorological observations begun last year has been continued, and in view of the exceptionally stormy character of the winter months, and the equally exceptional amount of sunshine experienced during the summer, a record of the average temperature of the air and sea may not be without interest.

MONTH.	9-30 a.m. AIR.	3-30 p.m.	9-30 a.m. SEA.	3-30 p.m.
October, 1898 ...	54° F.	55°	55°	56°
November ...	48°	49°	51°	52°
December ...	48°	48°	50°	50°
January, 1899 ...	44°	45°	46·5°	47·5°
February ...	43°	46°	45°	47°
March ...	42·5°	45·5°	39°	47°
April ...	46·5°	49°	48·5°	50°
May ...	50·5°	54°	52°	54°
June ...	59°	65°	58°	61°
July ...	60°	61°	59·5°	60·5°
August ...	65°	65·5°	61·5°	60°
September ...	57°	59°	58·5°	60°

“The aquarium has not proved quite so attractive to visitors this year as last, only 310 persons having paid for admission. This is probably in large measure due to the exceptionally fine weather which prevailed throughout the summer, enabling visitors to Port Erin to spend most of their time in boating and other out-door amusements. Still, the interest shown by the visitors has been well maintained, and the preserved specimens on the shelves have been scarcely less attractive to many than the living occupants of the tanks. Cracks extending from top to bottom of the plate glass fronts of both wall tanks in the

basement, appeared, one at the beginning of the winter and the other early in the present year; the result, most probably, of slight settlement of the building. Fortunately, they have not interfered with the usefulness of the tanks. Each still holds a depth of 18 inches of water without appreciable leakage.

“During the early part of March all the tanks were emptied, thoroughly cleansed and, where necessary, restocked. A considerable number of the animals introduced at Easter, 1898, survived the winter, but during the excessive heat experienced at the end of August, the mortality amongst them was great, and few now remain. A specimen of *Sabella pavonia*, placed in one of the shallow table tanks in July, 1898, is still (December, 1899), alive. Several Shannies (*Blennius pholis*) and a Sting-fish (*Cottus scorpius*) spawned in one of the tanks during the first week in March, but the eggs were not fertilised. The last named fish has well maintained its reputation for pugnacity and voracity by attacking and killing every fish that has been placed in the tank, with the exception of a young Dragonet (*Callionymus lyra*), which escaped the fate of three others placed in the tank at the same time, and still survives. I have several times seen the Sting-fish swallow so many young plaice that it could only with some effort raise itself from the bottom of the tank.

“A small lobster, about 3 inches long, was captured and placed in one of the wall tanks, about the middle of February, and it now appears to be thoroughly acclimatised. One morning in March I found the dead body of a Sting-fish, which had been in a sickly condition for several days, buried in the gravel at the bottom of the tank. On removing it I found that it had been partly eaten. A fortnight later a hermit crab was killed, and its body similarly buried. As the lobster was the only

animal in the tank capable of doing this, I did not disturb it, and found, on the following morning, that it had been disturbed and re-buried. The next morning nothing remained but the chelæ and walking legs. The lobster has now established itself in a particular crevice in the rock-work, to which all food given to it is carried.

“In February I was fortunate enough to see a large number of ova extruded by a specimen of *Nereis pelagica*. I kept the worm in a small dish, and one day noticed that the parapodia on the left side of the ninth and tenth segments had become much swollen. On the next day the swelling had increased, and while watching the movements of the worm I saw the ova extruded from the swollen region, probably from the nephridiopores of the affected segments. I then fixed and preserved the worm, and it has since been photographed by Mr. E. Schuster, of New College, Oxford.

“In regard to Faunistic work, I have availed myself of every opportunity afforded by low tides to collect on the shores of Port Erin and the neighbouring bays, and thirteen dredging excursions have been undertaken in small boats. The courses dredged over, and the animals collected, were carefully recorded. The harbour buoy was brought ashore for its annual cleaning on August 11th this year, and again yielded over thirty species. Amongst them was an abnormal specimen of the Nudibranch, *Eolis glottensis* (?), in which the foot is divided into two quite distinct portions of exactly similar shape, one in front of the other. Amongst the additions to our lists are the Hydroid *Campanulina repens*, and the Nudibranch *Hermaea dendritica*, both discovered in ‘Pat’s Dub’ by Miss Sollas.

“I have devoted some time during the past year to the study of the Polychæta of the bay, and have gained a

good deal of knowledge of the habitats and times of occurrence of the different species. During the ensuing year it is my intention to devote special attention to some of the other less known groups, so that at its close, the detailed report on the shore and bottom fauna of the bay (illustrated by charts), which has been alluded to in former annual reports, may be completed and issued.

“Experiments with various reagents have been made from time to time, with a view of discovering new and improving old methods of narcotising and fixing marine animals. Menthol, recommended by Dr. H. C. Sorby, has proved very useful for Hydroida, Siphonophora, and Polyzoa. By dropping a few crystals on the surface of the water in a trough in which I examined *Agalmopsis elegans*, I was able to keep the specimens quite motionless and in a fully extended condition for some time. The usually refractory Sertularians give very good results. A 1 % solution of Cocaine has been used with complete success in narcotising the Lamellibranch, *Tapes pullastra*, with its siphons fully extended.”

EASTER COLLECTING PARTY.

The usual dredging expedition of the Liverpool Marine Biology Committee in the Easter vacation opened very successfully, but was brought to a sad and untimely end on the third day by an unfortunate boat accident in Port Erin Bay. On March 31st dredging and trawling to the east of the Calf Island were carried on from the fisheries steamer “John Fell,” and on the following forenoon the working of the “Tanner” closing net, and the method of pumping plankton from the bottom by means of a hose-pipe, were demonstrated to the Students on the steamer. On the afternoon of Saturday, April 1st, two of the workers at the Biological Station went out to collect

surface plankton in the smaller station boat. While hauling in the tow-net, when returning, the boat capsized, and both men were thrown into the water. One of them (Mr. E. J. W. Harvey, of Liverpool) was picked up by the other boat from the Biological Station, but his companion (Mr. Eric T. Townsend, of Prestwich) was unfortunately drowned before assistance could reach him. The body was eventually recovered. Mr. Townsend was a student of the Owens' College, and was the occupant of the College work-table at the Biological Station for the Easter vacation. He was a promising Student, keenly interested in his biological work, and much esteemed by his fellow-workers. The party broke up after this sad occurrence. It is the first serious accident of any kind that has taken place on the L.M.B.C. expeditions or at their Biological Station during the fifteen years of work.

NOTES ON WORK DONE AT THE STATION.

A good deal of the Laboratory work this year has been not so much that of Specialists as of Advanced Students, which is not intended for publication, and in regard to which little that is of interest can be said. Two of the other workers, Mr. I. C. Thompson, F.L.S., and Mr. J. T. Jenkins, B.Sc., have given me special notes about Copepoda and Fishes, which will be inserted at the end of this section. Of those that remain:—Mr. A. R. Jackson, B.Sc., was engaged in adding to his list of Arachnids of the district, and met with some success; Mr. F. J. Cole continued his studies on the budding of Compound Ascidians, and collected and preserved much material for future work in Liverpool; and Mr. H. S. Harrison, B.Sc., has written me a letter telling of the Hydroid and Medusoid material that he collected, and ending with the

following words :—" I hope some time to make a longer stay at Port Erin at a more favourable time of year, for at that time I felt that I had not a fair opportunity of doing justice to the splendid facilities for study and research offered by the fauna of the district. However, in spite of the shortness of my stay and the unfavourable weather, I found everything very instructive."

NEW COPEPODA.

Mr. THOMPSON has kindly drawn up the following note upon his work :—

" During the year I have regularly received for examination from our Curator, Mr. H. C. Chadwick, bottles of plankton material collected by him in and about Port Erin Bay. In addition to these, I have myself, on several visits to Port Erin, used the tow-net for collecting about the district. As Mr. Chadwick will discuss the other organisms noted in the collections, I will refer here only to the COPEPODA, which, however, usually form the chief proportion of the organisms in the tow-net.

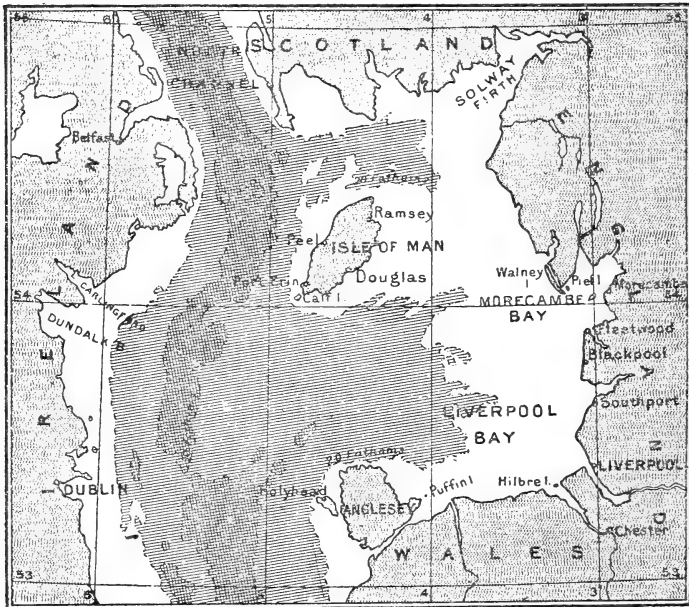
" The most notable feature of the year has been the appearance of two species of Copepoda new to the district, viz., *Candacia pectinata*, and *Corycæus anglicus*, each of which has been taken on several separate occasions. The former occurred during January, June, and July, and was taken both at or near the surface, and also at a depth of 33 fathoms. The latter species was taken during the early winter (Nov. 26th, 1898), and a shoal of it was also captured on May 29th.

" *Candacia pectinata* appears to be generally, but very sparingly, distributed about the British Isles. It was first found by Drs. Brady and Robertson, at a depth of 40 fathoms, off the Scilly Islands. I have on several occasions found it on the west coast of Scotland, and Mr. Thomas

Scott, F.L.S., reports it from the Frith of Forth. About the Channel Islands I have taken it sparingly, and more plentifully about Valencia in Ireland. Dr. Brady reports the "Challenger" captures of this species about Australia, the Phillipine Islands, and between Ascension and the Azores. I found it common about the Canary Islands, and have lately detected it in plankton taken near Madagascar, by Capt. Fred. Wyse, a record of whose collecting results I hope shortly to publish.

"This and the other species of the genus *Candacia* are easily distinguishable by their dark-coloured antennæ, spines and plumes, and the terminal spines of the swimming feet.

"*Corycæus anglicus* is fairly common about the south and south-west coasts of England and Ireland, but with the exception of its occasional appearance in the Forth,



Plan of the L. M. B. C. District.

as reported by Mr. Thomas Scott, it has, I believe, been hitherto unknown on our northerly coasts.

“During an inspection cruise of the spawning grounds off the west of the Isle of Man, on the fishery steamer “John Fell,” in January last, when, by the kindness of Mr. Dawson, the Superintendent of the Lancashire Fishery District, some of the L.M.B.C. were invited to be present, some interesting observations were made as to the quantity and comparative character of the plankton collected under similar conditions at the surface and at the sea bottom. I have already recorded the results in a paper ‘Notes on Mid-Winter Surface and Deep Tow-Nettings in the Irish Sea,’ see L.B.S. Trans., vol. XIII., pp. 156—62. It is hoped that we may be able at other seasons of the year to continue observations on a similar plan.

“In addition to the forms noted above, Mr. Andrew Scott has found several other species of Copepoda new to our district and one, at least, new to science, during the past year in his work at the Piel Hatchery, on the Lancashire coast. These will be described in a joint paper by Mr. Scott and myself, which will be laid before the Biological Society, and published in the ‘Transactions.’”

THE FISH OF PORT ERIN.

Mr. J. T. JENKINS, as the result of one part of his work at the Biological Station, has drawn up the following report upon:—“The Distribution of Fish in and around Port Erin Bay during August and September, 1899.”

“The total number of species captured during these two months was 32. Taking the families in order, we get:—

SPARIDÆ. — *Pagellus centrodonatus* (Sea Bream) was abundant outside the Bay, more especially to the north of Fleshwick. It was taken with mackerel bait a short distance off the ground.

COTTIDÆ.—Four species were captured. *Cottus scorpius* and *C. bubalis* (Bullheads) were taken in rock pools at low tide all round the Bay, from the breakwater to the north side. They may be taken either with a hand net or with a hook, using *Littorina* as bait. Young ones were also captured in the dredge; they are voracious feeders.

Trigla gurnardus (Grey Gurnard) are very common. They can be taken within the Bay and outside from the Calf to two or three miles north of Fleshwick. They are voracious feeders, will bite readily at *Arenicola*, herring or mackerel bait. *Trigla cuculus* (Red Gurnard) are not so common as *T. gurnardus*, but fairly abundant; distribution similar; some very large specimens were captured.

SCOMBRIDÆ.—*Scomber scomber* (Mackerel) is occasionally taken in the Bay. It is plentiful outside from Bradda Head to the Calf. It is taken with artificial bait, india rubber tubing with a piece of skin of a fish. Five dozen were taken in one afternoon (Sept. 12th) by “whiffing” with two lines from a yacht.

GOBIIDÆ.—*Gobius niger* (the Goby). Distribution as for the *Cottus* species. *Callionymus lyra* (Dragonet). Frequently taken in the dredge from Bradda Head to Bay Fine.

DISCOBOLI.—*Cyclopterus lumpus* (Lump Sucker). A single specimen was found adhering to the buoy.

Two species of *Lepadogaster* (Suckers) were obtained: viz., *L. gouanii* and *L. decandolii*. These were obtained in rock pools at low tide and also in the dredge within the Bay.

BLENNIIDÆ.—*Blennius pholis* (Shanny) is a littoral form; in rock pools between the Biological Station and Spaldrick Bay at low tide. Also, along with it, *Centronotus gunnellus* (Butter fish), taken in rock pools throughout the Bay.

GASTEROSTEIDÆ.—*Gasterosteus spinachia* (15 spined Stickleback) is a littoral form; distribution as for the last species.

LABRIDÆ.—*Labrus mixtus* (Cook Wrasse) is abundant round the breakwater, and was occasionally taken off Bradda Head and in Bay Fine.

GADIDÆ.—A large number of young forms of various species of *Gadus* are found around the breakwater.

Gadus virens (Saithe): young taken in the dredge within the Bay. *Gadus pollachius* (Pollack) is abundant: taken within the Bay near the buoy; also taken outside frequently from north of Fleshwick to Halfway rock. *Gadus morrhua* (Cod) and *Gadus æglefinus* (Haddock): generally taken a few miles outside the Bay.

Molva vulgaris (Ling) is taken to south of Port Erin (Bay Fine and off the Calf). *Merluccius vulgaris* (Hake): distribution as for *G. morrhua*. *Motella mustela* and *M. tricirrata* (Rocklings) are taken in the vicinity of the breakwater.

OPHIDIIDÆ.—One species only, *Ammodytes tobianus* (Lesser Sand Eel). This is taken at low tide in pools on the south side of the Bay near the landing stage.

PLEURONECTIDÆ.—I only succeeded in capturing two species of flat fish—*Pleuronectes platessa* (Plaice) and *P. limanda* (Dab). I should be inclined to think that other Pleuronectids are common. Both species mentioned were taken frequently in the Bay and outside the Bay from the breakwater to Halfway rock. Young forms were frequently taken in the dredge, both inside and outside the Bay. On Aug. 21st, a shoal of young Pleuronectids were observed at low water opposite the Laboratory.

SCOMBRESOCIDÆ.—*Belone vulgaris* (Garfish) is taken when "whiffing" for mackerel. Probably accompanies mackerel shoals.

CLUPEIDÆ.—*Clupea harengus* (Herring) is taken abundantly a few miles south-west of the Calf.

MURÆNIDÆ.—*Conger vulgaris* (Conger Eel) is taken outside the Bay from north of Fleshwick to the Calf. Evidently prefers mackerel to any other form of bait, and undoubtedly selects it in preference to herring.

SYNGNATHIDÆ.—*Syngnathus acus* (Pipe fish) is captured at low tide and in rock pools. Seems to prefer neighbourhood of *Chorda filum*, to detached or floating portions of which it presents some resemblance.

ELASMOBRANCHII.—*Raja maculata* (Skate) and *Scyllium canicula* (Dog fish) were taken outside the Bay when ground fishing with mackerel bait for other forms.”

WORK ON OYSTERS AND DISEASE.

As the progress of the investigation upon the conditions under which oysters flourish, and the connection between unhealthy oysters and disease in man, carried on for some years now by Prof. Boyce and myself, has been noted from time to time in these Annual Reports, it may interest some readers to know that the work is now concluded, and that the final results have been published (October, 1899) under the auspices of the Lancashire Sea-Fisheries Committee, as the first “Lancashire Sea-Fisheries Memoir.” This is a thin quarto volume* of about 70 pages, illustrated by eight partly coloured plates, and giving the details of the histological, chemical, and bacteriological evidence upon which the conclusions as to oysters printed in last year’s report were based. Since that report was published last year it is satisfactory to know that (1) the “British Oyster Industries Association,” on very much the lines that we suggested, has been

* “Oysters and Disease,” published by George Philip and Son, London and Liverpool, at 7s. 6d. nett.

formed, and (2) an Oyster Bill has been laid before Parliament and referred to a Select Committee of the House of Lords. The Bill, although capable of improvement in some details, does much to meet the present difficulties; if, however, the Oyster Association takes a sufficiently high view of its responsibilities and duties, the provisions of the Bill may become unnecessary.

I may, finally, give here a few sentences of the practical conclusions at which Prof. Boyce and I have arrived as the result of the bacteriological work:—

“ It is evident from the result of these experiments, and a consideration of all the facts brought to light in recent years in regard to the bacteriology of shell-fish and its influence on public health, that we must regard oysters, mussels, cockles, and the like as nutritious food matters which, from their nature and the circumstances of their cultivation and sale, are liable to become contaminated with organisms—pathogenic or otherwise—and their deleterious products.

“ Once this is recognised, the practical applications are largely a matter of common sense. Shell-fish must not be taken as food from grounds where there is any possibility of sewage contamination; after removal from the sea, while in transit, in store, or in market, they should be carefully protected from any possibility of insanitary environment; they should not be kept longer than is absolutely necessary in shops, cellars, &c., in towns, where, even if not running the risk of fresh contamination, they are under conditions favourable to the reduction of their vitality, and the growth of their bacterial contents—the fresher they are from the sea the more healthy they are likely to be. Finally, only absolutely fresh shell-fish should be eaten uncooked, and

those that are cooked must be *sufficiently cooked*, raised to boiling point, and kept there at least ten minutes."

INTERNATIONAL EXPLORATION OF THE SEA, AND THE STOCKHOLM CONFERENCE.

In our last Report the further exploration of the North Atlantic and the Arctic Seas, in the interests both of fisheries work and of scientific investigation, was discussed at some length, and suggestions were made as to the lines along which series of observations were highly desirable. This matter has been before the minds of scientific men both in this country and abroad for some years now, and many biologists would, no doubt, gladly do the work if the necessary observing vessels were provided by the European governments concerned in the coast fisheries. When it was announced, early in 1899, that our government had accepted the invitation from the Swedish government to take part in an International Conference on the whole subject, to be held at Stockholm during the summer, hope ran high that at last the opportunity had come when strong representations would be made to the governments of north-western Europe, such as would lead to the provision of the required boats and men for a number of years sufficient to carry out the biological investigation of the seas around the British Isles.

The Conference was held at Stockholm in the latter part of June, and a great deal of the credit of having brought the matter to that point must be given to the Secretary of the Swedish Committee, Dr. Otto Pettersson, the distinguished Hydrographic expert. The Hydrographic element was probably very strong amongst the delegates present, and certainly seems to be the dominant note in the published account of the deliberations. Probably,

that is the reason why the official Report*, now published, is a somewhat disappointing document in the eyes of biologists. It consists of a number of resolutions in regard to what is desirable, or what is required in the investigation of the sea, and of one recommendation as to the formation of a central bureau to control the work and conduct a laboratory.

One section is called a "Programme" of work, but there is no practical programme of biological work—laying down how, when and where the investigations are to be carried out—such as was expected, and is required. For, surely, what we need most at the present time, in the interests of more exact fisheries† knowledge, is the nearest possible approximation to a "census" of our seas, beginning with the territorial waters. Most fisheries disputes and differences of opinion are due to the absence of such exact knowledge. If such an approximate census, or record of really reliable statistics, had been taken fifty years ago it would now be invaluable to fisheries inspectors, superintendents and local authorities, as well as to biologists. Our descendants will justly reproach us if, with our increased knowledge and opportunity, we let the twentieth century commence without inaugurating some such system of statistics.

The Report of the Conference says nothing of all this. In place of asking for boats and men, it expresses many admirable sentiments and pious wishes as to what is desirable and what should be done—sentiments and wishes that are quite unexceptionable, but which have been before the public now for some years, and which are in the main

* "Conférence Internationale pour l'Exploration de la Mer, réunie à Stockholm, 1899."

† The British Government, we are told, only joined in the Conference in the interests of the fisheries applications of marine exploration.

agreed to on all hands. We looked for something more from this Conference. Their one definite recommendation (see "Résolutions Textuelles," p. 12) to the governments concerned, is in regard to the establishment of the central bureau, in which the work will apparently, in large part, be that of a physico-chemical laboratory. I do not think that, after what I have written in previous L.M.B.C. Reports, I can be accused of under-valuing the importance of hydrographic work, in its connection with the fisheries, as carried out of late years chiefly by the Scandinavians; but it seems curious, to say the least of it, that the obvious biological investigations of primary importance have been passed so lightly over, while the secondary hydrographic investigations are strongly urged. The impression given by the Report is, certainly, that it has been drawn up by hydrographers, and not by biologists.

There are points of detail in the report that might be criticised if it were worth while—such as that the sea-area, proposed by the Conference, to be covered by the hydrographic investigations should certainly be extended so as to include the English Channel and the Irish Sea—and probably, also, the west coast of Ireland. At any rate, the omission of the whole of the Irish Sea from a scheme undertaken (so far as our government delegates were concerned) in the interests of the British fisheries requires explanation.

It has been pointed out, by another critic, that the best course for the British government to pursue, in order to give effect to the report of the Stockholm Conference, is to develop, and, as far as possible, co-ordinate the work of the various institutions already in existence, such as the Marine Biological Association and the Scottish Fishery Board, at the same time encouraging the formation of

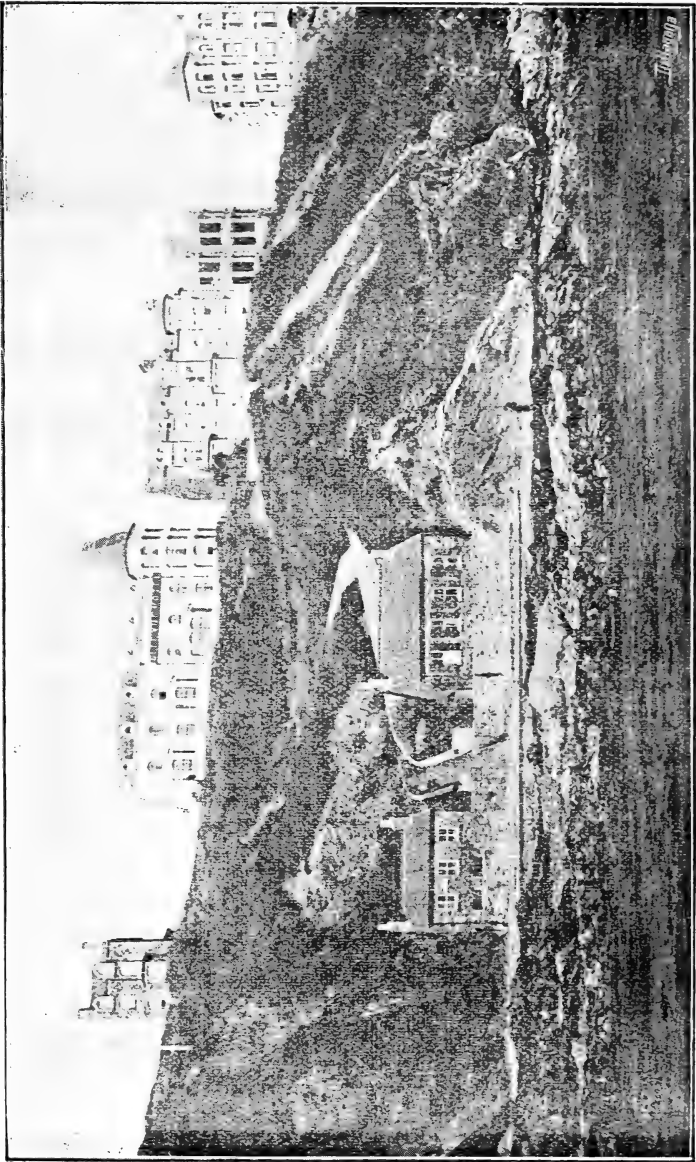
local laboratories at various points around the coast, such as those of the Liverpool Committee (at Port Erin), of the Lancashire Sea-Fisheries (at Piel), and of the Northumberland Committee (at Cullercoats). In place of any such scheme of biological collaboration between existing marine stations, the report of the Conference urges the institution of the new central bureau and laboratory—an elaborate and expensive organisation, which will probably appear to most biologists a matter of quite secondary importance, against which objections may be made. The following one has already been raised*—“With an elaborate organisation, such as that suggested by the Conference, there is a danger that the work of the biological stations would degenerate into the mere taking and recording of routine observations, whilst original work and the development of new methods of research, which are in reality of far greater importance, would receive a check. Good men would certainly not be attracted to work which consisted merely in recording observations taken according to a stereotyped plan dictated by a central bureau. A large amount of individual freedom to the workers is absolutely essential in order to secure the best results from scientific research.”

In my opinion, what we want at the present time is not conferences or committees, or a central bureau, so much as boats, men, and *work at sea*.

THE FUTURE OF THE BIOLOGICAL STATION.

Since last Report the Bellevue Hotel (and with it the Biological Station, built on the grounds of the hotel), like so many other hotels in the Isle of Man, has passed into the hands of a syndicate. After some negotiations, the

* “Nature,” Nov. 16th, 1899.



Port Erin Biological Station and its surroundings, at low tide, from the sea. [From a photo by Rev. T. S. Lea.]

Committee have arranged to continue their tenancy of the buildings: so our landlord is no longer Mr. Thomas Clague, but a Company.

We have no desire to make a change at present, but we feel that the question of expansion will have to be faced soon. We have the doubtful advantage of being, perhaps, the smallest Biological Station (so far as regards buildings) in the world, our space is much cramped, each year we are, at holiday times, over-crowded with workers, and there are many additions and improvements in laboratory and aquarium that are badly wanted. Our last Annual Report was most favourably commented upon in an editorial review in the well-known journal "Natural Science," and the article ended with the following sentences* :—

"We cannot, indeed, but regard it as remarkable
 "that a wealthy city like Liverpool, with all its
 "traditions as a sea-port, should be unable to offer
 "its Marine Station more than the very small sum
 "at present at its disposal. If successful and per-
 "severing work with small means deserves encour-
 "agement, it certainly should not be lacking to the
 "Port Erin Station. We wish Professor Herdman
 "and his colleagues all success in the carrying out of
 "their enlarged conception of local research."

We thank our unknown friend, and hope that his view of the matter may be adopted by the citizens of Liverpool.

But we do not ask merely for money to enable us to carry on more work. We want more than material support. We wish to have the moral support afforded by knowing that we are of use to the community. At present we educate (in the laboratory) a small number of Science and Medical Students: we should like to educate all kinds

* "Natural Science" for March, 1899, p. 186.

of students. We do, in a sense, through the aquarium convey information to all visitors who enter the building, and through our Reports to all who read them. But much more use might be made of our institution, even on its present small scale, and there is scarcely a limit to the uses to which it might be put if re-built on a larger scale and adequately equipped. When one thinks of the *hundreds* of school teachers and students of arts and theology who, in America, flock to the Marine Biological Stations during the summer vacation, in order that they may have the opportunity of becoming acquainted with biological thoughts and methods, and of studying under expert guidance the facts and ways of living Nature, one cannot but be struck by the contrast here; and one is led to wonder how long it will be before the elements of nature-knowledge are recognised as an essential part of a liberal education.

It is evident to some of us, from experience of and conversations with school teachers, that the demand for vacation work at Biological Stations is with us—it is the means of satisfying the demand that is absent. The immense success of the movement in America (*e.g.*, at the Woods Holl Biological Station, Massachusetts) not only justifies but requires us to urge its adoption here. If any Technical Instruction Committee, or other educational body (or individual), will build me a new biological station from my plans, within reasonable distance of Liverpool, and containing a laboratory in which, say 30, students can carry on work, I will undertake to admit school teachers free, and teach them in a free vacation class, and I feel sure, from some experience I have had, that the room would always be full, and that the students would find they were spending not merely an instructive, but also a most enjoyable vacation—learning new things every day,

but in a manner so different from their ordinary school life that it would be a rest and a mental refreshment.

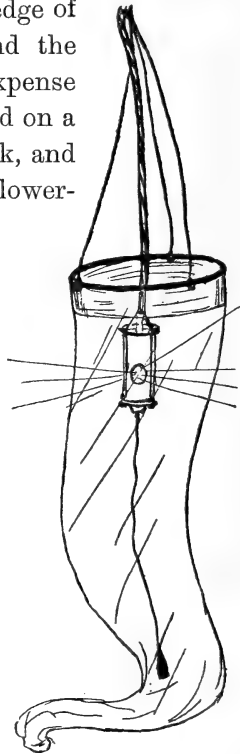
The importance of studying living Nature, and the uses that ought to be made of Biological Stations in education, are rapidly coming to be recognised in many other parts of the world. Here these institutions are not yet recognised as university laboratories, and time spent in them does not count in the curriculum for degrees. But in far Japan, Professor Mitsukuri tells me all the Biological Students of Tokio University are required to spend *at least* one season at the Marine Station of Misaki, which is a recognised institution of the University, while those who propose to graduate in Biology must spend a considerably longer period in such work. Many of the American Universities have Biological Stations as a necessary part of their equipment; and, in some cases, professors, staff, and students regularly migrate for the summer term to the sea-side laboratory.

Although England led the way in the past in Marine Biology, we are now behind other countries in the facilities and arrangements which cannot be provided by private enterprise. But all these things will come in time. We shall have University Biological Stations and Municipal Biological Stations some day. The pity is that we cannot have them *now* instead of 10, 20, or 30 years hence. Sir Michael Foster, in a recent address, has said:—"It is a matter of regret that the enthusiasm of the young learner should be spent wholly on the museum and the laboratory, that he should be pushed by compulsion and drawn by rewards into morphological and physiological studies of the more formal and mechanical kind, while no encouragement is given to him to look Nature face to face in the field, and to catch direct from her lips the Catholic teaching which she alone can give."

PLANKTON.

It was shown in last year's Report that one of the most important things the Biologist can do to add to our knowledge of life in the sea, with a practical view to the explanation of the movements and distribution of fish, is to make a systematic survey of the microscopic floating and drifting life of the sea, and its relation on the one hand to the physical conditions at the time (especially the temperature and salinity of the water), and on the other to the food materials found in the stomachs of the fish.

We have continued our efforts during the past year to contribute our share towards a knowledge of this "plankton" life of the sea round the British coasts. At some considerable expense we purchased a small hand pump, fitted on a stand for convenience of work on deck, and 20 fathoms of india-rubber hose-pipe for lowering to the bottom. This apparatus was used on several occasions early in the year, with rather disappointing results. It may be the more exact method in so far that it only gives organisms from the definite depth to which the end of the hose-pipe is lowered, while an ordinary open tow-net, lowered to the depth in question and raised again, may show some small admixture of organisms from the water above; but, on the other hand, the open tow-net catches far more material, and therefore gives a more complete knowledge of the fauna.

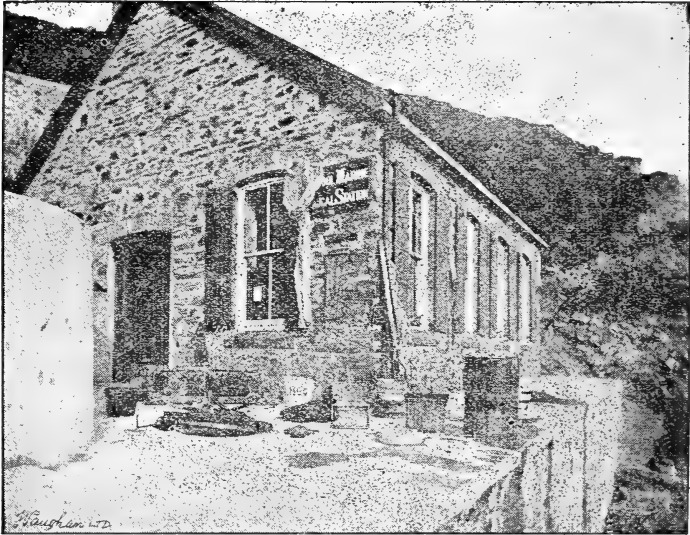


A Tow-Net.

There is a tendency, in trying to attain to more exact methods in biology, towards arguing and collecting, as if organisms were evenly distributed through the particular layer of water or region they inhabit—as if, in fact, they were like the salts dissolved in the water, so that one sample from a locality ought to be exactly like any other sample. This is far from being the case. One gallon or cubic foot of water, though, in the main, like its neighbours, may contain one of the rarer organisms not present in the next gallon examined. Consequently, in a net hauled up vertically, or in a comparatively small volume of water drawn up from a special layer through the hose-pipe, there is considerable risk of missing some of the less frequent organisms; while the ordinary tow-net, through which a very much greater mass of water passes, will probably contain a more completely representative gathering. This is, in the main, our objection to the pump-plankton method which we tried at Port Erin at Easter on board the fisheries steamer “John Fell.” Equal times of working with the ordinary open tow-net and with the pump and hose gave results, both at bottom and at surface, which were absurdly disproportionate. The open tow-net collected in the same period many times as much material, and far more species than the pump showed.

Mr. Thompson, in his note on a previous page as to Copepoda, has referred to the interesting differences we found between surface and bottom (30 fathoms) plankton in mid-winter. We hope to continue such observations in the deeper water lying between the Isle of Man and Ireland. That, however, can only be done on our comparatively rare steamboat expeditions. In the meantime our Curator at the Station has endeavoured, during the whole of the past year, to take at least one ordinary surface tow-net gathering across Port Erin Bay in the

week. Of course, such a scheme is dependent to some extent upon weather, and cannot always be carried out with absolute regularity. A few weeks have been missed now and then when it was practically impossible to work from a small boat in the Bay; but in all about thirty gatherings are fairly equally spread over the year, and every month is represented.



Apparatus brought back from a dredging expedition.

Mr. Chadwick has examined all these gatherings in the fresh condition, and they have then, after preservation, been carefully investigated by Mr. Thompson for Copepoda, while Mr. E. T. Browne, a former worker at Port Erin, has kindly identified the Medusæ sent to him. Mr. Chadwick has compiled MS. lists of all the gatherings, and has compared and summarised these with the object of ascertaining how far they bear out, correct, or supplement the conclusions we gave in a previous Report (No. XI., p. 17). The following summary of the results

obtained from the examination of the past year's plankton, at Port Erin, has been drawn up by Mr. Chadwick for this Report. Mr. Chadwick has also provided us with the two carefully drawn plates which illustrate this section of the Report, and represent some of the more interesting larval forms captured during the year.

SUMMARY OF PORT ERIN PLANKTON IN 1899.

The following summary is the result of careful examination of the series of tow-nettings taken in Port Erin Bay during the year 1899. It has not been possible to identify all the organisms taken, nor yet, in some few cases, to refer them to their respective classes, and this is especially the case with some of the larval forms. All the organisms taken during an hour's tow-netting were examined alive, under a low power, immediately after capture, and the figures on Plates VI. and VII., with which these notes are illustrated, were drawn from living specimens under appropriate magnification.

The occurrence of *Pelagia perla*, *Gattiola finmarchica*, *Autolytus incertus*, and the larvæ of *Phoronis* and *Balanoglossus* in Port Erin Bay is here recorded for the first time. With reference to the Medusæ, Mr. E. T. Browne writes:—"The occurrence at Port Erin of *Pelagia*, *Mitrocomella*, *Melicertidium*, and *Laodice* tends to show that you have had a northerly current this summer, bringing down animals through the north channel from the Atlantic shores of Ireland and Scotland." We hope to publish a more complete account of the times of occurrence and distribution of the Medusæ at a future time.

As an example of what may be looked for in a summer tow-netting across Port Erin Bay, the following list of organisms, taken on June 22nd, will be interesting. The

time was 9-45 to 11-30 a.m.; temperature of sea, 59°; wind, E.S.E.; light, sky overcast.

- Diatoms, many.
Ceratium tripos, few.
Phialidium cymbaloideum, many.
P. temporarium, many.
Sarsia tubulosa, several.
Margelis bella, few.
Mitrocomella polydiadema, several.
Aurelia aurita, many.
Hormiphora, many.
Pleurobrachia, many.
 Asterid larvæ, few.
 Echinoid plutei, several.
 Ophiuroid plutei, many.
 Pilidium larva, several.
 Mitraria larva, several.
 Tornaria larva, several (figs. 7, 9, 10, Pl. VII.).
 Trochophores, several.
 Post-larval stage of *Polygordius* (?), few.
 Post-larval stage of *Pectinaria*, few.
 Post-larval stage of *Amphitrite* (?), several.
 Post-larval stage of Polynoe, few.
 Cyphonautes larva, many.
 Actinotrocha larva of *Phoronis*, several.
 Nauplii, very few.
Evadne nordmanni, numerous.
Podon intermedium, many.
Calanus finmarchicus, numerous.
Pseudocalanus elongatus, numerous.
Temora longicornis, many.
Centropages hamatus, few.
Acartia clausii, numerous.
Oithona spinifrons, few.

Candacia pectinata, few.

Zoëæ, many.

Oikopleura, few.

A few notes on the prevalent forms in the different months will now be given.

In the only tow-netting taken in January, the most notable forms were a Radiolarian (*Acanthometra*), of which there were many; the Hydromedusa *Hybocodon prolifer*, which, curiously enough, has not again been noted during the year; a Holothurian larva (fig. 1, Pl. VII.), and the three stages of the development of an Asterid larva, figured on the same plate (figs. 4 to 6).

There were also several trochophore and post-larval stages of Polychæta, and single specimens of *Tomopteris onisciformis* and *Autolytus cornutus*. *Sagitta*, recorded in the Eleventh Annual Report as abundant in January, was not seen. There were a few Molluscan veligers and several specimens of *Oikopleura*. Lastly, a single specimen of the curious larva represented on Pl. VI. (fig. 5), was seen, and kept under observation for some time.

In the February tow-nettings the Acanthometrids were well represented, and the Hydromedusæ *Obelia* and the first stage, with four tentacles, of *Phialidium temporarium*, appeared. Bipinnaria and Auricularia larvæ were in force, and a few Echinoid plutei, of two species, were noted. *Sagitta*, the larva of a Bopyrid, Nauplii, and Zoëæ appeared in increasing numbers as the end of the month drew near. Fish eggs appeared in small numbers on February 3rd, and fish larvæ, of two species, were taken on the 23rd.

A tow-netting, taken on March 13th, showed the Radiolarians to be present in diminishing numbers. Several very young specimens of *Hormiphora* appeared, and many Echinoid plutei, of three species, along with small numbers of Auricularia and Bipinnaria larvæ, and segmenting eggs

of *Asterina gibbosa*, were seen. One specimen of *Autolytus incertus* was noted. On March 24th Cirripede nauplii were present in such large numbers that the water in the shore pools appeared to be muddy, and the quantity of Diatoms and other Algæ reached its maximum about the same date.

On April 14th two specimens of a minute Planarian worm (Plate VI., fig. 1), and a single specimen of the larva of *Loxosoma*, were noted. Post-larval stages of Polychæta (Pl. VI., figs. 7 and 8), and nauplii of Cirripedia and Copepoda were very numerous. A general increase in numbers was noted on the 27th, and the Hydromedusæ *Saphenia mirabilis* and *Phialidium cymbaloideum* appeared.

On May 23rd a Diatom (*Rhizosolenia*) was present in enormous numbers. On the 29th the Medusæ *Phialidium temporarium*, *P. cymbaloideum*, *Laodice calcarata*, *Sarsia tubulosa*, and *Pilema octopus*, and the Siphonophore *Agalmopsis elegans* were all represented, as also was the interesting larva of *Cerianthus* known as *Arachnactis bournei*. On the same date *Autolytus cornutus* was represented by half-a-dozen specimens, and the post-larval stage of *Pectinaria* was noted for the first time this year. *Sagitta*, represented by a few specimens on the 23rd, was fairly common on the 29th. On the latter date Nauplii of several species were still abundant, and several Megalopas were noted. *Oikopleura* was common.

On June 1st the Hydromedusæ, especially *Phialidium temporarium*, and the Siphonophore *Agalmopsis elegans* were more numerous, and *Pleurobrachia* appeared in great force. *Sagitta* and *Tomopteris* were common. Post-larval stages of Polychæta and Nauplii had almost disappeared, while Zoeæ of several species were tolerably common. On this date the Actinotrocha larva of *Phoronis*, one of the most interesting additions to our lists, was seen

for the first time. Fish eggs and larvæ were still present in small numbers. Echinoid plutei of two, possibly three, species were present in large numbers in a tow-netting taken shortly before sunset on June 5th, and during the following week Ophiuroid plutei became almost equally numerous. Auricularia and Bipinnaria larvæ reappeared in small numbers. In addition to the Medusæ previously recorded, *Margelis bella*, *Euchilota pilosella*, and *Aurelia aurita* were present in fair numbers, and the medusa of *Corymorpha nutans* and the Actinula larva of *Tubularia* were represented by several specimens of each. *Sagitta* was common, as also was the post-larval stage of *Pectinaria*. *Evadne nordmanni* and *Podon intermedium* were found in increasing numbers in every tow-netting taken during this month. The number of larval forms reached its maximum during the last week in June.

The tow-nettings taken in the early part of July were similar to those of the latter end of June, the only addition to the organisms then recorded being the post-larval stage of *Chaetopterus variopedatus*. On July 16th and during the following week *Aurelia aurita* and *Beroë ovata* were present in the Bay in enormous numbers, and *Tiara pileata* was common at the surface during the calm evenings of the following week. A species of *Cyanea* also occurred sparingly at this time.

During the early part of August several of the Hydromedusæ disappeared from the tow-nettings, while *Melicertidium octocostatum* was noted for the first time on the 11th. A species of *Obelia* was then common, and *Agalmopsis elegans* was still represented. Amongst a few Echinoid plutei that of *Echinocyamus pusillus* was noted. On the 19th Ophiuroid plutei were again numerous, and on the 22nd the Zoea and later larval stages of *Macrura* and *Brachyura* reached their maximum in numbers.

The early part of September brought unsettled weather, and with it a general diminution in the number of organisms present in the tow-nettings. With the exception of Nauplii, very few larval forms were seen. On the 15th a single specimen of the free-swimming Polychæte, *Gattiola finmarchica*, was taken. *Oikopleura* attained its maximum numbers at the end of this month.

Early in October large numbers of *Pelagia perla* appeared in the Bay, and with them *Pleurobrachia* and *Hormiphora* reappeared, as also did the Radiolarians noted in January and February. *Sagitta* and *Oikopleura* were again common on the 18th. Two specimens of the trochophore represented on Plate VI. (fig. 2) were seen on the 28th, when post-larval stages of two Polychætes were common. Molluscan veligers and Lamellibranch fry were present in small numbers on the same date.

The November tow-nettings revealed a marked increase in the numbers of Diatoms and Molluscan and Tunicate larvæ. The gastrulating blastospheres represented on Plate VII. (figs. 2 and 3) appeared towards the end of the month, as did two stages of the Holothurian larva (fig. 1).

In December the gastrulating blastospheres just mentioned increased in numbers, but no further stages of their development were seen; and the Holothurian larva again occurred. *Sagitta* was represented on the 17th and 30th by two or three specimens. Several specimens of the trochophore represented on Plate VI. (fig. 3) were noted on the latter date. Post-larval stages of four species of Polychæta had each a few representatives.

Comparison of the foregoing summary with that contained in the Eleventh Annual Report, already cited, shows that, in the main, the various organisms appear and disappear about the same times year after year.

Finally, we print a complete list of the organisms found

in the tow-nettings in 1899, with the times at which they occurred.

Diatoms, throughout the year.

Ceratium tripos, *C. fusus*, and *C. furca* throughout the year.

Tintinnus, September to December.

Codonella, November.

Dictyocysta, December.

Radiolarians, October to March.

Actinula larva of *Tubularia*, June.

Phialidium temporarium, January and May to August.

P. cymbaloideum, May, June, and July.

Hybocodon prolifer, January.

Sarsia tubulosa, May to August.

Obelia, February to November.

Corymorpha nutans, June and July.

Mitrocomella polydiadema, June and July.

Margelis bella, May to July.

Tiara pileata, July, August, and December.

Saphenia mirabilis, April.

Euchilota pilosella, June to August.

Laodice calcarata, May.

Melicertidium octocostatum, August.

Aurelia aurita, June to August.

Pelagia perla, October.

Pilema octopus, March, May, and October.

Cyanea, July and August.

Agalmopsis elegans, May to August.

Hormiphora, March to November.

Pleurobrachia, June to October.

Beroe ovata, July and August.

Arachnactis bournei, May and June.

Gastrulating blastospheres, probably Asterid,
November to March and June.

- Bipinnaria and Auricularia larvæ, Feb., Mar., & June.
 Echinoid plutei, January, March, June to December.
 Pluteus of *Echinocyamus pusillus*, August.
 Ophiuroid plutei, February, March, June to Sept.
 Holothurian larvæ, January, August, Nov., and Dec.
 Pilidium larva, June.
 Mitraria larva, June and November.
 Tornaria larva, June and July.
 Planarian worm, March and April.
Sagitta bipunctata, throughout the year.
 Trochophore larvæ, February, June, Nov. to Dec.
 Post-larval stages of Polychæta, throughout the year.
 Post-larval stage of Polynoe, June to September.
 Post-larval stage of *Chaetopterus variopedatus*, July.
 Post-larval stage of *Pectinaria*, May to July.
 Post-larval stage of (?) *Amphitrite*, June and July.
Autolytus cornutus, January, May, July, and Sept.
Autolytus incertus, March.
Gattiola finmarchica, September.
Tomopteris onisciformis, June to January.
 Larva of *Loxosoma*, April.
 Cyphonautes larva, Jan., Feb., June to Dec.
 Actinotrocha larva of *Phoronis*, June to August.
 Nauplii of Copepoda, throughout the year.
 Nauplii of Cirripedia, March and April.
 Pupa stage of Cirripedia, March to May.
Evadne nordmanni, June to September.
Podon intermedium, June to September.
Calanus finmarchicus, throughout the year.
Pseudocalanus elongatus, throughout the year.
Acartia clausii, throughout the year.
Oithona spinifrons, throughout the year.
Eutерpe gracilis, Jan., Feb, April, and Oct.
Temora longicornis, March to October.

- Centropages hamatus*, March to September.
Isias clavipes, May, June, and September.
Corycæus anglicus; June and November.
Candacia pectinata, June to August.
Metridia longa, August.
Anomalocera patersoni, October.
Lernæa branchialis, November.
Monstrilla sp., November.
 Larva of Bopyrid, December to February.
 Zoeas, January to June, August and November.
 Megalopas, May to August.
 Molluscan veligers, January to April, Sept. to Dec.
 Lamellibranch fry, September to February.
 Gastropod fry, January to March, July to October.
 Tunicata larvæ, Jan., Feb., July, August, and Nov.
Oikopleura, throughout the year.
Fritillaria, October and November.
 Fish eggs, February, March, June.
 Fish larvæ, February to July.

It will probably be convenient to readers if the EXPLANATION OF THE PLATES is given here rather than at the end of the Report.

PLATE VI.

- Fig. 1. Planarian worm, Oct. 28th, 1898.
 Fig. 2. Trochophore larva, Oct. 28th, 1898.
 Fig. 3. Trochophore larva, showing early stage of metameric segmentation, Dec. 17th and 30th, 1898.
 Fig. 4. Trochophore-like larva, with three bands of cilia. Pale-green, highly refractive bodies in interior. Dec. 30th, 1898, and Jan. 24th, 1899.
 Fig. 5. Unknown larva. Organ *o* is paired, and the granules in the interior vesicle were in active rotation. Jan. 24th, 1899.

Fig. 6. Trochophore larva, Dec. 30th, 1898, and Feb. 3rd, 1899.

Figs. 7 and 8. Post-larval stages of Polychæta, of which many were taken during April, 1899.

PLATE VII.

Fig. 1. Holothurian larva, Jan. 24th, 1899.

Fig. 2. Echinoderm Blastosphere, at close of segmentation, Dec. 17th, 1898.

Fig. 3. Gastrula stage of fig. 2, in optical section. *a.c.*, Amœboid cells budded from the invagination.

Fig. 4. Asterid Gastrula, Jan. 24th, 1899.

Fig. 5. Later stage of fig. 4, showing the archenteron, *ar.*

Fig. 6. Still later stage, from ventral surface. *ar.*, archenteron, from which the enterocœlic vesicles, *v.p.d.*, are derived. The water vascular rosette is derived, according to Metschnikoff, from the left vesicle, that on right of figure.

Fig. 7. Tornaria larva of *Balanoglossus*, June 5th, 1899.

Fig. 8. Bipinnaria larva, Feb. 23rd, 1899, from dorsal surface. *æ.*, Oesophagus; *a.*, Anus; *hy.*, Hydro-pore; *v.p.d.*, anterior enterocœlic vesicles.

Figs. 9 and 10. Tornaria larvæ of *Balanoglossus*, June 23rd, 1899. *p.p.*, Proboscis pore; *p.c.*, Proboscis cavity. Figure 10 is most probably identical with the Tornaria figured by Mr. G. C. Bourne (Journ. Mar. Biol. Assoc., vol. I., p. 63, Pl. VIII., fig. 13).

PUBLICATIONS.

During the past year the following papers dealing with biological work in the L.M.B.C. District have been published :—

1. The Twelfth Annual Report (Trans. Biol. Soc., vol. XIII., pp. 21—65), with illustrations, 1898.

2. The Sea-Fisheries Laboratory Report for 1898 (Trans. Biol. Soc., vol. XIII., pp. 69—155, and Plates I. and II). By W. A. Herdman, Andrew Scott and James Johnstone, with additional Articles by R. L. Ascroft, C. A. Kohn, F. W. Gamble and F. W. Keeble, 1899.

3. List of the Araneida of Port Erin and District. By A. R. Jackson (Trans. Biol. Soc., vol. XIII., pp. 66—68), 1899.

4. Note on Mid-Winter Surface and Deep Tow-Nettings in the Irish Sea. By I. C. Thompson (Trans. Biol. Soc., vol. XIII., pp. 156—162), 1899.

5. Lancashire Sea-Fisheries Memoir, No. I. Oysters and Disease. By W. A. Herdman and R. Boyce; pp. 60, and eight Plates; quarto. G. Philip and Sons, London and Liverpool, 1899.

6. L.M.B.C. Memoirs, No. I. Ascidia. By W. A. Herdman; pp. viii. and 60, and five Plates; octavo. Dobb and Co., Liverpool, 1899.

This last item brings us to the consideration of our last new series of publications :—

THE L.M.B.C. MEMOIRS.

It will be remembered that in last year's Report I proposed a scheme for the issue of a series of special Memoirs upon typical British marine plants and animals.

In our twelve years experience of a Biological Station (five years at Puffin Island and seven at Port Erin), where

college students and young amateurs formed a large proportion of the workers, the want has been constantly felt of a series of detailed descriptions of the structure of certain common typical animals and plants, chosen as representatives of their groups, and dealt with by specialists. The same want has probably been felt in other similar institutions and in many College laboratories.

The suggestion has been received so cordially that we have been encouraged to carry out the scheme without delay, and the first papers of the series are now being issued. They will be called the "L.M.B.C. Memoirs," each will treat of one type, and they will be issued separately as they are ready, and will be obtainable Memoir by Memoir as they appear, or later bound up in convenient volumes. It is hoped that such a series of special studies, written by those who are thoroughly familiar with the forms of which they treat, will be found of value by students of Biology in our laboratories and in Marine Stations, and will be welcomed by many others working privately at Marine Natural History.

It is proposed that the forms selected, should, as far as possible, be common L.M.B.C. (Irish Sea) animals and plants of which no adequate account already exists in any text-book. Probably most of the specialists who have taken part in the L.M.B.C. work in the past, will prepare accounts of one or more representatives of their groups. The following have already promised their services, and in some cases the Memoir is already far advanced. The first Memoir (No. I., *Ascidia*) was published in October, price 1s. 6d.; the second (No. II., *Cardium*) is now in type, and will be issued in a few weeks; the third (No. III., *Echinus*) will appear before the end of 1899. A couple of Botanical Memoirs will, it is hoped, be ready early in 1900, and others will follow in rapid succession.

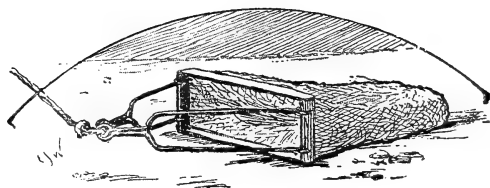
The complete list, so far as arranged, is as follows :—

- Memoir I. ASCIDIA, W. A. Herdman, 60 pp., 5 Pl., 1/6.
 II. CARDIUM, J. Johnstone, 92 pp., 7 Pl., 2/-.
 III. ECHINUS, H. C. Chadwick, ... pp., 3 Pl., 1/-.
 IV. CODIUM, R. J. H. Gibson and Helen Auld.
 HIMANTHALIA, C. E. Jones.
 PERIDINIAN, George Murray & F. G. Whitting.
 ALCYONIUM, S. J. Hickson.
 DENDRONOTUS, J. A. Clubb.
 ZOSTERA, R. J. Harvey Gibson.
 DIATOMS, F. E. Weiss.
 GIGARTINA, O. V. Darbishire.
 PLAICE, F. J. Cole and J. Johnstone.
 CUTTLE-FISH, W. E. Hoyle.
 OSTRACOD, Andrew Scott.
 BOTRYLLOIDES, W. A. Herdman.
 PATELLA, J. R. Ainsworth Davis.
 CALANUS, I. C. Thompson.
 ACTINIA, J. A. Clubb.
 BUGULA, Laura R. Thornely.
 CALCAREOUS SPONGE, R. Hanitsch.
 PORPOISE, A. M. Paterson.
 ARENICOLA, J. H. Ashworth.
 OYSTER, W. A. Herdman and J. T. Jenkins.

I desire now to acknowledge that a generous donation from Mr. F. H. Gossage, of Woolton, has met the expense of preparing the plates in illustration of the first few Memoirs, and so has enabled the Committee to commence the publication of the series sooner than would otherwise have been possible. At the end of last year's Report, after stating my suggestion as to the L.M.B.C. Memoirs, I made an appeal for funds to meet the expense, in the course of which I happened to say:—"Liverpool is the

right and natural place for a School of Marine Biology, and I hope that Liverpool will consider that it is creditable to the city that such local researches should be published by a Liverpool Society. An addition of about £100 a year to our funds is necessary in order to enable us to do justice to the work now being produced by our colleagues and students."

Shortly afterwards I received from Mr. F. H. Gossage a most welcome and gratifying letter, enclosing a cheque for £100 to be used at my discretion for the benefit of the Marine Biological work. A part of this kind gift has been devoted to the purchase of much-needed books and instruments, and the remainder is now meeting the expense of the plates in these L.M.B.C. Memoirs.



APPENDIX A.

THE LIVERPOOL MARINE BIOLOGY
COMMITTEE (1899).

- 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.
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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.

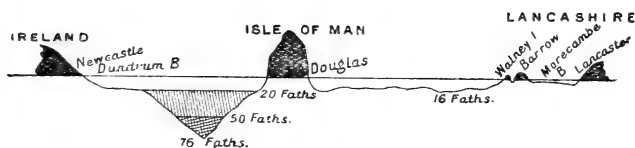
VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away 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 communication in regard to the scientific work should be made to Professor Herdman, F.R.S., University College, Liverpool.



Diagrammatic Section Across the Irish Sea.

APPENDIX B.

HON. TREASURER'S STATEMENT.

From the balance sheet appended it will be seen that the year again ends with a small debit balance, although all due economy has been observed, consistent with efficiency.

The British Association (1896) fund has, to a considerable extent, enabled the Committee to continue the extra expense involved in securing the services of a competent Resident Curator at the Port Erin Station, which has already proved of marked benefit to workers and students, the number of whom have thereby considerably increased.

The appeal made by the Director in his last year's 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 responded to by Mr. Gossage by a donation for the present year. This fund is being separately applied for the publication of a valuable series of well-illustrated Biological Memoirs now appearing, the accounts of which will be published later.

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, fifteen years ago.

SUBSCRIPTIONS and DONATIONS.

	Subscriptions.			Donations.		
	£	s.	d.	£	s.	d.
Ayre, John W., Ripponden, Halifax ...	1	1	0	—		
Bateson, Alfred, Harrop-road Bowdon ...	1	1	0	—		
Beaumont, W. I., Cambridge ...	1	1	0	—		
Bickerton, Dr., 88, Rodney-street ...	1	1	0	—		
Bickersteth, Dr., 2, Rodney-st. ...	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	—		
Buckley, W., Hulme, Manchester ...	0	10	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., (research table) ...	1	1	0	—		
Coombe, John N., 4, Paradise-sq., Sheffield	1	1	0	—		
Comber, Thomas, J.P., Leighton, Parkgate	1	1	0	—		
Corker, J., Moss Side, Manchester ...	0	10	0	—		
Crellin, John C., J.P., Andreas, I. of Man	0	10	6	—		
Crossland, Cyril, Clare College, Cambridge	2	10	0	—		
Dickinson, Dr., 8, Croxteth-rd., Liverpool	—			2	2	0
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	1	0	—		
Gotch, Prof., Museum, Oxford ...	1	1	0	—		
... Forward ...	£32	11	0	3	3	0

136 TRANSACTIONS LIVERPOOL BIOLOGICAL SOCIETY.

	Subscriptions.			Donations.		
	£	s.	d.	£	s.	d.
Forward ...	32	11	0	3	3	0
Halls, W. J., 35, Lord-street ...	1	1	0	—		
Hanitsch, Dr., Museum, Singapore ...	1	1	0	—		
Harmer, F. W., Cringleford, Norwich...	1	1	0	—		
Harrison, H. S., Univ. Coll., Cardiff ...	0	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. George, 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	—		
Jenkins, J. T., Univ. Coll., Liverpool ...	3	10	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, 3, Wellington-fields	1	1	0	—		
Leicester, Alfred, Aston Clinton, Bucks...	1	1	0	—		
Macfie, Robert, Airds ...	1	0	0	—		
Mackay, J. R., Longsight, Manchester ...	1	1	0	—		
Meade-King, H. W., J.P., Sandfield Park	1	1	0	—		
Meade-King, R. R., 4, Oldhall-street ...	0	10	0	—		
Melly, W. R., 90, Chatham-street ...	1	1	0	—		
Monks, F. W., Brooklands, Warrington	1	1	0	—		
Muspratt, E. K., Seaforth Hall ...	5	0	0	—		
Newton, John, M.R.C.S., 44, Rodney-st.	0	10	6	—		
Okell, Robert, B.A., Sutton, Douglas ...	1	1	0	—		
Paterson, Prof., University College ...	1	1	0	—		
Poole, Sir James, Liverpool ...	2	2	0	—		
Rathbone, Mrs. Theo., Backwood, Neston	1	1	0	—		
Forward ...	£74	17	6	3	3	0

	Subscriptions.			Donations.		
	£	s.	d.	£	s.	d.
Forward ...	74	17	6	3	3	0
Rathbone, Miss May, Backwood, Neston	1	1	0	2	2	0
Rathbone, W., Greenbank ...	2	2	0	—	—	—
Roberts, Isaac, F.R.S., Crowborough ...	1	1	0	—	—	—
Schuster, E. H., New College, Oxford ...	2	10	0	—	—	—
Simon, R., Broughton, Manchester ...	0	10	0	—	—	—
Simpson, J. Hope, Annandale, Aigburth-dr	1	1	0	—	—	—
Smith, A. T., junr., 24, King-street ...	1	1	0	—	—	—
Sollas, Miss, Oxford ...	1	1	0	—	—	—
Talbot, Rev. T. U., Douglas, I. 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	—	—	—
Torrance, Gilbert, North Quay, Douglas	1	1	0	—	—	—
Walker, A. O., Maidstone ...	3	3	0	—	—	—
Walker, Horace, South Lodge, Princes-pk.	1	1	0	—	—	—
Walters, Rev. Frank, B.A., the late ...	1	1	0	—	—	—
Watson, A. T., Tapton-crescent, Sheffield	1	1	0	—	—	—
Weiss, Prof. F. E., Owen's College, Man'tr.	1	1	0	—	—	—
Westminster, Duke of, Eaton Hall ...	5	0	0	—	—	—
Wiglesworth, Dr., Rainhill ...	1	1	0	—	—	—
Yates, Harry, 75, Shude-hill, Manchester	1	11	0	—	—	—
	<hr/>			<hr/>		
	£108	11	6	5	5	0
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SUBSCRIPTIONS FOR THE HIRE OF COLLEGE "WORK-TABLES."

Owens College, Manchester ...	£10	0	0
University College, Liverpool ...	10	0	0
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	£20	0	0
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Fig. 1.

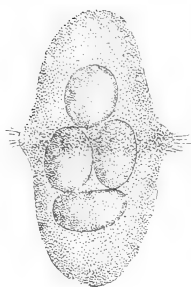


Fig. 2.



Fig. 3.

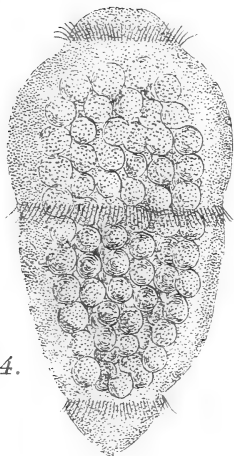


Fig. 4.

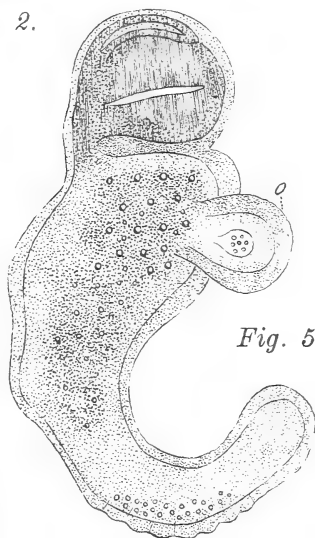


Fig. 5.

Fig. 6.

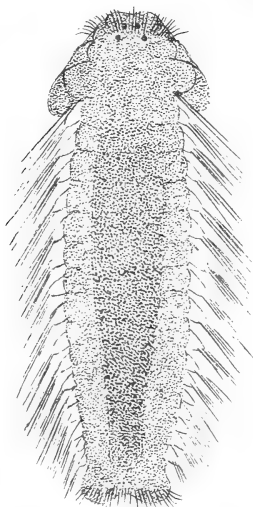


Fig. 7.

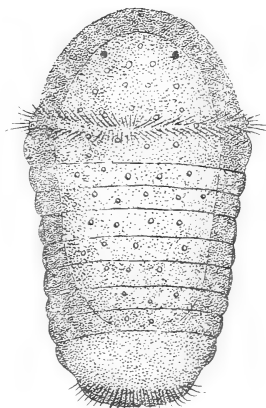


Fig. 8.

100^{ths} of an inch.

Scale for figs. 1 to 3 & 6 to 8.

100th of an inch.

Scale for figs. 4 & 5.



Fig. 1.

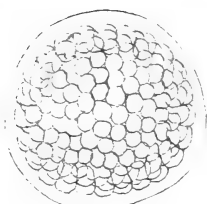


Fig. 2.



Fig. 3.

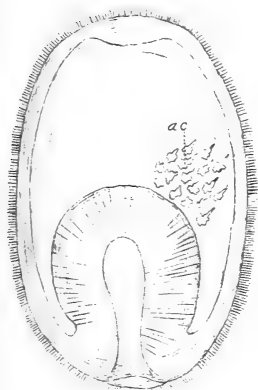


Fig. 4.

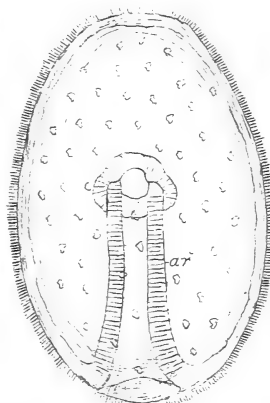


Fig. 5.

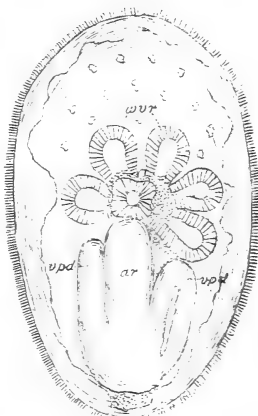


Fig. 6.

Scale for figs 2, 3, 7, 8
100th of an inch

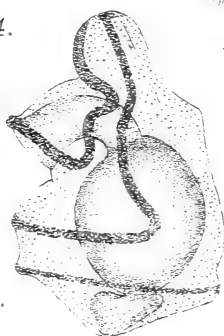


Fig. 7.

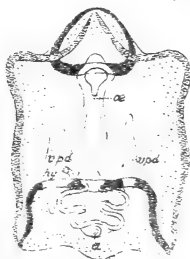


Fig. 8.

Scale for figs 4, 5, 6,
100th of an inch

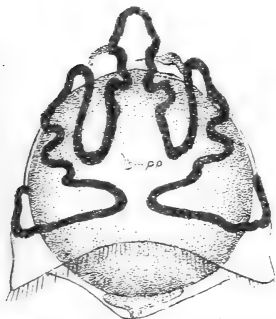


Fig. 9.

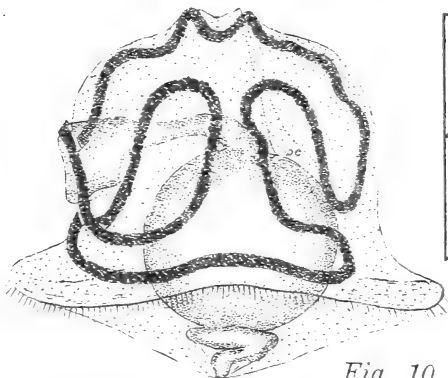
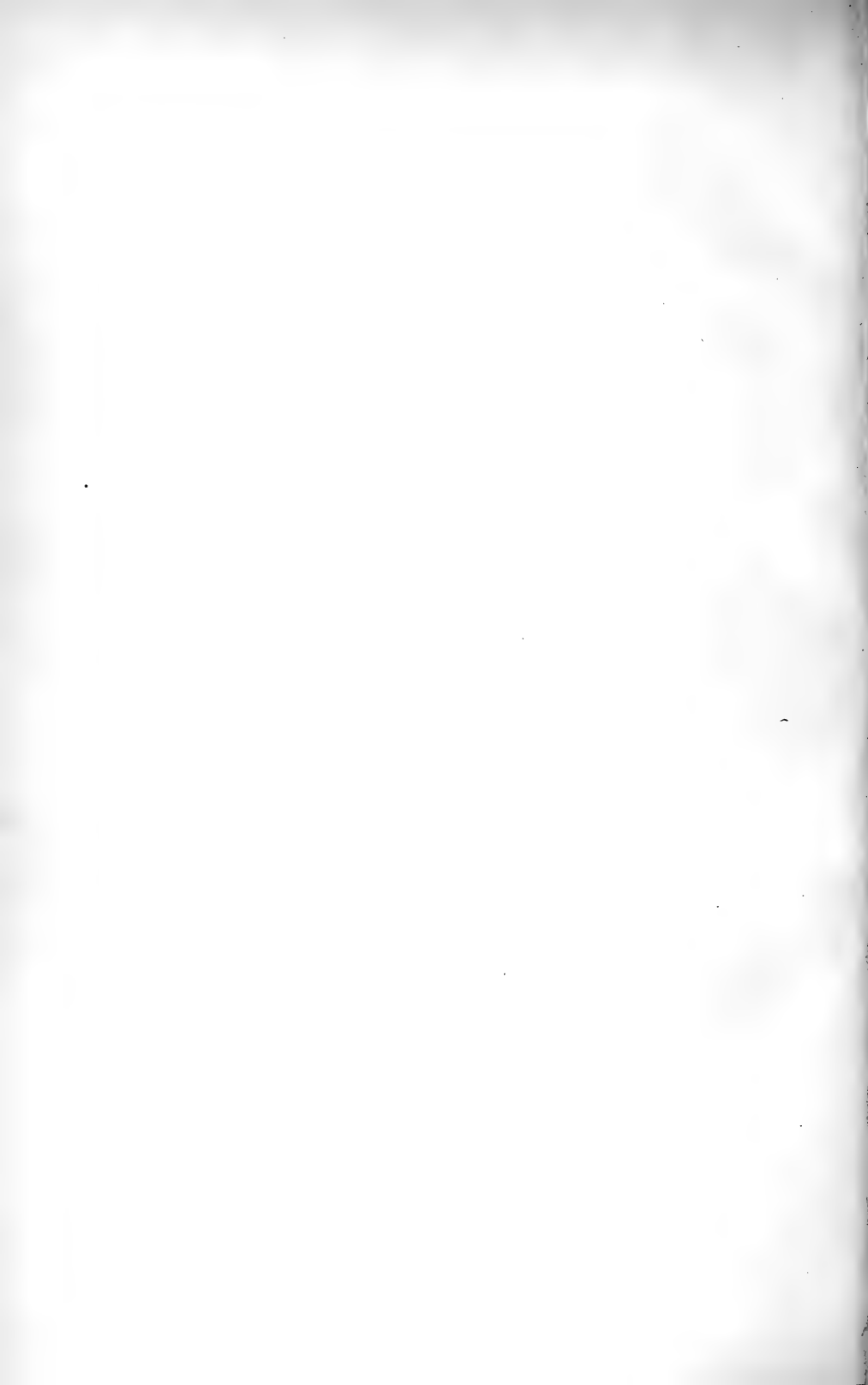


Fig. 10.

Scale for figs 9, 10,
100th of an inch



SOME RECENT ADDITIONS to the COPEPODA of
LIVERPOOL BAY.

By I. C. THOMPSON, F.L.S., and ANDREW SCOTT.

With Plate VIII.

[Read November 10th, 1899.]

THE collection and examination of tow-net and dredged material, which is carried on more or less continuously at Port Erin, Isle of Man, and in the vicinity of Piel, Lancashire, still proves a means of adding fresh names to the extensive list of species from the district, which was published in connection with the meeting of the British Association in Liverpool in 1896. That list represents all the species of marine animals and plants recorded by the workers of the L.M.B.C. during the first ten years of its history, and practically brings us down to the end of 1896. We now wish to place on record the various additions to the list of Copepoda that have come under our notice during the three years that have passed since the complete list was published.

The present report represents an addition of fifteen species new to the district, including one new to science, *Leptosyllus herdmani* (Pl. VIII.), and five species of Copepod fish parasites. Of these, two are open sea free-swimmers, the other (non-parasitic) species have either been obtained from dredged material or by digging holes in the shore between tide marks, the water being allowed to collect, and then bailed out, pouring it out through a fine sieve.

1. *Candacia pectinata*, Brady, Copepoda of the British Islands, vol. I., p. 49, Pl. VIII. and X., 1878.

This species was taken in the open sea near Port Erin in January last, and on several occasions during June and

July, 1899, both at or near the surface, as well as at a depth of 33 fathoms. It appears to be generally, but very sparingly, distributed about the British Isles, and throughout the Atlantic, Pacific, and Indian Oceans.

It and the other species of the genus *Candacia* are easily distinguishable by their dark-coloured antennules, spines and plumes, and the terminal spines of the swimming feet.

2. *Corycæus anglicus*, Lubbock, On Eight New Species of Entomostraca found at Weymouth, Ann. and Mag. of Nat. Hist., 2nd Ser., vol. XX., Pl. XI., 1857.

A single specimen of this species was taken by tow-net off Port Erin on November 26th, 1898, and a shoal of it was captured there on May 29th, 1899. It is a fairly common species about the south and south-west coasts of England and Ireland, and Mr. Thomas Scott has reported it from the Forth, and more recently, we understand, he took it in the Clyde, but it is entirely new to the L.M.B.C. district.

3. *Ameira exilis*, T. and A. Scott, Ann. and Mag. Nat. Hist., Ser. 6, vol. XIII., Feb., 1894. Length 1·5 mm.

This slender and characteristic species was taken amongst material collected from holes dug in the soft mud near the remains of the old steamboat pier, Piel; not uncommon. March, 1899.

4. *Stenhelix intermedia*, T. Scott, 15th Ann. Rept. Scot. Fish. Board, part 3, p. 169. Length ·7 mm.

In the same locality as the last. Aug., 1898; rare.

5. *Delavalia mimica*, T. Scott, 15th Ann. Rept. S.F.B.. part 3, p. 150. Length ·65 mm.

This peculiar little species occurred sparingly in material dredged from a depth of 33 faths. off the Isle of Man. Jan. 29, 1899.

6. *Laophonte denticornis*, T. Scott, 12th Ann. Rept. S.F.B., part 3, p. 246. Length .85 mm.

A slender species, not unlike *L. serrata* at first sight, but on closer examination, is seen to be quite distinct. From the same gathering as the last, which contained 31 species of Copepoda.

7. *Leptosyllus intermedius*, T. and A. Scott, Ann. and Mag. Nat. Hist., Ser. 6, vol. XV., 1895. Length .57 mm.

This little species belongs to a curious genus, the members of which, from the structure of their appendages, appear to live entirely amongst the mud and sand, and have not apparently so far been obtained at any depth. In material collected from holes dug in the sand in front of the Laboratory at Port Erin; common. Jan., 1897.

Leptosyllus herdmani, n. sp., Pl. VIII., figs. 1—9.

Description of the female:—Length, exclusive of caudal setæ, .65 mm. ($\frac{1}{4\frac{1}{2}}$ of an inch). Body, seen from above, elongate and moderately robust. Antennules short and stout, composed of eight joints, of which the sixth and seventh are the shortest, as shown by the following formula—

Proportional length of

the joints	34	22	18	14	10	8	7	15
Number of joints	1	2	3	4	5	6	7	8

Antennæ and mouth organs (figs. 1—4) nearly similar to those of *L. robertsoni*, T. and A. Scott. Both branches of the first pair of swimming feet (fig. 5) composed of two joints, the basal joint of the inner branch reaches considerably beyond the end of the outer branch; second joint very short, being only about one-sixth the length of the basal joint, and having at its apex one short and one moderately long seta. The second joint of the outer branch is furnished with four moderately long setæ, all

placed on the apex. Second (fig. 6) and third pairs of swimming feet nearly alike, the outer branches being composed of three joints, and the inner of one only, which has a slight constriction on its outer margin near the apex. In the fourth pair (fig. 7) the outer branch is also composed of three joints, but the inner branch is distinctly two-jointed, there being a small apical joint carrying one seta, and a moderately long basal joint. The fifth pair of feet (fig. 8) consists of one broad lamelliform shield, due to the complete coalescence of the basal joint of each pair. The end of the coalesced basal joints is rounded, with a slight concavity in the middle, on either side of which are two short setæ. The length of the plate is equal to nearly two-thirds of the breadth at the widest part; outer branches very small, longer than broad, and bearing one marginal and two terminal setæ. Abdomen composed of four segments, the first or genital segment being the largest, the second or third segments are nearly of equal length, the fourth segment is very small, being about half the length of the second or third. Caudal stylets (fig. 9) short and stout, the breadth being equal to about two-thirds of the length. There are three setæ on the extremity of the inner angle, and one on the outer angle, with an intervening space. There is also one small seta on the outer margin near the base. The male is yet unknown. In the same gathering as the last; not common.

This new member of the genus *Leptosyllus* is easily distinguished from previously described species by the elongate joint of the inner branch of the first pair of swimming feet, and by the structure of the fifth pair.*

We have much pleasure in naming this species after Professor Herdman.

* This species has recently been taken in the Clyde, off Millport, by T. Scott.

9. *Lichomolgus hirsutipes*, T. Scott, 11th Ann. Rept. S.F.B., part 3, p. 206. Length 1·4 mm.

This well-marked species was obtained from collections made in the *Zostera* beds near Piel. July, 1899.

10. *Hersiliodes littoralis* (T. Scott), 10th Ann. Rept. S.F.B., part 3, p. 260. Length 1·1 mm.

This species, which is readily recognised by the structure of the fifth pair, occurred sparingly in gatherings made on the mud flats near Piel. June and August, 1899.

11. *Caligus diaphanus*, Nordmann, Microgr. Beitr., 11, 26. A parasitic Copepod on the Cod. April 19th, 1897.

12. *Caligus gurnardi*, Kr., Bidrag til Kundskab om Snyltekrebsene, p. 150, Pl. II., fig. 3, a—g.

One specimen was taken in the dredge, at 26 faths., off Port Erin Bay. Nov. 4th, 1898.

13. *Trebius caudatus*, Kr., Tidsskrift., II. ; 30, t. I., fig. 4.

A parasitic Copepod on the Hake. April 19th, 1897. This species and *Caligus diaphanus* have already been referred to in the 11th Ann. Rept. of the Marine Biological Station, Port Erin, p. 11.

14. *Chondracanthus radiatus*, (see Bidrag Kundskab om Snyltekrebsene of Kroyer).

Found on the fins of a Codfish. Dec. 6th, 1897.

Nicothæ astaci, Aud. & M. Edw., Ann. Sc. Nat., Ser. I., vol. IX., Pl. XLIX.

This peculiar parasitic Copepod, which has all its appendages fully developed, is found occasionally in considerable numbers on the branchiæ of the common lobster, caught on our coasts. We have noted its occurrence on lobsters from Holyhead, Port Erin, and Piel. The wing-like projections of the fourth thoracic segment give it an unusual appearance.

Although this species does not appear to have been taken apart from its host, yet it looks quite capable of leading a free existence.

EXPLANATION OF THE PLATE.

Leptosyllus herdmani, n. sp.

Fig. 1.	Female seen from above.	× 106.
Fig. 2.	Antennule of female.	× 500.
Fig. 3.	Antenna.	× 500.
Fig. 4.	Posterior foot-jaw.	× 500.
Fig. 5.	First pair of swimming feet.	× 500.
Fig. 6.	Second " "	× 500.
Fig. 7.	Fourth " "	× 500.
Fig. 8.	Fifth " "	× 500.
Fig. 9.	Last two segments of abdomen and caudal stylets.	× 260.

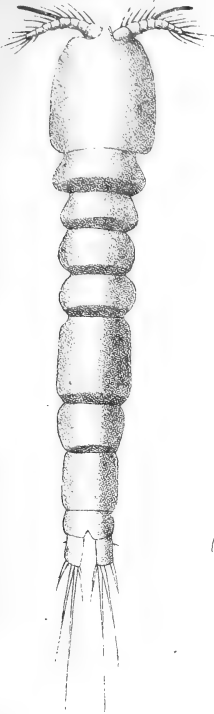


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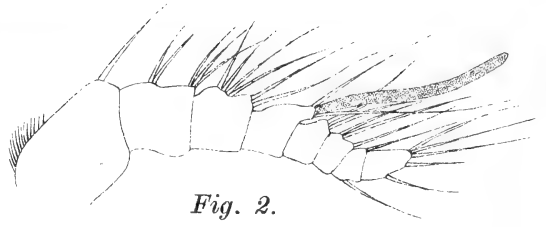


Fig. 2.

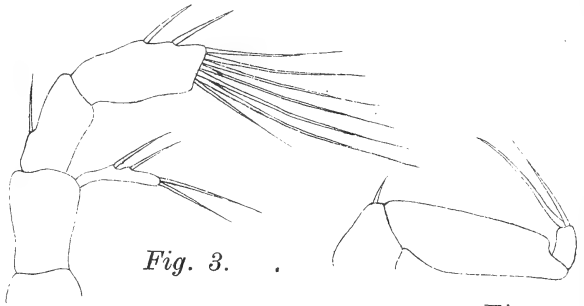


Fig. 3.

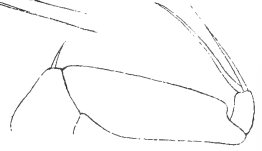


Fig. 4.

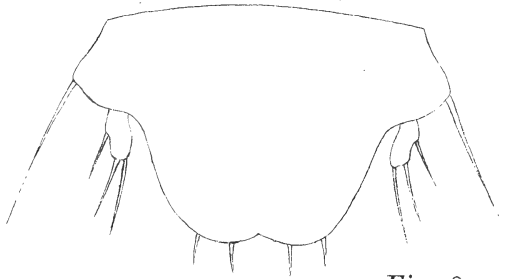


Fig. 8.

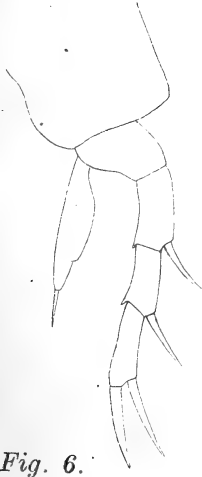


Fig. 6.

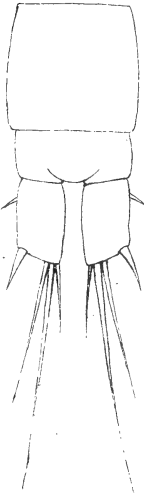


Fig. 9.

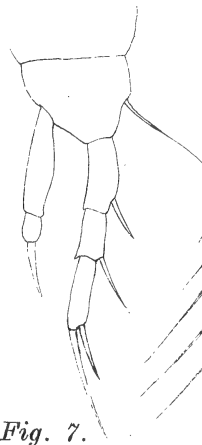


Fig. 7.

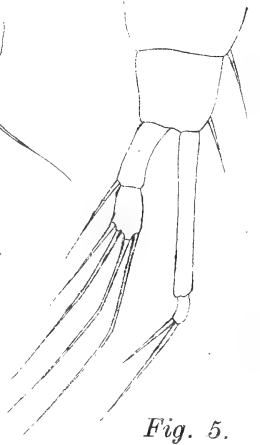


Fig. 5.

A. SCOTT, del.

LEPTOPSYLLUS HERDMANI, n.sp.

REPORT on the INVESTIGATIONS carried on in 1899 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, Fisheries Assistant at Liverpool.

With Six Plates and a Map.

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INTRODUCTION AND GENERAL ACCOUNT OF THE WORK.

(W. A. HERDMAN.)

As in the case of last year's Report, I shall give first a brief sketch of the work of the year, dealing with those minor matters which require mention, and merely referring here to those larger investigations which are treated fully in the separate sections which follow.

I mentioned last year that I had then set Mr. James Johnstone, as part of his work in the Liverpool laboratory, to make a detailed examination of the complete structure, and as much as could be ascertained of the life-history of the common cockle. This investigation has been Mr. Johnstone's chief work during the year, and, as the result,

he has now drawn up the exhaustive account of the structure of this important economic Mollusc which I have put at the end of the present Report. In addition to the account of the structure—illustrated by six plates—there is an Appendix upon Cockling in the Lancashire District, based upon statistics supplied by Mr. Dawson, Mr. Ascroft, some of the bailiffs, and the Furness Railway Co., and illustrated by a map showing the distribution of the cockle beds.

It is interesting to notice that, from comparison of these figures for last year with the Report of the Commissioners (Mr. F. Buckland and Mr. Spencer Walpole) who examined the Morecambe Bay fisheries in 1879, we can come to the important conclusion that there is no reason to suppose that there has been any serious falling off in the productiveness of these beds during the 21 years, or, at least, that the annual produce of the Morecambe district is very much the same now that it was 21 years ago.

Mr. Johnstone has, however, found it no easy matter to get statistics for the two periods that are really comparable. It is not easy to realise, until one goes into the matter, how difficult it is to get full and reliable statistics in regard to any fishery in our own district, even as recently as last year, and it is quite exceptional to have any information in regard to one 20 or 50 years ago. This is another example of the necessity for a more perfect system of recording the extent, nature, and value of our coast fisheries than we at present have, an additional argument in favour of the scheme for obtaining an approximate census of our territorial waters, which I suggest further on in this Report (see p. 158).

The rest of Mr. Johnstone's time—in addition to helping me with general work, correspondence, the examination of any specimens that arrive, the preparation of "memo-

randa" throughout the year, and of this Report—has been taken up with the removal of the travelling Fisheries Exhibition from town to town. The packing and unpacking of specimens, the renewal of labels, &c., takes up a good deal of the time both of Mr. Johnstone and also of the laboratory boy—for the first half of the year Thomas Mercer, now William Raw.

The Exhibition, it will be remembered, was opened by Mr. Fell in Liverpool in October, 1897, and has now been exhibited at the following institutions in Lancashire:—University College, Liverpool, from Oct., 1897, to March, 1898; Royal Museum, Peel Park, Salford, from March, 1898, to Oct., 1898; Free Public Museum, Preston, from Oct., 1898, to April, 1899; Chadwick Museum, Bolton, from May, 1899, to Oct., 1899; and is now at University College, Liverpool, from Oct., 1899, to March, 1900.

Mr. Mullen has reported that while the exhibition was at Salford it was visited by 120,000 persons, Mr. Branwell has estimated that during the six months at Preston it was visited by, on an average, 500 persons daily, say 75,000 in all, while Mr. Midgley writes to me—"During the time of its exhibition in Bolton it has been visited by upwards of 50,000 people, and no doubt some in the district have been led to take a deeper interest in the subject of our food supply, and in the work of the County Council in respect to fish-culture than previously." The Exhibition is at present in Liverpool being re-fitted and re-arranged and re-labelled. Early in spring it will be removed to the Gamble Institute, St. Helens, where it will remain for six months; after that it is promised to Warrington; Southport will, I believe, apply for it, and visits to Barrow and other places have been suggested.

I am disappointed that the scheme for Fisheries Scholarships and studentships, which was outlined in the last

Report, has not yet come into active operation. There seems now, however, a fair prospect that this branch of Technical Instruction will soon receive here the attention that it merits. The principle of the scheme—the course of instruction and the allotment of the money—have been approved by the Sea-Fisheries Committee, the County Technical Instruction Committee, and the Senate of University College, Liverpool. The Lancashire County Council has decided to offer two Fisheries Scholarships of £60 a year each for two years, and a number of Fisheries Studentships of £10 to £15 each. The details of the entrance examinations were, however, not arranged in time to permit of the scheme being started at the beginning of the present College Session. The Liverpool City Technical Instruction Committee have allowed certain of their scholarships to be used by "Fisheries" students, and two such scholars have already (Oct., 1899) commenced work in the Zoological department. It is to be hoped that at least one Lancashire County "Fisheries" scholar may be enabled to start his curriculum in January, 1900.

Turning to still higher Fisheries Education and Research, the Committee will be interested to know that I have now working with me at University College one of the holders of the "1851 Exhibition" from the University of Wales, Mr. J. T. Jenkins, B.Sc.; who, in addition to other pieces of work, is engaged on an investigation of the digestive glands of oysters, and other edible shell-fish, and the changes they undergo with varying conditions of health. We have had as visitors during the year, at the Liverpool Laboratory and at the Piel Hatchery, Mr. Woodall of Scarborough, Mr. Fryer of the Board of Trade, Mr. Gray of Millport Biological Station, Dr. Knut Dahl of Thronhjem, Dr. Oscar Nordgaard of Bergen, and finally, Mr. K. Oku (Chemist to the Imperial Fisheries Bureau at Tokyo) who

was sent to me by Professor Kishinouye, the head of the Bureau, to gain information as to "the recent methods of investigation, and also the technical teaching of the Science of Fisheries" in our country. In addition to these professional fisheries authorities and workers, we have had a number of non-professional visitors at Piel during the year, including—The Duke of Buccleuch, Sir John Hibbert, Admiral Barnett, Mr. Fell, Mr. E. Wadham, Mr. Bennion, Dr. Allan, Dr. Carmichael, the members of the Barrow Field Naturalist's Club, and many others. Mr. F. W. Gamble, M.Sc., of Owens College, Manchester, carried on some work on the colours of Crustacea in the Piel Laboratory during last winter, and he proposes to continue his work there during a part of the present Christmas vacation.

I think it will be of interest if I quote here, as an example of what is being done in Sea-Fisheries Instruction and Research elsewhere, the following passage from a report upon "The Work at the Biological Laboratory of the United States Fish Commission at Woods Holl, Massachusetts." It is taken from the American journal "Science" for July 22nd, 1898:—

"Three months ago the United States Fish Commission announced that its Biological Laboratory would be re-opened; that it would be equipped for investigation; that men of science would be welcome, and that every effort would be made to collect all needed material, and to furnish, within certain limits, all necessary instruments and apparatus for research. The Station has the most extensive plant for the study of marine life and practical fish-culture in the world. There are four buildings: The Hatchery, Laboratory, and Aquarium; the Residence; the Shops and Store House; and the Power House. It is in possession of

“ a small fleet of steam and sailing vessels, and by
“ special enactment the officers are empowered to use,
“ at their discretion, any means for the capture of fish
“ or other marine organisms.

“ The Commission has refurnished the Biological
“ Laboratory and added ten new rooms for research.
“ It has equipped a laboratory for physiology. It has
“ purchased a bacteriological outfit, and a creditable
“ library of biology and fish-culture has been installed.
“ Two steam launches and the schooner ‘ Grampus ’ have
“ been attached to the Station, several fine-mesh seines,
“ trawls and tow-nets have been purchased, and a large
“ fish-trap has been placed at a favourable locality.

“ From the day of the opening of the laboratory,
“ April 1st, several tables have been continuously occu-
“ pied, and, at the present time, the scientific force
“ numbers twenty-four. Several have expressed the
“ desire of extending their work during the autumn and
“ winter months, and it is proposed to keep the labora-
“ tory open throughout the year.

“ The Commission does not attempt to instruct or to
“ dictate as to what lines of research are to be pursued,
“ how the work shall be carried on, or where the results
“ shall be published. It is convinced that all lines of
“ biological research are indirectly, if not also directly,
“ helpful to its more immediately practical work, and it
“ happens that fully one-half of the investigators are
“ busy with problems bearing directly upon the anatomy,
“ embryology, physiology and pathology of fish. The
“ large corps of collaborators has made it possible to
“ secure definite data respecting the breeding habits of
“ many marine forms. The floating fauna has been
“ systematically examined; valuable information has
“ been gained respecting the larval life of the star-fish,

“the developmental stages of the clam, the rate of
“growth of the scallops, the causes of mortality of
“lobster fry, and the pathogenic bacteria infesting fish.

“With the co-operation of the Marine Biological
“Laboratory, it is proposed to make a series of syn-
“chronous observations on the temperature and floating
“fauna of Vineyard Sound. The combined vessels of
“the two laboratories provide a sufficiently large fleet
“to make these observations of special interest. It is
“also proposed to resume again the deep-sea work
“begun by the Commission many years ago, though the
“temporary use of the ‘Fish Hawk’ by the United States
“navy will prevent the work from being undertaken
“the present season.

Mr. Andrew Scott's work at the Piel Laboratory and Hatchery has consisted in the hatching of young food fish and lobsters, and certain experiments in their rearing, in the examination of tow-nettings taken by the bailiffs along the coast, and in carrying on observations for me in regard to the conditions under which oysters and other shell-fish become green. A little further on (p. 163) will be found Mr. Scott's own report upon the hatching operations, but I desire to make a few remarks here as to the conclusions to be drawn from the experiments.

In the first place, *hatching* must be carefully distinguished from *rearing*. So far as regards the hatching out of a very large proportion of the ova supplied to the tanks, the operations at Piel have been entirely successful.

Out of about four million of healthy fertilised ova supplied, a total of 3,319,000 larvæ were hatched and set free in suitable localities on the off-shore grounds.

In the case of lobsters, the ova on 13 berried females were, with almost no loss, retained in a healthy condition

on the appendages during the embryonic stages, and were hatched out as larvæ.

These numbers of successfully hatched fish and lobsters compare favourably with the proportions given by other similar institutions abroad and in America; and with an adequate supply of spawn—which the absence of a spawning pond has prevented us from having in the past—there could be no difficulty in rivalling the grand totals of Capt. Dannevig in Norway and of the United States Fish Commission.

We have not, however, been content with merely hatching the ova, and setting free the larvæ, but have endeavoured to keep them for a time with the view of tiding over the younger and more defenceless stages. It is in this second attempt—the rearing, not the hatching—that we have had as yet poor success. The larval fish have lived with us for a short time, and have continued to grow and develop up to a certain stage. But there has been no evidence that they have fed systematically upon what we have supplied, and eventually all have died off before reaching the period of metamorphosis into small flat fish.

In regard to the rearing of the young lobsters, although Mr. Scott took great pains to try to supply them with various kinds of food, and kept them under varied conditions in the hope of hitting upon the environment they required, the larvæ seemed unable to get over the successive periods of ecdysis, or casting of the shell—always a critical period in the life of a Crustacean. Some lived as long as three weeks after being hatched, but none survived the third moult. However, the matter will be tried again with further variations in the food and surrounding conditions.

With a view of seeing what was done elsewhere with

the young fish larvæ after hatching, Mr. Dawson and I visited in April the hatchery at Dunbar, an institution established by the Fishery Board for Scotland, and very similar to our own hatchery in equipment and in purpose. There we were shown, by Mr. Harold Dannevig, how the millions of young plaice were kept only a few days, or at most a week, and were then transferred to the upper parts of Lochfyne on the west coast—an operation which is conducted with very little loss. I sent a special report on the visit to Dunbar to the Chairman in April, and this was printed as an appendix to Mr. Dawson's quarterly report in June. Many of the little details we saw at Dunbar may be useful to us in our further work at Piel.

Although it was Mr. H. Dannevig at Dunbar who had been most successful in keeping and feeding the young plaice, still it must be remembered that those he dealt with were a comparatively small number of isolated specimens, and not the bulk of the season's hatching.

We propose, then, to continue our rearing experiments, but only to make use of the odd hundreds and tens—setting free at a very young stage (as they do in Scotland and America) the round millions and thousands. I do not say that I regard this as absolutely satisfactory. It still leaves in doubt the ultimate fate of the fry set free. We do not know what proportion of them are killed off at early stages in the sea, although we suspect that proportion to be a large one. But it is the only practical method until we determine by further experiment the conditions under which it is possible to rear large numbers of larvæ through their metamorphosis into small fishes.

We are certainly greatly retarded in our work at Piel by the want of a large open-air tank, which could be used as a spawning pond. Of the various schemes that have been before the Committee of late years in regard to

such a pond, the only one that now seems possible to biologists and engineers alike, is to build the concrete tank above the ground on the garden site close to the engine-house. Here there is space for a pond 60 feet by 20 feet, and 10 feet deep, which would have a capacity of about 75,000 gallons. Our present pumps are capable of supplying about 2,500 gallons per hour, and the tides allow of pumping for about 4 hours out of 12, two and a half hours before and one and a half hours after high water. When the pond is full it would be possible to change at least one-seventh of the whole contents each tide, and in the intervals between the periods of pumping this seventh part, over 10,000 gallons, would be used for working the apparatus in the tank room. It is most desirable that permission to proceed with the erection of the required pond be obtained from the Board of Trade with as little delay as possible. Such a pond could be made available for various useful purposes, such as fish spawning, lobster hatching and rearing, and oyster spatting and cultivation. In the early spring over 600 mature fish could be accommodated, which should provide an abundant supply of eggs for the hatching boxes.*

At the close of each fish-spawning season it would probably be necessary to set the spawners free, and collect a fresh stock in time for the next season in order to ensure having healthy parents. As lobster hatching and oyster spatting both take place in summer, the pond would then be free from fish, and it would be a simple matter to arrange temporary partitions across the pond, dividing it into two or more compartments, one of which would be used for the berried lobsters and another for oysters and collecting tiles. It is, perhaps, unnecessary to go further

* The Scottish Fishery Board aim at having 2,500 adult plaice in their spawning pond this season.

into the details of such proposed additional work until the scheme for the formation of the pond has been approved of. The primary object of the pond is the provision of an abundant supply of healthy fish spawn for the hatchery, but its use will be by no means restricted to that object. A spawning pond in which the eggs can be produced naturally from healthy parents is essential to successful hatching on a sufficiently large scale.

The special parts of this Report which follow consist of:—my remarks upon the Oyster Bill, and a discussion of Fisheries Conferences and the need of a “Census” of our territorial waters; Mr. Scott’s account of the hatching operations at Piel; notes by Mr. Ascroft on the American Shad and the White Fluke; and finally, Mr. Johnstone’s detailed account of the structure of the edible Cockle, with an Appendix on the Cockling Statistics of our District. This section on the Cockle is illustrated by six plates, and a map showing the distribution of the cockle beds.

I desire, in conclusion, to ask for a very careful consideration by the Committee of my remarks and recommendations on pages 158 to 162 in regard to a scheme for obtaining an approximate “Census” of our fisheries district.

W. A. HERDMAN.

UNIVERSITY COLLEGE, LIVERPOOL,
December, 1899.

OYSTER MEMOIR AND OYSTER BILL.

(W. A. HERDMAN.)

The work I have been doing at intervals during the last few years, along with my colleague Professor Boyce, upon oysters and their supposed connection with disease in man having come to a conclusion, the Committee have printed and issued an account of the investigation as a thin quarto volume* of about 60 pages and 8 partly coloured plates, under the heading of "Lancashire Sea-Fisheries Memoir No. I." I hope it may be regarded as creditable to the Committee to have undertaken the publication, in this manner, of researches which add to our knowledge of an important shell-fish, and have a bearing upon public health questions, upon proposed legislation, and upon valuable fishing industries.†

As this Oyster Memoir has recently been sent to all members of the Committee, I need not refer to it further than to say that it brought out clearly the need of some control of the oyster trade in order that injurious oysters might not be offered for sale. Two events have recently occurred, either of which might lead to the effective control required. These are the formation of the Oyster Industries Association and the introduction of an Oyster Bill into the House of Lords by Lord Harris. The Bill met with considerable criticism, and was referred to a Select Committee of the House, which reported in July; but the Bill was eventually dropped. It is to be hoped

* "Oysters and Disease," published by Geo. Philip and Son, London and Liverpool, 1899; price 7s. 6d. net.

† It may serve to remove in part the reproach levelled against the Sea-Fisheries Committees when, in the evidence given last June before Lord Harris's Select Committee on the Oyster Bill, it was said by the medical authorities at the Local Government Board, that these Committees had never done anything to investigate the sanitary condition of our fisheries.

that it will come up in an amended form next session. Lord Harris's Bill, although it certainly did much to meet the present want of control, was susceptible of improvement in several respects, and it may be useful that I should state briefly what the more important of the amendments should be, in my opinion :—

1°. The duty of inspecting and the power of prohibiting removal of oysters from the layings should rest with the Sea-Fishery Committees rather than with the County and Borough Councils :—that is, these important functions should be given to an authority concerned neither with the trade aspects of the oyster industries nor with the medical aspects of the sanitation of the neighbourhood, but to one primarily concerned with the prosperity of the fisheries—which includes their cultivation under healthy conditions. The Sea-Fishery Committees are in a position to hold the balance fairly between trade interests and sewage schemes. It is true that at present some of the more important oyster layings are not topographically within the jurisdiction of the local Sea-Fishery Committees ; but that is a matter which should be capable of easy remedy by an extension of the powers of the Committees in so far as regards oysters and other shell-fish.

2°. From the point of view of public health, the sale of oysters from any suspected laying should be stopped *forthwith*. Ten days' notice, or twenty-one days' notice in the case of an appeal, if the oysters are infected, allows of the possibility of an indefinite amount of damage to health. Several epidemics might be started before the sale of the oysters could be stopped. In this respect the provisions of the Bill do not meet the present difficulty.

3°. It is necessary that oysters should be protected from insanitary environment, not merely in the layings

but also when in storage, markets, cellars, and shops—in short, until they reach the consumer.

4°. Foreign oysters, unless imported direct from layings which are periodically inspected and certified by an authority approved of by, say, the Fisheries Department of the Board of Trade, must be relaid or subjected to quarantine before entering our markets. Many foreign oyster layings are situated in pure water, others are not. The reasons given, in the evidence taken by the Select Committee, for regarding all Dutch oysters as being free from any sewage contamination will not bear careful examination.

5°. Finally, shell-fish industries should not be forced, in all cases, to give way to sewage schemes. There ought to be power given in the Bill to consider in each case whether, in the interests of the general public, it is the oyster laying or the sewage that should be removed.

SEA-FISHERIES CONFERENCES AND THE NEED OF A
“CENSUS OF OUR SEAS.”

(W. A. HERDMAN.)

During the last few years there have been a large number of conferences, congresses, and other meetings, which have dealt either formally or informally with the subject of Sea-Fisheries, and especially their control and scientific investigation. At several recent meetings of the British Association discussions have taken place in the section of Zoology bearing upon artificial hatching, the life and growth of sea-fishes, and the closure of areas of territorial water; in July, 1898, an International Fisheries Congress was held at Bergen under the auspices of the Society for the Encouragement of Norwegian Fisheries; in September, 1898, a Conference met at

Dieppe; in July, 1899, a Conference took place at Biarritz; in September of the same year a meeting was held at Boulogne, in which some members of the French and British Associations took part; finally, and perhaps most important of all, because of the extent to which the governments concerned took official part in the meeting, was the International Conference for the Exploration of the Sea which met at Stockholm in June, 1899, on the invitation of the Swedish government.

At most of these meetings something of interest arose, such as, *e.g.*, the description of the remarkable natural oyster culture ponds on the west coast of Norway, given by Herman Friele at the Bergen Congress; but it may well be doubted whether such results are at all commensurate with the time, trouble, and money that has been expended upon the meetings. The discussions of vexed questions have certainly been in most cases quite inadequate, and have led to no definite results. Perhaps one cause of this partial failure has been that the men who can afford the time to attend such meetings have not always been really representative of the fisheries science of their countries; but a still more important cause of the futility of many discussions, and of the reason why the arguments used do not always carry conviction, is the absence of definite observations and reliable statistics.

Consequently, I am of opinion, an opinion in which I am confirmed by conversation with many fisheries authorities and investigators during the last few years, 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 of both fishes, in all stages of growth, and the lower animals with which they are associated and upon which they feed. Holding an opinion such as this,

one is naturally much disappointed that the Report of the International Conference for the Exploration of the Sea held at Stockholm last June does not contain a definite programme of biological investigation which would lead to the acquisition of the desired knowledge.

Last summer, when the arrangements for that Conference were announced, hopes of detailed explorations on a grand scale ran high, and it was very naturally and confidently anticipated that the Report when issued would contain strong representations to the governments concerned involving the use of sufficient boats and men to carry out a definite scheme of biological investigation during a definite period. For surely what we need most at the present time in the interests of more exact fisheries knowledge is the nearest possible approximation to a census of our seas—beginning with the territorial waters and those off-shore grounds that supply them and are definitely related to them. Most fisheries disputes and differences of opinion are due to the absence of such exact knowledge.

If anything approaching a census or a record of trustworthy fisheries statistics had been taken fifty years ago, it would now be invaluable to fisheries committees, inspectors, superintendents, and other local authorities, as well as to biologists. Our successors will justly reproach us if, with increased knowledge and opportunity, we let the twentieth century commence without inaugurating a scheme of practical work which will give us the desired statistics.

As, unfortunately, the Stockholm Report says nothing to the point in regard to all this, it remains for each nation or district to carry out the plan that it considers best according to its convictions and means; and I venture to hope that Lancashire will lead the way. I would submit that our Joint Committee owes it to its position, reputa-

tion, organisation, and opportunities to start during the coming year this

“CENSUS OF THE TERRITORIAL WATERS”;

and I now ask that if the Committee approve of this suggestion, they should forthwith refer the matter to the Scientific Sub-Committee for a detailed practical scheme. The investigation would naturally fall into two great divisions: first, the collection of fisheries statistics to replace or supplement those at present taken by the Board of Trade, and which are admittedly inadequate and incorrect; and secondly, what may, for the sake of brevity, be called the “scientific” part, in contra-distinction to the “statistical.” The scientific investigation would consist of periodic (weekly, if possible) observations at fixed points on the distribution and approximate numbers of the adult and young fishes, of the spawners, of the embryos and larvæ, and of the Molluscs, Crustacea, and other invertebrates on the feeding grounds of the fish. I have thought out some of the further details of the work, but pending the approval by the Committee of the general principle of the scheme, I need not yet go further into that part of the matter.

I must, however, say in conclusion, that it seems to me that it is only by such a scheme as this that it is possible for us to settle such important questions as:—

- (1) The proportionate number of fishes on the different grounds,
- (2) the seasonal or periodic distribution (and migration) in our district,
- (3) the existence, or not, of definite localities as “feeding grounds” and “nurseries,” and their extent,
- (4) the proportionate number that spawn in the year,
- (5) the ratio between the annual production of spawn

and the number of young fish that appear in-shore some weeks later,

(6) and thus the death rate in the larval and post-larval stages,

(7) the effect of adding artificially hatched larvæ to a district the population of which is approximately known,

(8) whether any areas are overstocked with young fish and any others not sufficiently occupied,

(9) and, therefore, whether transplantation, such as is carried on in Denmark, would probably be an economic success,

(10) whether, in the course of years, a coast fishery is increasing or diminishing.

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 to is a rough approximation, but even that will be of use, and it is an approximation which will approach more and more nearly to the truth with each successive year of work.

In the first of these Annual Reports, in 1892, I printed a scheme of observations at sea which has been carried out by the steamer in her trawling over the district. The observations on each occasion have been recorded on a separate sheet, and as the result of this eight year's work, we have accumulated about a thousand of these sheets of statistics. These local fishery statistics are now being arranged and summarised in our laboratory. Mr. Johnstone is taking out for me, in the first place, every entry in regard to certain fish, such as the plaice, and is arranging them, in each year, under months, localities, and sizes. The analysis and consideration of these observations will form an important part of our work during the coming months.

There is a great deal of valuable material in these statistics which, whether or not it leads to any definite conclusions, will at least help us to see what further observations are required, and what measure of success we may hope to attain in the proposed census of the sea.

HATCHING WORK AT PIEL.

(ANDREW SCOTT.)

I. FISH HATCHING.

At the conclusion of the spawning season of 1898 it was found that, in order to deal with large quantities of fish eggs we should have to increase the capacity of our hatching apparatus. After careful consideration it was decided that the "Dannevig system," which has given satisfactory results in Norway and in Scotland, should be adopted. This apparatus for incubating fish eggs consists of a series of movable boxes, each of about a cubic foot in capacity, all floating in separate compartments of a tank. The bottom of each box is covered with fine silk gauze or hair cloth, the meshes of which are of sufficient size to allow the water to pass through freely and yet keep back the smallest size of egg. Each box is placed in a separate water-tight compartment, to one side of which it is hinged. The water enters the box over a small shoot, and passes out into the compartment through the perforated bottom and then overflows into the next box. The apparatus is constructed in sets, each set consisting of a double row of five boxes in their compartments. At the ends of each row there are smaller compartments, one at the top for the distribution of the inflowing water, and one at the bottom for collecting the waste, which is led away to the nearest drain by an overflow pipe. The whole apparatus, when placed in working order, is set on the floor at a

sufficient incline to ensure a good current of water passing through. Five sets of these boxes were obtained, which gives us accommodation for at least 25 millions of cod eggs, each box holding with ease 500,000 eggs. In the case of plaice eggs 300,000 can be incubated in each box.

In order to make room for the new apparatus, the movable tanks, &c., were removed into the adjoining verandah, which had been enclosed and sufficiently lighted, and to which an entrance had been made from the tank room. A wooden bench running along the whole length of the new room was fitted up, on which were placed the smaller tanks and other apparatus. This left the whole floor of the tank room free for the Dannevig boxes, which were placed in position with the necessary supply pipes from the filter, a branch being also led into the new room. It is usual when hatching operations are going on to have the movable boxes rising slowly and falling rapidly once every half minute. This keeps the eggs moving and prevents them from gathering together in masses on the surface. During the past season no movement was given, but in future, motion will be used for at least some of the boxes. There is still room for some additional sets of apparatus, which can be added when we have better facilities for collecting the eggs.

The three wooden tanks, used in previous hatching work, were also fitted with floating boxes, each box being of the same capacity as those of the Dannevig set, but in this case there was a separate jet of water to each box, the method adopted in America.

As soon as the whole apparatus was ready for work—about the end of January—the crew of the steamer commenced to look out for eggs. They visited the spawning grounds and trawled with the steamer's gear, and also boarded the commercial trawlers in order to examine the

condition of the fish caught. This work was continued practically till the end of May, when the spawning season had finished.

With the exception of a few eggs obtained by the tow-nets from the surface of the sea, no fertilised eggs were secured until the end of February. From that time onwards to the end of the spawning season eggs in various quantities, from a few thousands to nearly four millions on some occasions, were collected. The total number landed during the season was just a little over nine millions. Owing, however, to their unripe condition more than half of these 9 millions were unfertilised or otherwise unsuitable for incubation. These were, therefore, rejected, leaving about four millions fit to incubate in the boxes. As in the previous season, the Fishery Board for Scotland kindly allowed the steamer to trawl for a few days, for scientific purposes, in the closed waters of the Firth of Clyde, and it was there, on February 28th, that the first fertilised eggs were collected. They were taken from plaice. A small lot of cod and another lot of witch eggs were also collected at the same time, but these were not fertilised. On March 10th, 14th, 16th, 17th, and 23rd, and on April 6th and 12th, supplies of cod, haddock, plaice, and flounder eggs were collected from fish caught by the trawlers working on the off-shore grounds. On April 28th another small supply was obtained from the Clyde.

The incubation of the various lots of eggs, after the unsuitable ones had been removed, proceeded satisfactorily. The plaice eggs collected in the Clyde on February 28th began to hatch out on March 17th. Four days later 113,000 fry from these eggs were set free from the steamer near the Morecambe Bay Light Vessel. On the morning of March 31st, 2,751,660 fry, comprising cod, haddock, plaice, and flounders were set free, about eight miles from

the above vessel. On April 6th, 364,250 plaice fry were set free on the way to the off-shore grounds between Lancashire and the Isle of Man. On April 9th, 90,000 flounder fry were distributed about the same locality as the last, making 3,318,910 in all.

Besides bringing in the eggs, the steamer also, on various occasions, collected numbers of nearly mature fish, chiefly plaice and flounders. These were kept alive in our tanks, where the eggs were shed as they became ripe, and the majority of them were fertilised. The emission and fertilisation of these eggs, which always took place in the dark, went on in the tanks probably much in the same way as under natural conditions in the sea. The eggs rose to the surface and were carried along by the water, which was allowed to overflow into a floating collecting box, where they were retained, and afterwards transferred to the hatching apparatus. The subsequent incubation of these eggs and hatching out of the larvæ was accompanied by a much smaller mortality than in the case of the eggs obtained by the steamer. The fry hatched out from these eggs numbered 78,000 plaice and 90,000 flounders (included in the 3,318,910).

When the spawning period of the sole approached, special visits were made to the off-shore grounds to collect mature fish, which were brought in and kept alive in the tanks. In the course of a few days some of them began to shed their eggs, which rose to the surface and were collected from the overflowing water. On being submitted to microscopic examination it was found, however, that not a single egg was fertilised. Various attempts were then made to bring about fertilisation by dissecting the male fish and squeezing up the reproductive organ amongst the eggs, but all attempts failed owing probably to the immaturity of the male fish.

The fact that mature or nearly mature fish eggs may float at the surface is not conclusive proof that they have been fertilised. From a number of experiments made at Piel during the past season it was found that unfertilised plaice eggs would remain floating even up to five days after being emitted by the fish. To the unaided eye these eggs looked healthy enough, but when submitted to microscopic examination, were at once seen to be dead. Therefore, although nine millions of floating eggs were landed at Piel, probably less than half were in a suitable condition for incubating. Indeed, it must be evident that a very large proportion of the eggs belonging to the pelagic group, which are obtained by pressing the sides of the fish, are not mature enough to be fertilised. From previous observations it is known that a female plaice may take at least two weeks to discharge the whole contents of her ovaries. In nature only a small proportion of the eggs are emitted at a time. Eggs that naturally incubate on the bottom of the sea, on the other hand, may be entirely deposited in a day. Much of the above-noted very considerable loss would be avoided if we had a suitable open-air pond where we could keep mature fish and allow them to spawn of their own accord. We have already tried this on a small scale, with satisfactory results, but our present indoor tanks are much too small to accommodate a sufficient number of fish to produce enough eggs to fill the hatching boxes.

The present capacity of the whole hatching apparatus may be conveniently stated by representing it in plaice eggs. The number of these that can be incubated at one time is 23 millions. Under favourable circumstances two such quantities could be dealt with in one season. To put it in another way:—a mature female plaice produces, on an average, 300,000 eggs, it would therefore take 75

female plaice to fill the boxes once, and counting in the males required to fertilise the eggs, another 25 would be wanted, making 100 in all, or 200 to fill the boxes twice.

Under the existing arrangements, where we have no spawning pond, and only a small steamer to depend on for our supplies, it is practically impossible to collect the number of eggs required. This has been fully demonstrated during the past season. Instead of even 23 millions, only about 4 millions in good condition could be obtained. The weather, on the whole, was suitable for the work; with unfavourable weather the results would have been much worse, as the steamer is not of sufficient size to carry on such work in a rough sea.

The system of collecting eggs by means of the steamer has some disadvantages. It is liable to be interrupted at any time through accidents to trawl gear, or by a continuation of bad weather, and a large number of eggs are necessarily collected which are not suitable for incubation. At the same time, it ought to be remembered that the fry hatched out from eggs collected in such a manner and afterwards set free, as has been done this season, represents a great gain. Practically 95 % of the fry set free were hatched out from eggs taken from fish caught by the trawlers for the market, and these eggs would, in the ordinary run of work, have been entirely lost. Much could be done to minimise the enormous loss to the fish population of the sea which accompanies the capture of ripe fish during the spawning season if the steamer were of sufficient size to visit the trawlers for the purpose of collecting eggs in all ordinary weather.

The scheme advocated by Professor McIntosh and others, that trawlers should be furnished with suitable vessels for the collection and fertilisation of the eggs, which would then be returned to the sea, is certainly a good one if it

could be carried out. Unfortunately, the whole time of a trawler's limited crew is fully taken up in reaping the harvest from the sea, in attending to their gear, and in preparing the fish for market. This leaves them little opportunity to collect and plant fresh seed, even although it be practically placed in their hands.

The results accomplished this year, again under certain difficulties, clearly show that eggs can be successfully incubated in the water of this part of the Lancashire coast. At times care is required in filtering the water, especially during a prevalence of southerly gales, when much mud is brought up. On the whole, the water after passing through the filter, is sufficiently clear. In the earlier part of the year "white felt" was used for covering the filter frames, but latterly we have adopted "Turkish towelling," which gives quite as good results, and is more economical. The specific gravity of the water was again satisfactory, and during the hatching season only varied from 1.0026 to 1.0027.

Preparations are now being made for next season, and already a considerable number of nearly mature flounders have been collected and placed in the tanks for spawning in the spring. We have chosen the flounder or white fluke for work this year as being a fish that is of importance in the neighbourhood, is hardy in captivity, and which naturally spawns nearer the coast than most other flat fish, and is therefore the more likely to shed and fertilise its eggs successfully in our tanks. Mr. Ascroft gives a brief sketch (see p. 30) of its life-history and habits as known in our district, which is of interest in this connection.

TABLE showing number of FISH FRY set free:—

March 21.	113,000	plaice,	Morecambe Bay	Light Vessel.
„ 31.	88,960	„	8 miles from	above ship.

on was concerned, very few being shaken off. In the course of a week after arrival, hatching of the larvæ commenced from the more advanced eggs, and continued during the next few weeks, but only in small numbers at a time. With one or two exceptions no larvæ hatched out in the day-time, practically all emerged at night, between 10 p.m. and 2 a.m.

Each morning the larvæ were removed from the collecting boxes. At first they were kept in glass aquaria, where a constant circulation of water was maintained. Afterwards we tried keeping them in the dark, and finally in the floating boxes of the Dannevig apparatus, all light being carefully excluded.

During the first few days the larvæ fed vigorously, and swam about actively. Towards the end of the first week of their life they ceased feeding, and kept more to the bottom of the apparatus. From seven to ten days after hatching the larvæ commenced to moult for the first time. Many died at this stage, some with the skin partly shed. Many of the survivors failed to recover from the strain of moulting a second time, and before the period of the third moult had arrived, all had gradually died off. The longest time that any lived was just over three weeks.

Various methods were tried to keep the larvæ alive. The food, water supply, and light were varied from time to time, but with no effect.

The food found most suitable was minute fragments of the liver of freshly-killed shore crabs. Some larvæ took it readily, clinging tenaciously to the pieces, which could be seen gradually passing into the stomach; while others refused it altogether, although it was held in front of them at the end of a thin piece of wood. The larvæ made no attempt to follow this food if it fell to the bottom, but sometimes, when walking over the fine gravel, they would

come across it accidentally, and occasionally eat it. It was found that when light was entirely excluded the larvæ kept more on the bottom, and advantage was taken of this to keep a good supply of food there for them, the stale pieces being removed each day and a fresh supply added. Other forms of food were also tried, such as minute Crustacea, chiefly young Copepoda, which were collected amongst the *Zostera*, and the larvæ of shore crabs that were occasionally sent off in swarms from a stock of berried shore crabs kept in one of the tanks. The young lobsters swam amongst these little Crustaceans where they had gathered on the lighted side of the jars, and sometimes even appeared to pursue them, but the most careful observations failed to show that they were capturing them. Fragments of freshly-killed mussels, shrimps, and fish were tried, and although sometimes eaten, at other times such food would be refused, so that no particular kind of food could finally be adopted with success. The larvæ were also kept in both filtered and unfiltered sea-water, but with no definite results. On the whole, it was found that the larvæ kept entirely in the dark and supplied with a mixture of crab liver and crushed shrimps lived longer than those treated in any other way; but the moulting process always proved fatal in the end.

There is thus apparently considerable difficulty in rearing the larvæ of lobsters in confinement. Unless future experiments bring out some satisfactory method of dealing with them, it will be necessary to set them free almost as soon as hatched.* Berried lobsters have occasionally been found on the rocky scars in the Barrow Channel, so that these places would, no doubt, be suitable ground on which to set our larvæ free.

* Professor Herdman has discussed this matter both in regard to young fish and lobsters in the introduction (see page 7).

NOTE ON THE AMERICAN SHAD.

(R. L. ASCROFT.)

The American Shad (*Clupea sapidissima*) which is nearly allied to our Shad (*C. alosa*), but has no markings on the back, is a native of the rivers of the Eastern States and part of Canada. It is found from eastern Florida to the entrance of the gulf of St. Lawrence.

It is a fish of the herring tribe, but of far larger growth, reaching a weight of eight pounds, and an average of four pounds each. When the spawning fish are approaching maturity, and the temperature of the river waters have reached 60° F., they migrate up the streams. If a freshet caused by warm rains exists in a river it is followed by a rush upward of many fish at the same time; but if the rise in the temperature is slow, the fish come in small numbers at a time. If the waters on the flats, at the side of a stream, are warmer than those in the main channel, the fish will keep in the warmer waters.

They mostly choose for spawning places sandy shores or bars of sand, and during spawning a pair of fish swim along together at the surface, the female emitting her spawn and the male his milt. The fishermen on the Potomac, at Washington, D.C., call it "washing." The time is between sunset and 11 p.m. The number of eggs averages 25,000 per fish, but sometimes a female has given 100,000. The eggs take from three to six days to hatch out, and the young, although incumbered with a larger yolk sac than young salmon, are, unlike them, quick, active, little fish. The fry stay about six months in the river, growing to 2½ to 3½ inches in length, migrating to the sea when the temperature falls below 60° F.

Their food consists almost entirely of Crustaceans, such as Copepoda, and as they grow they do not despise any

small fish, such as minnows, that come in their way. The larger fish during their stay in the river do not feed, and do not remain very long after they have deposited their spawn.

Plants have been made of the shad in the Sacramento River in California, with the astounding result that they are now found in every river of the west coast from California to Puget Sound. This success has suggested the idea that it might be worth while to experiment on their introduction into Lancashire rivers. Before undertaking the placing of any American shad in our rivers, it is desirable, if not already done, that accurate records of temperature be taken in the Ribble, Lune, and Kent, during the months of March, April, and May, to see if our temperatures are high enough for the shad.

It would certainly be a great addition to our food supply, and, although it may be a little trouble, yet, now with refrigerating chambers, I do not see that there could be any real difficulty in getting a supply of impregnated eggs brought over from the United States.

NOTES ON THE WHITE FLUKE OR FLOUNDER.

(R. L. ASCROFT.)

The fish known by the name of "White Fluke" on the north west coast of England, "Butt" in Lincolnshire, "Flounder" in the rest of England and Scotland, "Bot" in Holland, "Butt" in Germany, "But Flynder" in Norway, Sweden, and Denmark, and "Flet" in France, is one of the flat fishes. The scientific name is *Pleuronectes flesus*, given to it by Linnæus, the founder of scientific nomenclature.

The flounder is the fish having the greatest number of eggs for the weight of the body—one million for each

pound weight. They are, like the great majority of food fish eggs, pelagic or floating on or near to the surface during the period of hatching. The flounder on this coast proceeds to sea to a depth of 17 fathoms or over to spawn. It has been thought by many fishermen that the egg sacs of some of the Polychæte worms that are found on the shore, of bladder shape and moored by filaments in the sand, are the eggs of the flounder; and when the embryo worms had attained to the development of the eyes (which are red) causing the whole bladder to appear red instead of green (the colour before development), it was then taken to be plaice spawn because of the plaice having red spots on them.

Spawning takes place in our district from the beginning of the year to the end of April. The hatching period is not so long as that of the plaice egg, being from 12 days at the beginning of the season, to as little as 6 days at the end, but regulated in a great measure by the temperature of the water.

Very little is known of the development of the egg until the young fry enter the rivers in June. When they arrive in the rivers they are about three-quarters of an inch in length, perfectly transparent, without any colour, but their eyes are dark blue and iridescent, and one is able to detect them by that.

They proceed up the rivers, and live in the fresh-water and estuaries until they return to the sea for spawning purposes in November and December. The old fish, after spawning, return to the rivers in the middle of May and during June. They proceed up the rivers for long distances, having been taken at Clitheroe and Whitewell in Bowland, distances of over 30 miles from the sea.

The flounder is easily distinguished from the plaice or dab by the china-white colour of the under-surface, resem-

bling the halibut in that respect. The name of the halibut is derived in Dutch, German, and French from the name for flounder—"Heilbot," "Heilbutt," and "Fletan."

Under favourable conditions the flounder has a very rapid growth. They have been known to reach the weight of 5 lbs. A few years ago some young flounders, under an inch in length, were taken from the Ribble, at Preston, and placed in a reservoir near to Blackburn, and they arrived at 1 lb. weight each in two years. They would be most valuable fish to keep the water snails down in reservoirs used for the supply of towns.

All flat fish rest on one side of the body, and that one of the eyes which is underneath in the young, passes over the nose, so that both eyes are on the same cheek in the mature fish. The flounder generally rests on the left side, but one finds many reversed individuals resting on the right side; while it is a very rare occurrence in the other flat fish to so vary.

The flounder, as a food fish, is highly esteemed in London, but it is not so much esteemed in Lancashire. In my opinion you cannot have a much worse tasted fish when going from the rivers to the sea for spawning purposes, or a much better or firmer fish when returning from the sea after spawning.

The food of the flounder consists principally of worms and Crustacea. It is very fond of *Corophium longicorne*, which frequents in enormous numbers the mudflats in our estuaries. The flounders follow the rise of the tide on to the mudflats, and retiring to the channels on its return, they bury themselves in the sand until the tide again enables them to reach feeding grounds. They also eat a quantity of bi-valve Molluscs and fresh-water snails. I have seen their borings for bi-valve Molluscs close to high-water line on the flat sands of Morecambe Bay.

Flounders are taken by stake nets, trawl nets, and many have been taken by salmon nets drifting over the banks at high-water time. Some few are taken by means of "Tees," a method of set-line fishing, but having pins instead of hooks. The pins are bent to an obtuse angle, and form a toggle when taken by the fluke, they are baited with worms (*Arenicola*), shrimps, cockle, or mussels. Many are also taken by means of the fluke rake, that is, a rake about 3 feet wide with teeth 6 inches apart and of the same length, but lineable with the shaft and not at right angle to it, as in the ordinary rake. Each tooth is barbed on one side, and the rake is used from a boat drifting slowly with the current (the drift is regulated by a heavy stone to the cable over the centre of the length of the boat, and so she is kept broadside to the current), by a man probing ("probbing" locally) the rake into the sand to a depth of 4 to 5 inches. When he feels any extra resistance to the rake entering the sand, he lifts the rake above water to see if he has a fish or not. Half a hundred weight is not an uncommon catch in a tide by this method of fishing.

The white fluke, being for the most part of its life within reach of our fishermen using second class boats, it is the fish, above all others, which it would be most profitable to hatch and set free in large numbers with the view of assisting our local fisheries.

ON THE STRUCTURE AND LIFE-HISTORY OF THE COMMON
COCKLE, WITH AN APPENDIX ON THE LANCASHIRE
COCKLE FISHERIES, with Pls. I.—VI. and Map.

(J. JOHNSTONE.)

[NOTE:—This investigation into the structure of the cockle was carried out mainly in the Fisheries Laboratory at University College, Liverpool; but in part also at the Sea-Fish Hatchery at Piel—which was found most convenient for the study of living specimens. Most of the material used was obtained from the cockle beds in the Mersey estuary, and was collected and sent to the Laboratory by Mr. G. Eccles, chief fishery officer at New Brighton. Specimens were also sent by Mr. Andrew Scott from the Baicliiff beds and those in the immediate neighbourhood of Piel.]

THE edible cockle (*Cardium edule*) is by far the commonest member of the genus *Cardium*, a group of eulamelli-branchiate Mollusca having a world-wide distribution and containing a great number (about 200) of species. The number of British species is, however, limited to ten, most of which (*C. echinatum*, *C. fasciatum*, *C. edule*, *C. minimum*, *C. norvegicum*, *C. nodosum*) are recorded as being present in the Irish Sea; of these the only abundant species is *C. edule*; *C. norvegicum* (*Lævicardium*) is fairly common, the others being only occasionally found. The different species seem to have a fairly well-marked bathymetrical range, but *C. edule* is found from between tide marks out to 1360 fathoms. Here and over the greater part of Europe *C. edule* is the only species of any economic importance; in Jersey, however, *C. norvegicum* is used for food, and in the Mediterranean various other species are eaten.

The edible cockle is gregarious all along the coast line where suitable bottoms exist, but the great cockling beds

are, as a rule, found only in sheltered waters, in shallow bays, and at the mouths of estuaries. There is great constancy in the characters of the cockles from the various parts of the Lancashire and Cheshire coasts, no well-marked varieties being found. The difference in size observed in specimens from various parts of this district are most probably due to the extent to which the beds have been fished or disturbed in late years. Generally the influence of some fresh water* seems to be favourable in that cockles are more abundant in the neighbourhood of the mouths of rivers, but the largest specimens are found only in areas far removed from the influence of fresh water. Large cockles, with shells two inches in length, are found on some parts of the North Coast of Devon, in Barra, in the Western Hebrides, and in the Scilly Isles. In Barra these large cockles are sufficiently numerous to form the material for an important fishery. Such giant forms are not found on the Lancashire coast, where the average length is about one and a half inches. Here the marketable cockle has a minimum breadth of $\frac{3}{4}$ inch, the size being fixed by the Sea-Fisheries Committee's Bye-law. With the exercise of proper care on the part of fishermen to take only well-grown animals, there can be no doubt that the Lancashire and Cheshire cockle fisheries might be more largely developed, since the physical conditions are so suitable.

The cockle inhabits the topmost layer of the sand, burying itself to the depth of an inch at most. It lies in an oblique position, and, when the bed is covered with water, with the siphons projecting slightly above the surface

* The influence of extreme salinity or freshness, as might be expected, is to produce well-marked variations in the character of the shell. See Bateson, *Phil. Trans. Roy. Soc.*, vol. CLXXX. B., pp. 297—330, 1889; and Forbes and Hanley, *History of the British Mollusca*, 1850, vol. II., p. 21.

An exceptional habit has been noted by R. D. Darbishire* when the cockles become anchored by the byssus threads of *Mytilus* and grow and develop freely in the water. Only on the posterior margin of the shell, from which the siphons protrude, are there any other attached animals or plants. Among these are green or brown Algæ (*Sphacelaria*), Zoophytes (*Obelia*), small anemones (*Actinia*), and rarely, barnacles (*Balanus*). In some places the cockles commonly bear a tuft of algæ, and the position of the animal in the sand can be determined by the presence of this projecting tuft. The animal, as a rule, remains in nearly the same position, but is able to shift about by means of the strongly developed muscular foot. Where the sand is not much disturbed by the tidal current, as round the stake of a net for instance, the cockles are generally more abundant.

A current of water continually entering the mantle cavity by the lower, and passing out again by the upper siphon, bears the food supply in the form of suspended microscopic animals and plants. The cockle feeds on spores and other young stages of lower algæ, fragments of filamentous algæ, vegetable debris, Foraminifera, Diatoms, and probably also the smaller micro-crustacea. The animal exercises no selective action on the food taken in; all that is contained in the entering current of water, including a large quantity of sand and suspended inorganic matter, is carried in by the cilia of the labial palps and passed on into the stomach. The greater part, therefore, of the contents of stomach and intestine is sand and fine mud.

The chief enemies of the cockle are fishes and birds. They also are eaten by starfish and bored by dog whelks. They form an important food for many fishes, chiefly

* Fauna of Liverpool Bay. Report I., p. 241.

plaice and dab. There is said to be enormous destruction by the larger sea-birds. According to the fishermen who gave evidence to the Commissioners of 1879, the decrease in some cockle beds may be directly attributed to the increase in sea-gulls due to the operation of the Sea-Birds Preservation Act. Whole cockle beds may be destroyed by a hard frost or by an encroachment of sand.

At the beginning of the year the reproductive glands are nearly ripe, and spawning commences at the end of February or the beginning of March. The spawning period is prolonged, and ends about June or July. The reproductive glands then pass into the "spent" condition and after a short time begin to ripen again. Eggs and milt are shed freely into the water, where fertilisation and development go on. The minute larva swims freely in the water for some time, then settles down in the sand as a small shelled cockle.

After a detailed account of the anatomy of the cockle as a typical Lamellibranchiate Mollusc, an Appendix follows, containing an account of the animal from the economic aspect, with special reference to the cockle fisheries in the Lancashire Sea-Fisheries district.

THE SHELL.

As in the case of most Lamellibranchs, the shell is equivalve, that is, the two valves are precisely alike in shape; it is inequilateral, the straight central rib or groove on each valve dividing it into unequal anterior and posterior parts; as regards the form and relative proportion of the two parts so delimited, and the ratio of length to lateral breadth or depth, great variability is found. The number of ribs varies from 20 to 24. The external surface is marked by a series of fine concentric grooves and ridges indicating the growth of the shell margin. Some of these

grooves are very prominent, and, in a full grown shell, 3 to 6 such can readily be observed which probably mark the limits of as many successive years of growth. Occasionally these grooves are very distinct. Looked at from the outside the margin is nearly even; on the inside it is deeply notched, the depressions corresponding in position with the ribs on the outside (see fig. 1, Pl. I., and fig. 10, Pl. II.).

The hinge line is gently curved, and the concavity of the shell is continued dorsally beyond the hinge into the umbo; along this hinge line is a series of double teeth on each valve which interlock when the valves are closed. On the right valve the central cardinal tooth has the form of a deep depression with sharp cusps arranged anteriorly and posteriorly. On the left valve this arrangement is reversed, there being a single median cusp with depressions in front and behind; similarly on the right valve each of the two lateral teeth (which are really anterior and posterior) consists of a prominent ventral and a smaller dorsal cusp with an elongated depression between. On the left valve this arrangement is reversed. The hinge ligament, which represents the dorsal uncalcified portion of the shell, lies posterior to the umbones and is external; it is hollow and arched, underneath it the dorsal margin of the valves do not come into contact when the shell is closed, and a median glandular fold of the mantle projects up into the cavity beneath the arch of the ligament, and is in contact with the internal surface of the latter. The ligament is very elastic and serves for the divarication of the valves when the adductor muscles are relaxed.

There is little pigmentation on the shell except at the posterior margin, where, particularly on its internal surface, it is tinted a chocolate brown or green. This pigmentation may extend on to the scar of attachment

of the posterior adductor muscle, which is often striped with brownish yellow and white. This posterior margin is much denser than any other part of the shell, and dissolves slowly in dilute acid, always remaining after the rest of the shell has disappeared; the organic matrix is more abundant here than at any other part.

The scars indicating the attachment of the muscles show plainly on the dry shell (fig. 10). The posterior adductor scar (*Adl.p'*) is large and usually pigmented. The anterior adductor scar (*Add.a'*) is rather smaller, and is always unpigmented. Both approach very near the margin of the shell, and lie just beneath the hinge line. On the dorsal margin of the posterior adductor is a small oval scar (*Ret.p'*), sometimes not very obvious. This indicates the place of attachment of the posterior retractor of the foot. Two scars are to be seen in a similar position over the anterior adductor scar. The more dorsal of these (*Ret.a'*) is the scar of attachment of the anterior retractor pedis. The other (*Pro'*) shows the attachment of the protractor pedis. The pallial line indicating the place of attachment of the radial series of muscle fibres serving for the retraction of the mantle edge runs parallel to the ventral shell margin, at a distance of about 8 mm., and is slightly indented in correspondence with the notches on the margin. There is no siphonal sinus, but at the posterior margin of the shell the pallial line becomes much broader as the retractor muscle of the mantle edge passes into the retractor of the siphons. A small scar hidden in the umbo serves for the attachment of a small bundle of muscle fibres attached to the dorsal margin of the wall of the visceropedal mass.

The shell in the region of the umbones is always thin, and the periostracum is worn off in the fully grown specimen. Towards the margin, and especially at the

posterior margin, it is much thicker, and both periostracum and organic matrix are present. The internal structure is very peculiar, differing from that of most lamellibranch shells, and corresponding closely to what Ehrenbaum,* who has investigated various species of *Cardium*, describes as the gastropod type of shell structure. The calcareous substance is distributed in two ill-defined layers (fig. 29, Pl. V., *Sh.i.*, *Sh.e.*), which must be termed inner and outer shell layers since the terms prismatic and nacreous layers are not applicable here. The shell is composed of a great number of exceedingly thin laminæ which lie, for the most part, parallel to the shell surface. But since the mantle edge is folded over the shell edge, each lamina begins as a curved plate, the convexity of which is turned towards the margin, and since the whole shell grows by the addition of successive laminæ to those already formed, its most external layer is formed by the edges of the laminæ coming out on the surface at an angle of from 45° to 60°. The deposition of calcareous matter seems to be effected principally by a rather wide zone of the external surface of the mantle, extending back from the margin. Hence the dorsal parts of the shell are thin, since there seems to be little, if any, formation of lime over the general mantle surface.

Each lamina has a very fine fibrous structure, the fibres lying longitudinally in the thickness of the layer. In any two successive laminæ the directions of the fibres are at right angles to each other. Thus, starting from any one, in laminæ 1, 3, 5, 7, the fibres are parallel to each other, but in laminæ 2, 4, 6, 8, they are at right angles to the fibres in the first set. This is not easily observed in sections perpendicular to the surface of the shell and to the margin, owing to the excessive thinness of the laminæ.

* Zeitschr. f. wissensch. Zool. Bd. XLI., pp. 1—47, 1885.

In sections taken in a plane perpendicular to this, that is, perpendicular to the surface of the shell and tangential to a line of growth, it is evident that in the centre of the section the laminae must lie in planes approximately parallel to the surface, since, owing to their upward bending near the surface of the shell, they must lie at one point in planes perpendicular to that surface. So here the section is marked out into irregular areas representing small portions of the bent laminae. In any two such contiguous areas the directions of the fibres are at right angles to each other. Further, since the laminae are very thin, several are superposed in the thickness of the section, and in any one such area, by focussing, a system of parallel lines crossing each other at nearly a right angle may be easily seen.

The structure of the shell is greatly complicated by the sculpturing at the margin. Once the formation of the definitive ribs and grooves has been initiated, the deposition of successive laminae proceeds upon the surface so laid down, and so at the edge of the shell the surface of a lamina is a very irregular one. Further back from the margin, as one observes in a vertical section tangential to the edge, the laminae are very regularly crumpled, the contour of a single lamina being concentric with that of the internal surface of the shell at its extreme margin. It is obvious that this arrangement causes great irregularity in the appearance presented by a vertical section made with the intention of passing perpendicular to the shell edge, for it is difficult or impossible to make the section pass exactly through a rib or hollow without cutting, in some part, the margin of the rib where the planes of the laminae are approximately perpendicular to the surface and margin of the shell. This causes the coarse pseudo-prismatic appearance observed in a vertical section

perpendicular to the margin (fig. 29). These apparent prisms are, of course, the obliquely cut edges of the laminae.

The shell is everywhere penetrated by very fine tubes and irregular channels. These are more apparent in the vertical section taken perpendicular to the shell margin, where they seem to be cut, for the most part, transversely. In a section at right angles to this they are by no means so obvious. It is evident from this that the black appearance of these cavities is due not so much to pigment, as Ehrenbaum supposes, as to the air included in the process of preparation of the section. They are very regular, following the planes of deposition of the shell laminae.

The periostracum (*Epic.*, fig. 29) appears in section, not as a regular layer on the external surface, but rather in irregular fragments and patches.

GENERAL ORGANISATION, MANTLE AND FOOT.

In the ordinary cockle not preserved by any special method, the animal is completely retracted within the shell. The shell margins fit together very closely except at the posterior extremity where, in the relaxed condition, the siphons protrude. Even here on account of the contraction of the siphonal tubes, the mantle cavity is completely closed. In this condition it is difficult or impossible to open the shell without injury to the soft parts, and, when this is done, the animal is so much distorted owing to muscular contraction that the true relations of the parts are not evident. The animal is best prepared for dissection either by gradually adding a 4% solution of cocaine to the water in which the expanded animal lies, or by placing it at once in a 1% solution, and allowing it to extend, which generally happens in the course of an hour. The irritability of the siphons and

mantle edge is first lost; the foot never becomes quite insensitve. The animal is then killed in a 20% solution of formol, a small piece of wood having been previously placed between the edges of the valves to prevent the slow contraction of the adductor muscles which occurs after death. Only a slight amount of contraction takes place in the formol, the siphons and foot being generally moderately extended. If it is desired to prepare the animal for sectioning, both valves are removed by placing it in a 10% solution of nitric acid in 70% spirit; if for dissection, it is propped up on a couple of glass slides in a dish with the shell margin horizontal, and the acid solution poured in so as to cover one valve. Either of the two valves can be dissolved off in this way, the other being left to fix the animal in the dissecting dish. A great inconvenience is caused by the accumulation of carbon dioxide, resulting from the decomposition of the shell, within the cavities of the body. If the specimen is being prepared for sectioning, it is best to remove this gas by allowing it to remain for some days in 70% spirit containing a little ammonia.

Except at the margin, and for a reddish strip at the dorsal surface which is the pallial portion of Keber's organ, the mantle lobe is thin and transparent. Removal of this by cutting along the line *Mn'*, seen in fig. 2, exposes the gills and labial palps. The gills pass obliquely backwards from the dorsal surface of the body beneath the umbo at an angle of about 30° to the vertical axis of the visceropedal mass.

The labial palps are triangular in shape. Their shorter or anterior sides are attached to the body-wall, and their most anterior extremities pass into the upper and lower lips respectively. The dorsal margins are thin, smooth, and slightly uneven. The internal surface of the outer, and the external surface of the inner palps are marked

with deep grooves parallel to the anterior margins, and are ciliated. The other surfaces are smooth and non-ciliated. Cilia are present on all surfaces of the grooves and ridges. Each ridge is roughly quadrangular in section (fig. 24). The outer faces and the faces turned towards the apices of the palps are covered with long columnar cells bearing long cilia, and having abundant eosinophilous cells. The rest of the surface of the ridges and furrows is covered with cubical cells, carrying shorter cilia. The smooth surfaces of the palps have an epidermis of flat, almost squamous cells. Within the palp there is a very loose connective tissue, rather denser in the interior of the ridges and containing blood corpuscles in its interspaces.

The mantle lobe of each side (*Mn.*, fig. 4, Pl. II.) is inserted into the extreme dorsal margin of the body, and round the lower margin of each adductor; anteriorly the right and left lobes fuse together at the dorsal surface of the anterior adductor. Posteriorly there are two fusions; dorsal to the posterior adductor the mantle roofs in a portion of the mantle cavity which passes upwards over the adductor (*Mc.1*, figs. 3 and 6), and in which the terminal portion of the rectum and the anus lie. The first fusion forms the septum between the dorsal and ventral siphons. It is prolonged inwards from the mantle edge forming a horizontal shelf (*Mn.1*, fig. 3), which separates the cavity of the dorsal siphon (*Mc.2*, figs. 3 and 6) from the general mantle cavity (*Mc.3*, figs. 3 and 6). The second fusion forms the lower wall of the ventral siphon. Between the posterior margin of the mantle and fusion one, and between the first and second fusions, the mantle edges are prolonged outwards to form the siphons. In the full grown animal these have a maximum length, when extended, of about 1 cm. In the young cockle their length is relatively much greater.

The siphons differ slightly in structure; the dorsal, or exhalent one (*Si.d.*, figs. 2 and 3), is the shorter of the two. Its free edge is quite even and a small portion of the wall of the tip is exceedingly thin. This thin tip is contractile, and is generally closed forming a little cone at the end of the siphon. The tentacles, which are rather over 1 mm. in length when fully extended, are situated in an irregular ring at the base of this cone. Other and larger tentacles are borne on the wall behind this ring. At intervals the conical tip of the siphon opens and water and faecal matter are suddenly expelled. The ventral or inhalent siphon (*Si.v.*, figs. 2 and 3) remains permanently open. The free edge bears a great number of very delicate tentacles, smaller and thinner than those borne on the outer wall and differing slightly in structure. Behind this, as in the upper siphon, is a ring of tentacles with others scattered irregularly upon the wall. At the tip of both upper and lower siphons are a number of brown pigment spots which are the openings of little pigmented crypts or glands.

The mantle edge (fig. 23) is thrown into longitudinal folds extending along its entire length. There is an inner strong fold projecting into the mantle cavity, a smaller median fold, and an outer fold which dips into the grooves on the shell margin. On the surface applied to the shell, the epidermis consists of rather irregular cubical cells, except towards the extreme edge, where the cells become spindle shaped and are crowded with brownish pigment granules. Over the rest of the mantle edge (ventral and internal surfaces), there is an epidermis consisting of a very regular layer of cubical cells with very distinct nuclei and a strong cuticle. On the inner of the three folds mentioned above, and in the deep groove separating this from the small median fold, the cuticle

becomes very strongly developed. From it a cuticular structureless membrane passes off over the free edge of the shell forming the epicuticula or periostracum (*Epic.*). When the shell is dissolved off in acid, this cuticular investment is seen to be really continuous with the mantle edge, so that the latter is firmly attached to the outer surface of the shell.

On the inner surface is a ciliated zone which begins a little way back from the free edge of the inner fold, and ceases or begins to die out opposite to the line of attachment of the pallial muscles to the shell. Coincident with the distribution of the cilia is that of a zone of mucous glands opening on to this ciliated surface on the mantle margin. These glands are very similar to those which will be described as present on the ciliated tip of the foot (p. 194), but are, as a rule, unicellular, the body and conducting stalk being formed from a single cell. Occasionally several cohere together forming a structure of the same nature as those found on the foot, but they are very generally much smaller individually. Their stalks passing out through the epidermis give the latter an irregular appearance. The tips of these stalks project out among the cilia as prominent little knobs.

The pallial muscles (*Ret.m.*, fig. 23) have a narrow zone of attachment to the shell (*Ret.m'*, fig. 10). Here the epidermic cells disappear completely from the mantle surface. The muscle bundles, passing ventrally, parallel to the surface, are attached to the shell at a very acute angle. The bundles run along the outer surface for a short distance, then divide into two series. One of these continues to run along the outer surface, and terminates in the connective tissue in the outer and median folds, the other series, consisting of stronger bundles, crosses over to the inner surface and breaks up into smaller bundles,

and isolated fibres which terminate in the inner mantle fold.

Within the mantle there is, at the margin, a filling tissue composed of fine connective tissue fibres, in which run the muscle bundles and the trunks and finer branches of the pallial nerve plexus; passing inwards, this begins to include large irregular communicating spaces, and is soon reduced to a mere lining to the epidermal surfaces from which trabeculæ pass inward, forming a very coarse network. The trabeculæ consist of rather dense fibrous tissue with scattered nuclei. Far back from the edge this becomes reduced to little more than a layer of small nuclei and a few fine fibres. Delicate bridges of fibrous tissue unite the two epidermes, so that the whole cavity in the interior of the mantle lobe is divided into a system of inter-communicating spaces which are generally empty in sections, but are most probably blood sinuses. The inner epidermis is composed of flat squamous cells. Near the point of attachment of the mantle lobe to the body-wall the former becomes much thicker, and the spongy tissue in its interior attains a greater development.

If now, the mantle lobe being removed, the labial palps be cut away along their attached borders, and the gills be carefully removed by cutting close to their bases, the portion of the body lying between the adductors is laid bare. The base of the ctenidium (*Br'*., fig. 3) extends downwards obliquely from the region of the body extending up into the umbones, to the lower horizontal level of the posterior adductor. Here the bases of the right and left ctenidia become free from the body-wall, and continue to pass ventrally and posteriorly till their posterior extremities fuse with each other in the middle line, and with the horizontal shelf, referred to above, as formed by the extension inwards of the first fusion of the mantle lobes

between the siphons. At this point of concrescence of the two ctenidia, a peculiar little semicircular flap of membranous tissue projects downwards and forwards into the general mantle cavity.

This horizontal shelf is further prolonged anteriorly by the inner lamellæ of the internal branchiæ. Part of these inner lamellæ (*Br.I.2*, figs. 3 and 4) have the ordinary filamentar structure and are connected to the outer lamellæ of the same branchiæ by the inter-lamellar junctions. But the remainder of the inner lamellæ are simply membranous, and fuse with each other across the middle line of the body, and thus form the floor of the ventral supra-branchial chamber (*M.c.4*, fig. 4), which continues forward the cavity of the dorsal siphon. The outer reflected lamellæ of the external branchiæ, on the other hand, fuse with the body-wall just beneath the origin of the mantle lobes. It is evident from a consideration of fig. 4 that the inner and outer lamellæ of each external branchia must enclose a cavity, which is also continuous with the cavity of the dorsal siphon; this is the dorsal supra-branchial chamber (*M.c.5*, fig. 4). The ventral supra-branchial chamber is single and median. There are paired, right and left, dorsal supra-branchial chambers.

Since the inner lamellæ of the internal branchiæ do not fuse with the body-wall but with each other, the ventral supra-branchial chamber is incomplete anteriorly; the dorsal chambers end blindly in front. Evidently water entering the general mantle cavity by the ventral siphon or through the ventral opening of the shell has three courses open to it. It may pass forward between the labial palps into the mouth and so reach the dorsal siphon *per anum*; it may enter the ventral supra-branchial chamber through the space included between the posterior surface of the foot and the anterior margin of the fused inner lamellæ of the

inner branchiæ ; or, finally, it may pass through the inter-filamentar gaps in the branchial lamellæ into either dorsal or ventral suprabranchial chambers and so into the dorsal siphon.

Two regions of the body can be distinguished (figs. 2 and 3, Pl. I.), the visceropedal mass (*Ped.1* and *Ped.2*) and the portion of the body lying behind this and in front of the posterior adductor. This latter portion contains the pericardium (*Per.*) and heart, and the renal organ (*Ren.*) with the terminal portion of the rectum. The visceropedal mass contains, besides the muscular foot, the greater part of the alimentary canal, the digestive gland, and the gonads. It is sharply marked off from the posterior region by the differentiation of a sub-epidermal muscular sheath, but the same epidermal layer covers both portions of the body.

The pericardium is situated dorsally, occupying the whole dorsal area between the visceropedal mass and the posterior adductor, beneath it is the renal organ, the ventral wall of which forms the roof of the ventral suprabranchial chamber.

The visceropedal mass is defined by the continuous muscular sheath (*cf.*, fig. 11) extending ventrally from the dorsal body-wall. In horizontal section it is elliptical. It consists of a proximal or vertical, and a distal or horizontal limb which, both in the contracted and relaxed condition, form an angle of about 90° with each other. The distal limb is directed forward, it is very much flattened laterally and has a deep groove, the pedal groove, (*By'*, fig. 3) running along its ventral edge from near the tip to a point beneath the axis of the vertical limb. About a third of the length of the distal limb, from the tip posteriorly, has an epidermis composed of short columnar ciliated cells which also form the lining to the pedal

groove. The rest of the epidermis of the visceropodal mass consists of short columnar, non-ciliated cells, with a continuous thick cuticle.

As on the internal surface of the mantle edge, this ciliated portion of the foot is also an area provided with unicellular mucus-secreting glands. These form a continuous dense layer beneath the ciliated epidermis, and are imbedded in the loose muscular sheath of this part of the foot. Each of these glands (figs. 21 and 22, Pl. IV.) consists of either a single cell or a group of from 2 to 6 cells aggregated together. Single-celled glands are uncommon, and are only found near the posterior limit of the glandular area. Towards the tip of the foot they are more complex; the largest groups measure about 0.3 mm., the stalks being about half that length. Such a complex gland consists of a group of cells forming a bulb with a long stalk. The limits of the separate cells are not always clearly distinguishable. The cell bodies consist of a reticulum, some of the bars of which are rather coarse; these are, however, continuous with a very fine meshwork, which apparently makes up the cell substance. This reticulum is continuous from cell to cell. Nuclei are not evident, but in every cell there is a nodal point at the intersection of several of the coarser bars of the reticulum; reticulum and nodal points, and the finest ground substance, stain an intense blue with haematoxylin. The stalk is non-tubular, has the same structure as the bulb, and breaks up at its free end into a small number of branches which penetrate between the epidermal cells and form little knobs among the cilia on the surface of the foot. The structure and staining reaction of these bodies, coupled with the habit which the very young cockle has of pulling itself along a smooth surface by causing the tip of its foot to adhere to

the surface, indicate their probable nature—that of a simple mucus-secreting apparatus.

The pedal groove itself is not a glandular structure, nor do the glands above described open on to its surface. Passing backwards from the tip of the foot the cilia disappear, and the groove is lined with an epidermis consisting of simple columnar cells. The groove becomes deeper, and may be thrown into longitudinal folds. Finally, it passes into a duct which runs upwards and backwards into the proximal limb of the visceropedal mass, and terminates in a swollen bulbous head, which lies on the right side of the caecal prolongation of the straight intestine (*By.g.*, fig. 3). A single delicate hyaline fibre may sometimes be seen projecting from the opening of this duct, and indicates, what the histological character of the gland in fact demonstrates, that the apparatus is a byssus secreting structure. Sections of the duct show only an epithelium consisting of short columnar, ciliated cells. Further up, the duct expands into a wide cavity (fig. 19) from which lateral diverticula are given off; these may branch again. Their lumina are always restricted. Each of these secreting alveoli (fig. 20) is lined with an epithelium of rather club-shaped cells which do not seem to bear cilia, but from between which a number of fine threads pass out into the lumen where they become agglutinated together, forming a filament. The filaments from the various alveoli unite together in the duct to form the single byssus thread.

That *Cardium* possesses a true byssus was demonstrated by Gosse,* who shewed that in the young *C. aculeatum* this was actually functional. Carriere† and Barrois‡ have

* Ann. and Mag. Nat. Hist. Ser. II., vol. XVIII., pp. 257—8.

† Arb. Zool.-Zoot. Institut, Wurtzburg. Bd. V., pp. 56—92, 1882

‡ Comptes Rendus Acad. Sci. T. C., pp. 188—190, 1885.

also shown that in *Cardium* "*oblongum*," *C. echinatum*, and *C. rusticum* a rudimentary byssus gland, corresponding in all respects to the structure above described, is present. Finally, Gwyn Jeffreys* mentions a case of *C. edule* itself in possession of a functional byssus.

Of the apertures of the body, the mouth (*M.*, fig. 3) is a wide slit lying between the visceropedal mass and the anterior adductor; the anus (*An.*) lies on the dorsal surface of the posterior adductor. The apertures of the gonad and renal organ are rather difficult to observe. They may be seen by folding back the internal branchia (see fig. 3). The ureter (*Ren'*, fig. 4) is a mere slit in the wall of the renal vestibule, and lies on the lateral wall of the renal organ just dorsal to the origin of the posterior retractor muscles of the foot. The external opening of the gonad lies in nearly the same position, but on the lateral and posterior wall of the visceropedal mass; it is slightly elongated and sometimes has tumid lips.

THE MUSCULATURE.

The muscles may be conveniently arranged into four groups: (1) the adductor muscles of the shell; (2) the extrinsic muscles of the foot; (3) the intrinsic muscles of the foot; and (4) the pallial muscles. The extrinsic and intrinsic pedal musculature form really one system. The pallial muscles may be divided into the pallial muscles proper and the muscles of the siphons.

(1) There are two adductor muscles of the shell (*Add.a.* and *Add.p.*, fig. 3), anterior and posterior. Each is a strong bundle inserted on the dorsal oblique surface of the shell near the margin, and running across in an exact transverse direction from valve to valve. Owing to the curve of the shell the scars of attachment (*Add.a'* and *Add.p'*.,

* British Conchology, vol. II., p. 208.

fig. 10) are much larger than the areas of transverse sections of the muscles. The posterior muscle forms a thicker bundle than the anterior. In the extended condition of the animal, the structure of the muscle bundle is rather loose, being penetrated by blood spaces usually filled with corpuscles.

The force of contraction of the adductor muscles is very great. Plateau* has measured this in terms of the weight required to force open the valves. Two hooks were inserted under the ventral edges of the valves. The hook sustaining the upper valve was fixed to a support. The other, which was carried by the lower valve, supported a scale pan. Weights were placed in the scale pan till the valves were separated to the extent of 1 mm. As the mean of eight such experiments it was found that the weight required was 1134 grms. And taking the transverse area of both adductors into account, this gives the force necessary to overcome the contraction per sq. cm. of the sectional area of the adductor muscles of *Cardium* as equal to the weight of 2856 grms. Plateau also made the converse experiment. An animal in a completely relaxed condition, with the shell gaping, was supported with the lower valve resting on a firm support. A loop was passed round the upper valve, from the lower end of which was suspended a scale pan. The mean weight required to overcome the elasticity of the hinge ligament was found to be 106 grms.

(2) The extrinsic muscles of the foot take their origin from the superficial muscular sheath of the visceropedal mass. The posterior retractors of the foot (*Ret.p.*, figs. 3 and 11) originate in the posterior margin of the proximal limb of the latter, and run backward as a short apparently single median bundle (*Ret.p.*, fig. 4), this bifurcates into

* Bull. Acad. Roy. Sci. de Belgique. Ser. III., t. VI., pp. 226—259, 1883.

the right and left muscle bundles, which are inserted, one into each valve, at the dorsal margin of the posterior adductor scar (*Ret.p'*, fig. 10). There is a well-marked decussation of the fibres forming each muscle. That is, the fibres forming the left retractor originate in a flattened band, lying on the right side of the middle line, on the inside of the muscular posterior wall of the visceropedal mass, and *vice versa*. This crossing of the fibres is effected by two or three smaller inter-digitating bundles from each side, and is complete, none of the fibres remaining uncrossed. The band from which these muscles take the origin (*Ret.p.*, fig. 11) can be traced round the bend of foot into the ventral and lateral walls of the distal limb, after which its further course becomes very complex.

The anterior retractors of the foot lie through almost all their course in the interior of the visceropedal mass. Together they form a flattened band of fibres on the inside of the anterior wall (*Ret.a.*, fig. 11). At the upper level of the anterior adductor they come to the surface as two paired bundles which are inserted into the shell on the dorsal margin of the anterior adductor scar (*Ret.a'*, fig. 10). As in the case of the posterior retractors, a certain amount of crossing takes place, though this is not so evident as in the case of the other. Below the bend of the foot the further internal course of the fibres is difficult to make out.

The protractor muscles of the foot form right and left short bundles, which are inserted into the shell near the scars of attachment of the anterior retractors. Internally the fibres spread out in a fan-shaped sheet on the lateral dorsal walls of the proximal limb of the visceropedal mass, but there are no obviously distinct bundles, as in the case of the retractor muscles. Many of the fibres seem to pass

round and meet on the posterior margin, and the bundles may be regarded as being constituted by a break in the continuity of the circular muscular sheath of the proximal limb, the free ends being gathered up into two short bundles and attached to the shell. Judging from the direction of the fibres, the only effect of the contraction of these muscles will be to slightly rotate the whole visceropedal mass about its dorsal attachment on the shell, so that the term "protractor" is rather a misnomer.

The superior retractors of the foot (elevatores pedis, Pelseneer) form two paired muscle bundles, which are inserted one into each valve in the most dorsal part of the umbo. The scars cannot be easily seen without breaking the shell. Each bundle consists of fibres gathered up from the transverse and oblique musculature of the dorsal body-wall.

(3) The intrinsic muscles of the foot include all the pedal muscles, which are not inserted into the shell, but have their attachments within the visceropedal mass itself. There is a thick hypodermal muscular sheath (fig. 25) in which typically four muscle layers can be distinguished. Beneath the epidermis is a thin layer of fibrous connective tissue within which is a layer of muscle fibres running transversely round the foot. This is succeeded by a thick layer of obliquely running fibres, which passes into another layer of transverse fibres, and internal to all is an irregular sheath of longitudinal fibres. The precise arrangement is variable at different levels, and all the layers may not be present. The oblique and circular layers are always represented. Here and there in a transverse section through the proximal limb of the visceropedal mass, strong muscle bundles (*M.p.i.*, fig. 11) may be seen passing across between the lateral walls in a transverse direction. In the extended condition the structure of these is rather

loose, but the ends of each bundle are gathered up into a tendinous root, which penetrates the muscular layers of the body-wall, and has its attachment in the fibrous connective tissue which is present among the muscle fibres. These straight transverse bundles occupy the greater portion of the cavity of the proximal limb. Towards the axial portion they separate, leaving a space in which the convoluted and straight portions of the intestine are lodged. Between them penetrate the tubules of the gonads.

(4) The pallial muscles consist of the retractor muscles of the mantle edge and siphons and the intrinsic musculature of the siphons. The former (*Ret.m.*, fig. 3) form a radial series which extend round the mantle edge from adductor to adductor. They are inserted into the shell along the pallial line (*Ret.m'*.; *Ret.s'*.; fig. 10), and extend into the folds in the mantle edge where their distribution has already been described. Their length in the extended specimen is about 0.5 cm. Towards the posterior margin of the shell they become very much stronger in correlation with the development of the siphons, for the retraction of which they serve. In the walls of the siphons they form a dense longitudinal sheath which extends outwards to the tips. This sheath lies principally on the inner portion of the wall. Special circular and radial intrinsic fibres are present in the siphonal walls. The former are distributed in bundles lying just beneath the outer wall, and less evident bundles situated midway between outer and inner walls. The radial fibres pass across from inner to outer epidermis. The outer zone of the siphonal wall consists of connective tissue with included blood spaces.

THE ALIMENTARY CANAL.

By far the greater portion of the alimentary canal lies entirely within the proximal limb of the visceropedal mass, and may be easily dissected in a specimen hardened with formol by removing the muscular body-wall of one side, cutting through the attachment of the transverse muscle bundles as close to the integument as possible. The attachments of these to the opposite wall are then cut through beneath the intestine and the bundles removed, the digestive gland and the gonad are picked away, and the stomach and intestine lie exposed to view.

The mouth (*M.*, fig. 3, Pl. I.) is at first a wide slit extending across the body between the anterior body-wall and the anterior adductor. It is bounded dorsally and ventrally by the prominent upper and lower lips, the outer extremities of which are produced laterally to form the dorsal and ventral labial palps respectively. The opening soon contracts, so that the perforation in the muscular body leading into the œsophagus is oval in form. The latter (*Al.c.1*) is a short tube passing backwards and slightly upwards towards the posterior and dorsal part of the visceropedal mass, where it expands into the stomach (*Al.c.2*), which forms a capacious sac, increasing in diameter from before backwards. The stomach is surrounded on all sides by the dark-green mass of the digestive gland (*D.g.*). This is really paired, and forms a thick lobe on each side. Each lateral lobe, however, expands over the dorsal anterior and posterior sides of the stomach, so that it seems to nearly envelope the latter. If the digestive gland is carefully picked away prior to laying bare the stomach, two ducts may be seen opening into the latter. One is small, and opens on the posterior and dorsal margin; the other is much larger, and opens into the stomach at its junction with the œsophagus; it

passes at first forwards and downwards, then comes round into the mass of the gland. A great number of smaller lateral ductules open into these principal ducts, and on them are arranged in clusters the secreting alveoli of the gland.

The epithelium of the stomach passes gradually into that of the ductules of the gland. The tricuspid body disappears; the long spindle cells become shorter, and a corresponding decrease in length of the cilia takes place. But the epithelium of the ductules (fig. 17, Pl. III.) always consists of spindle cells carrying cilia, and their walls are thrown into slight longitudinal folds; at the passage of the lumen of the ductule into that of a secreting alveolus a rapid transition from this ciliated epithelium into that characteristic of the alveoli takes place (fig. 15, Pl. III.).

The fixation and subsequent treatment of the digestive gland, so as to exhibit the nature of the secretory epithelium, is difficult, but good results are to be obtained by McMunn's method. A very small piece of the gland is rapidly removed from the living animal, and at once put into a 20% solution of commercial formaldehyde in water. The tissue is allowed to remain in this for about 24 hours, and is then transferred to 70% spirit and dehydrated, embedded and cut in the ordinary way. The sections are stained with Mayer's glychaemalum and eosin, or with Heidenhain's iron haematoxylin. With fixing reagents of less penetrative power the epithelium breaks up in the process.

The lumen of the alveolus is always a very restricted one, and is usually cruciform in transverse section. The spindle cells becomes cubical and the cilia disappear (fig. 15, Pl. III.). Then the cubical epithelium becomes replaced by four groups of large club-shaped cells (fig. 16, Pl. III.). In tangential sections of the alveolus these cells, which are then cut transversely, have very definite polygonal out-

lines. Their cell substance is coarsely granular, with many round clear spaces; the nuclei are placed at their lower extremities. Only four to six cells are found in each group. The groups are delimited by the arms of the cross-shaped lumen, which extend nearly to the walls of the tubule, and here at the thinnest portion of the wall the cells composing it are small and irregular, and have relatively large nuclei. If the section has been stained with Heidenhain's haematoxylin a very distinct basement membrane, staining dense black, can be seen investing each alveolus. The whole mass of the gland is bound together by fibrous connective tissue, in the interspaces of which are crowded corpuscles of various kinds.

The lining epithelium at the animal's mouth consists of elongated columnar cells bearing cilia, and supported on a rather distinct basement membrane. Passing inwards this epithelium is thrown into a close series of longitudinal folds, and the height of the cells diminishes. The cells have distinct striated free borders, the nuclei are situated about their middle, the lower ends are rather loose and seem separated from each other; rounded faintly granular eosinophilous cells are found here and there wedged in between the columnar cells.

As the œsophagus widens out to form the stomach these cells gradually elongate to form the epithelium lining the cavity of the latter. This gastric epithelium (fig. 18, Pl. III.) is of variable thickness, but the cells are always longer than in the œsophagus. A gelatinous looking substance—the “fleche tricuspide” (*F. tri.*, fig. 18)—lines a large portion of the stomach-wall, and underneath this the epithelium becomes much thicker, consisting of long spindle-shaped cells, the long oval nuclei of which occupy any position within a rather wide zone about their middle. The lower ends of these cells are

very distinctly rounded off, forming an uneven lower margin, which rests on a fibrous sheath consisting of several layers, and which passes into the loose connective tissue surrounding the digestive gland tubules.

The thickness and extent of the tricuspid body is variable, some portions of the stomach-wall being bare; the latter is thrown into folds and pads, into which the substance of the tricuspid body dips. In most parts this substance is closely adherent to the gastric epithelium, in other parts it is distinctly separated; where it lies in close contact with the epithelium the striated free border of the latter is very evident. Where it is separated the epithelium is seen to bear cilia which, at other places, must be embedded in its substance. It stains slightly with eosin. No obvious structure can be discerned in it except that in favourable preparations, delicate striæ, parallel to the surface of the epithelium, and other striæ perpendicular to the surface may be seen, which seem to indicate that it has been deposited round the cilia and in laminae, perpendicular to the surface of the epithelium. Where the tricuspid body is wanting the gastric epithelium is composed of much shorter spindle cells than are found elsewhere. The average length of the cells beneath the tricuspid body is 0·08 mm., on the rest of the stomach-wall 0·04 mm.

The whole posterior part of the stomach contracts to form the straight portion of the intestine (*Al.c.3*, fig. 3). This extends downwards nearly in the axial line of the proximal limb of the visceropedal mass. It is slightly curved, the concavity being anterior. The diameter, the average value is 1·25 mm., decreases from above downwards. At the lower end and on the anterior side, the spiral portion of the intestine takes origin, below this there is a short anteriorly directed caecum.

As the stomach contracts to form this division of the intestine, two folds of its wall (fig. 11, Pl. III.), which are anterior and posterior, are formed, and are continued down the straight intestine dividing the lumen of the latter into two longitudinal cavities, both of which communicate with the stomach by wide openings and with each other by a long wide slit. Of the two communicating semi-tubes so formed, the left (*Al.c.3'*) is the larger, and is exactly circular in transverse section; it lodges the crystalline style. The right semi-tube (*Al.c.3''*) is irregular in section, and forms the channel along which the ingested food travels. Morphologically, this is the portion of the intestine immediately following the stomach. The left semi-tube is a diverticulum of the stomach cavity—the pyloric caecum* (sac of the crystalline style). Pyloric caecum and intestine are separate in some Lamellibranchs (*Pholas*, *Donax*), but in *Cardium* and others have fused together, the anterior and posterior folds being the remains of the primitively adjacent walls. At the tip of the straight intestine, in the short caecum already referred to, is a vestige of the originally separate condition of the two channels.

Three very distinct kinds of epithelium are present in the straight portion of the intestine. On the wall of the sac of the crystalline style there is a single layer of spindle-shaped cells (*Ep.I.I*, fig. 12, Pl. III.), having an average height of about 0.03 mm. These bear a very close set series of long and stiff cilia, having an average length of $\frac{2}{3}$ that of the cells carrying them. The cell bodies are finely granular, with rather highly refractive free borders, the nuclei are situated at their lower extremities; the cells fit together very closely, except at their lower extremities,

* Purdie, A. Studies in Biology for New Zealand Students. No. 3. Anatomy of the common Mussels. Wellington, 1887.

where large clear spaces are seen, which are either intercellular spaces or cell vacuoles, probably both. The epithelium in the intestinal division (*Ep.I.3*) is made up of much shorter cells, which bear short cilia. The free extremities of these cells fit closely together, but the lower ends are rather loose. Scattered abundantly throughout the epithelium are large, round, oily masses, staining faintly with eosin, and quite homogeneous in structure. Similar bodies can be seen in the tissue lying outside the epithelium. Here they are seen to be true cells, with the nucleus compressed against one portion of the cell wall and the greater part of the cell space filled up with an oily globule. In many the cell contents are very coarsely granular, and stain strongly with eosin. Others are finely granular, and all transition stages between the coarsely granular condition and the homogeneous appearance, which the bodies in the epithelium present, can be found. Similar oily globules can be found projecting into the lumen of the intestine, or even lying free in the cavity. Nuclei are not evident in these structures in the latter positions. The nuclei of the ordinary cells are found near their bases. Above each nucleus is a large clear cell vacuole, the occurrence and position of which seem to be fairly constant.

In the sac of the crystalline style and near the anterior fold is a very remarkable strip of epithelium (*Ep.I.2*), which extends all the way from the opening of the sac into the stomach to the point from which the spiral division of the intestine takes origin. This appears in transverse section as a crescentic area of the wall made up entirely of very long spindle cells. On the left side these long cells pass gradually into the epithelium lining the sac of the crystalline style. On the right side they are very sharply demarcated from the short cells lining the

intestinal division of the straight intestine. Their maximum length is about 0.2 mm. They are finely granular, with the nucleus at any level from near the free extremity to near the bottom of the cell. They bear a covering of very short cilia. Sometimes, at the middle of the free surface, there is a little groove in which the cilia are matted together. This is not constantly present, and it is probably due to the action of reagents.

The epithelium, of the intestinal portion especially, rests on a layer of dense connective tissue, which fills up the spaces between the epithelia forming the anterior and posterior folds, and is found in patches all round the intestine. This presents no very obvious structure. It seems to be largely fibrous, with nuclei scattered through it. It stains densely with haematoxylin. It includes large irregular spaces, evidently blood channels; in its substance are seen corpuscles of various kinds, blood corpuscles and corpuscles containing a greenish substance.

The crystalline style (*St.*, fig. 12, Pl. III.) completely fills the lumen of the left division of the straight portion of the gut. In sections made from hardened specimens, the style is usually seen to be retracted away from the wall of the sheath. But since, in such preparations, it may be observed that the superficial layer of the ciliated epithelium is in some parts torn away and adherent to the substance of the style, it is evident that this contracted condition is due to the process of embedding; and the same cause most probably gives rise to cavities sometimes observed in its marginal part. In hand sections of the animal, simply killed with formol and examined under a low magnification, the style appears perfectly homogeneous, and completely fills the sac.

No obvious structure is to be observed in the style except a very delicate concentric lamination. It is per-

fectly transparent, and seen singly, colourless; in mass the substance is very slightly yellowish. The length, when taken from full-grown specimens, varies from 20 to 26 mm. The diameter decreases from above downwards, and may be taken as about 1 mm. The proximal extremity always projects into the cavity of the stomach, and is opaque and slightly frayed; the distal extremity does not fill the lumen of the ventral portion of the sheath, but remains adherent to one portion of the wall. It is firm, somewhat elastic, but breaks easily.

Barrois,* in an exhaustive memoir on the Morphology and Physiology of the Lamellibranch Style, gives an account of the chemical composition and reactions of the substance of which it is composed, which may be briefly summarized here. Barrois made his analysis and experiments on the crystalline styles of *Cardium edule*. The style has an average weight of 0·026 gm. It is a colloidal substance. A number placed together coalesce to form a transparent jelly, which takes the form of the vessel in which it is contained. Dried at a temperature of 120°, the mass contracts considerably in volume, but still remains perfectly transparent and somewhat moist. On ignition a small amount of inorganic ash remains. The fresh style is rapidly soluble in concentrated hydrochloric acid to a bluish solution; it is slowly soluble in water, forming a slightly opaque and viscous solution. Millon's reagent gives a red colouration in the warm. Treated with copper sulphate solution and caustic potash, a fine blue colouration is obtained. These reactions indicate the presence of an albuminoid substance.

When the solid styles are boiled with dilute sulphuric acid, and the acid solution neutralized and precipitated with alcohol, a solution in the latter solvent is obtained.

* Revue Biologique du Nord de la France. T. I. and II., 1889—90.

This solution is filtered off from the flocculent precipitate, formed by the addition of the alcohol. It is evaporated nearly to dryness, and the dissolved matter again taken up by water; the aqueous solution so obtained reduces Fehling's solution. This series of reactions is characteristic of mucine and chondrine, since glycogen or other carbohydrates capable of yielding sugar on treatment with dilute acid, and consequently reducing Fehling's solution, are absent.

Further the addition of crystals of magnesium sulphate in excess to the aqueous solution of the styles, gives an abundant precipitate which contains practically all the proteid matter present in the solution. This behaviour with magnesium sulphate, which agrees with that of a globulin, and the reaction with dilute acid, indicate the nature of the substance. It is allied to, but apparently not identical with mucine.

Leaving out of account the older views concerning the function of the crystalline style, such as that of von Heide, that it was an accessory genital organ, or that it was a skeletal structure (Carus and Garner), or the representative of the radula of the Glossophora, and consequently a masticatory organ (Meckel), only two hypotheses as to its nature seem to survive modern investigation. Hazay* as the result of a series of observations and experiments, concluded that it represented a store of reserve food material, resulting from the metamorphosed excess of food matters taken in during the warm season, and lodged in the pyloric caecum to be utilized by the animal during periods of hibernation. Practically the same conclusion was arrived at by Haseloff† from a series

* Die Mollusken-Fauna von Budapest II. Biologischen Theil. Cassel, 1881.

† Ueber den Krystallstiel der Muscheln nach Untersuchungen verschiedener Arten der Kieler Bucht. Osterode, 1888.

of experiments carried out on *Mytilus*, from which it appears that not only is the style absorbed during the starvation of the animal by keeping it in filtered sea-water, but it is formed anew on abundant food being supplied. Haseloff inferred that the style "is the product of the chemical transformation of the excess of food material taken in by the animal, the change being effected by the agency of the digestive ferments." More lately, Woodward* working on the same mollusc, was able to confirm Haseloff's experiments.

Barrois rejects the conclusion of Hazay and Haseloff, basing his objections chiefly on the chemical composition of the style which is very different from that of most reserve food materials, and on the unusual form in which the substance is stored up. In both these points it differs notably from all undoubted physiological reserves. In *Helix pomatia*, which undergoes a true hibernation, abundant reserve food material is stored up in the liver in the form of glycogen. This substance undergoes a gradual change into sugar in the course of the hibernation period, and ultimately disappears completely. Moreover, neither in *Mytilus* nor in *Cardium* taken during all times in the year was he able to observe any change in the volume of the style. Specimens of *Cardium* were placed in filtered sea-water and starved for eleven days. Only after the eighth day was any diminution in volume observed, and in general complete disappearance only occurred on the death and partial decomposition of the animal. The disappearance of the style during this experiment Barrois regards as due, not only to the solution of its substance in the stomach which goes on, as under normal conditions, but also to the profound bodily disturbance brought about by

* On the Anatomy of Pterocera, with some notes on the crystalline style. Proc. Malacological Soc., London. Vol. I., pt. 4. 1894.

the experiment. At the same time, the secretion of the substance from the walls of the sac ceases, and the remains of the style are pushed into the stomach by the action of the cilia.

Barrois' own view, based chiefly on the chemical composition of the style, is that it is a cuticular structure secreted by the wall of the sac, which acts as a lubricating material and invests sharp particles of sand, &c., with a viscous coating which prevents damage to the intestinal wall. As it is formed it is moved forward into the cavity of the stomach, where its free extremity is continually being worn away by the attrition of the food particles and the solvent action of the digestive fluids. The viscous fluid so formed also unites the food matter into a coherent bolus which easily traverses the intestine.

The view that the style is a cuticular structure secreted by the wall of the pyloric caecum seems rather difficult to reconcile with the appearance of that epithelium, for, with the possible exception of the longitudinal strip of elongated cells in the caecum, the wall of the latter does not present the appearance usually associated with a secretory surface. The compact layer of columnar cells, the refractile free border, and the dense layer of long stiff cilia contrast strikingly with the wall of the right division of the lumen of the straight portion of the gut, where secretion into the cavity of the intestine is most probably taking place, and is far more suggestive of a surface performing a mechanical function than of an actively secreting epithelium. And it seems unnecessary to locate the mucus-secreting epithelium in the wall of the crystalline style sac. All along the course of the intestine there is abundant evidence of some substance being poured out into the lumen, in the rounded homogeneous bodies found in the wall or projecting from the

wall into the cavity, or even free in the cavity of the intestine itself. Many of these are possibly migrating cells taking up food matters and again passing back through the intestine into the blood stream, but there can be little doubt that many are the products of secretion of cells in the intestinal wall itself or in the tissue lying round that wall. Masses of a dense tissue staining with haematoxylin in the same manner as the mucus-secreting cells in the foot and mantle are to be found along the whole length of the intestine.

The faecal matter is expelled from the intestine in the form of coherent strings, frequently of great length, in which the particles are certainly bound together by some viscous material. On Barrois' view this faecal matter ought to contain a substance chemically identical with the substance of the style, otherwise, transformation of the latter goes on in the intestine, and the substance of the style must function otherwise than as a simple lubricant. On the whole it would seem as if the presence of the style were associated with the ingestion of a large quantity of foreign matter, such as mud and sand, and the separation, to some extent, of the nutrient material therefrom. The substance of the style need not be regarded as physiologically a store of reserve material, but as a first separation out of some constituents of the food which are continuously lodged in a portion of the stomach by the action of the ciliated wall of the latter, and as continuously dissolved away.

A narrow slit on the anterior surface of the straight portion of the gut leads into the next division—the spiral portion of the intestine. This lies nearly in the axis of the proximal limb of the visceropedal mass, and anterior to the latter. It is twisted into a close spiral of five or six turns (*Alc. 4*, figs. 3 and 11) the planes of which are

nearly horizontal. At its upper extremity the coiling becomes rather irregular, and the tube passes into the succeeding coiled portion of the intestine near the axis of the latter. The crystalline style passes the opening of the spiral intestine, and its narrowed end is lodged in the short caecum already referred to. The anterior fold in the straight intestine continues on into the spiral portion, and passes into a thick pad, nearly filling up the lumen of the latter (*Ty.*, fig. 13, Pl. III.). This pad or typhlosole is formed by the same tissue which fills up the space in the anterior and posterior folds which divide the straight gut into right and left divisions. Owing to the presence of this typhlosole the spiral gut appears externally as a round tube, although in section the lumen is contracted and crescentic in form; the tissue filling the typhlosole is continuous with a narrow layer surrounding the gut and with the general connective tissue of the visceropedal mass.

After making about six turns the typhlosole disappears, and the intestinal tube passes into a loose coil of four or five turns, which may be described as the coiled portion of the intestine (*Al.c.5*, figs. 3 and 11), and which lies anterior to the spiral gut. The average diameter of this coil is from 0.6 to 1 cm. Its most anterior turn joins the spiral intestine; its most posterior one passes off into the rectum, which passes to the right side of the straight intestine, and runs up along the posterior part of the visceropedal mass (*Al.c.6*, figs. 3 and 11) to near the dorsal portion of the latter, where it pierces the muscular body-wall and enters the pericardium. After passing through the ventricle of the heart, the rectum runs along in the dorsal body-wall over the posterior adductor, and terminates in the anus (*An.*, fig. 3).

The histological character of the epithelium of the intes-

tine behind the typhlosolar portion resembles that described as present in the right division of the straight intestine. The wall may be smooth or thrown into three or four longitudinal ridges. The whole surface is ciliated. The oily eosinophilous globules already referred to are particularly abundant in the coiled intestine, and many may be found lying freely in the cavity. The average diameter of this portion of the intestine is about 0.5 mm.

Towards the anus the epithelium becomes arranged in a very peculiar manner (fig. 14, Pl. III.). Passing over the posterior adductor the wall becomes thrown into longitudinal folds, which, towards the anus, become more complex, secondary foldings being developed, and the bases being narrowed till some folds have, in transverse section, an almost dendritic appearance. Within they are filled up by the dense tissue already noted. A continuous sheet of connective tissue with a few muscle fibres surrounds the gut, but does not enter into the folds. Near the anus this dense filling tissue becomes restricted to the dorsal half of the intestinal tube, where it forms a crescentic pad lying on the epithelium beneath. This epithelium differs completely from that forming the ventral half. While the latter is thrown into complex foldings and bears long cilia which, on account of the proximity of the folds to each other, become matted together in the lumen, the upper epithelium is smooth, is non-ciliated, and consists of long clear spindle cells, with nuclei lying at their lower extremities, which form a sharp contrast with the cubical epithelium of the lower half. The transition from upper to lower epithelium is quite a sharp one. The tissue forming the pad lying on the upper half of the tube differs somewhat from the dense tissue lying outside the intestinal tube in its more anterior parts. Here it seems to consist of a dense mass

of cells, the bodies of which stain with haematoxylin, so that nuclei and cell bodies are not clearly distinguishable.

THE VASCULAR SYSTEM.

The pericardium (*Per.*, figs. 3 and 4) is a spacious sac which occupies the whole dorsal surface of the body between the posterior wall of the visceropedal mass and the posterior adductor. Its anterior wall is closely applied to the former. Its ventral wall rests on the upper surface of the renal organ. Dorsally and laterally the pericardial wall is also the body wall, and is thin and delicate, except in the median dorsal line where it is produced upwards into a strong ridge, and also on the lateral dorsal borders where the mantle lobes take origin. It is widest in front and contracts as it approaches the posterior adductor. It is nearly filled by the heart consisting of the median ventricle and the two auricles.

In the animal which has been killed after treatment with cocaine, the ventricle is usually fixed in the condition of diastole and then, together with the two auricles, fills almost the whole pericardial cavity. The ventricle (*Ven.*, figs. 3 and 4) is constricted medially, forming two rather well-marked lateral lobes. The walls are muscular but rather thin. Abundant muscular trabeculae run across the cavity in all directions. The rectum passes through its cavity, suspending the ventricle in the centre of the pericardium. The auricles (*Aur.*, figs. 3 and 4) are triangular in shape, the apices being attached to the ventricle, the bases to the bases of the ctenidia. Their walls are very thin, except at the apical portions, where they are thickened and composed of dense fibrous tissue; these portions project into the ventricle; the openings are horizontal slits bounded by the thickened tissue which forms a pair of

valves preventing the reflux of the blood into the auricles during the ventricular systole. On the floor of the pericardium, beneath the ventricle, are the openings of the reno-pericardial canals. On the anterior part of the floor are several openings which are the terminal portions of systems of tubules forming the paired pericardial glands. The tubules are lined with cells containing brownish-red concretions, and are distributed over a wedge-shaped area of the mantle extending, ventrally, from the most dorsal portion.* The ventricle is prolonged backwards into a short narrow neck which still contains the rectum. A transverse membranous partition, beginning at the dorsal surface of this neck, extends backwards and downwards across its cavity, embracing the rectum, and ends so that its free edge lies near the ventral surface. This must form a valve preventing the reflux of blood into the ventricle from the posterior part of the body. Behind this valve the tube expands forming a "bulbus arteriosus" (*B.a.*, fig. 30) with thin muscular walls. This terminates in two lateral branches, the right and left posterior pallial arteries which diverge from each other and pass backwards beneath the posterior adductor. Here their walls become very ill-defined and communicate freely with a system of lacunæ between the bundles of the muscle. The arteries, which are now difficult to trace, reach the mantle margin and terminate in the sinuses there and in the walls of the siphons.

Anteriorly the ventricle passes into a single median vessel with well defined walls, the anterior aorta (*A.o.*, fig. 30); this pierces the posterior wall of the visceropedal mass, and travels along in the dorsal region of the latter, giving off, in its course, small vessels to the digestive gland. Near

* Grobben, Dr. C. Die Pericardialdrüse der Lamellibranchiaten. Arbeit. Zool. Inst. Wien. Bd. VII. 1888.

the anterior margin of the visceropedal mass the aorta bifurcates; one vessel runs straight forward over the anterior adductor to the mantle lobes, forming the anterior pallial artery (*Art.p.a.*), the other passes straight downwards as the visceropedal artery. In its course this gives off a vessel from its anterior side which soon bifurcates, forming the right and left labial arteries (*A.lab.*). Still further down a large vessel is given off from the posterior side, the visceral artery (*Art.v.*), this runs back horizontally until it meets the straight portion of the intestine; branches are given off which supply blood to the rest of the gut. The main vessel is continued beyond this branch to the ventral surface of the foot as the pedal artery (*Art.p.*).

Only the above described vessels, constituting the arterial portion of the vascular system, have definite walls. The further course of the circulation lies in irregular lacunæ between the various organs, between muscle bundles, and in cavities in the connective tissues. The first focus of this system of venous channels is the renal sinus (*Sin ren.*, figs. 4 and 30), an irregular blood space surrounding the tubules of the renal organ. Anteriorly this begins as a pair of blood spaces lying underneath the pericardium on each side of the middle line of the body ("venæ cavæ"). These unite into a large median cavity in the middle of the renal organ, from which the blood filters outwards round the system of tubules constituting that organ. Blood enters the renal sinus dorsally from the mantle lobes, and anteriorly from a vertical sinus in the posterior part of the visceropedal mass (*Sin.p.*, figs. 11 and 30). This communicates with the renal sinus through an opening in the muscular wall of the former, where the posterior retractor muscles of the foot take origin from the muscular body-wall. Here the arrange-

ment of the muscles is such as to constitute a valve regulating the flow of venous blood outwards from the visceropedal mass.

From the renal sinus the blood reaches the heart by passing through the gills. The precise path taken will be considered in connection with the structure of those organs and of the kidney.

THE RENAL ORGAN.

The renal organ is a single median structure. As seen from the ventral side it forms a crescentic mass with the convexity facing posteriorly, and the two horns, which are anterior, embracing the posterior retractor pedis (fig. 31, Pl. VI.). It forms part of the lateral and the whole ventral wall of that portion of the body lying between the visceropedal mass and the posterior adductor. Its posterior wall lies against the adductor. Its dorsal wall is applied to the ventral wall of the pericardium.

In front the renal organ consists of a single wide sac with a few secretory tubules opening into it along each side, but the diverging retractor muscles of the foot passing upwards through it on their way to their insertions in the shell, break up the posterior portion of this sac into three separate cæcal divisions (*Ren.*, fig. 7, Pl. II.). The median posterior division passes backwards between the diverging muscles, the right and left posterior divisions pass to the outside of the right and left muscles respectively. Each of these three divisions branches out behind the muscles into a great number of irregular secreting tubules, owing to which the mass of the organ is greatest at its most posterior part, that is, at the convex margin of the crescent.

It is, of course, not the actual renal sac, but the outer body-wall that is seen from the outside: between the renal

sac and the outer wall is the blood sinus surrounding the secretory tubules. The renal sinus communicates with the pedal sinus by perforations in the muscular wall of the visceropedal mass, as the pedal retractors originate from the latter. The muscles lie actually in the blood sinus. In front of them the sinus is a wide central cavity lying beneath the flattened renal sac, with renal tubules dipping into it on all sides except dorsally. The body-wall is gathered up into a pair of lateral folds, which take part in the formation of the bases of the ctenidia, and the blood from the central cavity filters through the spaces between the tubules into these lateral folds, and so into the gills.

The reno-pericardial canals (*Ren.per.*, fig. 4, Pl. II.) are a pair of large tubules which take origin on the lateral internal walls of the lateral posterior divisions of the renal sac. In sections they may be found on the part of the wall lying on the outside of each retractor muscle. They open into the renal sac by wide fimbriated mouths. Their walls near these openings are often peculiarly modified, and are produced out into several small diverticula, resembling the renal tubules. The canals pass downwards and forwards along the ventral wall of the renal sac, and come to open into the pericardium on the floor of the latter underneath the ventricle, by a pair of prominent slits. All along their course the tubules carry a lining of long cilia, and on the openings of the canals into the pericardium these are very prominent, especially in young specimens (0.5 to 1 cm.), where they sometimes form a ciliated fringe projecting into the latter.

The form and course of the renal tubules are very irregular, and in sections through the posterior margin of the renal organ it is at first sight difficult to distinguish between the tubules themselves and the blood sinus. This

can be done, however, by the character of the wall; the internal surface of the renal tubule (fig. 9) is formed by an irregular epithelium composed of large non-ciliated cubical cells with clear or very faintly granular contents. The cell walls are very definite; the nuclei lie at the bases on the lateral walls. The epithelium is supported on a sharply defined basement membrane, from which bridges of delicate fibrous tissue stretch across the blood spaces. The wall of the renal sac, other than that lining the tubule, has the same characters, except that the cells are smaller and more irregular.

THE BRANCHIÆ.

The general arrangement of the branchiæ (ctenidia) with respect to the other parts of the body, has already been described above. There is a single ctenidium on each side. Each of these organs consists of two branchial plates lying side by side in the mantle cavity, attached to a base containing blood vessels. Each branchial plate or branchia is again folded on itself so that it consists of two lamellæ. The lamellæ of the same branchia are bound together, but there is no connection between the two branchiæ except at the base of the ctenidium from which both take origin.

The base of the ctenidium (*Br'*, fig. 3, Pl. I.) is a ridge of the body-wall containing the blood vessels—the common afferent and efferent branchial vessels. The afferent vessel carries blood to both branchial plates, while the efferent vessel carries away the blood oxidised by contact with the water flowing through the mantle cavity. A flat band of muscle fibres runs along the ctenidial base from the posterior to the anterior extremities. The branchial nerve terminates in the posterior portion of the base.

The ctenidium of the left side is shown in fig. 2. The

inner branchia (*Br.I.*), which is the larger of the two, is narrowest behind where it fuses with the corresponding structure of the right side, and increases gradually in width towards its anterior margin which is attached to the body-wall, and is slightly overlapped by the labial palps. The outer branchia (*Br.E.*) is narrower than the inner, and is broadest at about midway between its two extremities. The two branchiæ of each side fuse together behind the visceropedal mass at their posterior extremities.

Each branchia consists of a large number of hollow filaments connected together at intervals. The direction of these filaments is at right angles to the ctenidial base. At the free ventral margin, where each branchia is folded on itself forming the two lamellæ, the filaments of the inner pass over with some modification in structure into those of the outer lamella. The whole ctenidium is cut obliquely to the base in fig. 4, and each of the two branchiæ is seen to be made up of a direct and a reflected lamella. For the greater part, these two lamellæ are intimately bound together: the precise nature of the connections is not, however, shown in the figure. In the inner branchia the external lamella (*Br.I.1*) which is inserted into the base of the ctenidium, is the direct one, and the internal lamella (*Br.I.2*) is the reflected one. Conversely in the outer branchia, the internal lamella (*Br.E.1*) is the direct one, and the external lamella (*Br.E.2*) is the reflected one. This difference in the disposition of the two branchia will be noticed, the inner lamellæ of right and left internal branchiæ fuse together in the middle line, and here the lamellæ (*Br.I.3*) are simply membranous plates, showing no sign of filamentar structure. These membranous portions of the inner lamellæ are continuous at the posterior extremities of the ctenidia

with the horizontal septum, which continues forward the fusion of the mantle edge between the two siphons, and consequently they form the floor of the ventral supra-branchial chamber which is a continuation forward of the cavity of the dorsal siphon. This ventral supra-branchial chamber is continuous with a series of cavities between the two lamellæ of the right and left inner branchiæ. The reflected lamellæ of the outer branchiæ, on the other hand, are filamentar in structure through all their width, and extend dorsally beyond the ctenidial base to be inserted into the body-wall in the angle formed by the latter and the mantle lobes. This dorsal extension of the reflected lamellæ of the outer branchiæ is common to a number of Eulamellibranchs, of which *Cardium* forms the type, and is the "appendice" of Pelseener, which is regarded by him as the beginning of a third lamella of the outer branchia.*

The branchiæ of *Cardium* are of the "fluted or compound type," that is, each is thrown into a number of deep furrows and ridges, the direction of which is perpendicular to the base of the ctenidium. Two such ridges, with a furrow between, are represented in fig. 26—where the branchia is cut in a plane at right angles to the filaments. Each ridge consists of a group of from 20 to 30 filaments. One or two filaments may occupy the summit of the ridge, the bottom of the furrow is constituted by two filaments which have opened out and fused by their edges forming a membranous plate. In each branchia these ridges and furrows are symmetrically opposed to each other, ridge against ridge, and furrow against furrow. The supra-branchial cavity extends into the interior of each ridge.

Morphologically the branchia consists only of this

* Bull. Sci. de la France et de la Belgique. Ser. III., t. XX., pp. 27—52
1889.

double series of hollow filaments which were primitively vascular channels, the wall of the filament itself serving as the membrane through which the gaseous interchange between the blood and the surrounding water is effected. This simple arrangement is complicated here by the process of folding, which is described above, and further by a partial coherence of the filaments, which with the development of other vascular tissues, form two series of junctions within the branchia:—1st, a series of inter-filamentar junctions (*Br.j.1*, figs. 26 and 28, Pl. V.) joining the separate filaments in each lamella, and 2nd, a series of inter-lamellar junctions (*Br.j.2*, fig. 26) joining the two lamellæ of the same branchia. It will appear from a consideration of figs. 26 and 28 that this conjunctive tissue is not formed simply by the branchial filaments themselves, but also by vascular tissue developed from the base of the ctenidium. The whole of an inter-lamellar junction is constituted by this vascular tissue, the inter-filamentar junction, on the other hand, is formed both by the union of the adjacent walls of the filaments and by a separate vascular tissue. Wherever such an inter-filamentar junction occurs, the filaments taking part in it have split (fig. 28) and the adjacent edges of separate filaments have united. But underneath this place of union the vascular channel is completed by a sheet of connective tissue continuous with the tissue of the efferent or afferent vessels, as the case may be. If the whole lamella could be flattened out, it would appear as a trellis work of which the vertical bars would be formed by the filaments, the horizontal bars by the vascular inter-filamentar junctions. At intervals of every 40 or 50 filaments, vertical afferent and efferent vessels occur alternately, and between these vessels the blood circulates in the horizontal inter-filamentar junctions. But there must also be a

limited circulation of the blood through the filaments themselves.

There is a very regular segmental or repetitional structure in each branchia, which is due to the fluting and to the regular occurrence of the afferent and efferent vessels. At the base of each furrow is a vessel, the external wall of which is formed by the two flattened-out filaments already referred to. The rest of the vessel is formed from extra-filamentar tissue. Afferent and efferent vessels so formed alternate with complete regularity along the whole length of the branchia. There is this difference between the two series:—the afferent series (*Br.aff'*.) consists of a number of hollow plates extending uninterruptedly from the base to the ventral edge of each branchia, and also stretching across from external to internal lamellæ; each afferent vessel is thus common to the two lamellæ of the branchia; the efferent series consists of a number of nearly cylindrical vessels (*Br.eff'*.), one of which is present at the base of every alternate furrow. They must necessarily be double the number of the afferent vessels. The afferent vessels form the inter-lamellar junctions. It also follows from this arrangement that the suprbranchial cavity in the inter-lamellar space is divided up into a series of separate cavities having no connection with each other except at the base of the branchia.

Fig. 26 represents such a double segment in the internal branchia of one ctenidium. There are from 50 to 60 such segments in the length of the organ.

The separate filament (fig. 27) is in transverse section ellipsoidal in shape, the broader end is external, the more pointed end is internal. The outer surface is composed of large cubical cells, the inner surface of smaller cells. Within is an elongated cavity across which bridges of

delicate fibrous tissue pass from wall to wall, and which contains blood corpuscles. There are no skeletal structures.

In any section of the wall four cells are very obvious. Two of these are very large, one being situated on each lateral wall. Their nuclei are prominent but stain lightly. There is a very evident striated free border, and the cell bears a number of long and coarse cilia. The two other cells lie nearer the broad end of the filament, and resemble those described. The nuclei are, however, very large and stain intensely, so that they are very evident even under a low magnifying power. Between these two cells the outer wall of the filament is composed of cubical cells bearing short cilia. The inner surface consists of small cubical or even flattened cells.

Both the vertical afferent and efferent vessels and the inter-filamentar vessels have very thin walls composed of a flattened epithelium. Only a few fine trabeculæ cross the cavities of these vessels. It is obvious from a comparison of the area presented by this vascular tissue with the area of the filaments themselves, and from a comparison of the nature of the epithelia in each case that by far the greater part of the gaseous exchange in respiration must be effected through the wall of the vascular tissue proper and not through that of the filaments. The latter, in fact, form a mechanical tissue supporting the series of vascular channels, and by the action of their ciliated epithelium, causing the current of water from without to flow through the bars of the trellis work of each lamella into the supra-branchial cavities.

THE COURSE OF THE CIRCULATION.

The heart is a systemic one. Blood, with the waste products eliminated in the renal organ, and having under-

gone oxidation in the gills, is distributed through the body by two series of vessels; posteriorly it leaves the heart by the right and left posterior pallial arteries (*Art.pp.*, *Art.pp'*., fig. 30, Pl. V.), and reaches the siphons and the posterior mantle margin; anteriorly it traverses the aorta (*Ao.*), which soon bifurcates; one branch, the anterior pallial artery (*Art.pa.*), passes over the anterior adductor and reaches the anterior mantle margin; the other branch descends the anterior part of the visceropedal mass as the visceropedal artery (*Art.vp.*). In its course this supplies blood to the labial palps through the right and left labial arteries (*A.lab.*), and again bifurcates, one branch, the visceral artery (*Art.v.*), penetrates the visceral mass and, passing first to the straight portion of the intestine, supplies the whole length of the latter, the other continues on to the bend of the foot.

Further than this, it is impossible to trace the afferent blood channels. Both in the mantle margin and in the visceropedal mass the arteries become lost in an irregular system of lacunæ, lying principally in the interspaces between the muscle bundles. This lacunar system represents the capillary and venous portions of the vascular system of a more highly organised animal, and it is here that the interchange between blood stream and tissues, in the metabolism of the latter, is effected. Two foci exist towards which the blood circulating in this lacunar system converges. From the anterior and posterior margins of the mantle lobes it flows in the ventral mantle edge towards the centre, then dorsally through the spaces in the interior of the thin mantle lobes towards the umbonal parts of the latter. Here there is a direct communication between the intrapallial lacunæ and the renal sinus, but the greater portion of the blood, after bathing the tubules of the pericardial gland, reaches the anterior corners of the auricles.

The second focus of the venous blood is the renal sinus, towards which all the blood circulating in the visceropedal mass converges. There are two large sinuses in the latter, an irregular sinus lying on the anterior margin and a posterior pedal sinus (*Sin.p.*) lying beneath the internal part of the posterior retractor muscles of the foot. As the latter are gathered up into the two compact muscle bundles which run upwards through the renal organ, they leave an opening in the muscular wall of the foot which leads into the two short longitudinal trunks, these, finally, open into the large central sinus in the middle of the renal organ (*Sin.ren.*, figs. 7 and 30).

From this central space the venous blood flows outwards, bathing the renal secretory tubules in its course, and enters two longitudinal vessels which run along the bases of the ctenidia. These are the common afferent branchial vessels (*Br.aff.*, fig. 30). From them a series of vessels, running perpendicularly to the bases of the ctenidia, enters each branchia—the afferent branchial vessels (*Br.aff'*, figs. 26 and 30). These communicate through the interfilamentar branchial junctions with a series of similarly disposed vessels—the efferent branchial vessels (*Br.eff'*, figs. 26 and 30), which fall into a pair of common efferent branchial vessels (*Br.eff.*), and these finally open into the auricles. From the auricles the blood enters the ventricle through the openings at the apices of the former, reflux being prevented by the action of the valves guarding these openings.

Menègaux* bases a theory accounting for the protrusion of the foot, siphons, and mantle edges, on the anatomical relationships indicated above, *i.e.*, the presence of a valve

* Recherches Sur le Circulation des Lamellibranches Marins. 296 pp., Besançon, 1890. Also Comptes Rendus de l'Acad. Sci., Paris. T. CVIII., pp. 361—364, 1889.

behind the ventricle and at the opening of the posterior pedal into the renal sinus. Since it has been proved that there is no entrance of water from without, either into the blood stream or into a closed water vascular system, the mechanism of the erection of the foot and siphon must be sought for in the intrinsic musculature of those parts or in arrangements whereby the blood pressure in localised regions of the animal's body can be varied at will. Since there appears to be no arrangement of muscles which can possibly bring about the protrusion of the siphons, the only other evident cause of this must be their distension with blood which is forced in from the heart through the posterior pallial arteries. The condition of "turgescence" in the siphons is probably initiated by the simultaneous relaxation of the constrictor muscle fibres at their bases, and of the retractor muscles. The lacunar spaces are thus enlarged and become distended with blood. The radial muscles and, to a certain extent, the constrictor muscles must function in preventing lateral expansion so that the blood pressure is distributed towards the tips of the siphons and is directed largely towards increasing their length. The valve behind the ventricle prevents the reflux of blood back into the heart. Retraction is abundantly provided for by the constrictor fibres of the siphonal walls and by the retractor muscle bundles.

Similarly the turgescence of the foot is initiated by the relaxation of the posterior and anterior retractores pedis. The entrance of the posterior pedal sinus into the renal organ is guarded by an arrangement of muscle fibres which is in effect a valve, and the closure of this is most probably the first effect of the relaxation of the posterior retractor of the foot, since in sections through this region, in an extended specimen, the opening is difficult to find.

Blood which is forced into the visceropedal mass by the increased action of the heart, is now retained there since there is no other exit than that into the renal sinus, and, as in the case of the siphons, an area of increased pressure is established. This, of itself, must tend to straighten out the two limbs of the foot, and this is in fact observed in cases of extreme distension. But the action of the intrinsic circular and transverse fibres also aids in the protrusion of the foot, since by their correlated contraction both diameters can be reduced and the increased pressure distributed towards the tip. Within the distal limb the courses of the intrinsic fibres are so various that no reliable deduction as to the result of their contraction can be made.

Retraction of the foot is provided for by the contraction of the posterior retractor pedis. This, first of all, opens the passage leading into the renal sinus and allows the blood in the foot to enter the latter space. Then both anterior and posterior retractors operate by their contraction in reducing the length of the proximal limb, and waves of contraction passing upwards from the tip chase the blood in the whole foot into the renal sinus. It does not appear from the disposition of the muscle, regarded here as the homologue of the "protractor pedis" in other Lamellibranchs, that its contraction can have any appreciable effect in the protrusion of any part of the visceropedal mass.

It follows from the above that in the condition of turgescence, the large blood spaces in parts of the body, other than the visceropedal mass, are relatively emptied of blood; and that conversely, in the contracted condition, those spaces are gorged. In sections made from the turgescient animal the empty condition of the renal sinus in particular is evident. In the contracted condition, blood

accumulates in the more dorsal intrapallial lacunæ and in the spaces round the adductors. The lacunæ in the contracted foot itself are only potential, and the circulation there must be largely confined to that taking place in the visceral artery and in the venous lacunæ round the intestine. This explanation of the condition of turgescence assumes that the quantity of blood contained in the body is sufficient to produce the distension of the parts in question. Fleischman has shown that this is the case for *Anodonta*, and the assumption may not unreasonably be made that it is the case also in *Cardium*.

THE NERVOUS SYSTEM.

The central nervous system in *Cardium* is constituted by the two separate, paired, cerebral ganglia, each of which represents the fusion of originally distinct cerebral and pleural ganglia; the single median pedal ganglion, formed by the fusion of originally lateral and paired pedal ganglia, and the single median parieto-splanchnic ganglion also formed from originally separate, right and left, ganglionic masses. There are two pairs of connectives, the cerebro-visceral connectives joining the cerebral and parieto-splanchnic ganglia, and the cerebro-pedal which connect the cerebral and pedal centres. The whole nervous system is bilaterally symmetrical.

The cerebral ganglion of each side (fig. 3, Pl. I., *Ga.c.*) lies quite superficially in the loose connective tissue between the bases of the labial palps, the anterior dorsal wall of the visceropedal mass, and the anterior adductor; and is easily exposed by removing the palps close to their attachments, and parting slightly the adductor from the adjoining body-wall. It is oval in shape and unpigmented. The right and left ganglia are joined together by the long cerebral commissure (*Com.*) which runs in the base of

the dorsal palp; four conspicuous nerves leave the ganglion on each side, and are easily observed.

The cerebro-visceral connectives (*Con.cv.*) run backwards and upwards in the loose tissue surrounding the ganglion; they pierce the muscular body-wall, and pass through the upper portion of the visceropedal mass embedded in the substance of the digestive gland. Leaving the latter they again pierce the posterior muscular body-wall near the external openings of the gonads, and slightly above the origin of the retractor muscles of the foot. Then they pass along the lower wall of the renal sinus to join the parieto-splanchnic ganglion.

The pedal connective of each side (*con.cp.*) runs downwards in the loose tissue round the ganglion for a short distance, then pierces the anterior muscular wall of the visceropedal mass, and passes vertically downwards on the internal surface of the latter to the pedal ganglion. The connectives are quite distinct, but lie close together in the middle line of the body; about half-way down in the course of each, a nerve is given off which passes backwards into the visceral mass.

A large nerve, the anterior common pallial nerve (*N.pa.*), leaves the anterior surface of each ganglion, and passes along the lower surface of the anterior adductor, and outwards from this on to the most anterior and dorsal corner of the mantle lobe. Just before leaving the adductor each pallial trunk bifurcates.

A very small nerve, the anterior adductor nerve (*N.add.*), leaves the ganglion near the origin of the anterior pallial nerve, and plunges into the posterior surface of the anterior adductor muscle.

Lastly, there is the strong cerebral commissure running over the dorsal wall of the mouth.

These are all the nerves that can be observed in the

course of dissection. In addition to these, several smaller twigs can be seen in sections, passing off from the ganglion into the surrounding tissue, some of these most probably innervate the labial palps.

The parieto-splanchnic ganglion (*Ga.sp.*, fig. 31, Pl. VI.) is best dissected by placing the animal (removed from the shell), ventral surface uppermost, and cutting through the wall of the lower siphon, the fused inner lamellæ of the internal branchiæ, and the horizontal shelf formed by the concrescence of the two ctenidia and the septum between dorsal and ventral siphons. These parts are then folded back and the ganglion and its nerves are fully exposed.

This is the largest of the ganglionic centres, it is nearly square in shape. Indications of its origin from paired and lateral ganglia are seen in the two little anterior lobes, from which the connectives take origin. It is covered only by a single layered epithelium, and lies in a cavity; three nerves leave it on each side.

The cerebro-visceral connectives are the most delicate of the nerves leaving the ganglion. Each connective originates in one of the anterior lobes already referred to, and at once plunges into the renal sinus and passes through the latter, lying apparently free in the blood space. The further course has been described above.

The branchial nerves (*N.br.*) leave the ganglion from the anterior corners, and pass along in the wall of the afferent branchial vessels to the bases of the ctenidia. Where the latter become free from the body-wall the nerves bend round at a right angle, and pass backwards to the tip. Following Duvernoy and Drost* I have termed these the "branchial nerves," though I have been

* Drost, K. *Über das Nervensystem u. d. Sinnesepithelien der Herzmuschel (Cardium edule), &c.* Morphologisches Jahrbuch. Bd. XII., pp. 164—201; Taf x., 1886—7.

unable to demonstrate their actual endings in the tissues of the ctenidia.

The posterior common pallial nerves (*N.pp.*, fig. 31), are the stoutest of the nerves proceeding from the visceral ganglion. They leave the latter from its most posterior corners, and pass over the ventral surface of the adductor, reaching the mantle at the most lateral and posterior corners of the former. As they leave the muscle each nerve bifurcates; and the external branch, which is the largest, runs along the mantle edge as the external pallial nerve (*N.p.1*); the internal branch again divides, the outer of the two nerves so formed also runs in the muscular tissue of the mantle margin as the median pallial nerve (*N.p.2*); the inner one has its whole course in the thin tissue of the mantle within the line of insertion of the retractor muscles. This internal pallial nerve (*N.p.3*) is by much the most delicate of the three.

As each common pallial nerve passes over the adductor, two branches are given off from its external surface. These enter the wall of the dorsal siphon. Three other nerves leave the trunk after the branch forming the median and internal pallial nerves is given off. These enter the wall of the ventral siphon. Thus the two siphons are innervated by five nerves on each side, of which two enter the dorsal, three the ventral siphon. Anastomoses between the first three of these siphonal nerves are common, and gangliform enlargements may be observed at their points of origin from the mantle nerve or further out on their course.

The pedal ganglion (fig. 3, Pl. I., and fig. 33, Pl. VI.) is best exposed by removing the visceropedal mass, with the bases of the labial palps, and, therefore, the cerebral ganglia attached, and pinning it down in a dish with the anterior margin uppermost; the muscular body-wall is

then cut through in the middle line, and the two sides reflected outwards from below upwards, the attachments of the transverse muscle bundles being cut through as close to the body-wall as possible. The whole course of each cerebro-pedal connective is then exposed from the point where it perforates the muscular body-wall to its ending in the ganglion. The latter, with its nerves, is further exposed by picking away the transverse muscle fibres and the tubules of the gonad.

The ganglion (*Ga.p.*) is elongated in a transverse direction, and is rather oblong in shape. The cerebro-pedal connectives (*Con. cp.*) leave its upper and external borders. Half-way between the pedal and cerebral ganglia each connective gives off a small branch from its internal surface, which enters into the viscero-pedal mass.

Exclusive of the connectives four pairs of nerves radiate out from the ganglion. These enter into the surrounding tissue. One nerve, however, which is very thick, and which leaves the lower border of the ganglion, can be traced as far as the tip of the foot.

The pallial plexus is formed by the three pallial nerves described above. The anterior common pallial nerve, it has been stated, bifurcates on leaving the anterior adductor muscle; the inner of the two branches so formed gives off a very fine nerve on its internal side, and thus three pallial nerves, as in the case of the posterior common pallial trunk, are formed. These three nerves are, of course, identical with the three formed from the posterior trunk, and so each pallial nerve has a double origin, one extremity proceeding from the cerebral ganglion, the other from the visceral. At about the centre of the mantle margin, the middle and external nerves, which have hitherto kept widely apart from each other, come together and separate again, and at this point of contact a gangli-

form enlargement is formed. The external nerve gives off an abundant series of branches which pass outwards to the extreme mantle edge; between external and median, and to a less extent between median and internal nerves, there are numerous anastomosing branches. These anastomoses are particularly abundant in the neighbourhood of the branching of the common pallial trunks.

SENSE ORGANS.

The sensory structures in *Cardium* are:—(1) Sensory epithelial cells (Flemming's cells) in the integument; (2) visual organs borne by the siphonal tentacles; (3) a pair of otocysts in the proximal limb of the visceropedal mass.

(1) The sensory epithelial cells are found over the general body surface, but are more abundant on the mantle edge and on the siphons. On the latter they are present in groups in the depressions at the free extremities of the tentacles borne by the outer wall.* They are either spindle-shaped cells with the nucleus at the middle and a bundle of long hairs on the free extremity, or elongated cells with the nucleus at the base and the free end swollen out into a disk, which bears short hairs. Probably they act both as tactile and as olfactory organs, the latter function being subserved more especially by the cells on the mantle edge and siphons.

(2) The structures generally regarded as visual organs (fig. 36, Pl. VI.) are found on the summits of the tentacles borne by the outer walls of both siphons. At the free end of each tentacle there is a small depression. The lip of this depression which faces the siphon is gently rounded,

*Flemming. Untersuch. u.d. Sinnesepithelien der Mollusken. Archiv f. Mikr. Anat. Bd. VI., pp. 439—471, 1870.

and bears a somewhat crescentic patch of pigmented epithelium (*Ep.op.*); the other lip, which is turned away from the wall of the siphon, is sharp, and is raised up to form a screen. The nerve branch entering the tentacle from the posterior pallial plexus runs in the axial part, and at the summit swells out into a nearly globular ganglion (*Ga.op.*) consisting of large, clear, oval cells and a network of fibres. On the siphonal side of the tentacle this ganglion lies close to the wall. It is invested on all sides except towards the tip and the outer wall by a capsule of fibrous tissue, which stains deeply and homogeneously with staining reagents, has no nuclei, and shows little indication of cellular nature. On the tip of the tentacle the hair cells, referred to above, can be traced into the tissue of the ganglion. Nerve fibres from the latter probably spread round the edge of the incomplete fibrous capsule, not through its tissue.

The cells covering the tentacle generally are cubical in form with a continuous cuticle. Towards the tip, however, they become higher and columnar in shape, and the cuticle becomes less evident. On the pigmented spot the outer two-thirds of each of these columnar cells is filled up with brownish pigment, which takes the form of a dense mass of spherical granules lying perfectly free from each other. The nucleus is in contact with the lower layers of this mass of granules, but is usually quite free. The cell body seem to be composed of clear cell substance, in which are embedded the round pigment granules. Beneath the nucleus it is faintly fibrillar, the direction of the fibrillæ being that of the long axis of the cell. A narrow space separates this epithelium from the capsule surrounding the ganglion, and this space is filled by fine fibrous tissue. It is very probable that nerve fibres from the ganglion, passing round the edge of the capsule, form part of this layer, and some at least terminate in or among the cells

on the pigment patch, though the existence of such is difficult to demonstrate.

There can be little doubt that the structure so described functions as a very simple eye, capable only of distinguishing differences in the intensity of the incident light. Thus, if a shadow be rapidly thrown on a cockle lying in a shallow dish, with the siphons fully extended, retraction of the latter generally follows, and it seems reasonable to locate the sensitive parts in the structures on the tips of the tentacles. Very similar organs are found in other species of *Cardium*, and in *C. muticum*, Kishinouye* has described organs on the tip of the siphonal tentacles which have all the characters of an eye—a multicellular lens composed of flattened cells, beneath which is a retinal layer of elongated cells, and beneath this again a pigment layer. The only other conjecture as to the nature of the structures described in the common cockle has been made by Brock,† who supposes them to be luminous organs; but it does not appear that there are any observations in support of this suggestion.

(3) A pair of otocysts (fig. 34, Pl. VI.) are present in the proximal limb of the visceropedal mass. They are very small—0.07 mm. in longest diameter, and can only be observed in sections taken in the neighbourhood of the pedal ganglion. They are situated a little way above the latter, right and left of the middle line and internal to the cerebro-pedal connectives. They are probably innervated from the latter. They are oval in form, the longest diameters lying parallel to the transverse axis of the foot. A

*Note on the Eyes of *Cardium muticum*, *Reeve*. Journal Roy. Coll. of Science, Imp. University, Tokyo. Vol. VI., pt. 4, pp. 279—285, Pl. IX., 1894.

† Uber die sogenannten Augen von *Tridacna*, &c. Zeitsch. f. wissensch. Zool. Bd. LXVI., pp. 270—88, Pl. XXI. (English translation in Ann. Mag. Nat. Hist., 1888, pp. 435—52).

prominent otolith, marked with concentric and radiating lines, exactly spherical in form, and about 0.02 mm. in diameter, is present. The wall of the otocyst is composed of a single, rather irregular, layer of cells; at the extremities of the long diameter are two single, nucleated cells, the cell bodies of which stain deeply, and on either side of each of these are several clear, apparently non-nucleated, spindle cells. The remainder of the wall is composed of irregular cubical cells. Hairs or cilia are not clearly shown. The nerves seem to enter at the internal poles of the organs. Each otocyst is surrounded by a loose investment of fibrous connective tissue, and but for this, lies freely among the transverse muscles of the foot.

THE REPRODUCTIVE ORGANS.

The gonad is paired and consists of a branching tubular gland. The external opening (see fig. 3, Pl. I.) is situated on the lateral and posterior body-wall, near the origin of the posterior retractor muscle of the foot. This leads into a very short terminal duct which immediately branches into three main divisions (fig. 3). One of these runs dorsally along the posterior margin of the visceropedal mass, the second downwards along the body-wall, the third duct runs obliquely forwards and downwards towards the bend of the foot. Branches are given off laterally from all these ducts on which are borne botryoidal clusters of secreting alveoli (fig. 37, Pl. VI.). These lateral branches penetrate among the transverse muscle bundles, between the convolutions of the intestine and between the lobes of the digestive gland. They lie principally in the peripheral zone of the proximal limb of the visceropedal mass. There is no extension at any time into the distal limb of the latter, nor into the mantle lobes.

In *Cardium edule* the sexes are separate. In at least

one other species of *Cardium*—*C. serratum* (= *C. norvegicum*), investigated by Lacaze-Duthiers,* the animal is hermaphrodite; on the same branch duct alveoli are present, some of which are filled with ova, some with spermatozoa; and both genital products may be found even in the same alveolus. In the edible cockle there is little difference between the gonads of different sexes apart from their contents. The male gonad is less voluminous and more opaque.

In the animal taken during the spring or early summer the gonad is nearly filled with ova or spermatozoa, as the case may be. In a transverse section through an alveolus of the male gland (fig. 39, Pl. VI.) there is a peripheral zone of small, dense cells lying close to, and obscuring the wall. Where the latter can be observed it is seen to consist of a single layer of small, rounded cells supported on a delicate basement membrane. Within this is the zone of cells referred to, which results from the proliferation of the germinal epithelium forming the wall. Towards the centre of the alveolus these become smaller and denser as they become transformed into the mature spermatozoa. The elongated head pieces of the latter are arranged in radial streaks converging towards a portion of the wall, which does not consist of germinal epithelium, and where there is generally a slight space. The long tail pieces are directed towards this space and alternate with the rows of heads. In the alveoli this part of the wall, towards which the streaks of spermatozoa converge, is thin and presents no particular structure. In the larger ducts, however, it consists of a strip of ciliated epithelium where the cells are irregular and have clear cell contents. In

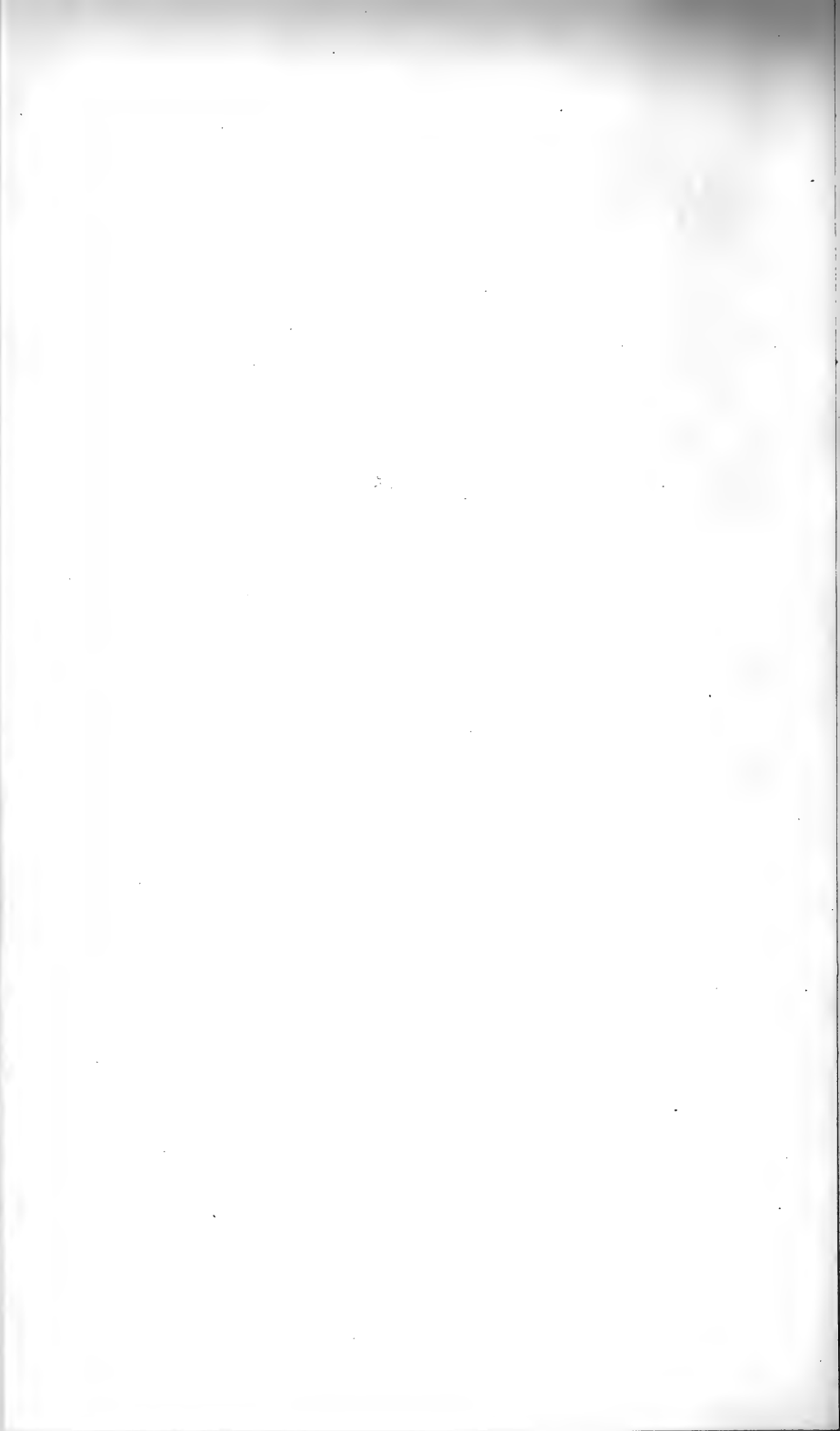
*Recherches sur les organes genitaux des acephales Lamellibranches Annales des Sciences Nat. Ser. VI., t. II., Zool., pp. 153—248, Pl. V.—IX., 1854.

the duct, as in the alveolus, this only forms a small strip of the wall, the rest being composed of germinal epithelium.

In the female gonad (fig. 38), at a corresponding stage, the cavities of the ducts and alveoli are filled with eggs in various stages of development. As in the male gland there is a strip of the wall which in the alveolus is thin and membranous, and in the ducts is composed of a ciliated epithelium; the remainder of the duct consists of germinal epithelium which, in some parts, is composed of small, deeply staining cells with conspicuous nuclei. Many of these are enlarged and project out from the wall into the lumen; the largest eggs which are attached have a narrow, short stalk which forms part of the wall. The eggs lying freely in the cavity are flattened against each other by their mutual pressure, and are usually polygonal in section. Their true shape is oval (fig. 35, Pl. VI.). A very thick vitelline membrane (*M.vit.*), secreted apparently from the surface during the later stages of development, surrounds each. The cell contents are coarsely granular. The nucleus is a large, oval body, with a very sharp outline, faintly granular in texture, and with no apparent signs of chromatic material. A single, large, rounded, very distinct nucleolus is always present, the contents of which sometimes show a very regular vacuolation; within the ovary the eggs are frequently adherent together by their membranes.

The eggs and spermatozoa are shed in the early part of the year (March), and spawning apparently lasts till July or August. Fertilisation and development take place at large in the surrounding water, resulting in the formation of a typical veliger larva. After a short free-swimming stage, the velum is absorbed, the shell is formed, and the long vermiform foot is developed. The young cockle, then still less than 1 mm. long, settles down in the sand for the remainder of its existence.





APPENDIX.

THE ECONOMY OF THE COCKLE WITH SPECIAL REFERENCE
TO THE LANCASHIRE SEA-FISHERIES DISTRICT.

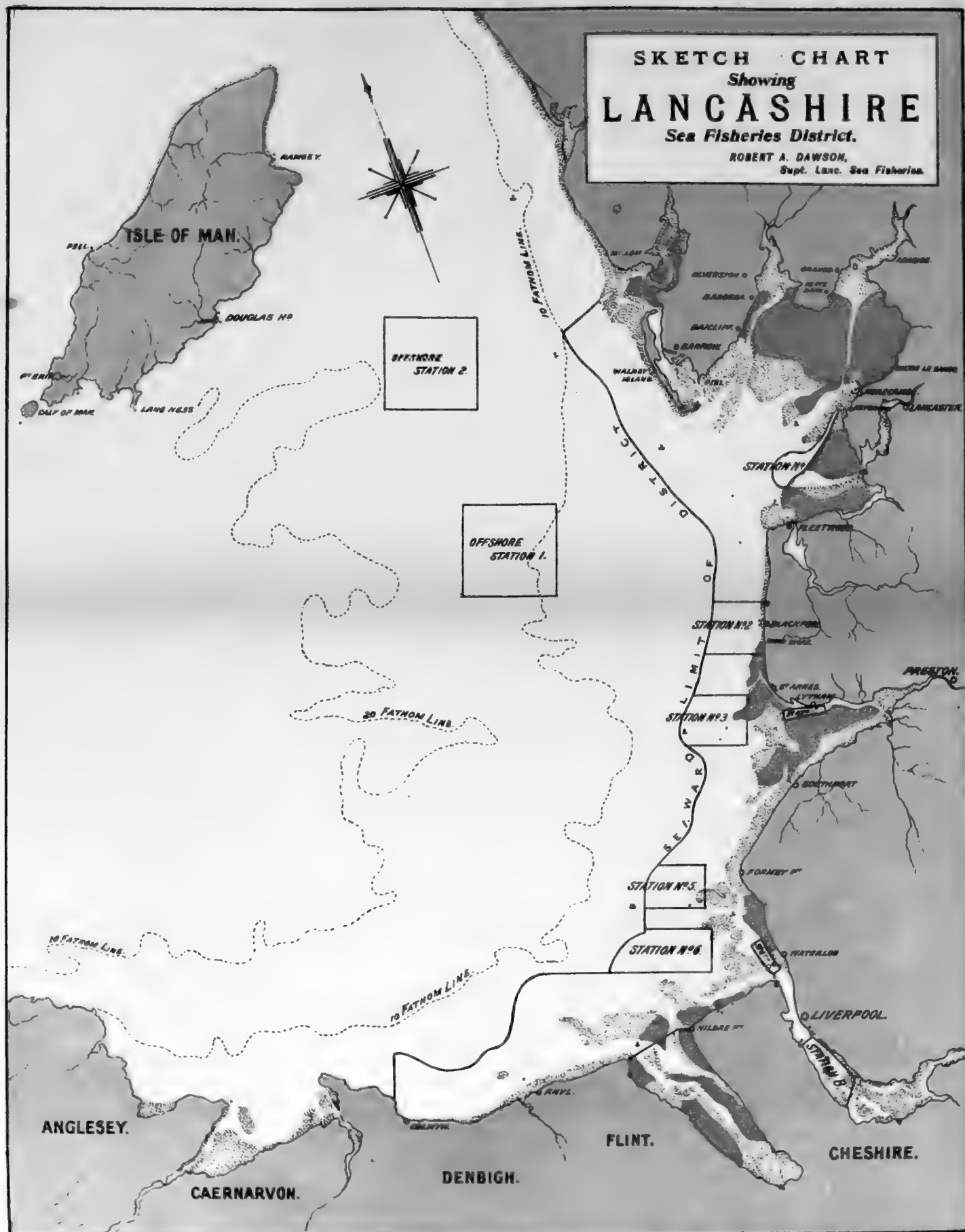
THE cockle derives its economic importance from the fact that it is a suitable article of food, and that it is sufficiently abundant, at the same time, on large portions of the coast to give employment to a large number of people in gathering it for the markets. To a less extent, it is economically valuable in that it provides an abundant supply of food to some of the more important flat fishes.

THE LANCASHIRE COCKLE FISHERIES.

A glance at the map of the Lancashire Sea-Fisheries District, reproduced in this Report, and which has been reduced from Mr. R. A. Dawson's sketch chart of the district, will show the great area covered by the cockle beds. Owing to the nature of the coast, where almost everywhere there are great stretches of clean sandy shore swept twice a day by the tides, there are very few places where the cockle may not be found. It is not, however, the mere occurrence of the animal that is considered in the chart, but its occurrence in sufficient quantities to render an area a sufficiently profitable fishing ground. The red coloured areas on the chart indicate approximately the position and extent of such profitable fishing grounds, and it is evident that these are numerous enough and of sufficient extent to render *Cardium* an animal of some importance to Lancashire fishermen, and to justify the regulation, to some extent, of the fishery.

SKETCH CHART
 Showing
LANCASHIRE
 Sea Fisheries District.

ROBERT A. DAWSON,
 Supt. Lanc. Sea Fisheries.



THE DISTRIBUTION OF THE COCKLE BEDS IS SHOWN IN RED.

The cockle beds in the whole district may be conveniently grouped into three principal divisions. At the most northern limit is the estuary of the Duddon, practically the whole of which is occupied by cockle beds. Then comes Morecambe Bay, the whole northern part of which is scattered over with cockle beds. On the western side of the Bay are the important Baicliff and Bardsea beds, and towards the eastward side are the Bolton-le-Sands beds. Between these, and reaching southward as far as Yeoman Wharf is a large stretch of sands over the whole of which cockle beds are found and regularly fished. The chart shows some coloured areas on the southern side of the Bay, but there the cockle fishery is very irregular. The Morecambe Bay and Duddon beds together form the Northern Division.

Between Rossall Point and Blackpool the coast is too exposed to admit of the formation of profitable cockle beds, but from Southshore to Southport is the estuary of the Ribble, containing some very important beds. The most northern of these, the Crusader Bank, is of little value, but the Salthouse and Horse Banks, lying further south, are very valuable, as a glance at Table I. will show. Those banks form the Central Division.

From Southport to below Formby Point is the second barren portion of the coast. Here cockles are to be found, but not in such quantities as to render the beds of any commercial value. South of Formby Point is a narrow strip of from two to three miles in length—Formby Bank—where cockles are very abundant. There are several important beds on the Cheshire Coast. The Formby, Leasowe, Hoylake, and West Hoyle beds are referred to hereafter as forming the Southern Division. There are also a number of areas containing cockle beds in the

estuary of the Dee, but these are not included in the Lancashire Sea-Fisheries district.

I estimate the area covered by cockle beds at 69 square miles in the Northern Division, 19 square miles in the Central Division, and 17 square miles in the Southern Division. Altogether there are not less than 105 square miles of cockle bearing sands in the whole district.

It must not be supposed that each of the coloured areas on the map represents a bank, or portion of a bank, over the whole of which cockles are abundant, and are continually being fished for. At any one time the fishing is practically restricted to one or more comparatively small portions of the bank, and as this becomes exhausted, or as the cockles become so small as to be under the legal size, the fishing shifts to some other part. The whole of a bank may become exhausted temporarily; this was the case in 1899 for the Formby Bank, though in 1897 it was a very profitable cockle fishing ground, as much as 180 cwts. being removed daily during the winter and spring. At present (1899) the cockles on this bank are, as a rule, under legal size; they are, however, exceedingly numerous, and a season similar to that of 1897 may be expected in 1900. Each coloured area on the map represents, in fact, a tract over which cockle beds are distributed. The precise position of the beds is continually shifting to some extent, old beds being exhausted by fishing, or being sanded up with the shifting of the sand banks. New beds are being formed, the position and extent of these being dependent on the deposition of the spat. The newly-hatched cockle leads, for a time, a free-swimming life, and with the acquirement of its shell, settles down for the remainder of its life in the sand. Obviously the conditions which determine the place on which the spat ultimately settles, and the consequent formation of a bed, are complex.

THE YIELD OF THE COCKLE BEDS.

In seeking for figures on which to base an estimate of the productiveness of the Lancashire cockle fisheries, one turns naturally to the published statistics of the Board of Trade which relate to fisheries. Here, however, there is little available information, for statistics are only collected at the most important ports, and although the collectors discriminate between the various animals landed, crustacea (crabs, lobsters and shrimps), and mollusca (oysters, mussels and cockles) are included in the figures relating to "shell-fish." Owing to this latter cause, comparisons between the amounts of cockles landed at the same port during different years is impossible, and from the fact also that no account is taken of the produce landed at many important cockling centres, even an approximate estimate of the value of the Lancashire cockle beds cannot be made.

In the absence of any published data, an estimate of the value of the fishery has been attempted by finding approximately the number of cocklers employed on the various beds, and the amount gathered daily by each during the time of the year when the fishing is most active. Obviously, only an approximation to the true output of the beds can be made by this method, and it has been regarded as preferable to under-estimate rather than over-estimate the produce of the fishery. The totals given in Table IV. then represent, at the least, the value of the Lancashire cockle fishery. The figures, as to the number of cocklers, &c., have been given for the most part by the officers of the Lancashire Sea-Fisheries Committee. Those for the Northern Division are given by Mr. J. Wright, chief fishery officer at Piel, and the corresponding statement for the Southern Division by Mr. G. Eccles, chief officer at New Brighton. Mr. R. L. Ascroft has

supplied the information relating to the Central Division. This consists of an accurate statement of the amount of cockles landed, month by month, during the year June, 1898—May, 1899, at Lytham. This does not represent all the fishing in the Ribble estuary, and the amount of cockles taken in the Central Division and landed elsewhere than at Lytham is taken as approximately one and a half times the total shown in Mr. Ascroft's table.

TABLE I.—AMOUNT of COCKLES landed at LYTHAM during the year June, 1898—May, 1899 :—

	Amount in cwts.	Relative values. (=R)
June, 1898	65	2
July	114	3·5
August	151	4·5
September	1250	37·5
October	3983	100
November	3254	100
December	2586	100
January, 1899... ..	3412	100
February	2278	69
March	1547	46·5
April	1316	40
May	1165	35
Total amount landed at Lytham ...	21121	
Amount taken in Central Division and landed elsewhere	30000	
Total amount taken from Central Division... ..	51121	

The figures in the third column show the relative values of the monthly takes expressed as percentages of the average take (3309) for the four months October—January.

In the construction of tables referring to the Northern and Southern Divisions it may be assumed, without serious error, that during the four months, October—January, the yield of the beds is practically constant. For the other

months it is further assumed that the amounts taken vary in a similar manner to those represented in the above table, since causes similar to those operating in the Central Division affect the monthly yield in the Northern and Southern Divisions. If, then, the amount taken in those districts in October be known, it becomes possible to construct a table showing the yearly take. The following table, compiled from information supplied by the fishery officers, shows approximately the amount taken in that month from the beds in the districts referred to.

TABLE II.—Showing the number of COCKLERS and the AMOUNT of COCKLES taken in October, 1899, in the NORTHERN and SOUTHERN DIVISIONS:—

		No. of Cocklers.	Amount gathered by each per day.	Total amount taken during the month of 25 days.
Northern Division.	Duddon	20	1 $\frac{1}{4}$ cwt.	625 cwt.
	Baicliff and Bardsea	50	1 $\frac{3}{8}$ „	2344 „
	Flookburgh Sands..	100	2 $\frac{3}{8}$ „	6250 „
	Bolton-le-Sands ..	15	2 $\frac{1}{2}$ „	937 „
Total take in October for Northern Division				10156 cwt. (=M)
Southern Division.	West Hoyle	20	3 $\frac{3}{4}$ cwts.	1875 cwts.
	Hoylake	10	2 $\frac{1}{2}$ „	625 „
	Leasowe	Average daily take = 7 $\frac{1}{2}$ cwt.		187 „
Total take for October in Southern Division (except Crosby and Formby)				2687 cwt. (=M')

No account is taken in the above table of the small amount of fishing which goes on on the southern side of Morecambe Bay. It has been stated above that the cockling here is very irregular. Mr. Ascroft informs me that in 1861 and 1862 as many as twenty carts, with four cocklers to each, from Bolton-le-Sands, fished regularly on

Pilling Sands. At present, however, the fishing there is of little importance.

From this table, showing the extent of the fishing during the best time of the year, and the relative monthly values of the cockles taken, which is exhibited in Table I., an estimate of the amount taken throughout the whole district can now be made. This is given in Table III.; it is there assumed that the fishing is constant during the four months October—January. The values for the other months are calculated; they vary with respect to the value for October—January as the values R in Table I.

TABLE III.—Total YIELD in CWTS. of the beds in the whole DISTRICT during the year June, 1898—May, 1899.

	Northern Division. ($=\frac{R}{100}M$)	Central Division.	Southern Division. ($=\frac{R}{100}M'$)
June, 1898	203	65	53
July	355	114	94
August	457	151	120
September	3808	1250	1007
October	10156	3983	2687
November	10156	3254	2687
December	10156	2586	2687
January, 1899	10156	3412	2687
February	7007	2278	1854
March	4722	1547	1249
April	4062	1316	1074
May	3554	1165	940
Total amount landed at Lytham		21121	17139
Amount landed in Central Division else- where than at Lytham		30000	
Total yield of Formby and Crosby beds during the year ... ..		...	650
Totals	64792	51121	17789

The money value of the cockles taken from the beds will depend on whether the price paid to the fishermen or

the price paid by the consumer is taken as the basis of calculation. Probably 2/- per cwt. represents the average value to the fisherman; this may possibly be too low, since a certain proportion of the cockles landed are hawked in the neighbourhood of the beds by the fishermen themselves. On the other hand, supposing the greater portion to be sent directly by rail to the markets, and adding the cost of freight and intermediate profits, 6/- per cwt. will represent fairly the price paid by the consumer.

TABLE IV.—MONEY VALUE of the COCKLE BEDS in the whole DISTRICT during the year June, 1898—May, 1899.

	Weight of Cockles in TONS.	Money value at £2 per TON.	Money value at £6 per TON.
Northern Division...	3240	£6480	£19440
Central Division ...	2556	5112	15336
Southern Division...	889	1778	5334
The whole District ...	6685	£13370	£40110

The striking variation in the monthly yield of the beds will be noticed. In the table relating to the Central Division the maximum amount is taken in October, and the monthly yield then decreases until, in the June following, only 2 per cent. of the amount taken in the previous October is landed. This variation in the fishing seems to be general in all parts of the district, and is apparently due to the difficulties encountered in sending the cockles to the markets, and in keeping them in the retail shops in a fresh condition during the relatively hot weather of June, July, and August. Other causes operate; in some parts of the district the cocklers leave the fishing for employment in the harvests, or in working pleasure boats at tourist resorts.

REGULATIONS AND METHODS OF FISHING.

The Bye-laws of the Lancashire Sea-Fisheries Committee are directed towards the regulation of the cockle fishery in accordance with local conditions in various parts of the district, and the methods of fishing vary, to some extent, in the three principal divisions. Over all the district the "craam" may be used, but it is employed chiefly in the Duddon and Morecambe Bay areas. The "craam" is a metal three-pronged fork, fixed on a handle of about 18 inches in length. The prongs are about six inches in length, and about two inches of the extremity of each is bent downwards at a right angle. The cockler pushes a fish basket along the sand in his left hand, and scoops the cockles, one by one, out of the sand into the basket, with the "craam." Often the tuft of Algæ on the shell of the cockle indicates its presence in the sand, but, as a rule, they are so abundant that the "craam" plunged into the sand brings up a cockle. Over the whole district the "Jumbo" may be used, but only from November to February, both months included. Fishing by means of the "Jumbo" is an extension of the method of treading on the sand with heavy boots, in which process the cockles are forced up to the surface and are then gathered. The "Jumbo" is a wooden frame, with a base consisting of a board, the maximum dimensions of which are $4\frac{1}{2}$ feet in length, 14 inches in width, and 1 inch thick. The frame, with this base-board resting on the sand, is rocked backwards and forwards, with the result that the cockles are forced out of the sand on to the surface, and are then gathered up.

Special regulations apply to the central and southern parts of the district: in the part of the Central Division lying between Formby Point and the Gut Channel in the Ribble, the use of a spade is permitted. The spade is

used to remove the upper layer of sand to the depth of about an inch and half. The cockles occupy this layer and are thus exposed. The use of a spade is not permitted in the other parts of the district. Southward of "Rossall Landmark," near Fleetwood, that is, over the whole of the Central and Southern Divisions, the use of the cockle rake is permissible; the cockle rake does not differ greatly from the ordinary garden rake, but may not exceed 12 inches in length. Thus, in the Northern Division the craam and the limited use of the Jumbo are permitted; in the Central Division the craam, Jumbo, rake, and spade; in the Southern Division the craam, Jumbo, and rake. Practically all the fishing in the Southern Division is done by the rake.

A minimum size, below which a cockle is not legally saleable, is fixed by the Committee's Bye-law, and extends to all parts of the district. This minimum size is that of a cockle which will exactly fit into a rectangular opening in the "gauge" carried by the fishery officer. This opening is two inches in length, and three-quarters of an inch in breadth; the ratio of length to lateral breadth in the cockle is, of course, variable within certain limits, and the smallest legal-sized cockle may be defined as the cockle whose lateral breadth, from valve to valve, when the shell is closed, is just over three-quarters of an inch. This standard of size is, of course, a purely arbitrary one, and has no definite relation to any particular phase in the life-history of the animal: the cockle becomes sexually mature before it has attained this size, and probably has spawned once. It most probably represents the size of the animal which is over two and less than three years of age. But the rate of growth of the cockle certainly differs, probably to a considerable extent, on various parts of the Lancashire and Cheshire coasts. On

the Baicliff and Bardsea beds the average cockle picked out of the fisherman's basket shows, at most, only three of the lines of growth on the shell, which are referred to at the beginning of this Memoir; in the Southern Division, on the Cheshire coast, four or five are generally present in the average specimen. Growth is most rapid in the summer months; on the Baicliff beds, according to the fishermen, the cockles in part of a bed, which are under gauge size in April, may be of legal size in June or July; in that period the shell has increased in girth by as much as half an inch.

The legal size is convenient and most probably eminently useful. On the principle that a marine food animal ought to be allowed the chance of spawning at least once before it is captured for the market, the Bye-law must be regarded as operating for the preservation of the cockle fishery. The present condition of the Crosby and Formby cockle beds is a case in point; here the difference in the output of the beds (180 cwts. daily in the winter of 1897—8, and $12\frac{1}{2}$ cwts. weekly during the year 1898—9) points to the over-fishing of the beds, which was, of necessity, followed by their temporary exhaustion. But since the cockles then became, on the average, so small as to fall under the gauge size, the fishing of the beds practically stopped for a time. During this period spawning of the remaining cockles went on, the beds being, to a large extent, undisturbed, and it is to be expected, from their present condition, that the fishing will again become abundant.

No close time, as in the case of the common mussel, is enforced. It will be seen from a consideration of the monthly output of the Ribble beds, exhibited in Table I., that natural causes lead to the suspension (to a great extent) of the fishing during the summer months. A certain amount of spawning goes on during May, June,

and July, so that, as in the case of the mussel, the animal is protected for at least a portion of its yearly spawning period.

No recent data exist on which to base an opinion as to whether the supply of cockles from the beds in the whole district is increasing or decreasing; but in 1879 Buckland and Walpole, in the course of an examination into the state of the Sea-Fisheries of England and Wales,* made a special investigation into the cockle fishery in Morecambe Bay, and obtained data which enable a comparison to be made between the output of the beds at the beginning and end of a period of 21 years.

The Commissioners estimated the value of the produce of the Morecambe Bay cockle beds for the year 1877 at over 3,943 tons in weight, and at £20,000 in money value. Cockles were taken by them as worth £5½ per ton. These figures agree fairly well with those given in this Memoir. For the year 1898—99 the amount landed is estimated at 3,240 tons, and their money value at £19,440. Here, however, £6 per ton is taken as representing the retail price. It is not certain from the Commissioners' Report whether they regarded £5½ per ton as the price received by the fishermen, or as the price paid by the consumer. It was also stated in evidence to the Commissioners that 100 carts, with six or seven people to the cart, were employed cockling in Morecambe Bay. This is far in excess of the number estimated as at present employed in the same area.

A more exact means of forming a comparison is furnished by the return from the Furness Railway Company, which is published in the Report for 1879. I am indebted to the courtesy of Mr. Aslett, the present

* Report of the Commissioners for Sea Fisheries on the Sea Fisheries of England and Wales. 1879, pp. 21—23.

manager of the Furness Railway Company, for a similar statement for the year 1898, which is here reproduced.

TABLE V.—WEIGHT OF COCKLES, IN TONS, forwarded from ten stations on the FURNESS RAILWAY for the two years 1877 and 1898 :—

Stations.	1877.	1898.
Barrow	10	0
Piel	70	0
Dalton	80	0
Askam	220	72
Millom	343	0
Ulverston	290	341
Cark	1160	1696
Kent's Bank	25	154
Arnside	5	0
Silverdale	50	0
Total	2253	2263

The above Table shews that the amount of cockles forwarded by the Furness Railway Company in 1877 from ten of their stations does not differ by so much as a half per cent. from the amount sent by them in 1898 from the same stations. These figures represent the greater portion of cockles sent from Morecambe Bay and Duddon. To complete the comparison the amount taken from the southern side of the Bay has to be estimated. The Commissioners valued this as worth £5,000, that is, about 940 tons were taken from the Bolton-le-Sands and Pilling Sands beds in 1877. Since these areas are served by the London and North-Western Railway Co., the amount stated does not appear in the Table. From the data obtainable in the course of the present inquiry, it appears that the amount of cockles taken from the same areas does not exceed 300 tons, and the falling off in the produce of these beds accounts for the apparent decrease in the

interval between 1877 and 1899; that is, in 1877 the weight of cockles taken from the whole Bay was approximately 3,940 tons, in the year 1898—99, considered in this Report, it was 3,240, the difference being approximately equal to the decrease in the produce of the beds on the southern side of the Bay. But the irregular nature of the fishing here has been already commented on, and it is fair to conclude that the decrease is only a temporary one.

In this comparison the change in the conditions of the fishery must be borne in mind. In 1877 the fishing was not regulated in any way, and cockles of any size might be sent into the markets, but at the present time, only cockles having the minimum breadth of three-quarter inch are allowed to be landed and consequently sent over rail, so that on the areas compared, cockles must now be more abundant than in 1877.

On the whole, it does not appear that there has been any permanent decrease in the cockle fishery of Morecambe Bay proper. Fluctuations from year to year have been experienced, and it may be gleaned from the Board of Trade Statistical Tables that though there have been some lean years, such as 1895—96, others—such as 1897—have been correspondingly fat, and that, on the whole, the fishing has been, if anything, improving. It has not been possible to investigate the rest of the District to the same extent, but it may be safely assumed that there also, the yield of the beds has been, on the whole, maintained. The Commissioners of 1879, as the result of their inquiries, stated that they had “been unable to trace any decrease in the fishery.” So far as the data obtained in the course of the present investigation go, that statement may be safely repeated.

EXPLANATION OF PLATES.

Reference Letters.

<i>Al.c.1.</i> œsophagus.	<i>Br.I.</i> internal branchia.
<i>Al.c.2.</i> stomach.	<i>Br.E.1.</i> inner lamella, external branchia.
<i>Al.c.3.</i> straight division of the intestine.	<i>Br.E.2.</i> outer " " "
<i>Al.c.3'.</i> sac of crystalline style.	<i>Br.I.1.</i> " " internal "
<i>Al.c.3''.</i> digestive division of the straight intestine.	<i>Br.I.2.</i> inner " " "
<i>Al.c.4.</i> spiral division of the intestine.	<i>Br.I.3.</i> " " " " membranous portion.
<i>Al.c.5.</i> coiled division of the intestine.	<i>Br.aff.</i> com. afferent branchial vessel.
<i>Al.c.6.</i> rectum.	<i>Br.eff.</i> com. efferent branchial vessel.
<i>An.</i> anus.	<i>Br.eff'.</i> efferent branch. vessel.
<i>Add.a.</i> ant. adductor muscle.	<i>Br.aff'.</i> afferent branch. vessel.
<i>Add.a'.</i> ant. adductor impression.	<i>Br.j.1.</i> inter-filamentar junct.
<i>Add.p.</i> post. adductor muscle.	<i>Br.j.2.</i> inter-lamellar junction.
<i>Add.p'.</i> post. adductor impression.	<i>By.g.</i> byssus gland.
<i>Art.pa.</i> anterior pallial artery.	<i>By'.</i> pedal groove.
<i>Art.pp.</i> right posterior pallial artery.	<i>By.</i> byssus thread.
<i>Art.pp'.</i> left post. pallial artery.	<i>Com.</i> cerebral commissure.
<i>Art.vp.</i> viscero-pedal artery.	<i>Con.cv.</i> cerebro-visceral connective.
<i>Art.v.</i> visceral artery.	<i>Con.cp.</i> cerebro-pedal connective.
<i>Art.p.</i> pedal artery.	<i>Dg.</i> digestive gland.
<i>A.lab.</i> right and left labial arteries.	<i>Ep.I.1.</i> epithelium of wall of crystalline style sac.
<i>Ao.</i> aorta.	<i>Ep.I.2.</i> elongated cells in wall of crystalline style sac.
<i>Aur.</i> auricle.	<i>Ep.I.3.</i> epithelium of intestinal div. of straight intest.
<i>Ba.</i> bulbus arteriosus.	<i>Ep.op.</i> pigment cells of an eye.
<i>Br'.</i> base of right ctenidium.	<i>Ep.p.</i> epidermis of the foot.
<i>Br.E.</i> external branchia.	

- Epic.* epicuticula (periostracum) *N.p.3.* internal pallial nerve.
F.tri. tricuspid body. *N.t.* tentacular nerve.
Go. right gonad. *Pro.* protractor pedis.
Ga.c. right cerebral ganglion. *Pro'.* protractor muscle im-
Ga.sp. parieto-splanchnic gang-
 lion. *Pa.d.* dorsal labial palp.
Ga.p. pedal ganglion. *Pa.v.* ventral labial palp.
Ga.op. optic ganglion. *Ped.1.* proximal limb of the
Lig. hinge ligament. visceropedal mass.
Lith. otolith. *Ped.2.* distal limb ,, ,,
M. mouth. *Per.* pericardium.
Mn. mantle lobe. *Ret.a.* anterior retractor pedis.
Mn'. cut edge of mantle lobe. *Ret.a'.* scar of attachment of
Mn.1. anterior prolongation of anterior retractor.
 intersiphonal partition. *Ret.p.* posterior retractor pedis.
M.c.1. anal division of mantle *Ret.p'.* posterior retractor pedis
 cavity. impression.
M.c.2. cavity of dorsal siphon. *Ret.m.* retractor muscles of the
M.c.3. general mantle cavity. mantle edge.
M.c.4. ventral suprabranchial *Ret.m'.* impression of retrac-
 cavity. tors of mantle edge.
M.c.5. dorsal suprabranchial *Ret.s.* retractor muscles of the
 cavity. siphons.
M.vit. vitelline membrane. *Ret.s'.* impression of retractors
M.p.i. straight transverse pedal of the siphons.
 muscles. *Ren.* renal organ.
M.p.c. circular pedal muscles. *Ren'.* external opening of renal
M.p.o. oblique pedal muscles. organ (ureter).
M.p.l. long. pedal muscles. *Ren.per.* reno-pericardial canal.
N.add. nerve supplying ant. *Si.d.* dorsal or exhalent siphon.
 adductor. *Si.v.* ventral or inhalent siphon.
N.br. branchial nerve. *Sh.e.* outer shell layer.
N.pa. ant. com. pallial nerve. *Sh.i.* inner shell layer.
N.pp. post. com. pallial nerve. *Sin.p.* posterior pedal sinus.
N.p.1. external pallial nerve. *Sin.ren.* renal sinus.
N.p.2. median pallial nerve. *St.* crystalline style.

<i>Ty.</i> typhlosole.	V ventral.
<i>Ven.</i> ventricle.	E external.
A anterior.	I internal.
P posterior.	R right.
D dorsal.	L left.

PLATE I.

- Fig. 1. Cockle with the foot and siphons moderately extended, seen from the right side. Nat. size.
- Fig. 2. External anatomy; the left valve and part of the left mantle lobe have been removed. Nat. size.
- Fig. 3. General anatomy; the right valve and mantle lobe have been removed, and the right wall of the visceropedal mass cut away to expose the intestine; the right wall of the pericardium is cut away; the right branchiæ are removed. Magnified $2\frac{1}{2}$ diameters. The figure is slightly diagrammatic; the convolutions of the intestine are represented as pulled apart, and for clearness, as being less in diameter than the magnification of the figure warrants. Their exact relations are seen in the section represented in fig. 11.

PLATE II.

- Fig. 4. Section passing through the ureters transversely to the long axis of the shell, and cutting the branchiæ obliquely. $\times 3$ diam.
- Fig. 5. Transverse section through the bases of the siphons. $\times 4$ diam.
- Fig. 6. Transverse section through the posterior adductor muscle. $\times 4$ diam.

- Fig. 7. Section through part of the body passing through the anterior part of the renal organ parallel to the branchial filaments. $\times 12$ diam.
- Fig. 8. Blood corpuscles from one of the branchial vessels. Zeiss apo. 1.5, compens. oc. 4.
- Fig. 9. Transverse section through a renal tubule. $\times 500$ diam.
- Fig. 10. The left valve of the shell, seen from the inside. Nat. size.

PLATE III.

- Fig. 11. Section through the middle part of the proximal limb of the visceropedal mass, transverse to the axis of the latter, and in the horizontal plane of the body. $\times 7$ diam.
- Fig. 12. Transverse section through the straight portion of the intestine. \times about 50 diam.
- Fig. 13. Transverse section through the spiral portion of the intestine. $\times 50$ diam.
- Fig. 14. Transverse section of the rectum near the anus. $\times 50$.
- Fig. 15. Section through part of the digestive gland, showing the transition from ciliated to glandular epithelium. $\times 50$ diam.
- Fig. 16. Transverse section of a secreting alveolus from the digestive gland. Zeiss apo. 1.5, compens. oc. 4.
- Fig. 17. Transverse section of part of a bile duct. $\times 500$ diam.
- Fig. 18. Vertical section through part of the stomach wall. $\times 280$ diam.

PLATE IV.

- Fig. 19. Transverse section of the secreting portion of the byssus gland. The section is cut transversely to the long axis of the foot. $\times 60$ diam.
- Fig. 20. Longitudinal section through a single alveolus of the byssus gland. $\times 570$ diam.
- Fig. 21. Vertical section through part of the body-wall of the distal limb of the visceropedal mass, showing a mucous gland cell opening through the epidermis on to the surface of the foot. Zeiss apo. 1.5 mm., compens. oc. 12.
- Fig. 22. An isolated mucous gland from the distal limb of the visceropedal mass. Zeiss apo. 1.5 mm., compens. oc. 12.
- Fig. 23. A radial vertical section of the mantle edge. $\times 30$ diam.
- Fig. 24. A section through the internal labial palp, passing parallel to the longest border. $\times 80$ diam.
- Fig. 25. Vertical section through the muscular body-wall of the proximal limb of the visceropedal mass. $\times 120$ diam.

PLATE V.

- Fig. 26. Part of a section through a branchia, transverse to the branchial filaments, and including two groups of filaments. $\times 80$ diam.
- Fig. 27. Transverse section of a single branchial filament. Zeiss apo. 1.5 mm., compens. oc. 4.
- Fig. 28. Transverse section through two adjacent branchial filaments, showing the interfilamentar junction. \times about 600 diam.

Fig. 29. Part of a section through the shell, passing vertically to the shell surface and perpendicular to a line of growth. \times about 25.

Fig. 30. A schematic representation of the course of the principal blood vessels and channels as seen from the right side.

PLATE VI.

Fig. 31. Dissection of a cockle from the ventral side, to show the visceral ganglion and nerves. Only the portion of the body behind the visceropedal mass is shown. The fused portion of the inner lamellæ of the two internal branchiæ is cut through in the middle line, and the septum between the siphons and the horizontal shelf continuing this forward are cut likewise. \times about 2 diam.

Fig. 32. Dissection to show the right cerebral ganglion and surrounding parts. The extremity of the anterior adductor has been cut away and the muscle separated slightly from the anterior wall of the visceropedal mass. The right labial palps are mostly removed. \times 4 diam.

Fig. 33. Dissection of the proximal limb of the visceropedal mass from its anterior margin to show the pedal ganglion and nerves. The anterior body-wall and the underlying muscles and genital gland tubules have been removed. \times 3.

Fig. 34. The otocyst of the right side in longitudinal section. Zeiss apo. 1.5 mm., compens. oc. 4.

Fig. 35. Section through an ovarian egg. \times about 200 diam.

J.J. del.
S.B. lith.

Fig 2

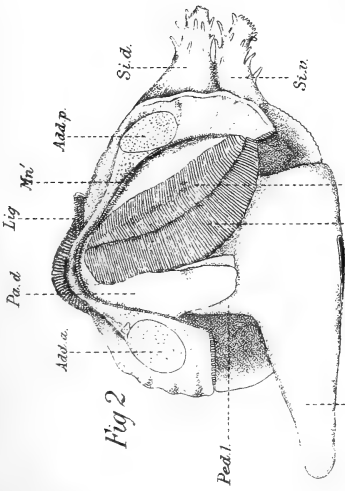


Fig 1.

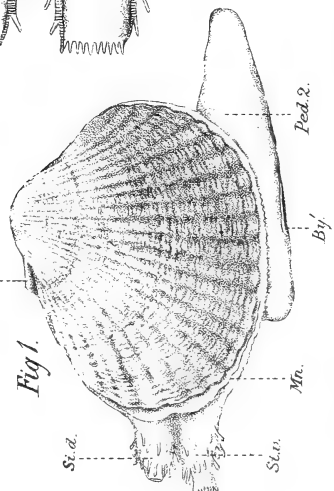
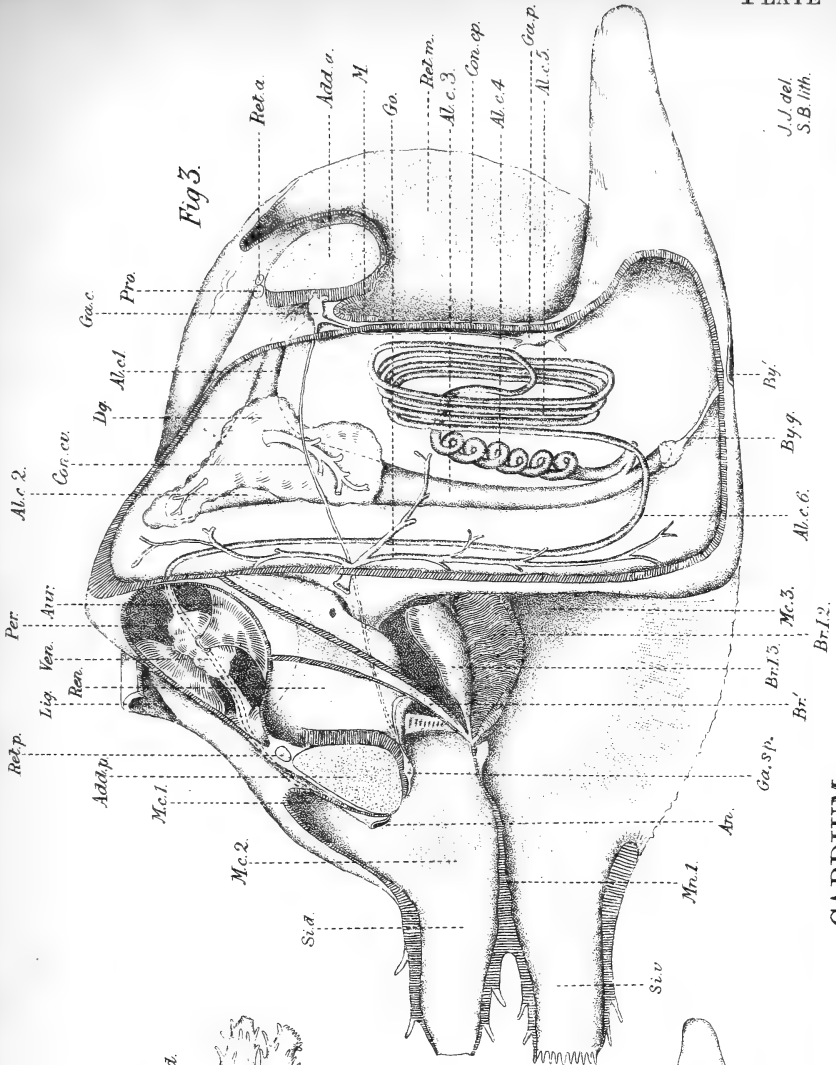
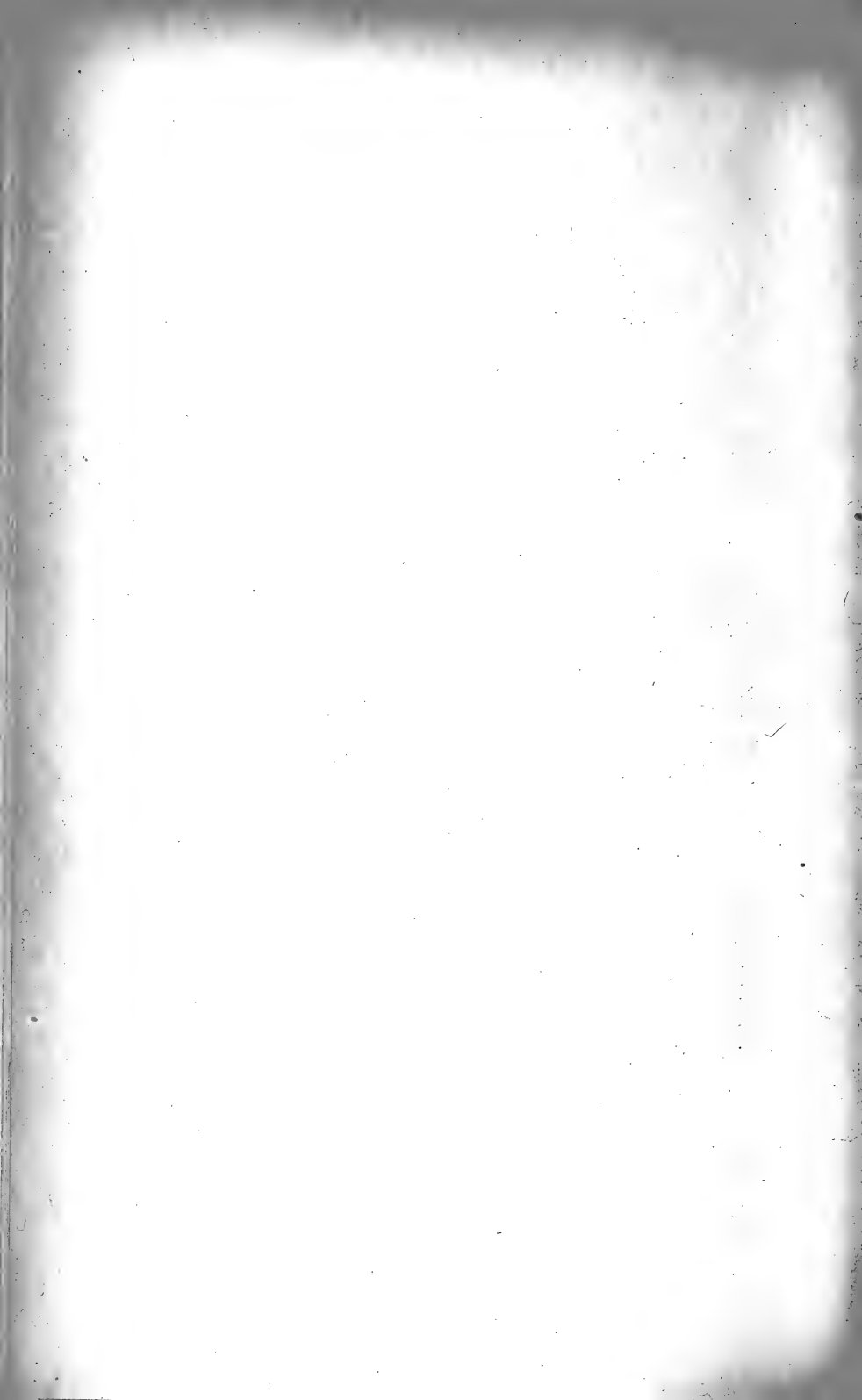


Fig 3.



CARDIUM.



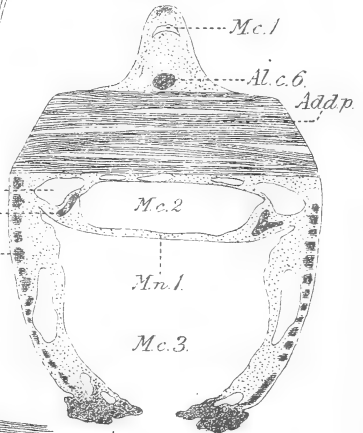
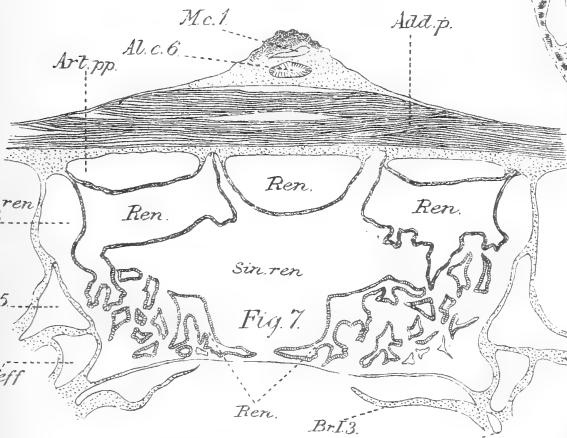
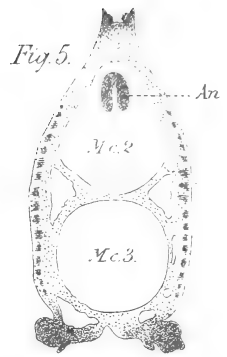
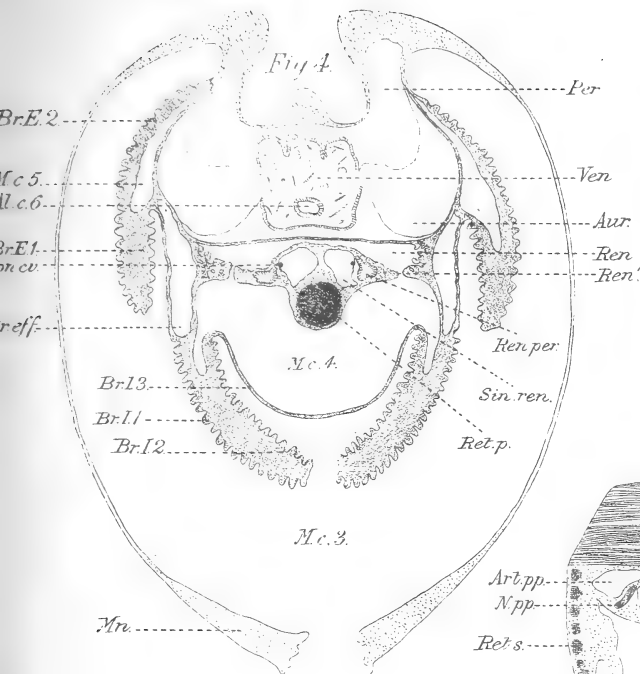


Fig. 6.

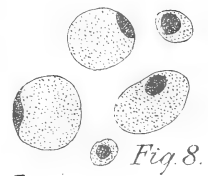


Fig. 9.

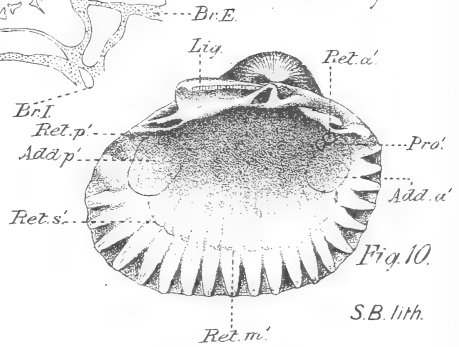
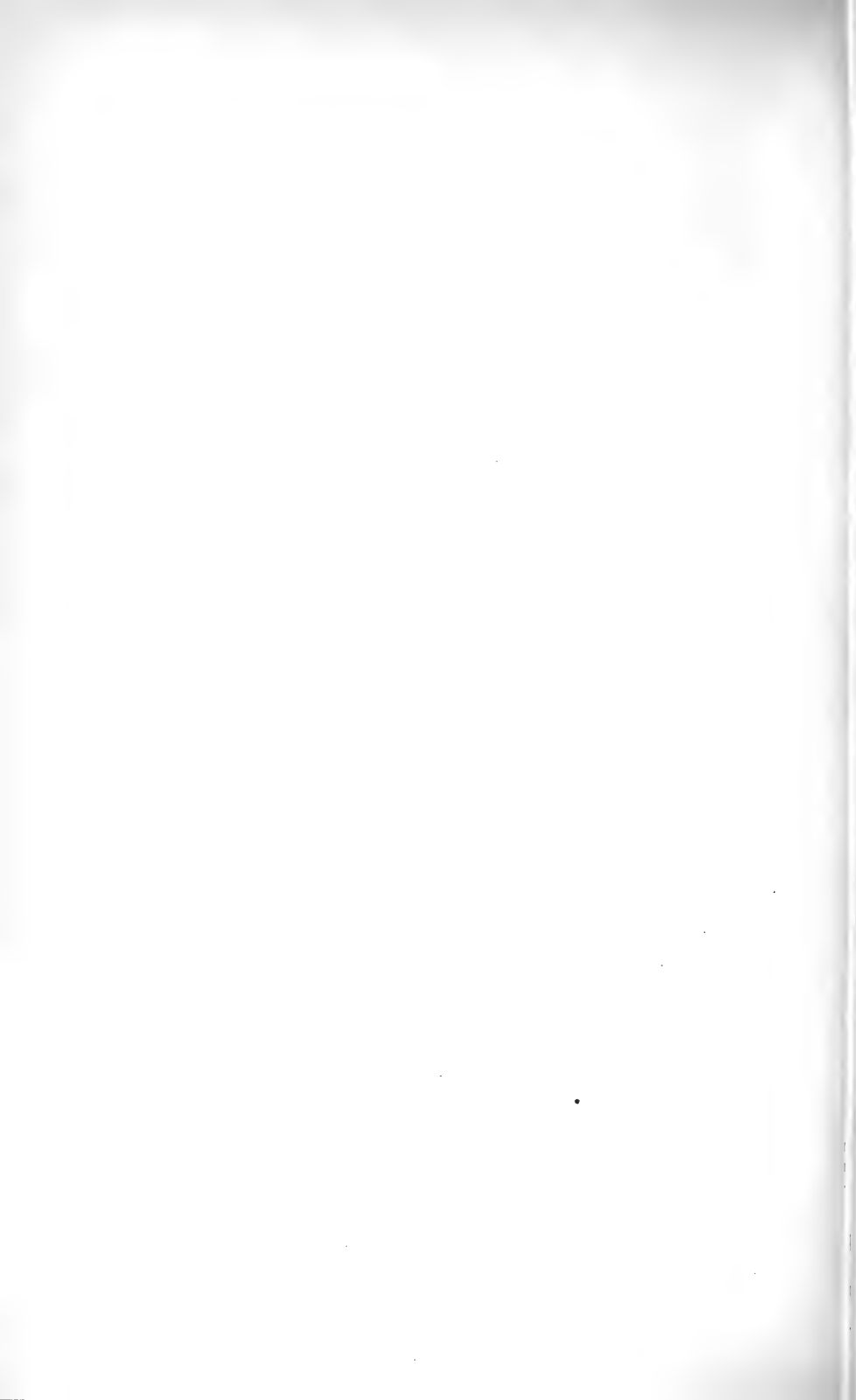


Fig. 10.

J.J. del.

S.B. lith.

CARDIUM.



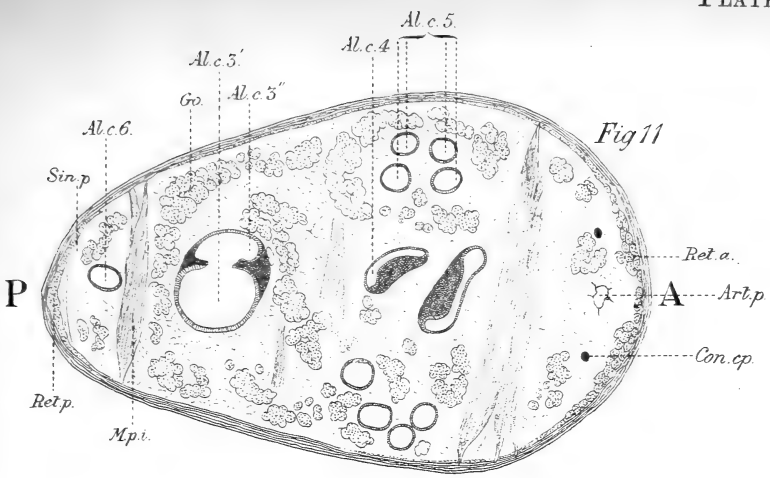


Fig 11

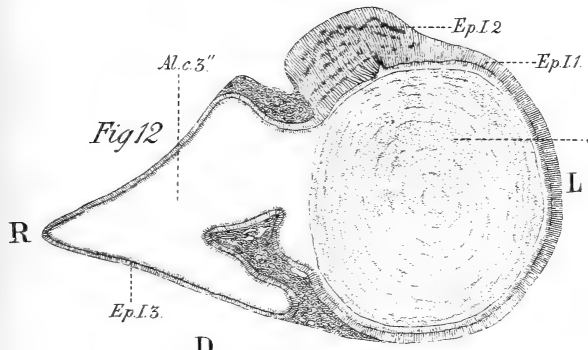


Fig 12

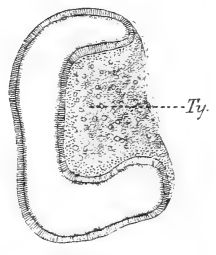


Fig 13

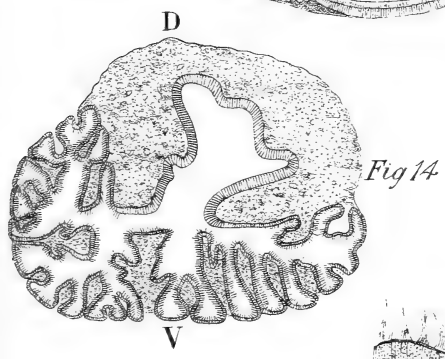


Fig 14

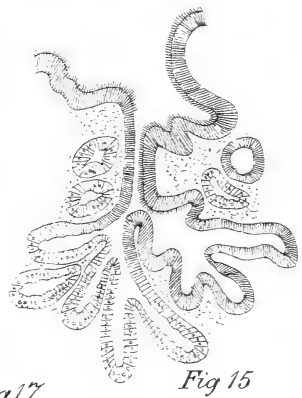


Fig 15



Fig 17

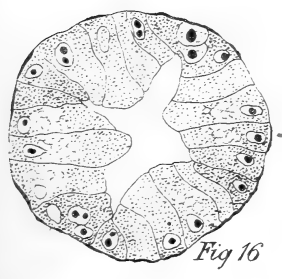


Fig 16

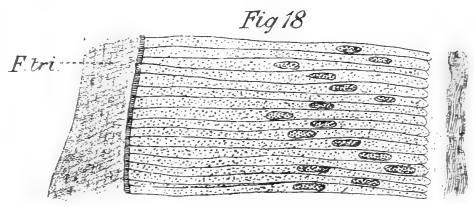


Fig 18

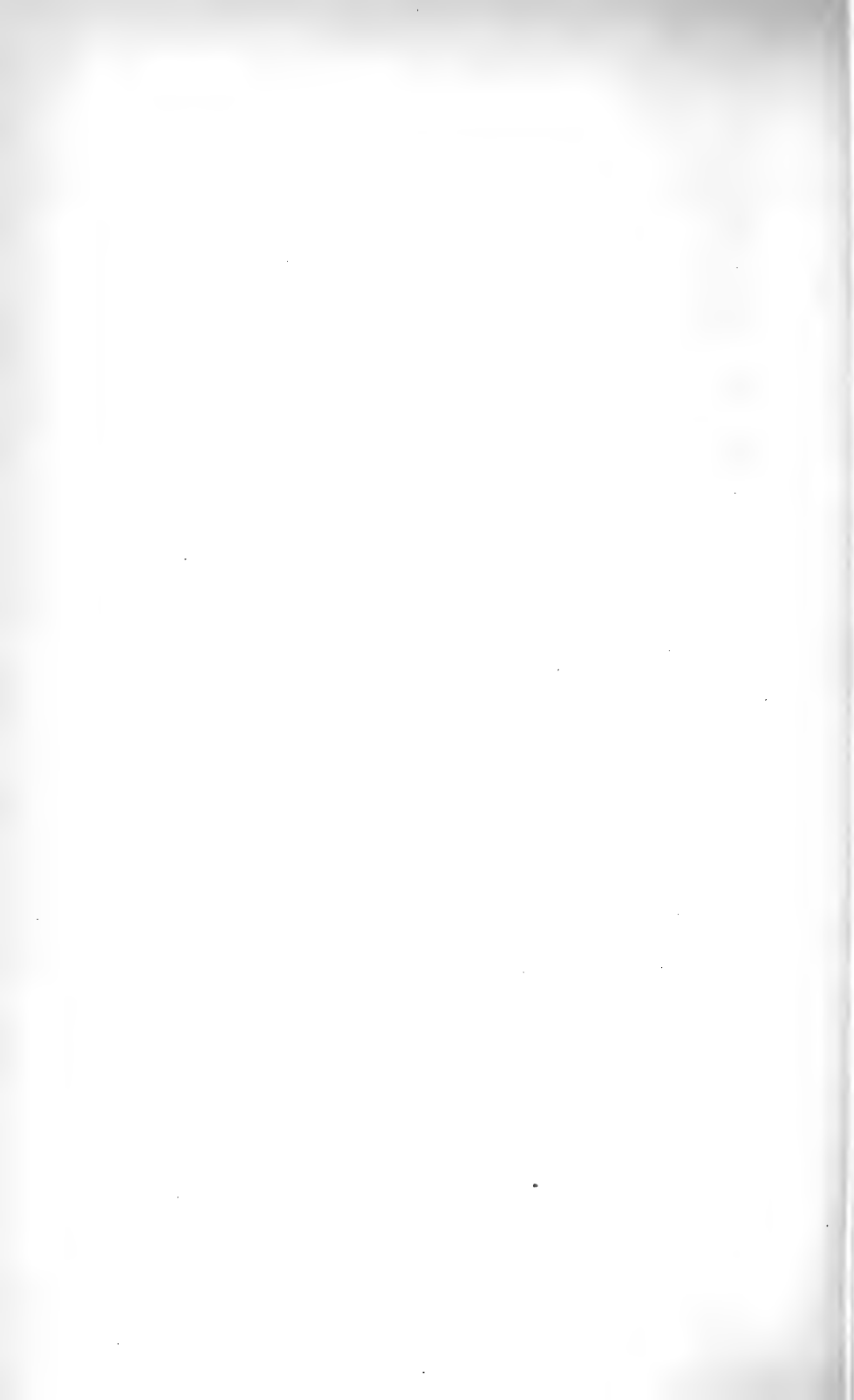




Fig. 19.



Fig. 20

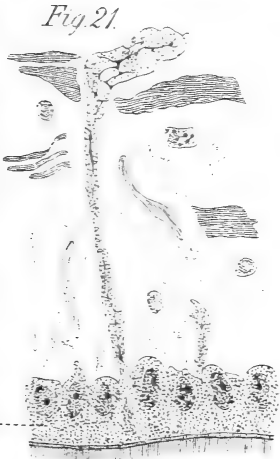


Fig. 21.



Fig. 22

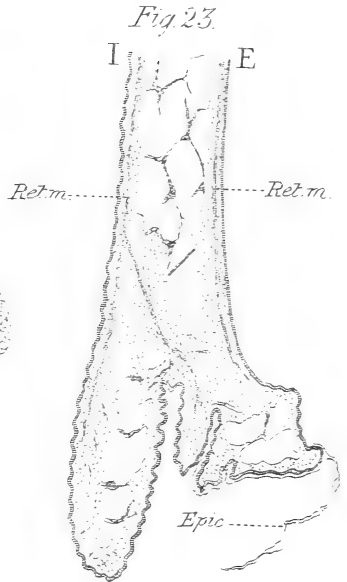


Fig. 23.

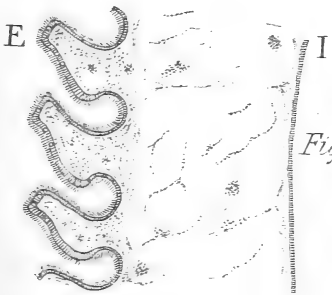


Fig. 24.

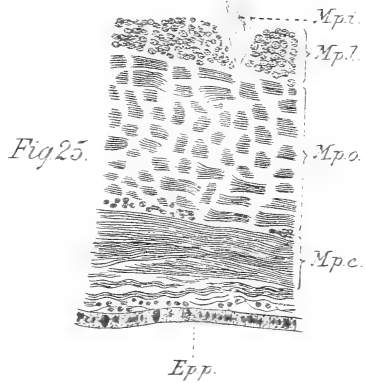
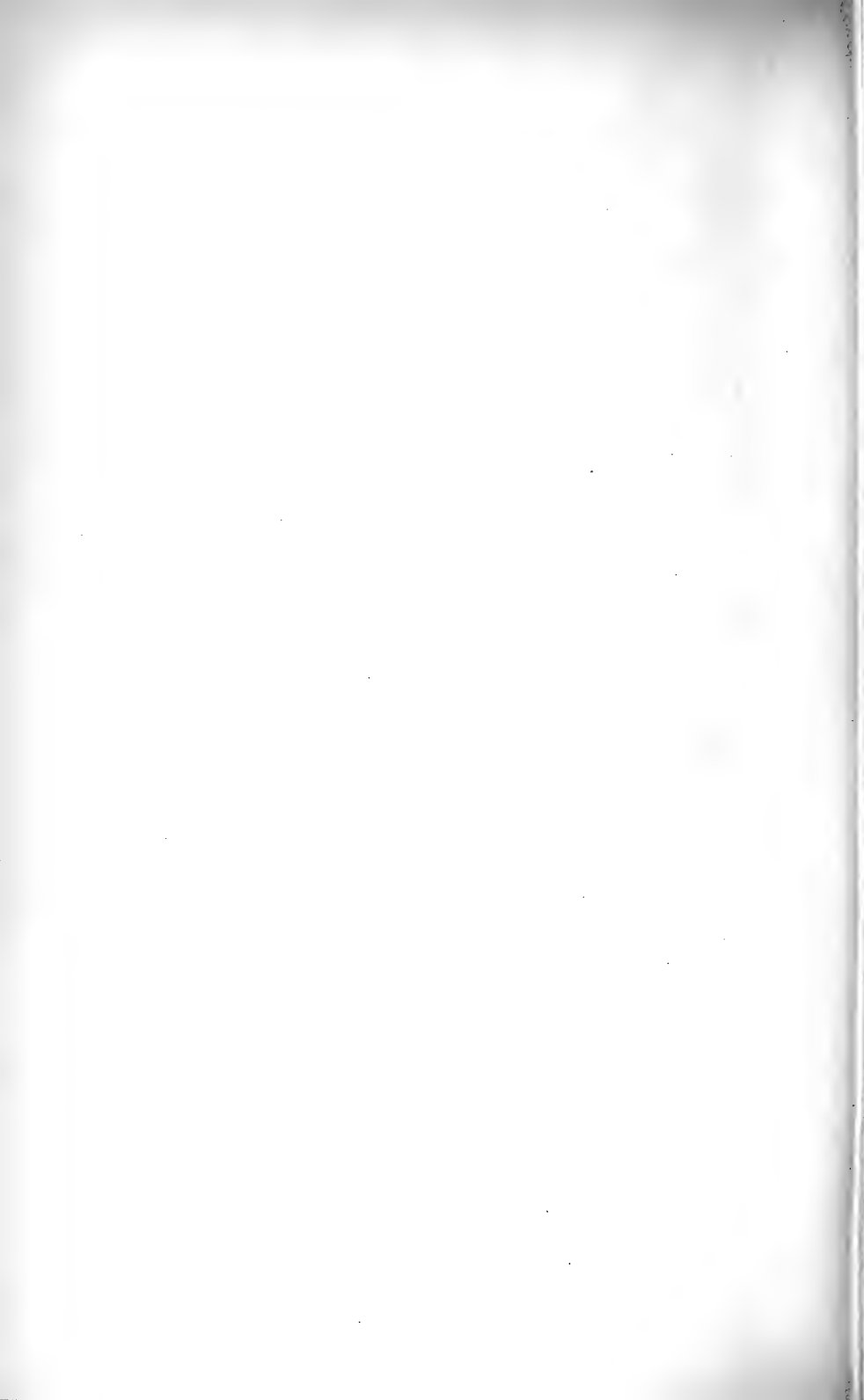


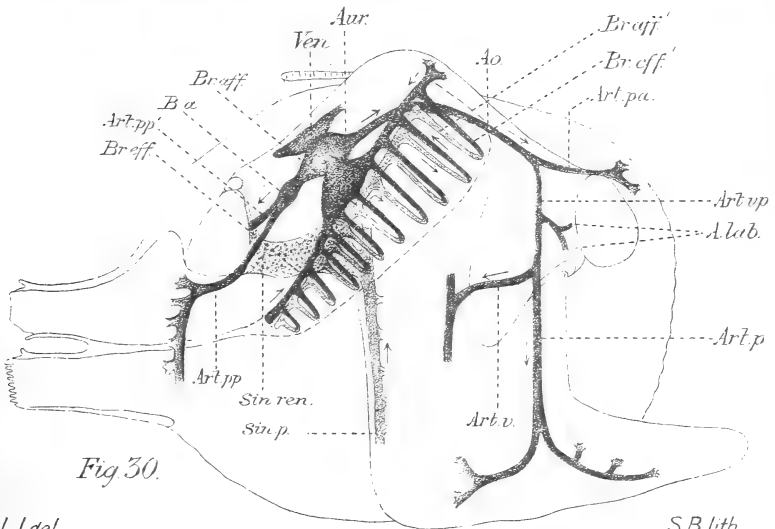
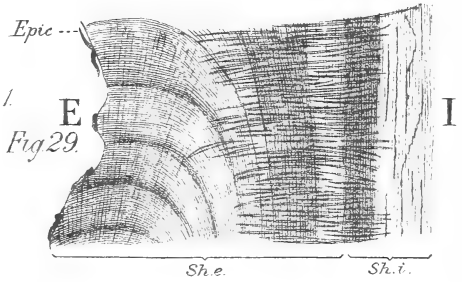
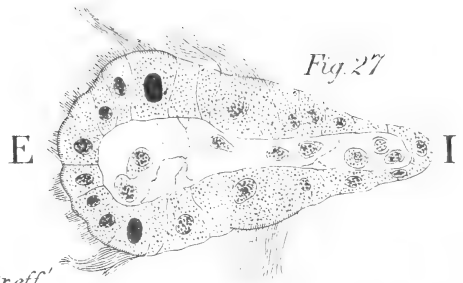
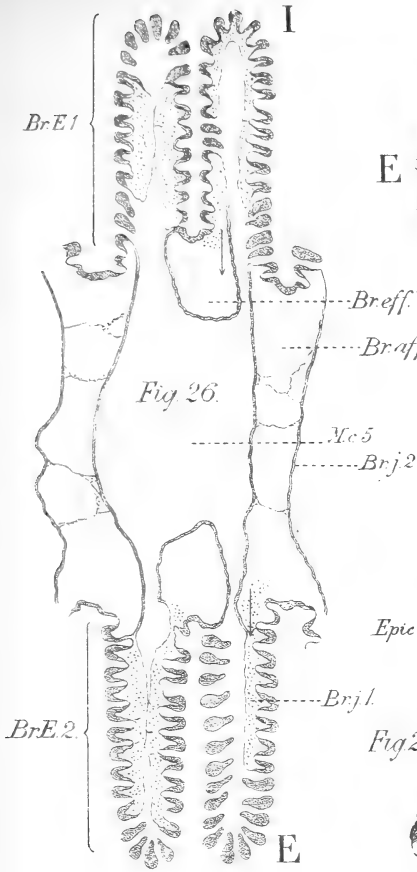
Fig. 25.

J.J. del.

CARDIUM

S.B. lith.

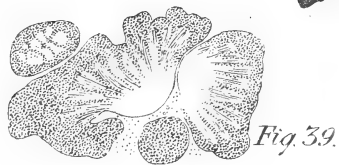
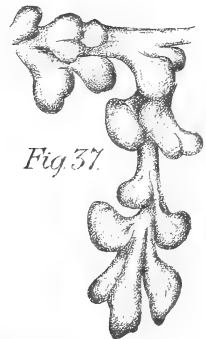
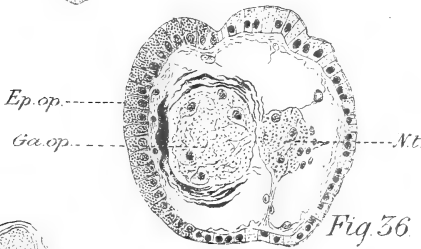
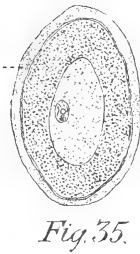
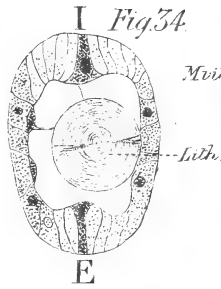
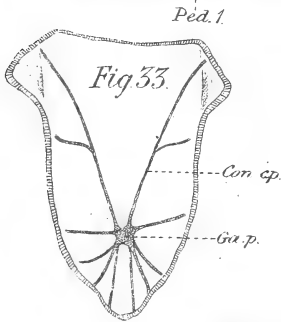
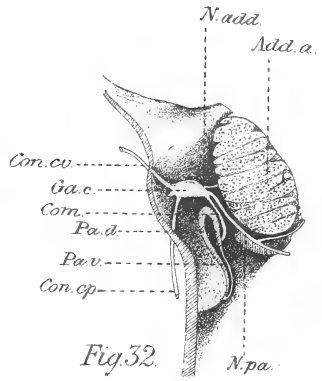
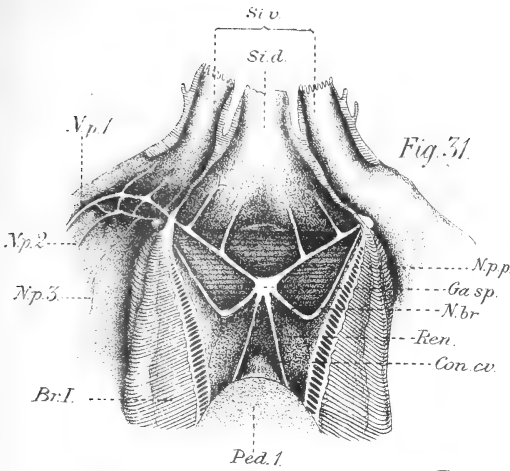




J.J. del.

S.B. lith.

CARDIUM.



J.J. del.

S.B. lith.

CARDIUM.



- Fig. 36. Transverse section through the tip of a siphonal tentacle passing through an "eye." Zeiss apo. 1.5 mm., compens. oc. 4.
- Fig. 37. A group of secreting alveoli from the nearly ripe ovary. $\times 25$ diam.
- Fig. 38. Transverse section through two contiguous alveoli from a nearly ripe ovary, showing the germinal epithelium and the eggs lying freely in the lumina of the alveoli. $\times 90$ diam.
- Fig. 39. Transverse section through three alveoli from a nearly ripe testis. $\times 90$ diam.

REPORT on TWO COLLECTIONS of TROPICAL
and MORE NORTHERLY PLANKTON.

By ISAAC C. THOMPSON, F.L.S.

With Plate XV.

[Read December 11th, 1899.]

THE two collections of plankton here treated of were kindly handed to me for examination by my friend Prof. Herdman, F.R.S., the first having been collected by his cousin, Capt. F. H. Wyse, of the ship "Johannesburg," and the second by his brother, Mr. G. W. Herdman, B.Sc. As a considerable portion of the area traversed was, in the two cases, almost identical, it was thought best to include them within one Report.

Both travellers were provided by Prof. Herdman with the needful supply of tow-nets, bottles, and preservative fluids, the general plan followed being that successfully carried out by Prof. Herdman himself while crossing the Atlantic in the summer of 1897.

The *modus operandi* adopted for continuous collecting by means of tow-nets fixed to running water taps while a vessel is steaming at full speed, was fully described and figured by Prof. Herdman in L.B.S.Trans., vol. XII., p. 33. As the paper referred to is out of print, and is frequently enquired for, I have thought it well to quote here in full the portion referred to:—

"The method adopted was the 'pump' one, by which the nets are not immersed in the sea, but are merely used to strain the organisms from the sea-water which has been pumped into the ship. My nets were made of the

best silk bolting-cloth, known technically as grit-gauze, and I used the following four kinds:—

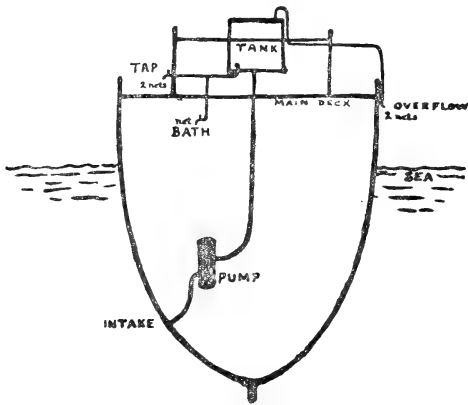
Net A, 32 meshes to the inch.

Net B, 72 meshes to the inch.

Net C, 80 meshes to the inch.

Net D, 172 meshes to the inch.

“On the port side of the ship I was allowed to have complete command of a large tap on the main deck, near the galley. This brought sea-water from a large tank in

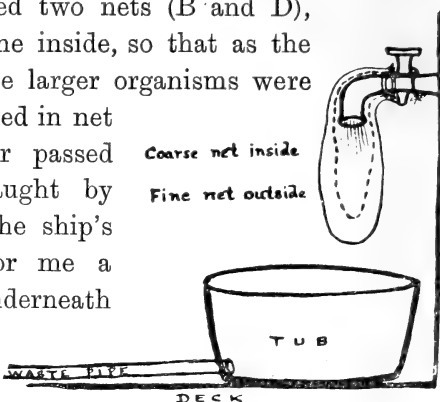


Arrangement for Collecting Plankton on SS "Parisian"
Aug. - Sept. 1897 - W.A. Henshaw.

FIG. 1.—Rough diagram to show position of tap, overflow pipe, &c.

the centre of the ship, which was kept constantly full for supplying baths, lavatories, &c., and for flushing purposes. The tap I used was an emergency one, rarely required. The tank is filled by a pump worked by the engines, so that it is in constant action while the ship is steaming. The sea-water enters by an aperture, provided with a valve, and covered with a grid of three-quarter inch mesh, placed in the ship's bottom, about 8 ft. above the keel and 14 ft. below the surface of the sea (fig. 1).

“Over the tap I tied two nets (B and D), the coarser meshed one inside, so that as the water ran through, the larger organisms were screened off and retained in net B, while the smaller passed through and were caught by D, the outer net. The ship’s carpenter fixed up for me a shallow tub placed underneath the tap, and into which my nets dipped, while, from a hole near the bottom of the tub a



Nets on Tap, Port side Main Deck.

FIG. 2.

the nearest scupper to convey the waste water overboard without flooding the deck (fig. 2).

“On the starboard side of the ship an overflow pipe from the top of the tank discharged over the side a little below the level of the main deck. I used this pipe by tying the two nets, A and C, over its open end, the coarser one being inside the finer (fig. 3).

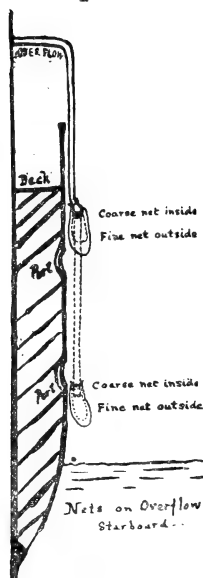


FIG. 3.

“The supply of water pumped into the tank is so much in excess of what is normally used, that during the whole voyage, water was pouring freely from the four-inch overflow pipe. When the ship is rolling, however, the discharge becomes somewhat intermittent—sudden rushes caused by the surging of the water in the tank alternating with a more steady flow. These great rushes of water led to the damage of some of the specimens collected in the coarser

net on the overflow pipe—this was especially the case with the Amphipoda, Schizopoda, and larger Copepoda. As similar specimens were not so much damaged in the nets at the tap on the port side, we may conclude that little or no damage is received in passing through the pump.

“With the help of the carpenter I made an estimate of the amount of water passing through each of my nets during the period of time for which they were set. At the tap, when turned on to the extent which I found could just enable the water to get away through the nets, four gallons passed out in 45 seconds, which is about 3,600 gallons in the 12 hours. At the overflow pipe I found that, on the average, about 21,600 gallons passed in the 12 hours, so these overflow nets strained six times as much water as did those on the tap. This, of course, accounts for the much larger quantity of material usually caught by the starboard nets. The difference in size of mesh between the two sets of nets also, no doubt, caused some difference in the results. A further cause of difference was this:—the tap was supplied by a pipe coming from a rose inserted near the bottom of the tank, while the overflow pipe left the very top of the tank, and so carried off the surface water. I noticed frequently that the larger animals and the more powerful swimmers, such as small fish, Amphipods, Schizopods, and Megalopas were nearly all caught in the nets at the overflow pipe, and I believe that was due merely to the fact that they swam nearer to the top of the water in the tank. This is an important reason for using the overflow pipe, as well as the ordinary taps leading from the tank, in such pump plankton work.

“The four nets were emptied and re-set regularly twice a day, at sometime between 8 and 9 a.m., and again between

6 and 7 p.m. Each gathering represents therefore roughly about 12 hours fishing, or more exactly, the day gathering extended over 10 hours, and the night one over 14 hours. The contents of each of the four nets was examined and entered in the note-book separately, but in a few cases, when there seemed no object in keeping them apart, two or more of the gatherings taken in the same locality and period of time, were preserved in the same bottle. Each day and each night, then, of the voyage is represented in the collection by one or more—sometimes four or five—separate bottlesful of plankton.

“I may state at once that I saw no marked difference between the day and the night gatherings. It must be remembered, in this connection, that the source of the water was not quite close to the surface, but at least 14 ft. down.”

It was in much the same method as the above that the two collections now described were made.

Captain Wyse's voyage extended from Delagoa Bay direct to Calcutta, leaving Africa on April 30th, 1898, and reaching Calcutta on May 14th. Thence, after six weeks' stay, on June 28th he steamed direct for Aden, through the Red Sea and Suez Canal and along the Mediterranean to Gibraltar.

Mr. G. W. Herdman travelled by a coasting steamer up the south-eastern African coast, starting from Durban on May 7th, 1899, and calling at intermediate ports. Thence, he followed Capt. Wyse's route through the Red Sea and Suez Canal into the Mediterranean, leaving Port Said on June 17th.

The two routes and the positions of the stations are shown upon the map (Pl. XV.) which illustrates this paper.

By a mere coincidence, each collection consists of 23 bottles of material, the preservative fluid in both being a weak (5 % from the 40 %) solution of formol. Besides the excellent preservative properties of formol, its portability is a great consideration, the 5 % solution being prepared as required with sea-water. It also often saves the annoying examination and duty frequently exacted by custom-house officers if alcohol be used as a preservative.

The actual amount of plankton collected was, in both cases, small—Capt. Wyse's bottles each contained from $\frac{1}{2}$ to 1 cc., and Mr. G. W. Herdman's less than half that quantity. Any lack of quantity was, however, made up to quality, the former collection especially proving very rich in species; but it is more than probable that more material would have resulted in many more species of animals. Biologists, and all who are interested in the science of Oceanography, are much indebted to both gentlemen for the trouble they have taken in making the collections, and for the care exercised in keeping exact records of locality and in preserving the material.

As might be expected, Copepoda constituted almost the entire bulk—70 species occurring in Capt. Wyse's collection, and 39 in Mr. G. W. Herdman's. In the former the Copepoda are distributed in the families, as follows, viz. :—

Calanidæ	...	...	17 species.
Centropagidæ	...	...	9 „
Candaciidæ	...	...	4 „
Pontellidæ	...	...	9 „
Cyclopidæ	...	...	2 „
Harpacticidæ	...	...	6 „
Corycœidæ	...	...	23 „

In Mr. G. W. Herdman's collection the Copepoda are distributed as follows:—

Calanidæ	...	...	8 species.
Centropagidæ	...	...	5 „
Candaciidæ	...	...	5 „
Cyclopidæ	...	...	2 „
Harpacticidæ	...	...	5 „
Coryceidæ	...	...	14 „

The various species in each collection will be found tabulated later, with the number of the bottles or stations in which they occur.

The other organisms found consist chiefly of Diatoms, Peridiniæ, Foraminifera, Globigerinæ, Radiolaria, Pteropods, Sagittæ, Ostracoda, Cladocera, Schizopoda, Amphipoda, Mysidæ, Salpæ—most of which were generally distributed throughout the area traversed. *Ceratium tripos* was the most common of the Peridiniæ; it was generally present throughout, always as the variety *macroceros*, Ehr., the three horns of which, and especially the lateral ones, are very long and slender.

Some complete Pteropod shells containing their molluscs fully expanded were found in No. 17 (Wyse), taken in the Red Sea. Also, in one of the Red Sea gatherings, was the well-known micro-alga, *Trichodesmium erythraeum*, which is said to give to the Red Sea its name. These minute cylindrical confervæ, are found in bundles of from 20 to 60 in each. Darwin, in the "Voyage of the 'Beagle,'" aptly describes them as like chopped bits of hay. He saw them in bands about 10 yards wide, and at least $2\frac{1}{2}$ miles long. They have been frequently observed in both the Atlantic and Pacific Oceans, in large patches of a brownish yellow, and sometimes blood-red colour.

It will be observed from Capt. Wyse's and Mr. G. W.

Herdman's notes that the water taps to which the tow-nets were fixed, received their supply from tanks into which the water entered by a valve at a distance of some 12 feet below the surface of the sea. This necessarily restricted the plankton collected to species living at about that depth. It is well-known that many animals, and particularly Copepoda, haunt chiefly the actual surface of the sea, while others are found at varying distances down to 100 or even 1000 or more fathoms.

This uniformity of depth for tow-net work is an unfortunate necessity of collecting from merchant or passenger vessels while maintaining a steady, rapid speed, and not allowing of stoppages. The large proportion of fractured specimens is another unavoidable drawback in this mode of collecting, necessitating much careful manipulation, selection, and dissection for un mutilated recognisable characters.

These facts must always be taken into consideration when dealing with plankton not collected by properly equipped vessels fitted out for Marine Biological work, when stoppages can be made as desired, and any required depth accurately gauged and worked at.

It is a most gratifying result of the trouble kindly taken by Capt. Wyse and Mr. Herdman in making these collections, that, as will be seen from the notes on the species, almost all show an extension of their hitherto known range of geographical distribution. Our further knowledge of these minute Crustacea which play so important a part both as ocean scavengers, and as themselves a very important constituent of the food of fishes and other animals, would be largely increased if other navigators would kindly, in the interest of science, follow the example of Capt. Wyse and Mr. Herdman, and so enable us to have collections from all parts of the world.

CAPTAIN WYSE'S REMARKS ON HIS COLLECTION.

No. of Bottle.	Date.	Latitude and Longitude.	Temp. of Bag.	Temp. of Sea.	
1	30/4/98	20° — S 38° 40 E	81°	80°	Taken, after 24 hours running, from bathroom tap which leads from a tank on the top deck kept full for flushing and other purposes, and is pumped up by an engine and through a valve about 12 feet below the surface of the sea.
2	1/5/98	16° 24 S 41° 40 E	83	83	Taken, after 24-hours running, from a tap in the main injection pipe which is about 2 feet in diameter and pumps up the sea-water for the condenser from 12 feet below the surface. The net is hung from a tap 4 feet from the ship's side, in the engine room, so has a very short and direct lead from the sea.
3	2/5/98	12° 30 S 44° 25 E	83	82	Taken, after 24 hours, same place as yesterday.
4	3/5/98	9° 24 S 47° 23 E	83	83	Being taken daily at 9-30 a.m. Between yesterday and to-day we experienced a current setting S. 79°, W. 42 miles, owing to the north end of Madagascar Island being opened out.
5	4/5/98	6° 12 S 50° 42 E	84	85	Taken at 9-30 a.m. Strong tide "rips" about, and experienced a favourable current, probably first part of the equatorial current coming from West to North and N.E.

6	5/5/98	3° 18 S 54° 22 E	87	87	· Taken at 9-30 a.m. Not so much current in our favour, probably in the recurve of current from westerly to N.W., N. and N.E.
7	6/5/98	1° 40 S 59° 6 E	86	86	Taken at 9-30 a.m. Owing to a temporary breakdown of the circulating pump the flow of water was stopped for 6 hours, while another pump was set to work leading through the same pipe and causing the ash to get in, as seen in the bottle. Experienced strong favourable current 38' in 24 hours.
8	7/5/98	0° 17 S 64° 16 E	85	86	Taken at 9-30 a.m. After running 24 hours. Have experienced a favourable current setting to the E.N.E. 40 miles in the last 24 hours.
9	8/5/98	0° 52 N 69° 27 E	85	84	Same as yesterday. Experienced same current.
10	9/5/98	2° 0 N 74° 21 E	85	86	Same as yesterday. 5-30 a.m., passed through 1½° channel off Maldive Islands. Current a little less but still strong.
11	10/5/98	4° 13 N 78° 41 E	84	83	Same as yesterday. Current setting east still, 20 miles in 24 hours.
12	11/5/98	7° 15 N 82° 22 E	85	84	Much the best catch. For about 8 hours from after emptying the bag yesterday till 6 p.m. we were passing through black water smelling strong of sea-weed and with numerous streaks of yellow stuff like fine pumice stone.
13	12/5/98	11° 0 N 84° 0 E	85	84	Taken at 9-20 a.m. After running 24 hours. Found ship had run quite out of the current and discoloured water.

14	13/5/98	14° 45 N 85° 26 E	86	85	Same as yesterday.
15	14/5/98	18° 38 N 87° 14	87	86	Same as yesterday.
<p>This finishes the passage from Delagoa Bay to Calcutta. Inside the collecting net enclosed in the box I hung a smaller bag of sponge-cloth, or what firemen generally call a sweat-rag. It is a kind of net-work with meshes of about $\frac{1}{4}$ inch. Most of the larger specimens were caught in this, but I used it with the idea of saving the outer finer net.—F. H. WYSE.</p>					
16	28/6/98	22° N 38° E	84	83	Taken at 9-30 a.m. in the Red Sea, after running 24 hours. Ship passing through numerous streaks of yellowish floating matter like ground pumice stone.
17	29/6/98	26° N 35° E		80	Taken at 9-30 a.m., Red Sea, after 24 hours. Passing through floating material (<i>Trichodesmium erythraeum</i>).
18	30/6/98	34° N	74	73	Taken after 18 hours running up the Gulf of Suez.
19	3/7/98	23° E			Taken, after 24 hours running, in the Mediterranean Sea, on the way home from Port Said to Antwerp.
20	4/7/98	35° N 18° E	78		Taken after 24 hours running from Port Said to Malta. Net not taking such large collections as from Delagoa Bay to Calcutta or in the Red Sea.
21	5/7/98	36° N 12° E	74		Taken after 24 hours running between Malta and Pantalaria Island.
22	6/7/98		74	73	Taken after 24 hours running from Pantalaria Island to Cape de Fer, passing over coral bank off Cani rocks and along coast between Galatea and the main land.
23	7/7/98				From Cape de Fer to off Cape Tenez. F. H. W.

MR. G. W. HERDMAN'S LIST OF BOTTLES AND LOCALITIES.

No	Date commenced, 1899.	ended.	Position.
1	7th May, 9-0 p.m.—	8th, 7-30 a.m.	5 hours from Port Natal to off Cape St. Lucia.
2	8th, 9-0 a.m.—	9th, 7-30 a.m.	Off Cape St. Lucia to Delagoa Bay.
3	10th, 8-0 a.m.—	11th, 7-0 a.m.	Delagoa Bay to Port Natal.
4	22nd, 3-0 p.m.—	23rd, 1-0 p.m.	Delagoa Bay to mouth of river at Inhambane.
5	24th, 11-0 a.m.—	25th, 2-0 p.m.	Inhambane to outside Beira.
6	26th, 9-30 a.m.—	26th, 9-0 p.m.	Outside Beira to near Quilimane.
7	29th, 10-0 a.m.—	30th, 7-30 a.m.	Outside Quilimane on
8	30th, 9-0 a.m.—	30th, 7-30 p.m.	up to Mozambique harbour.
9	31st, 10-30 a.m.—	1st Jun., 8 a.m.	From Mozambique harbour on
10	1st Jun., 9-0 a.m.—	2nd, 7-0 a.m.	on to Dar-es-salaam.
11	4th, 10-0 a.m.—	4th, 8-0 p.m.	Zanzibar to Tanga.
12	5th, 10-0 a.m.—	6th, 7-0 a.m.	Beyond Tanga, past Mombosa and on for 18 hours.
13	6th, 10-0 a.m.—	7th, 7-0 a.m.	on, passing Equator at 3 p.m., 6th.
14	7th, 10-0 a.m.—	8th, 7-0 a.m.	on,
15	8th, 9-0 a.m.—	9th, 7-0 a.m.	on, noon, long. 49°53 E., lat. 7°40 N.
16	9th, 10-0 a.m.—	10th, 7-0 a.m.	Passed Cape Guardafui.
17	10th, 10-0 a.m.—	11th, 1-0 a.m.	Reached Aden at 1 a.m. Very hot.
18	11th, 3-0 p.m.—	12th, 6-0 a.m.	Left Aden at 11 a.m.
19	12th, 8-0 p.m.—	13th, 8-0 p.m.	on,
20	13th, 8-0 p.m.—	14th, 8-0 p.m.	Entered Gulf of Suez, evening of 15th.
21	14th, 8-0 p.m.—	15th, 8-0 p.m.	Reached Suez, 10 a.m.
22	15th, 8-0 p.m.—	16th, 10-0 a.m.	Left Port Said at 9 p.m. 17th; at noon 18th, position 32°36
23	18th, 8-0 a.m.—	19th, 8-0 a.m.	N., 29°25 E.; noon 19th, position 34°21 N., 24°37 E.

- Bottles 1—18. Tow-net was on bathroom tap.
- „ 19. Tow-net was on tap in engine room on condenser.
- „ 20. One tow-net was on same condenser tap, other on pipe carrying away water after having been used to cool the shaft bearings. Catch of both tow-nets put together.
- „ 21—23. Tow-net on pipe as before (water for cooling shaft bearings).

G. W. H.

But little comment is necessary on the clear statement of each collector. Twice Capt. Wyse speaks of numerous streaks of yellow floating matter, like ground pumice stone (see reference to bottles 12 and 16, taken off Ceylon and in the Red Sea). I am unable to find anything in either bottle to account for this, further than the presence of a few very small masses of fine, yellow vegetable fibre in bottle 12, probably a mere coincidence. It is quite possible, as Capt. Wyse seems to suggest, to have been actually due to particles of pumice stone from a volcano. I well remember seeing and collecting quantities of pumice about the Canary Islands in 1887, the high-water mark being strewn with them, and these were almost certainly due to the recent volcano outbreak of Krakatoa.

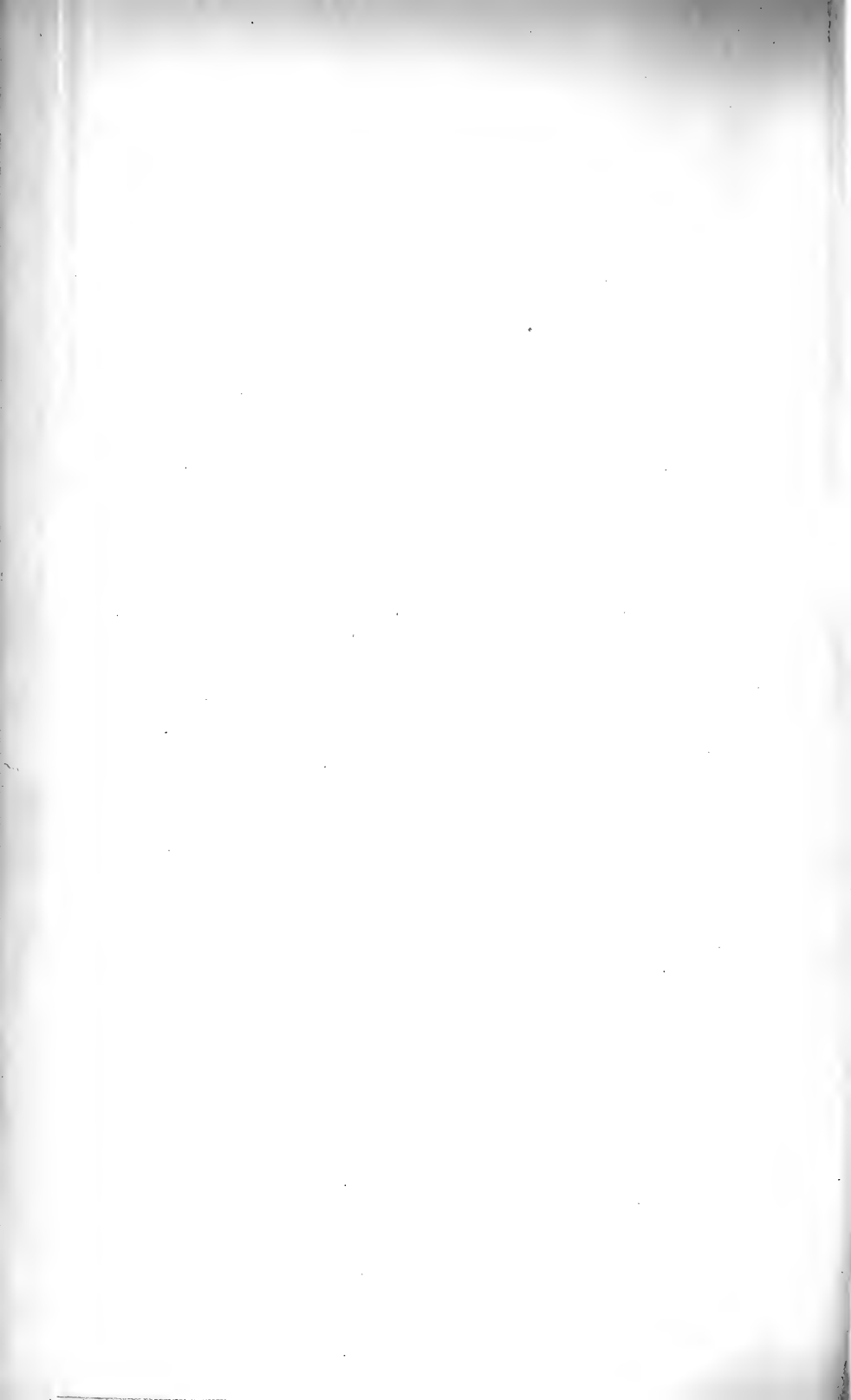
The confervoid Alga, *Trichodesmium erythraeum*, found in the Red Sea, has already been alluded to.

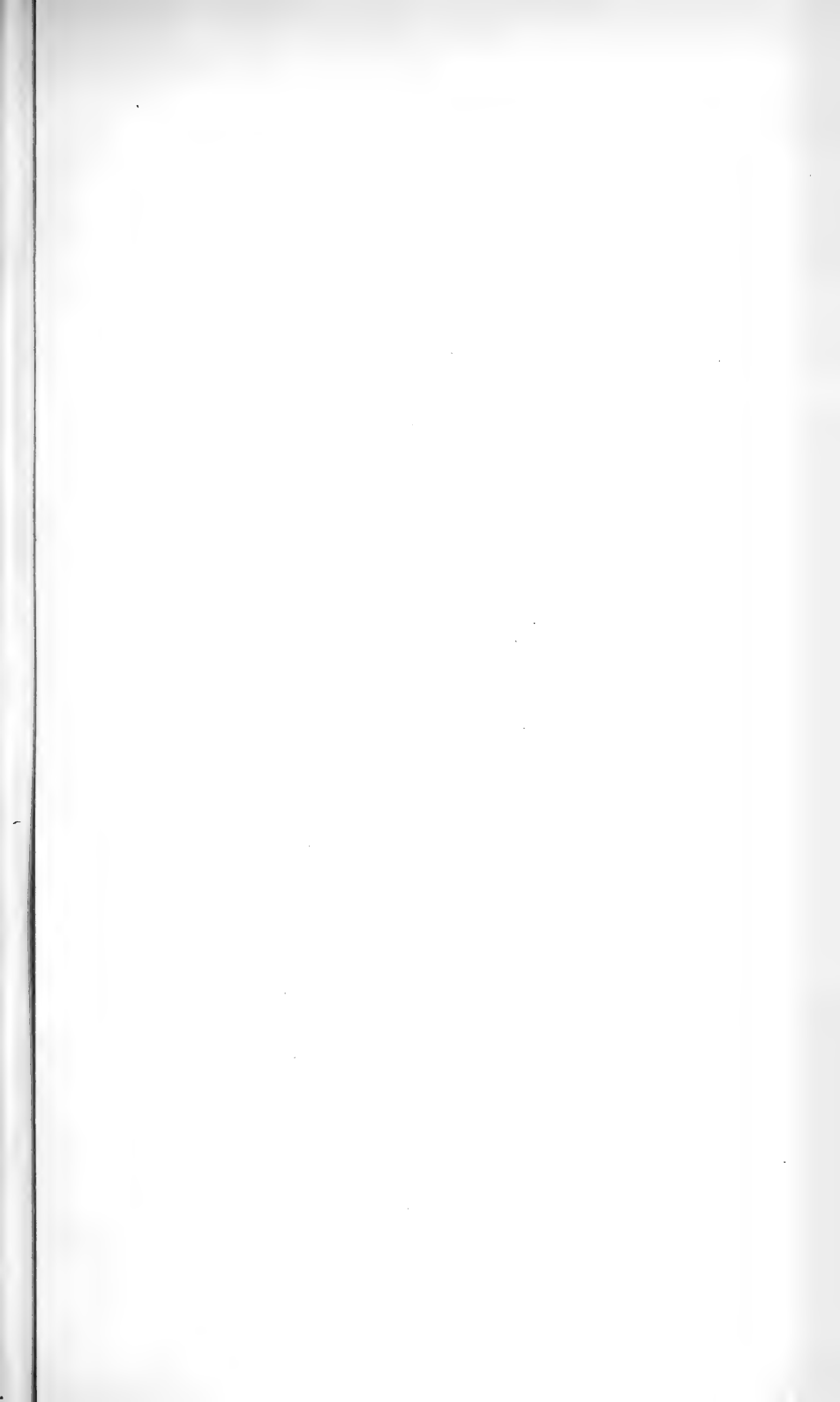
Captain Wyse does not appear to have used the tow-net in the Indian Ocean during the homeward voyage from Calcutta until reaching the Red Sea.





Family CALANIDÆ.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
<i>Calanus vulgaris</i> , Dana	x	x		x	x	x	x		x	x	x			x	x									
<i>C. pauper</i> , Giesbrecht																	x	x				x		
<i>C. darwini</i> , Lubbock													x	x							x	x		
<i>C. gracilis</i> , Dana																					x	x		
<i>Eucalanus attenuatus</i> , Dana	x	x			x	x			x			x												
<i>Rhincalanus cornutus</i> , Dana	x	x	x									x												
<i>R. gigas</i> , Brady	x																							
<i>Acrocalanus gibber</i> , Giesbrecht		x			x	x	x	x	x			x	x	x				x			x			
<i>Calocalanus pavo</i> , Dana								x																
<i>Clausocalanus arcuicornis</i> , Dana				x								x	x	x										
<i>Aetidius armatus</i> , Brady	x					x															x		x	
<i>Bradyidius armatus</i> , Vanhöffen	x				x		x	x				x						x						
<i>Undeuchæta major</i> , Giesbrecht															x									
<i>Euchirella pulchra</i> , Lubbock	x				x													x						
<i>Euchæta marina</i> , Prestandrar	x		x		x	x	x	x	x	x	x	x	x	x	x									
<i>Scolecithrix dana</i> , Lubbock								x	x	x		x	x	x										
<i>Phaenna spinifera</i> , Claus	x	x	x		x	x																		
Family CENTROPAGIDÆ.																								
<i>Centropages brachiatus</i> , Dana																							x	x
<i>C. furcatus</i> , Dana		x							x			x	x	x					x				x	x
<i>C. violaceus</i> , Claus			x	x	x			x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Temora stylifera</i> , Dana	x	x		x	x			x			x	x	x	x	x				x	x		x	x	
<i>T. discardata</i> , Giesbrecht																								
<i>T. longicornis</i> , Müller																x								
<i>Metridia longa</i> , Lubbock	x		x	x																				
<i>Pleuromma abdominalis</i> , Lubbock	x	x	x							x	x	x			x	x	x				x		x	x
<i>Lucicutia flavicornis</i> , Claus																								x
Family CANDACIIDÆ.																								
<i>Candacia longimana</i> , Claus								x																
<i>C. æthiopica</i> , Dana								x	x	x	x	x	x	x										
<i>C. pectinata</i> , Brady						x	x	x	x			x	x											
<i>C. truncata</i> , Dana	x	x	x	x	x	x	x	x								x								
Family PONTELLIDÆ.																								
<i>Calanopia elliptica</i> , Dana		x											x											
<i>Labidocera acutifrons</i> , Dana		x				x																		
<i>L. acuta</i> , Dana																x								
<i>Pontella spinipes</i> , Giesbrecht																x								
<i>Anomalocera patersoni</i> , Templeton		x																						
<i>Pontellopsis regalis</i> , Dana															x									
<i>Pontellina plumata</i> , Dana								x															x	
<i>Acartia clausi</i> , Giesbrecht	x		x		x		x	x		x	x		x	x				x	x	x			x	
<i>A. erythraea</i> , Giesbrecht									x															
Family CYCLOPIDÆ.																								
<i>Oithona plumifera</i> , Baird	x	x		x				x		x	x	x												x
<i>O. similis</i> , Claus	x	x	x	x	x			x					x						x	x				
Family HARPACTICIDÆ.																								
<i>Microsetella rosea</i> , Dana			x														x	x						
<i>M. atlantica</i> , Brady & Robertson			x	x		x	x			x	x	x	x	x	x	x	x	x	x			x		x
<i>Euterpe acutifrons</i> , Dana																	x							
<i>Setella gracilis</i> , Dana	x	x	x	x	x			x		x	x	x	x	x	x									
<i>Miracia offerata</i> , Dana	x	x						x	x						x									
<i>Clytemnestra scutellata</i> , Dana				x		x	x	x								x								
Family CORYCÆIDÆ.																								
<i>Oncæa venusta</i> , Phillipi	x	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x				x	x
<i>O. mediterranea</i> , Claus									x	x						x	x					x	x	x
<i>O. conifera</i> , Giesbrecht				x																				
<i>O. minuta</i> , Giesbrecht										x		x	x	x									x	
<i>Sapphirina salpæ</i> , Claus												x		x										
<i>S. nigromaculata</i> , Claus						x	x	x				x												x
<i>S. gastrica</i> , Giesbrecht															x									
<i>S. stellata</i> , Giesbrecht		x		x						x	x													
<i>S. serrata</i> , Brady												x												
<i>Copilia denticulata</i> , Claus																x								
<i>C. quadrata</i> , Dana									x			x												
<i>C. mirabilis</i> , Dana		x	x		x																			
<i>Corycaeus ovalis</i> , Claus										x	x												x	x
<i>C. venustus</i> , Dana						x	x		x			x	x					x	x	x				
<i>C. furcifer</i> , Claus		x	x																					
<i>C. rostratus</i> , Claus									x	x		x	x	x	x	x						x	x	x
<i>C. danae</i> , Giesbrecht												x	x											
<i>C. speciosus</i> , Dana		x	x																					
<i>C. alatus</i> , Giesbrecht						x																		
<i>C. longistylis</i> , Dana																								
<i>C. carinatus</i> , Giesbrecht								x																
<i>C. longicaudis</i> , Dana						x	x	x								x								
<i>C. gibbulus</i> , Giesbrecht									x	x	x				x	x	x							





NOTES ON THE COPEPODA.

Calanus vulgaris, Dana.

1849. *Calanus communis*, Dana, Proc. Amer. Acad., vol. II., p. 17.

One of the commonest ocean species, diffused over the the Atlantic, Pacific, and Indian Oceans. It occurs in most of the bottles of both collections between 20 S. lat. and 14 N., and again sparingly in the Red Sea.

Calanus pauper, Giesbrecht.

1888. *Calanus pauper*, Giesbrecht, Atti Acc. Lincei Rend., Ser. 4, vol. IV., p. 331.

In the Wyse collection this species does not occur in the Indian Ocean, but was present in two of the Herdman East African bottles, and again appears in the Red Sea and in the Mediterranean; all newly recorded areas, the Pacific being its hitherto only known area. It is not readily distinguishable except by the swimming feet, and especially the 5th pair, which were, in most specimens, considerably mutilated by the rush of water, a consequence of the necessary mode of ship collection.

Calanus darwini, Lubbock.

1869. *Undina darwini*, Lubbock, Tr. Linn. Soc., Lond., vol. XXIII., p. 7., Pl. XXIX.

This species was found in bottles 13 and 14 of the Wyse collection, both taken in the Bay of Bengal. Its only capture in the Herdman collection was to the south of Cape Guardafui. Its hitherto reported range is confined to the Atlantic and Pacific Oceans.

Calanus gracilis, Dana.

1849. *Cyclopsina longicornis*, Dana, Proc. Amer. Acad., vol. II., p. 18.

The long, graceful antennules—half as long again as the entire animal—characterize this species. It was present in four gatherings in the Wyse collection, all from the

Mediterranean. It has a wide range throughout the Atlantic and Pacific Oceans.

Eucalanus attenuatus, Dana.

1849. *Calanus attenuatus*, Dana, Crust. U.S. Expl. Exped., 1852, p. 1080, Pl. LXXV., fig. 2.

This easily recognised species occurs frequently in both collections throughout the Indian Ocean. It has a wide range, extending from the Faeroe Islands to the Phillipine Islands.

Rhincalanus cornutus, Dana.

1852. *Rhincalanus cornutus*, Dana, Crust. U.S. Expl. Exped., p. 1083, Pl. LXXVII., fig. 2.

This species is easily recognisable by its protruding triangular rostrum. It occurs in both collections—on three occasions between the mainland of Africa and Madagascar, and again off Ceylon, Wyse collection, and at stations 14, 15, 16, Herdman, off the African coast. It has a wide range in both the Atlantic and Pacific Oceans.

Rhincalanus gigas, Brady.

Rhincalanus gigas, Brady, Rep. Voy. "Challenger," 1883, p. 42, Pl. VIII., figs. 1—11.

This rare species was found only once, in No. 1, Wyse collection. Its range of distribution is very similar to that of *R. cornutus*.

Acrocalanus gibber, Giesbrecht.

Acrocalanus gibber, Giesbrecht, Atti Acc. Lincei Rend., Ser. 4, vol. IV., p. 332.

This species is widely distributed throughout both collections, its range extending from South Africa, throughout the Indian Ocean and Bay of Bengal, and up through the Red Sea into the Mediterranean, the latter being an addition to its hitherto recorded range of distribution.

Calocalanus pavo, Dana.

1849. *Calanus pavo*, Dana, Proc. Amer. Acad., vol. II., p. 13.

This, perhaps the most elegant of all Copepods, and, at the same time, the most fragile, is seldom or perhaps never found in a perfect condition. It is splendidly illustrated in colours by Giesbrecht—Fauna und Flora des Golfes von Neapel, Pl. IV., fig. 15.

The very long plumose antennules in the female, and the caudal stylets set at right angles to the abdomen, and each bearing four large beautiful plumes, easily distinguish it from any other species.

It occurs once in the Wyse collection, station 7, in the Indian Ocean, and twice in the Herdman collection, at widely different localities, viz., the South of Africa and the Mediterranean, stations 2 and 21.

As the few specimens found were so mutilated as to be hardly recognisable, it is possible there may have been more. I have taken it carefully by stationary tow-net about the Canary Islands in a nearly perfect condition, and now at once recognise it.

Clausocalanus arcuicornis, Dana.

1849. *Calanus arcuicornis*, Dana, Proc. Amer. Acad., vol. II., p. 12.

Found in the Wyse collection only, between Madagascar and the African mainland, and at stations 11, 12, 13, in the India Ocean and Bay of Bengal. Claus, Giesbrecht, and myself have recorded it from the Mediterranean.

Aetidius armatus, Brady.

1892. *Aetidius armatus*, Brady, Rept. Voy. "Challenger," Copepoda, p. 76, Pl. X., figs. 5—16.

This species occurs at four stations in the Wyse collection, Nos. 1, 6, 20, 23, in the Indian Ocean and Mediterranean. Its recorded range of distribution includes the Atlantic and Pacific Oceans. It is readily noticed by its

strong curved rostrum and posteriorly spined cephalothorax.

Bradyidius armatus, Vanhöffen.

1878. *Pseudocalanus armatus*, Brady, Cop. Brit. Isl., vol. I., p. 46, Pl. IV., figs. 1—9, 11.

This is a rare but well-known species about our shores, and is reported by Chun from the Antarctic. The present record of its distribution, occurring at stations 1, 5, 7, 8, 12, 17, Wyse collection, is an addition.

Undeuchæta major, Giesbrecht.

1883. *Euchæta australis*, Brady, Rept. Voy. "Challenger," Copepoda, p. 65, Pl. XXI., figs. 5—11.

This species occurred in the Wyse collection, stations 15 and 18, from the Indian Ocean and the Bay of Bengal. Its reported range has hitherto been confined to the Pacific Ocean.

Euchirella pulchra, Lubbock.

1856. *Undina pulchra*, Lubbock, Trans. Entom. Soc., Lond., 4th Ser. XXI., vol. IV., p. 20.

I found this species, twice in the Wyse collection, from stations 1 and 5, both in the Southern Indian Ocean. Its hitherto recorded range has been the Atlantic and Pacific Oceans.

Euchæta marina, Prestandreae.

1833. *Cyclops marina*, Prestandreae, Effern. scient. e let. per la Sicilia, Palermo, vol. VI., p. 12.

This is a very widely distributed species, having been recorded from 65° N. to 26° S. With the exception of stations 2 and 4, it was fairly abundant at all the Wyse Indian Ocean stations, and up the Bay of Bengal. Its occurrence at only one of the Herdman stations (No. 11) probably arises from its preference for the open ocean rather than near land. It is easily recognisable by its double toothed rostrum.

Scolecithrix dana, Lubbock.

1856. *Undina danae*, Lubbock, Trans. Entom. Soc., Lond., 4th Ser., vol. IV., p. 15, Pl. IX.

The range of distribution of this species in these gatherings is interesting, as it occurs only from the centre of the Indian Ocean, and, with one exception, at all the stations up to Calcutta. In neither collection was it taken near the African coast, nor in the Red Sea nor Mediterranean.

Phaenna spinifera, Claus.

1863. *Phaenna spinifera*, Claus, Freileb. Cop., p. 188.

This easily recognisable species occurs in stations 1, 2, 3, 5, 6, of the Wyse collection, but not elsewhere. It has a wide range in the Atlantic and Pacific Oceans, and Claus and myself have reported it from the Mediterranean.

Centropages brachiatus, Dana.

1849. *Pontella brachiata*, Dana, Proc. Amer. Acad., vol. II., p. 27.

This species also has a very wide range, but was only found at two of the Mediterranean stations, Nos. 22 and 23. In 1888 I reported it from Malta.

Centropages furcata, Dana.

1849. *Catopia furcata*, Dana, Proc. Amer. Acad., vol. II., p. 25.

Occurs frequently in both collections, and widely distributed throughout the entire distance traversed.

Centropages violaceus, Claus.

1863. *Ichthyophorba violacea*, Claus, Freileb. Cop., p. 199, Pl. XXXV.

This species was taken at 16 out of the 23 Wyse stations and at 4 of the Herdman stations, being generally distributed. Some of the plumes to the appendages are usually of a deep violet colour, as well as parts of the cephalothorax. The dark red pigment spots noticed by Claus were conspicuous in several of the specimens found.

Temora stylifera, Dana.

1849. *Calanus stylifer*, Dana, Proc. Amer. Acad., vol. II., p. 13.

Like the last species, present in 16 out of the 23 Wyse stations, but only in 2 of the Mediterranean Herdman stations. Its wide range throughout the Indian Ocean has not been before recorded.

Temora discaudata, Giesbrecht.

1889. *Temora discaudata*, Giesbrecht, Atti Acc. Lincei Rend., Ser. 4, vol. V., Sem. 1, p. 814.

The asymmetry of the long caudal stylets readily distinguish this species from the last, *T. stylifera*. Several specimens were found in No. 17, Wyse collection only, taken in the Red Sea, where Giesbrecht records it.

Temora longicornis, Müller.

1792. *Cyclops longicornis*, Müller, Entom., p. 116.

This has always been recognised as a distinctly northern species, the Mediterranean being its most southerly recorded habitat. Its southern range of distribution must now be considerably extended as it occurs in the Wyse collection at station 15—Bay of Bengal, and twice in the Herdman collection at stations 8 and 15—East African coast.

Metridia longa, Lubbock.

1854. *Calanus longus*, Lubbock, Ann. Nat. Hist., Ser. 2, vol. XIV., p. 127, Pl. V.

Another northern species, the range of which must now be far extended, as in both collections it appears at several stations almost between Madagascar and the African mainland.

Pleuromma abdominalis, Lubbock.

1856. *Diaptomus abdominalis*, Lubbock, Trans. Ent. Soc., London, N. Ser., vol. IV., p. 22.

This species is at once recognisable by a round black

knob of pigment on either right or left side of the cephalothorax. It was found generally plentiful at 13 out of the 23 Wyse stations, but not in any of the 6 most central of the Indian Ocean.

Lucicutia flavicornis, Claus.

1863. *Leuckartia flavicornis*, Claus, Freileb. Cop., p. 186, Pl. XXXII.

A few specimens were found in No. 20 Wyse collection, but not elsewhere.

Candacia longimana, Claus.

1863. *Candace longimana*, Claus, Freileb. Cop., p. 190, Pls. XXVII., XXXIII.

One specimen only was taken, and that in No. 7 Wyse collection, from the Indian Ocean, which shows its range to be more southerly than was previously known, the Mediterranean being its only previously recorded habitat.

Candacia aethiopica, Dana.

1849. *Candace aethiopica*, Dana, Proc. Amer. Acad., vol. II., p. 23.

The deep purplish black pigment covering to the dorsal side of the cephalothorax readily distinguishes this striking species. It appears to love the open ocean, occurring at eight consecutive Wyse stations, 7 to 14 in the Indian Ocean and Bay of Bengal, but not elsewhere. The previous records are from the Mediterranean and Atlantic and Pacific Oceans.

Candacia pectinata, Brady.

1878. *Candace pectinata*, Brady, Cop. Brit. Isl., vol. I., p. 49, Pls. VIII., X.

The southerly range of distribution of this species appears to be very similar to that of *C. aethiopica*, but it has a wide northern range about our British coasts, and was recently reported from Port Erin, in the L.M.B.C. district.

Candacia truncata, Dana.1842. *Candace truncata*, Dana, Proc. Amer. Acad., vol. II., p. 24.

This species occurred at 9 stations in the Wyse collection and at 4 stations in the Herdman series, being most plentiful near the African coast, and extending into the Indian Ocean and again appearing in the Mediterranean. Its general range of distribution is similar to that of *C. pectinata*.

Calanopia elliptica, Dana.1849. *Pontella elliptica*, Dana, Proc. Amer. Acad., vol. II., p. 27.

Occurs at 3 stations, widely apart, in each collection, viz., South African Coast, Indian Ocean, Bay of Bengal, Red Sea, and Mediterranean, adding considerably to its previous record.

Labidocera acutifrons, Dana.1849. *Pontella acutifrons*, Dana, Proc. Amer. Acad., vol. II., p. 30.

This striking animal appears to be uncommon in the routes traversed, as it occurs in stations 1 and 6 only of the Wyse collection. It has a known wide distribution in southern latitudes.

Labidocera acuta, Dana.1849. *Pontella acuta*, Dana, Proc. Amer. Acad., vol. II., p. 30.

Found at one station only in each collection, on the south-east African coast and in the Bay of Bengal. This species also has a wide range of distribution over the great oceans and extending up to the British Isles. I have recorded it from the L.M.B.C. area.

Pontella spinipes, Giesbrecht.1889. *Pontella spinipes*, Giesbrecht, Atti Acc. Lincei Rend., Ser. 4, vol. V., Sem. II., p. 28.

One specimen only of this rare species was found in No. 15, Wyse collection, taken in the Bay of Bengal. The Indian Ocean is its only previously recorded habitat.

Anomalocera patersoni, Templeton.

1837. *Anomalocera*, Trans. Entom. Soc., Lond., vol. II., p. 34.

This large, well-known, beautiful Copepod is a distinctly northern form, commonly met with round the British Isles and about the Norwegian coasts, and reported between Faeroe and Greenland.

Gibraltar has hitherto been its most southerly recorded limit, and it was therefore with some surprise that I found a specimen in No. 1, Wyse collection, taken near the southern extremity of Africa, which greatly extends its range of distribution.

Pontellopsis regalis, Dana.

1849. *Pontella regalis*, Dana, Proc. Amer. Acad., vol. II., p. 31.

Found in No 14, Wyse only, in the Bay of Bengal, about its most northerly recorded limit in the Indian Ocean. It has been recorded also from the Mediterranean and the Atlantic Ocean.

Pontellina plumata, Dana.

1849. *Pontella plumata*, Dana, Proc. Amer. Acad., vol. II., p. 27.

Found sparingly in both collections in the Indian Ocean and Mediterranean, both previously recorded habitats.

Acartia clausi, Giesbrecht.

1863. *Dias longiremis*, Claus, Freileb. Cop., p. 193, Pl. XXXIII.

This is one of the commonest northern species, abundant round the British Isles. It was found in fair quantity at 13 out of the 23 Wyse stations, and at 8 stations in the Herdman collection. Its range of distribution therefore extends from South Africa, through the Indian Ocean into the Bay of Bengal, and up the Red Sea. It requires careful dissection to distinguish it from *A. longiremis*, Lilljeborg, and it is quite possible that some of the latter may have been present, although all I dissected were of the former species.

Acartia erythraea, Giesbrecht.

1889. *Acartia erythraea*, Giesbrecht, Atti Acc. Lincei Rend., Ser. 4, vol. V., Sem. II., p. 26.

This is evidently a rare species. Only one specimen was found, No. 9, Wyse collection, taken in the Indian Ocean. Its previous record by Giesbrecht is from the Red Sea. *A. laxa*, Brady, recorded from the Phillipine Islands and elsewhere, much resembles this species, and may be identical with it.

Oithona plumifera, Baird.

1843. *Oithona plumifera*, Baird, Notes on Brit. Entomos., Zoologist, vol. I., pp. 193—199.

This beautiful Copepod was present in about half the Indian Ocean Wyse stations, and in Nos. 4, 7, and 8 of the Herdman stations, but not elsewhere, although it has been, by several writers, reported from the Mediterranean.

I have found it common about the Canary Islands. The lovely red plumose setæ on all parts of its body readily distinguish it from the next species, *O. similis*.

Oithona similis, Claus.

1866. *Oithona similis*, Claus, Die Copep. Fauna von Nizza, p. 14.

This minute Copepod was widely distributed through both collections. It is a very common northern species, and has been reported from the Mediterranean and also from the Canary Islands, but apparently not before from the Red Sea or Indian Ocean, which considerably extends its southern range.

Microsetella rosea, Dana.

1847. *Canthocamptus roseus*, Dana, Proc. Amer. Acad., Boston, vol. I., pp. 150—154.

In both collections a similar partial distribution of this species is noticeable, as it occurs in each between Madagascar and the African mainland, and again at four stations

in the Red Sea. Both habitats are an addition to its recorded range.

Microsetella atlantica, Brady & Robertson.

1873. *Microsetella atlantica*, Brady & Robertson, Ann. and Mag. Nat. Hist., Ser. 4, vol. XII., p. 130, Pl. IX., figs. 11—16.

This species has a much wider range than the last, being found in 15 of the Wyse gatherings and 5 of the Herdman series, and thus extending its recorded range over the Indian Ocean and Bay of Bengal. Brady and T. Scott have both reported it from the South Atlantic, and it is not uncommon on our own western coasts.

Eutерpe acutifrons, Dana.

1847. *Harpacticus* (?) *acutifrons*, Dana, Proc. Amer. Acad., Boston, vol. I., pp. 150—154.

This minute species is common to cold and warm waters, being frequently found about our own coasts, and throughout the Mediterranean and in the South Pacific Ocean. It occurred at 15 and 18 stations, Wyse collection, and at 4, 8, 15, 16, 21, 22, Herdman stations, thus adding the Indian Ocean and Bay of Bengal to its known range of area.

Setella gracilis, Dana.

1852. *Setella gracilis*, Dana, Crus. U.S. Expl. Exped., p. 1198, Pl. LXXXV., figs. 3 a—g.

This striking southern species was widely distributed throughout both collections, and was in especial profuse abundance in the Sea of Babel Mandeb in both, the latter being an extension of its known area. In the Herdman collection it extended into the Red Sea and the Mediterranean, both localities previously recorded.

Brady, in his "Challenger" Report, mentions it as common in many parts of the Pacific Ocean.

Miracia efferata, Dana.

1847. *Miracia efferata*, Dana, Proc. Amer. Acad., Boston, vol. I., pp. 150—154.

A most beautifully coloured tropical species. Very few specimens were found at stations 1, 2, 8, 9, 14, Wyse, and at station 7 only, Herdman; the latter corresponding with 1, 2, Wyse, between Madagascar and the mainland of Africa, the other stations being in the Indian Ocean and Bay of Bengal. It has been recorded by Dana, Lubbock, Brady, and Giesbrecht from the Atlantic, and by Scott from the Gulf of Guinea.

The present collection therefore adds considerably to the recorded range of this species.

Clytemnestra scutellata, Dana.

1847. *Clytemnestra scutellata*, Dana, Proc. Amer. Acad., Boston, vol. I., 1850—1854.

Isolated specimens of this species occurred in the Wyse collection only at the stations 3, 5, 7, 8, and 16, ranging from 14° S. lat., 43° long. to near the equator at 64° E. long., and again at the entrance to the sea of Babel Mandeb at 14° N. lat., 53° E. long., being a clear addition to its hitherto recorded range, which includes the Mediterranean, Red Sea, Pacific Ocean and Chinese Sea.

Oncaea venusta, Phillipi.

1843. *Oncaea venusta*, Phillipi, Copep. des Mittelmeeres Arch. Naturg., 9 Jahrg., I. Bd., pp. 54—71.

Considerable difficulty was experienced in many cases in determining the species of the genus *Oncaea*, the points of difference varying very much according to age. *O. venusta* was much the more common, being found in 16 Wyse stations and 3 Herdman stations, extending from the south-east of Africa, through the Indian Ocean and Bay of Bengal; again, in the Red Sea and Mediterranean. Lubbock

has reported it from between the Crozet Islands and the south of Africa, and from the Atlantic Ocean. It has also been reported from the Pacific, Mediterranean, &c. The Bay of Bengal and Red Sea habitats now reported are additions to its known range.

Oncaea mediterranea, Claus.

1863. *Antaria mediterranea*, Claus, Die. Freileb. Cop., p. 159, Pl. XXX, figs. 1—7.

This species occurred in fair abundance at 8 Wyse and 4 Herdman stations, in the Indian Ocean, Bay of Bengal, and Mediterranean. It has a wide range north and south, having been reported from Spitzbergen, British Isles, Mediterranean, and Atlantic and Pacific Oceans. The Indian Ocean and Bay of Bengal are additions to its known range.

Oncaea conifera, Giesbrecht.

1891. *Oncaea conifera*, Giesbrecht, Atti Acad. Lincei Roma, vol. VII., 1 Sem.

At only one station, No. 3, Wyse collection, was this species found, between Madagascar and the African mainland. The Mediterranean, Pacific Ocean, and Gulf of St. Lawrence appear to be the only previous recorded habitats.

Oncaea minuta, Giesbrecht.

1892. *Oncaea minuta*, Giesbrecht, F. and Fl. Neapel, vol. XIX., p. 590.

As its name aptly denotes, this species is very small. It occurs in both collections, Wyse, 9, 11, 12, 13, 14, 18, 22, Herdman, 8, 14, the location being African east coast, Bay of Bengal, Red Sea, and Mediterranean, the last being Giesbrecht's only previously recorded habitat.

Sapphirina salpae, Claus.

1859. *Sapphirina salpae*, Claus, Arch. Anat., Physiol., Wiss. Med., Jahrg., pp. 269—274.

This species was found at 2 Wyse stations, 11 and 13

only, in the Indian Ocean, to the south-west of Ceylon, and further north in the Bay of Bengal. Its previously recorded range is the Mediterranean and Atlantic and Pacific Oceans.

Sapphirina nigromaculata, Claus.

1863. *Sapphirina nigromaculata*, Claus, Die Freileb. Cop., p. 152, Pl. VIII., figs. 5 and 6.

This easily recognised species was found at 5, 6, 7, 8, 11, 15, 17, 19, 20 Wyse stations, and 7, 8 Herdman, showing a general distribution over the regions traversed. Its previous records are the Mediterranean, Red Sea, Atlantic and Pacific Oceans; the new records being the Indian Ocean and Bay of Bengal.

Sapphirina gastrica, Giesbrecht.

1891. *Sapphirina gastrica*, Giesbrecht, Atti Accad. Lincei Roma, vol. VII., pp. 474—481.

One specimen only of this apparently rare species was found at Wyse station No. 14, Bay of Bengal, its only previous record being the Pacific Ocean.

Sapphirina stellata, Giesbrecht.

1883. *Sapphirina ovalis*, Brady, "Challenger" Cop., p. 123, Pl. XLVII., figs. 1—12.

This species occurred at 1, 3, 4, 9, 10 Wyse stations, all in the Indian Ocean, its previous records being the Mediterranean and Pacific Ocean.

Sapphirina serrata, Brady.

1883. *Sapphirina serrata*, Brady, "Challenger" Cop., vol. VIII., p. 125, Pl. XLIX., figs. 1 and 2.

One specimen only of this species was made out, though it is quite possible others may have been overlooked from its general resemblance to *S. stellata*. Giesbrecht considers *S. serrata* a doubtful species, but I am inclined to

agree with Brady that the serrated edges on the abdominal segments give it a specific distinctness.

Copilia denticulata, Claus.

1863. *Copilia denticulata*, Claus, Die Freileb. Cop., p. 161, Pl. XXV. figs. 14—20.

One specimen only was found at station No. 14 Wyse, in the Bay of Bengal. Claus originally found this species at Messina, and Scott took it in the Gulf of Guinea. So we have it from three widely distant areas. The marginal denticulations on the ventral side of the abdomen are its chief distinguishing character, and may be easily overlooked. It is therefore possibly commoner than reported.

Copilia quadrata, Dana.

1849. *Copilia quadrata*, Dana, Proc. Amer. Acad., vol. II.

Found only at 8 and 11 stations Wyse, and the Indian Ocean. Its former records are the Mediterranean and Atlantic and Pacific Oceans, the present record widely extending its range of distribution.

Copilia mirabilis, Dana.

1849. *Copilia mirabilis*, Dana, U.S. Expl. Exped., p. 1232, Pl. LXXX., fig. 14, a—g.

This well-marked species was present in 3 of the Wyse tow-nettings taken between Madagascar and the mainland and one of the Herdman stations in the Red Sea. It is evidently widely distributed throughout the large southern oceans and the Mediterranean.

Corycæus ovalis, Claus.

1863. *Corycæus ovalis*, Claus, Die Freileb. Cop., p. 158.

The various species of the genus *Corycæus* proved to constitute the largest proportion of the number of Copepoda of any genus in each collection, eleven species being found in the Wyse tow-nettings and eight species in the Herdman

series. Giesbrecht, in his beautiful monograph, "Pelagische Copepoden, Fauna and Flora des Golfes von Neapel," gives twenty species besides a number of undetermined forms. A reference to his Pl. LI. will show the slight divergence of character which separates many of the species, and I found it no easy task always to determine to which species a particular specimen belonged. Some, indeed, seemed to vary from any described form, but not sufficiently so, in my opinion, to constitute a specific difference, and I am inclined to think that a more systematic study of the genus might result in grouping together, as one species, some now classed separately, rather than in an increase of their number.

The species before us, *Corycæus ovalis*, well illustrates my meaning. There seems to me no sufficient reason for separating *C. ovalis*, *C. robustus*, and *C. obtusus* into separate species. In general appearance they are remarkably alike in all particulars, the supposed difference being a slight relative variation in the length of a particular segment, or a variation in a bristle, or in the inclination of the caudal stylets. The representative species, *C. ovalis*, was present in 9, 10, 20, 22, 23 Wyse collection and in No. 9 Herdman collection, taken in the Indian Ocean and the Mediterranean, the former being an addition to the known range of any of the three species of *Corycæus* referred to.

Corycæus venustus, Dana.

1852. *Corycæus venustus*, Dana, U.S. Expl. Exped., p. 1222, Pl. LXXXVI., figs. 4, a—d.

The chief point of difference between this species and the last is the length as compared with the breadth of the last abdominal segment. In *C. ovalis* that segment is about twice as broad as long, the conditions being reversed in *C. venustus*. It was present in 5, 6, 8, 11, 13, 14, 17, 18,

19 Wyse tow-nettings and in No. 7 Herdman collection, showing a range over the Indian Ocean, Bay of Bengal, and the Red Sea, all new records. Its previously known range is the Atlantic and Pacific.

Corycæus furcifer, Claus.

1863. *Corycæus furcifer*, Claus, Die Freileb. Cop., p. 157, Pl. XXIV., figs. 7—12.

The very long, thin caudal segments, more than $1\frac{1}{2}$ times as long as the abdomen, distinguish this species from the other members of the genus *Corycæus*, with the exception of *C. longistylis*. It was present in 1, 2, 13 Wyse tow-nettings and in No. 11 Herdman series, being taken almost between Madagascar and the African mainland and in the Bay of Bengal, both being an extension of its range of distribution, its previous records being the Mediterranean and Pacific Ocean.

Corycæus rostratus, Claus.

1863. *Corycæus rostratus*, Claus, Die Freileb. Cop., p. 157, Pl. XXVIII., fig. 5.

The long wedge-shape of this species roughly distinguishes it. It was fairly abundant where present, and was found in 8, 9, 11, 12, 13, 14, 15, 16, 19, 21, 22, 23 Wyse tow-nettings, and in 2, 4, 7, 8, 10, 11, 13, 16, 20, 23 Herdman series, showing its prevalence over the entire district traversed. The Mediterranean appears to be its only previously recorded area.

Corycæus danæ, Giesbrecht.

1891. *Corycæus danæ*, Giesbrecht, Atti Accad. Lincei Roma, vol. VII., 1 Sem., pp. 474—481.

This species much resembles *C. ovalis*, the furcal segments being rather longer. Its range in the present collections is the Bay of Bengal and the Mediterranean. It was found in 12, 15, 16, 18, 20, Wyse tow-nettings only.

Giesbrecht found it in the Pacific Ocean, and I do not find it elsewhere recorded.

Corycæus elongatus, Claus.

1863. *Corycæus elongatus*, Claus, Die Freileb. Cop., p. 157, Pl. XXIV., figs. 3 and 4.

In this species the abdomen is one-jointed, and the caudal segments about two-thirds the length of the abdomen, a fairly easily distinguishable feature. It was found in five Herdman tow-nettings, Nos. 14, 15, 16, 21, 23, below Cape Guardafui on the East African coast, and in the Mediterranean, the latter and the Pacific Ocean being its known previous range of distribution.

Corycæus speciosus, Dana.

1849. *Corycæus speciosus*, U.S. Expl. Exped., p. 1222, Pl. LXXXVI., figs. 4 a—d.

The large size of this species, and the widely diverging caudal stylets of the female, easily distinguish it. It was fairly abundant when present, occurring at 1, 2, 3, 8, 9, 10, 12, 13, Wyse stations, and at 7, 8, 15, Herdman series, in the Indian Ocean, and most numerous between Madagascar and the African mainland. This is a new record; the Mediterranean and Atlantic and Pacific Oceans being its previously known range of distribution.

Corycæus alatus, Giesbrecht

1891. *Corycæus alatus*, Giesbrecht, Atti Accad. Lincei Roma, vol. VII., 1 Sem., pp. 474—481.

Evidently a rare species, and found only once, viz., No. 4, Wyse station. It somewhat nearly resembles *C. elongatus*, the caudal stylets being rather longer and narrower. Its only previous record is from the Pacific Ocean.

Corycæus longistylis, Dana.

1849. *Corycæus longistylis*, Dana, Proc. Amer. Acad., Boston, vol. II., pp. 8—61.

In the length of its caudal stylets this species closely resembles *C. furcifer*, but its abdomen being composed of one segment only, readily distinguishes it. It occurred in 17 and 20, Wyse stations only, the localities being the Red Sea and Mediterranean, both being an addition to its known range of distribution, which has hitherto been confined to the Pacific Ocean and the China sea.

Corycæus carinatus, Giesbrecht.

1891. *Corycæus carinatus*, Giesbrecht, Atti Acad. Lincei Roma, vol. VII., 1 Sem., pp. 474—481.

This species, which much resembles *C. rostratus*, except in the relative lengths of its abdomen and caudal stylets, was found only once, No. 7, Wyse collection, from the Indian Ocean, its previous record being the Pacific Ocean.

The specimen agreed with Giesbrecht's description and drawing, but I doubt whether time and future captures will not cause it to be classed as *C. rostratus*.

Corycæus longicaudis, Dana.

1849. *Corycæus longicaudis*, Dana, Proc. Amer. Acad., vol. II., pp. 8—61.

Like the last species, this one very nearly resembles *C. rostratus*, except in the relative lengths of abdomen and caudal stylets, which are in *C. longicaudis* more attenuated. It was present in 4, 5, 6, and 16, Wyse collection, and in 2, 8, 10, and 15, Herdman series, all from the western portion of the Indian Ocean. Its previous records are the Atlantic and Pacific Oceans.

Corycæus gibbulus, Giesbrecht.

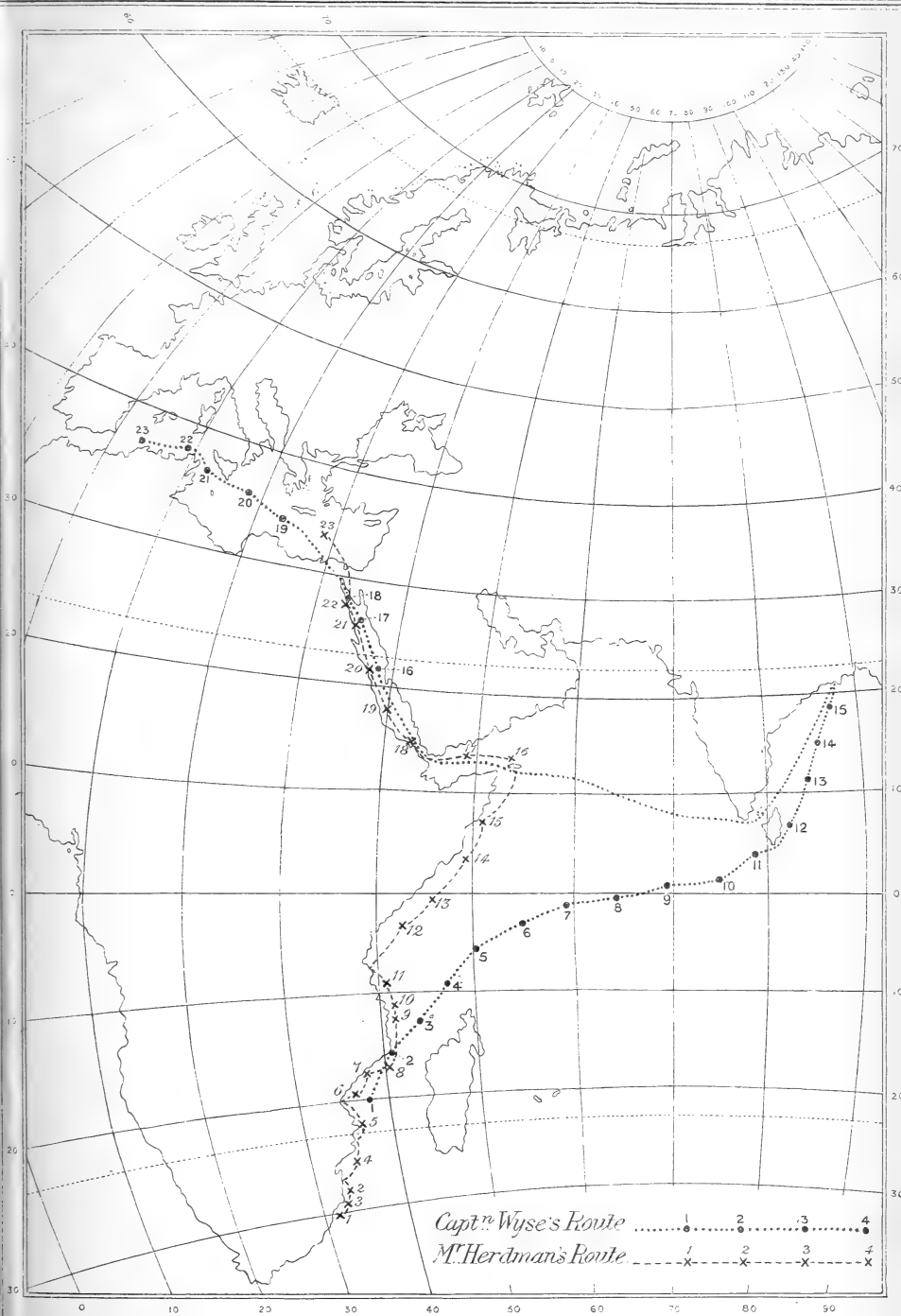
1891. *Corycæus gibbulus*, Giesbrecht, Atti Accad. Lincei Roma, vol. VII., 1 Sem., pp. 474—481.

This species rather closely resembles *C. rostratus*, but

may be readily distinguished from it by the width of the lower portion of the cephalothorax and abdomen. It appeared in 8, 9, 10, 14, 15, 16, Wyse tow-nettings, and in 11, 16, 17, 20, Herdman series, the localities being the Indian Ocean, Bay of Bengal, and Red Sea. When present it was usually fairly abundant. It does not appear to have been previously recorded except by Giesbrecht from the Pacific Ocean, and somewhat doubtfully from the Red Sea.

EXPLANATION OF THE PLATE.

The Map, Pl. XV., shows the respective routes traversed by Capt. Wyse and Mr. Herdman. The figures refer to the stations at which the plankton was collected.





NOTES on the BOTANY of WIDNES.

By the Rev. T. S. LEA, M.A.

[Read January 12th, 1900.]

I HAVE many doubts as to whether a paper of this kind has any right to expect a place in the records of the Liverpool Biological Society. One doubt is, that I can only represent it as the casual observations of one season. However, as some unscientific person has lately been making rash statements about "not a blade of grass," I venture to give a rough sketch of what does grow at Widnes.

It will be convenient to take the plants according to the stations where they were found. I first turned my attention to the waste tips, huge aggregations of chemical refuse, level at the top and steeply banked at the sides. The rain that falls on these soaks in rapidly and decomposes the stuff so that what exudes at the bottom is a noisome fluid, acid and sulphureous, varying in hue through many shades of green and yellow. No vegetation can live in this; but one grass, *Agropyrum repens*, grows in extraordinary proximity to it. But on the surface things are different.

I give a list of a score or so of weeds which have obtained a footing. The common dock (*Rumex acetosella*), abounds and I do not think I have ever seen the mouse-ear chickweed (*Cerastium vulgatum*) in such abundance as on the waste tip at Cuerdley. The flowers were fine and large, and an innumerable crop of seedlings has come up this autumn. Grasses, such as *Holcus mollis*, *Agrostis vulgaris*, *Poa annua*, *Lolium perenne*, and the greater willow herb, *Epilobium hirsutum*, occur. But the soil

cannot be called fertile, and this leads me to speak of the generally waste appearance of the region. The town straggles a good deal, and there is a great amount of building land unoccupied. Where this, as is often the case, is plentifully sprinkled with cinders, and the cinders well and continuously trodden into a mixture of glacial clay and sand, vegetation has not much chance, irrespective of chemicals.

Howbeit, there is an enclosed space rather to the N.E. of the chemical works near Tanhouse Lane Station which may be taken as typical. It is not extensive, but the crops on the arable land which bounds it show a decided falling off on the side next to the works, and I regard some of the land, though fenced, as undoubtedly affected by the chemicals. Yet on it grow and flourish *Agropyrum repens* and *Carex cespitosa*. And the moss, *Funaria hygrometrica*, abundant and luxuriant on the waste tips, manages to fruit even on the platform at Tanhouse Lane. At a little distance the ordinary town weeds assert themselves, and a mile or so into the country the ponds produce a large and varied aquatic flora.

But the really remarkable examples of resistance to chemicals are to be found on the marshes of the Mersey. I can hardly find a plant of which I can certainly say that it has been seriously affected by them.

I give a list of the saline plants; I took stock of them first on Cuerdley Marsh, well away from the smoke, and next examined Widnes Marsh. With the exception of *Triglochin maritimum*, a plant easily overlooked, I found the same species under the factory chimneys as on the open marsh. The sea-pink flowers, and to make up for the loss of *Triglochin*, the wild celery, *Apium graveolens*, appears; and, as for the grasses, I am told that Widnes Marsh is the better pasture.

To sum up. Undoubtedly in years past the chemicals have had a most deleterious effect on the trees and hedges. There are, however, unmistakable signs of recovery. Hedges are being planted again in the Farnworth district, notably on the Sheffield and Midland Railway (and a railway company usually makes very sure before incurring expense). Blackberries, and even young oaks, are springing up. The great drawback to vegetation is the unchecked violence of the gales. This is a direct result of the destruction of the trees. Houses only intensify the evil by collecting the wind into eddies and draughts. Some trees, a kind of balsam poplar and the golden elder, are planted and flourish fairly, and we may improve in this respect.

LIST I.

Weeds on Ditton waste tip :—

Cerastium vulgatum, *Rubus fruticosus*, *Epilobium hirsutum*, *Tussilago Farfara*, *Matricaria inodora*, *Cnicus arvensis*, *Cnicus lanceolatus*, *Hypochaeris radicata*, *Hieracium* sp., *Taraxacum officinale*, *Rumex acutus*, *Rumex acetosa*, *Atriplex patula*, *Plantago major*, *Plantago lanceolata*, *Salix cinerea*, *Poa annua*, *Lolium perenne*, *Poa pratensis*, *Agrostis vulgaris*, *Holcus mollis*.

LIST II. SALINE FLORA.

Widnes and Cuerdley Marshes :—

Cochlearia officinalis, *Spergularia rubra*, *Apium graveolens*, *Glaux maritima*, *Aster Tripolium*, *Atriplex patula*, *Plantago maritima*, *Plantago Coronopus*, *Armeria maritima*, *Triglochin maritimum*, *Juncus compressus*, *Poa maritima*, *Agrostis vulgaris*, *Agropyrum repens*.

L.M.B.C. MEMOIRS.

No. III. ECHINUS.

BY

H. C. CHADWICK.

THE common sea-urchin, *Echinus esculentus*, is the edible Echinoid well-known to marine zoologists as the *Echinus sphaera* of Forbes's "History of British Starfishes." It is found all around the British islands wherever a rocky or stony bottom and an abundant growth of *Fucus* and *Laminaria* provide its favourite haunt. It occurs also in the North Sea and the Mediterranean, off Port Natal, and on the John Adams Bank off the coast of Brazil. Its vertical range is from low-water mark down to 110 fathoms. In the L.M.B.C. district it is common on the Anglesey coast, and especially so off the south end of the Isle of Man. In Port Erin Bay it may be collected by hand on the beach, and on the ruined breakwater at low-water of spring tides; and it is seldom that a haul of the dredge is taken without one or more specimens being included. It does not appear to be used as food in any part of the district.

THE EXTERIOR AND THE TEST.

The test of an adult specimen is more or less pentagonal when viewed from above, the corners being gently rounded. In profile it is usually well rounded, but in some specimens

it is sub-conical, in others depressed. The region immediately surrounding the peristome (Pl. I., fig. 7, *per.*) is somewhat flattened. The outline seen when the test is viewed from either pole is the ambitus. The spines, with which the test is thickly covered, are usually whitish at their bases, more or less of their distal ends being tinged with pale violet. In what appears to be a rare colour variation, the spines are white, with an ill-defined blackish band about the middle of their length. In addition to the spines, the test bears a large number of pedicellariæ (Pl. II.). The mouth (Pl. I., fig. 7, *mo.*) occupies the centre of the broader and slightly flattened pole—hence the oral pole—of the test, and from it may be seen projecting five calcareous teeth (*to.*). It is surrounded by the membranous peristome. The anus (Pl. I., fig. 1, *an.*) is situated at the opposite pole of the test, a little to one side of the centre of a smaller but similarly membranous periproct (*pp.*).

The test is composed of twenty longitudinal rows of calcareous plates (Pl. I., figs. 3 and 4), and ten plates, which encircle the periproct, at the aboral pole. The latter form the so-called apical system (Pl. I., fig. 1). All the plates are firmly united by suture, and growth takes place at their edges, there being a thin and continuous layer of uncalcified connective tissue between the apposed margins. Of the twenty longitudinal rows of plates five double rows form the ambulacra or radii; the remaining five double rows alternate with them, and form the interambulacra or interradii. The structure and relations of the several kinds of plates will be readily understood by reference to figs. 1, 3, and 4, Pl. I. Figure 3 represents two plates taken from one row—the right, facing the observer—of an ambulacrum, in the region of the ambitus. The triangular ends on the left were apposed to exactly

similar plates in the left row of the ambulacrum; those on the right were similarly apposed to one of the plates of the adjacent interambulacrum. It follows from this arrangement that the suture uniting the two rows of plates of an ambulacrum forms a slightly irregular zigzag line. Examination of such an ambulacral plate with a lens reveals two oblique sutures (*sut.*), which sub-divide it into three minor plates. Each of these is traversed by a pair of pores (*po.*), through which the tube feet communicate with their ampullæ (Pl. IV., fig. 29), hence they are called pore plates.

The great majority of the ambulacral plates bear one large tubercle, and a variable number of smaller ones, upon which spines and pedicellariæ are seated. The apical extremity of each ambulacrum is composed of two small pore plates, which usually meet in the middle line. As growth of the test, as a whole, proceeds, such primitive plates are added between those already formed and the radial plates of the apical system; and it is by the ultimate fusion of three such primitive pore plates that the ordinary ambulacral plates are formed. As new pore plates appear, their predecessors are pushed towards the oral ends of the ambulacra; and, as they grow unequally, some remain in contact at the median suture, and are called primary plates. Others are pushed aside from the suture, and are called secondary plates. The outer ends of all the primary and secondary plates, except those last formed at the apices of the ambulacra, are in contact with the plates of the adjacent interambulacra.

The plates of the interambulacra (Pl. I., fig. 4) are similar in shape to those of the ambulacra, but are much larger, and are not sub-divided by suture. Each of the four or five last formed in each row bears one primary tubercle, and a variable number of very small ones. The

number of the former increases with age until, just below the ambitus, there may be from eight to twelve, according to the size of the test. The number of secondary and very small tubercles increases in like manner with the size of the plate. As the peristome is approached some of the tubercles disappear by absorption.

Of the ten plates which form the apical system of the test, five larger ones (Pl. I., fig. 1, *bas.*) immediately surround the periproct, and are usually in contact with each other by portions of their lateral edges. These coincide in position with the interambulacra, and are called basals or genitals, from the fact that each one is perforated near its apex by a pore (*gp.*) through which the spermatozoa or ova escape from the corresponding gonads. Each basal plate usually bears three primary tubercles, and a variable number of smaller ones; and one, the right anterior (*mad.*), is traversed by a large number of fine tubules through which the madreporic tube or sand canal of the water-vascular system is placed in communication with the exterior (Pl. III., fig. 24). This plate is the madreporite. The remaining five plates (*rad.*) are the radials. They are partially wedged in between the basals, and coincide in position with the ambulacra. In some few cases they completely separate the basals and form part of the boundary of the periproct. Each one bears a variable number of small tubercles, and is perforated by a small pore through which the terminal tentacle of the water-vascular canal is protruded (Pl. I., fig. 1). The terminal tentacles are pigmented, and were formerly supposed to be eyes; hence the term oculars, by which the radial plates are commonly known. The periproct is covered by irregular plates, the number of which increases with the age of the test. It has been shown that these occupy the position of an originally single plate, the dorso-central.

If an *Echinus* be placed mouth downwards, with the interambulacrum in which the madreporite is placed forming the right anterior (Pl. I., fig. 1), it will be found that one ambulacrum is anterior and one interambulacrum posterior. The anterior ambulacrum, with its fellows on the right and left, form the trivium; the remaining two, bounding the posterior ambulacrum, constitute the bivium. According to Lovèn's formula, the ambulacra forming the trivium are numbered, counting from right to left, I., II., and III.; the left bivial ambulacrum is IV. and the right one V.

The membranous peristome has embedded in it a number of detached plates, of which ten, much larger than the rest, are arranged in pairs, coincident in position with the ambulacra, and close to the margin of the mouth. These are the buccal plates (Pl. I., fig. 2). Each one is traversed by a double pore, and bears a corresponding tube-foot of relatively large size (Pl. I., fig. 7, *t.f'*.), in addition to minute clavate spines and pedicellariæ (fig. 7). The peristomial edge of the test bears five arches, which project upwards into its interior, and are connected by intermediate ridges. Each arch (Pl. III., fig. 23; Pl. V., fig. 37, *au.*) is an auricula, and is formed by a process or apophysis from each of the marginal plates of an ambulacrum, which bend towards each other and unite in the middle line, the point of union coinciding exactly with the median suture of the ambulacrum. The intermediate ridges are formed by apophyses arising from the marginal plates of the interambulacra, which unite with each other and with the auriculæ to form the perignathic girdle.

The external surface of the body is covered by an ectoderm, which is everywhere ciliated except upon the sucker discs of the tube-feet. The filamentous ends of many of the cells become continuous with the fibres of a nerve plexus

which lies beneath. Within this is a connective tissue layer of considerable relative thickness, in which the skeletal structures are developed. The calcareous substance of the test and spines takes the form of a more or less dense network, the meshes of which are everywhere filled with a protoplasmic ground substance. The ciliated epithelium of the body cavity may be in direct contact with the last-named, or a layer of muscular fibres may appear between the two.

The spines taper gradually from their bases to their more or less blunt tips, and are elegantly grooved from end to end. The base of each spine presents a saucer-shaped socket to the rounded tubercle of the test (Pl. I., figs. 1, 3, and 4) with which it is movably articulated. A capsular ligament binds the two together, and the movements of the spine are effected by the fibres of a similar capsular muscle, which lies outside the ligament. When viewed in transverse section the calcareous meshwork of the spines presents an elaborate pattern. A transverse section of a decalcified spine (Pl. II., fig. 20) shows that the fusiform cells of the ectoderm are arranged in linear groups, coincident in position with the ridges which traverse the spine from base to tip. Their basal ends are continuous with processes of the cells which form the ground substance of the spine. Though the spines are mainly protective, they also assist locomotion. A healthy *Echinus* placed on a hard surface, out of water, at once begins to move, solely by the aid of the primary spines of the oral face of the test.

Large numbers of pedicellariæ are scattered over the surface of the test and peristome. They are modified spines, and are attached to the test by ball and socket joints. There are four well-marked forms, but all agree in

the possession of a long stalk and a head composed of three blades.

The largest form is the tridactyle (Pl. II., fig. 13). A calcareous rod gives rigidity to about two-thirds of the length of the stalk, the remainder of which is flexible, and capable of movement in every direction. The blades composing the head are long and slender, and meet only at their bases and apices when apposed to each other. Ligamentous fibres bind the blades together; and they are moved upon each other by three powerful adductor muscles (Pl. II., figs. 13, 16, 19, and 21, *ad.m.*) which run between their adjacent sides. Nerve fibres pass upwards in bundles from the stalk, and are distributed to the sensory cells of the epithelium which clothes the inner surface of each blade (Pl. II., fig. 16, *nf.*).

The second form is the ophiocephalous or snake headed (Pl. II., fig. 15). In it the calcareous rod which supports the stalk is relatively shorter than that of the tridactyle form. The three blades forming the head are scoop-like, with blunt apices, and each one has a sort of handle at its base. Figure 19 represents the head, with blades open, of a very similar but much smaller form which occurs in numbers on the peristome.

The third form is the trifoliate, in which the blades of the head are broad and leaf-like, and meet only along their lateral edges when closed (Pl. II., fig. 17). The ectoderm forms a thick cushion on the inner face of each.

The fourth form is the gemmiform or glandular (Pl. II., fig. 14). In it the calcareous rod of the stalk extends to the head, which is consequently much less capable of independent movement. The apex of the calcareous skeleton of each blade is directed inwards and forms a strong tooth, to which are added several smaller teeth. Each blade contains a glandular sac (Pl. II., figs. 21

and 22, *gl.s.*), which lies outside the skeletal piece, and is bifid at its distal end in many cases. This sac has a glandular epithelium (*gl.ep.*), and is invested by a layer of circularly disposed muscular fibres (*mg.*). Near the apex of the sac is a minute aperture (*ap.*). On the inner face of each blade, just above the level of the adductor muscles, the ectoderm forms a projecting cushion (*tc.*). The cells forming this stain deeply, and, in addition to cilia, are said to bear tactile hairs. A nerve (*nf.*) passes upwards along the inner face of each blade, and its fibres become continuous with the filiform basal ends of the cells forming the cushion.

The function of the pedicellariæ has been the subject of much speculation and experiment. Romanes* concluded from his experiments that they assist locomotion by seizing foreign objects and holding on until the tube-feet can be brought into play, but he does not discriminate between the different forms. Other observers have regarded them as organs adapted to the capture and conveyance to the mouth of small animals, such as worms, Crustacea, &c., to be used as food. Others again have held that they are employed in freeing the neighbourhood of the anus from fæces, and the spines and test from injurious foreign particles. Prouho† found that the glandular pedicellariæ of *Strongylocentrotus lividus* were used to repel the attacks of hungry starfishes. It has been noticed that when a soft bodied animal, such as *Aplysia punctata*, comes in contact with an Echinus it always carries away with it a number of the glandular pedicellariæ.

In addition to spines and pedicellariæ, the plates of the ambulacra bear a number of minute knob-like organs, which project freely from the surface of the test. These

* "Jelly-fish, Starfish, and Sea-urchins," Int. Sci. Ser., vol. L., p. 253.

† Comptes Rendus, CXI. (1890), pp. 62—4.

are the sphæridia (Pl. II., fig. 18). They consist essentially of a hard, calcareous sphere, which differs from the ordinary skeletal structures in being concentrically laminated (*sp.h.*) The typical sphæridium is described as resting upon a short calcareous stalk, but this does not appear to exist in the present species, its place being taken by a cushion of nerve fibres. The typical sphæridium has also a circular nerve ganglion and a capsular muscle around its base, the ectoderm covering which is specially thickened and bears long cilia. The sphæridia are most probably sensory organs, and have been variously supposed to have an auditory or gustatory function, or, perhaps, to be concerned in the orientation of the test.

At the peripheral edge of the peristome five pairs of hollow, branched appendages project freely outwards, and form the external gills (Pl. I., fig. 7, *ex.g.*). One pair lies in each interradius, and the peristomial edge of the test is slightly notched for their reception. Their contractile walls consist of the ectoderm, of which the cells are deep and bear long cilia; a connective tissue layer containing C-shaped spicules and cribriform plates (Pl. I., figs. 5 and 6), and an inner epithelium continuous with that which lines the body cavity. The cavities of the gills open into the peri-œsophageal sinus.

ALIMENTARY CANAL AND "ARISTOTLE'S LANTERN."

The mouth is situated in the centre of the peristome, and the five pointed teeth project from its rounded opening. It opens directly into the pharynx (Pl. I., fig. 12, *ph.*), which passes upwards through the centre of the masticatory apparatus, or "Aristotle's lantern." The latter consists of twenty principal skeletal pieces, which together form a pyramid with five rounded sides, and a complex system of muscles and ligaments (Pl. III., fig. 23; Pl. V., fig. 37).

The great bulk of the pyramid consists of five pairs of jaws, each pair forming an alveolus (Pl. I., figs. 9, 10, and 12, *alv.*). Each alveolus is a hollow, triangular pyramid (fig. 11), two of the surfaces of which are lateral (figs. 9, 11, and 12), and applied to the corresponding surfaces of the alveoli on either side, while the third is outer and slightly rounded (fig. 10). The suture, which marks the line of union of the pair of jaws, runs down the centre of the outer surface (*sut.*). The lateral surfaces are traversed by fine transverse and slightly sinuous grooves (figs. 9 and 12), and the inner edges of these surfaces, which approach each other closely only at the base of the alveolus, are finely toothed. Each alveolus lodges a long, slender, and slightly curved tooth (figs. 9, 10, and 12, *to.*), the hard, pointed tip of which projects beyond its apex. The shaft of the tooth is convex towards, and closely applied to, the inner surface of the rounded outer side of the alveolus (fig. 11), exactly in line with the median suture. Its upper basal end projects some distance beyond the base of the alveolus, and curves upon itself in the direction of the axis of the lantern. A prominent longitudinal ridge or carina traverses the inner concave surface of the tooth from near its pointed tip to a point corresponding with the base of the alveolus. Here the substance of the tooth becomes soft and readily yields to the pressure of the fingers in the form of asbestos-like fibres. Here, too, growth of the tooth takes place. Five oblong intermediate plates, the rotulæ (Pl. I., figs. 8 and 12, *rot.*), rest upon the bases of the alveoli, in such a way as to touch the apposed lateral surfaces of every two, while five slender, curved rods, the radii (Pl. I., fig. 12; Pl. III., fig. 23, *rad.*), lie, one upon each of them. The peripheral ends of the radii are bifurcate, and project over the edge of the pyramid formed by the five alveoli. The alveoli are inter-

radial in position, the rotulæ and radii corresponding with the ambulacra.

Four sets of muscles and one set of ligaments (Pl. III., fig. 23) control the movements of the masticatory apparatus. The adductor muscles of the teeth are broad bands arranged as five pairs (Pl. III., fig. 23; Pl. V., fig. 37, *ad.m.t.*). The two muscles of a pair are attached below to the interambulacral apophyses of the perignathic girdle. Passing upwards they diverge slightly, and are inserted, above, along the outer edge of the arch-like base (Pl. I., fig. 10) of the corresponding alveolus. The contraction of these muscles draws the bases of the alveoli outwards and downwards, while their apices, with their teeth, move inwards towards the centre of the mouth, through which they tend to project. The opening muscles of the teeth (*op.m.t.*) also form five pairs, which run inwards and slightly downwards from the inner faces of the auriculæ to the halves of the alveoli nearest to them. When they contract the teeth are drawn apart, in the direction of the auriculæ, and the mouth is widely opened. The intermediate alveolar muscles run between the apposed lateral faces of the alveoli. Their contraction draws the latter close together, and probably assists in the reduction of the food in the pharynx. The muscles of the radii (*m.r.*), of which there are five, form a pentagonal ring which connects the five radii together; and, by their contraction, probably depress the whole apparatus in the direction of the mouth. A pair of ligaments (*lig.*) are attached to the forked peripheral end of each radius, and, diverging as they pass downwards, are attached to the interambulacral apophysis of the perignathic girdle on either side. The peritoneal membrane which lines the body cavity is continued over the lantern, and forms five projecting sacs, in which the soft bases of the alveolar

teeth lie. The included space forms part of the cœlom, and is the peripharyngeal sinus. It is, however, completely shut off from the general cœlomic cavity.

The pharynx is five-rayed (Pl. IV., fig. 31), and each ray is attached by a pair of bands of connective tissue to the inner edges of the lateral faces of the adjacent alveolus. The pharynx passes into the œsophagus (Pl. III., fig. 23; Pl. V., fig. 37, *œ.*), which ascends from the lantern to the apex of the test. Turning downwards again, the œsophagus passes into the first or inferior spiral of the intestine (Pl. V., fig. 37, *inf.s.*), the commencement of which is marked by a sac-like swelling, and a considerable increase in the diameter of the gut. The inferior spiral makes a complete circuit of the test, running in gracefully undulating folds through radius III. to IV., V., I., and II. into interradius 2. Here the intestine turns upon itself to form the superior spiral (*sup.s.*), which runs through radius II. to I., V., and IV. Thence, but with slightly reduced diameter, it turns again towards the apex of the test to form the rectum (Pl. III., fig. 23; Pl. V., fig. 37, *rec.*), which runs obliquely across interradius 3 to the anus, the opening of which is very small when compared with the diameter of the rectum. Mesenteric strands attach both spirals to the inner surface of the test, and separate from the cœlomic cavity a small space which surrounds the anal end of the rectum, and forms the perianal sinus. Near the point where the œsophagus passes into the inferior spiral, an accessory or co-lateral intestine, the siphon (Pl. V., fig. 37, *si.*), branches off from the intestine, along the inner (axial) side of which it runs to re-enter the main tube at or near the end of the spiral. Both coils of the intestine are extensively sacculated.

In a transverse section of the œsophagus (Pl. IV., fig. 32)

the following layers may be distinguished:—(1) an epithelium (*ep.*) composed of long fusiform cells; (2) a layer of connective tissue (*c.t.l.*) containing, in the inferior spiral, an extensive system of blood lacunæ; (3) a thin layer of muscular fibres (*m.f.l.*); (4) an outer and very delicate layer of connective tissue; (5) the ciliated epithelium of the cœlom (*e.b.c.*). A delicate cuticle (*cu.*) invests the epithelium of the gut, which is also ciliated. In the œsophagus and, to a much larger extent, in the inferior spiral, the epithelium contains numbers of gland cells (fig. 34, *gl.c.*). The relative thickness of the epithelial and connective tissue layers varies in different parts of the intestinal tract. The minute structure of the siphon is the same as that of the intestine. Its function has not been determined, but a suggestion has been made that it may subserve intestinal respiration.

The Echinus is probably wholly carnivorous; and the frequent occurrence, in the intestine, of fragments of the shells of barnacles and serpulid worms attests the destructive power of the alveolar teeth.

WATER-VASCULAR SYSTEM.

The water-vascular system consists of tubular canals, which communicate, on the one hand, with the exterior through the pores of the madreporite; and, on the other hand, with the cavities of the tube-feet and their ampullæ. The madreporite (Pl. I., fig. 1; Pl. III., fig. 24, *mad.*) is traversed by a large number of minute pores (*m.p.*), which converge towards and open into a cavity, the madreporic ampulla (*mad.amp.*), which lies beneath it. The external surface of the madreporite is covered by ectoderm cells like those which clothe the general surface of the test; but at the external openings of the pores the character of the cells suddenly changes, and the upper fourth of the

length of each pore is lined by ciliated columnar cells, which stain deeply. Lower down, the columnar cells gradually give place to others of rounded form, which are also ciliated. Some of the pores anastomose with neighbouring ones, but the majority take a nearly straight course from the outer to the inner surface of the madreporite.

The madreporic ampulla communicates through its lower or inner wall with a tubular canal, the madreporic tube or sand-canal (Pl. III., figs. 23 and 24, *w.t.*), lined with ciliated columnar epithelium. This, enclosed within the axial sinus of the cœlom (Pl. III., figs. 23 and 24, *ax.sin.*), runs directly to the base of the lantern, and opens into the circular water vessel (Pl. III., fig. 23, *c.w.v.*), which encircles the œsophagus at that point.

Five roughly pear-shaped and sacculated vesicular bodies, the Polian vesicles (fig. 23, *P.v.*), open interradially into the circular water vessel. From the latter, in each radius, there runs out a radial canal (fig. 23; Pl. V., fig. 37, *r.w.v.*) which, passing beneath the rotulæ, down the outer surface of the lantern, and through the arch-like auricula, traverses the whole length of the corresponding ambulacrum, on the inner surface of the test, to its apex, where it ends blindly in the pore of the radial plate (Pl. IV., fig. 30, *r.w.v.*). Before reaching the auriculæ, each radial canal gives off a pair of lateral branches to the corresponding pair of buccal tube-feet (Pl. I., fig. 7; Pl. IV., fig. 33, *t.f'*) which, unlike the tube-feet to be immediately described, have no ampullæ.

From the auricular archway upwards to their blind extremities the radial canals give off a large number of alternating lateral branches (Pl. III., fig. 23; Pl. IV., fig. 29, *l.b.w.v.*), which open into flattened, thin-walled vesicles, the ampullæ of the tube-feet (Pl. III., fig. 23;

Pl. IV., fig. 29; Pl. V., fig. 37, *am.t.f.*), which project, like the leaves of a book, into the interior of the test. Each ampulla communicates with the cavity of a tube-foot (*l.t.f.*) through two canals (Pl. IV., fig. 29, *c.t.f.*), which traverse a pair of pores of an ambulacral plate. The tube-feet are tubular organs which occur on the plates of the ambulacra only. They are exceedingly mobile, and can be extended far beyond the tips of the spines. Their free, imperforate ends take the form of circular sucker discs, by means of which the animal can attach itself with great firmness to the surface on which it rests.

Examination of a thin section of one of these organs (Pl. III., fig. 27) reveals the following structures:—(1) an external ciliated epithelium (*ect.*) continuous with that of the general surface of the body; (2) a delicate plexus of nerve fibres and ganglion cells; (3) a layer of connective tissue (*c.t.l.*) in which C-shaped calcareous spicules (Pl. I., fig. 5) occur; (4) a layer of longitudinally disposed muscular fibres (*m.f.l.*); (5) a ciliated epithelium lining the cavity of the organ (*ep.*). The terminal sucker is supported by an elegant, ring-like calcareous plate, composed of six or seven segments which, like the C-shaped spicules, lies embedded in the connective tissue layer. The sucker discs of the buccal tube-feet are, in like manner, supported by a ring-like plate, but in conformity with the shape of the discs, they are oval, and composed of four or five segments only. The epithelial cells which cover the external surface of the sucker discs are much longer than those of the tubular portion of the tube-feet, and are not ciliated.

The minute structure of the ampullæ is similar to that of the tube-feet. In a section there may be seen from without inwards:—(1) the ciliated epithelium lining the body cavity; (2) a layer of connective tissue, containing

minute calcareous corpuscles; (3) a layer of circular muscular fibres; (4) an inner ciliated epithelium continuous with that of the radial canal and the cavity of the tube-foot.

The fluid contained in the system of canals, now described, is said to be sea-water, with traces of albumen. It is of a pale yellow or reddish colour; and, in addition to amoeboid cells, corpuscles containing pigment are found floating in it. The question of the origin of this fluid has been much debated. The view which meets with general acceptance is, that the cilia borne by the epithelial cells which line the pores of the madreporite and madreporic tube induce a current of sea-water to flow from the exterior through the madreporite; but an exactly opposite view has been maintained. Though locomotion is the primary function of the tube-feet, there can be little doubt that they are also concerned in respiration. An Echinus always retracts its tube-feet when the supply of respiratory oxygen falls short in the water in which it is kept; but if the water be changed, the opposite effect immediately occurs, the tube-feet being extended to their fullest capacity, and moved about actively in all directions.

It has been suggested* that the water-vascular system is morphologically and ontogenetically a left nephridium (see account of its development on p. 320), and that the current induced by the cilia of the madreporic pores and water-tube can be shown by experiment to be outwards, and not inwards, as described above. This view has not met with general acceptance and a series of experiments conducted by Ludwig† confirmed the statements of most previous observers with regard to the inward direction of the current.

* Ann. and Mag. Nat. Hist. Vol. XX. (1887), pp. 321—6.

† Zool. Anzeig. XIII. (1890), pp. 377—9.

NERVOUS SYSTEM.

The nervous system consists of a ring of nerve fibres and ganglion cells, which encircles the pharynx (Pl. III., fig. 28, *pp.n.r.*) close to the mouth, and five radial trunks (Pl. III., fig. 28; Pl. IV., figs. 29 and 33, *r.n.*) which traverse the entire length of the ambulacra, upon the inner surface of the test, and in close relation with the radial canals of the water-vascular system. From the peripharyngeal ring, in the radii, nerves are given off to the oral integument (Pl. III., fig. 28, *n.ph.*) and the wall of the pharynx, in which they break up to form plexuses.

In traversing the ambulacra the radial trunks give off, at intervals which correspond with the lateral branches of the water-vascular canals, nerves which pass through the ambulacral pores (Pl. IV., fig. 29, *l.n.*), and are distributed to the tube-feet and the periphery of the test. In both cases the fibres become continuous with those of the sub-epithelial nerve plexus. In a sagittal section of the distal end of a radial trunk (Pl. IV., fig. 30, *r.n.*) this intercommunication of its fibres with those of the sub-epithelial plexus is specially obvious. In transverse section the peripharyngeal ring and radial trunks present the form of broad bands (figs. 26, 29, and 33). In ultimate structure they consist of ganglion cells, of which a well-marked layer lies upon the peripheral surface, *i.e.*, the surface nearest to the test, and nerve fibres, which run in a longitudinal direction, and amongst which a few ganglion cells are scattered.

In addition to the peripharyngeal nerve-ring and radial trunks, there are five lamellæ, consisting of ganglion cells and nerve fibres, which lie in close proximity to the nerve-ring at the points of origin of the radial trunks. From each lamella a pair of large nerves arise. These ascend

along the edges of the five alveoli, and are supposed to innervate their muscles. This has been described as the "deep oral nervous system," in contra-distinction to the well-known nerve-ring and radial trunks which constitute the superficial oral system.

No specialised sense organs, other than the sphæridia and the terminal tentacles of the water-vascular system appear to have been discovered in *Echinus esculentus*. The tube-feet are highly sensitive to external stimuli, and those of the allied species, *Echinus micro-tuberculatus*, have a tubercle-like thickening of the ectoderm close to the sucker disc, beneath which there is a ganglionic mass of nerve tissue.

VASCULAR AND CŒLOMIC SYSTEMS.

In addition to the radial canal of the water-vascular system, two other canals traverse the ambulacra, in close relation to the radial nerve trunks. One of these is the epineural canal (Pl. III., fig. 28; Pl. IV., figs. 29, 30, and 33, *r.ep.c.*). It runs along the peripheral face of the nerve trunk, between it and the test. At the apex of the latter it ends blindly, in close proximity to the terminal tentacle of the water-vascular canal (Pl. IV., fig. 30, *r.ep.c.*), and, at the opposite extremity, it thins out gradually as the mouth is approached, and does not open into the circular epineural canal (Pl. III., fig. 28, *c.ep.c.*) which surrounds the pharynx. In the Ophiuroidea the epineural canals have been found to arise by the growth of two lateral folds of the integument over the radial nerve trunks. The folds meet and unite and so form the canal-like space. It is probable that further research into the ontogeny of the Echinoidea will prove that their radial canals arise in a similar manner.

The second canal is the pseudhæmal (Pl. III., fig. 28; Pl. IV., figs. 29, 30, and 33, *r.p.h.c.*). This runs along the inner, axial face of the nerve trunk, and, like the epineural canal, ends blindly at the apex of the test. It also does not communicate with the corresponding circular pseudhæmal vessel (Pl. III., fig. 28, *c.p.h.c.*). The pseudhæmal canals contain a fluid similar to that found in the cœlom, and it is possible that their function may be the nourishment of the nerve trunks, with which they are so intimately associated. They give off lateral branches, which run parallel with those of the water-vascular canal and of the radial nerve.

Little is known concerning the ontogenetic history of the pseudhæmal system. The corresponding system in the Holothuroidea has a definite epithelial lining, which points to the conclusion that it is derived from the hydro-entero-cœl, and throws doubt upon the schizocœlomic origin which has been claimed for it in the starfishes.

The blood-vascular system of *Echinus* and its allies has been the subject of much discussion, and the descriptions published by Teuscher, Hoffmann, Ludwig, Hamann, Cuénot, Perrier, and Koehler, differ considerably in detail. There are undoubtedly two vessels, which run alongside the inferior coil of the intestine, in the mesentery which supports the latter. One—the ventral vessel (Pl. III., fig. 23, *v.v.*)—runs along the inner axial side of the intestine and is connected by numerous lacunæ with the dorsal vessel (Pl. V., fig. 37, *d.v.*), which runs on the outer side of the intestine. Both vessels have been described as opening into a circular vessel, which is said to surround the œsophagus in close proximity to, yet quite distinct from, the water-vascular ring-canal. The existence of such a separate circular vessel is, however, open to doubt; and this remark applies with greater force to the blood-vessels

which have been described as radiating from it, and traversing the ambulacra between the water-vascular and pseudhæmal canals. Such vessels are not evident in carefully prepared serial sections of the ambulacra of the present species.

In connection with the blood-vascular system, the central plexus or axial organ may be described. It is a fusiform body (Pl. III., figs. 24 and 25, *cen.pl.*), consisting of a network of connective tissue, which almost completely fills the cavity of the axial sinus (Pl. III., figs. 23, 24, and 25; Pl. V., fig. 37, *ax.sin.*), to the inner wall of which it is attached by connective strands. Its lower, oral end rests upon the circum-œsophageal vascular ring (fig. 23), and is said to open into the blood-vascular ring by those authors who maintain the existence of such a structure. Its upper apical end is attached to and perforates the septum which divides the axial sinus from the madreporic ampulla (Pl. III., fig. 24). The reticulum of connective tissue is densest at the periphery of the organ (Pl. III., fig. 25; Pl. IV., fig. 35). In the deeper cortical portion (fig. 36) the network is much more open, and its fibres more clearly defined. Numbers of nucleated cells of rounded form (fig. 35), from which lymph corpuscles are said to be derived, lie within the meshes of the reticulum. The central plexus has given rise to more discussion than any other structure found in the Echinoderm body; and the names "heart," "kidney," "plasti-dogenic organ," "lymph gland," indicate the functions which have been ascribed to it by various authors.

In addition to the peripharyngeal or lantern sinus and the axial sinus, the cœlom is further sub-divided by a circular membrane, which connects the anal end of the rectum with the surrounding body-wall, and encloses a small perianal sinus. Below this, another similar mem-

brane encloses a second and slightly larger periproctal sinus.

The fluid which fills the body cavity and sinuses has a peculiar musk-like odour, and is of a pale greyish red colour. It contains a small quantity of albuminoid matter, and has an alkaline reaction. Its specific gravity is the same as that of sea-water. Corpuscles of two kinds are found in it. One of these is a colourless amœboid cell, the finely granular protoplasm of which throws out long filiform and branched pseudopodia. The pseudopodia unite with those of other cells with which they come in contact. This is followed by coalescence of the cell bodies, and the process is repeated until large plasmodia are formed, in which an endosarc and ectosarc become differentiated. The second and rarer kind is a larger cell, also colourless, and containing a number of large, spherical refractive granules. The cœlomic fluid coagulates rapidly when drawn from the test, and a clot is formed consisting of a clear substance, allied to mucine, in which all the corpuscles are included.

REPRODUCTIVE SYSTEM.

The reproductive organs or gonads are five arborescent glands, suspended by mesenteric folds from the inner wall of the apical half of the test (Pl. V., fig. 37, *gon.*), and are very similar in position and appearance in the two sexes. They are interradiar, and open to the exterior through the pores of the basal plates of the apical system. Before reaching their respective pores, the five genital ducts perforate a ring-like cœlomic sinus which encircles the rectum. This is readily seen in young specimens in which the gonads are not ripe. The walls of the gonads are extensively sacculated, and form numerous follicles, on the inner surface of which the sexual cells are formed

When sexually mature the male gonads are of a milk-white or creamy hue, while the ovaries are yellowish or orange-brown in colour.

OUTLINE OF LIFE-HISTORY.

During the breeding season the spermatozoa and ova are discharged into the sea, where fertilisation of the ova takes place. Segmentation of the egg is total, though not quite regular, and results in the formation of a spherical blastula (Pl. V., fig. 38), consisting of a single layer of cells, enclosing a large segmentation cavity filled with fluid (*seg. cav.*). Each cell bears a single flagellum on its outer surface, by the vibration of which the blastula revolves.

Following immediately upon the completion of segmentation, a slight depression makes its appearance at one pole (Pl. V., fig. 39), and, at the same time, the cells forming the depression begin to bud actively. The resultant cells (*mes.c.*) are amoeboid; and, making their way all over the segmentation cavity or blastocœl, eventually form the muscular and connective tissue systems of the adult. The depression deepens, and forms the archenteron or primitive intestine of the larva (Pl. V., fig. 43, *arch.*). The blastula has now become a gastrula. The dorsal surface of the gastrula is convex; its ventral surface concave; and it is bilaterally symmetrical.

The blastopore (*blas.*) gradually moves forward on to the ventral surface, and the larva enters upon the "Pluteus" stage (fig. 42). At the same time, the first skeletal structures appear in the shape of two lateral calcareous spicules (fig. 42, *sk.r.*), which support the body of the larva and the posterior ventral arms (*p.ven.a.*), which begin, at this stage, to grow out from the ventral surface. The anterior blind end of the archenteric tube now develops, on each side, a small out-growth (fig. 42), which

curves round towards the posterior end of the larva. These are soon separated from the archenteron by a constriction (fig. 40), and then form a single horse-shoe shaped hydro-enterocœlic vesicle (*hy.ent.*). Concurrently with the formation of the vesicle, or immediately following it, the two limbs of the horse-shoe become separated by further constriction, and lie on the sides of the archenteron. The two vesicles again divide into anterior and posterior portions; and the anterior portion of that on the left ultimately opens to the exterior through a water pore, and gives origin to the water-vascular system of the adult. The remaining vesicles are enterocœlic, and ultimately form the lining of the body cavity. After the separation of the hydro-enterocœl vesicle, the blind end of the archenteron bends towards the ventral surface, in which, at the same time, a small invagination of the ectoderm takes place. The two eventually meet, and by the disappearance of their walls at the point of union, become continuous. The ventral invagination becomes the mouth, and the blastopore the anus of the pluteus. Three pairs of arms, in addition to the posterior ventral pair already mentioned, make their appearance and gradually increase in length as growth of the pluteus as a whole proceeds. The body becomes shorter, and its posterior end well rounded (Pl. V., fig. 41).

The metamorphosis of the pluteus into the young Echinoid has not yet been fully described in our species. A flask-shaped invagination of the ectoderm of the left side grows inwards towards the hydrocœl vesicle, to the exterior of which it is applied as the "Echinoid disc." Its floor thickens and becomes discoid, while from the hydrocœl five primary tentacles grow out, pushing before them the Echinoid disc, which is said to form the epithelium, and possibly the radial nerves, of the oral half of the

test of the young Echinus. The apical half of the test is said to be formed directly from the dorsal ectoderm of the pluteus. The four pairs of arms gradually disappear, and their skeletal rods are absorbed.

The young Echinus takes over the larval stomach and the enterocœlic and hydrocœlic vesicles, but the larval mouth and anus are succeeded by corresponding structures formed independently in the young urchin. The water pore, by which the original hydrocœlic vesicle opened to the exterior, becomes the madreporite. Pedicellariæ appear early, even before the close of the pluteus stage. Later on certain of the plates of the test and parts of the masticatory apparatus appear as minute lattice-like plates. Advanced plutei of *Echinus esculentus* have been taken in the tow-net, in Port Erin Bay, early in June, and the young Echini probably take to their adult mode of life towards the end of that month or the beginning of July.

EXPLANATION OF THE PLATES.

Reference Letters.

<i>ad.m.t.</i> adductor muscles.	<i>cu.</i> cuticle.
<i>am.t.f.</i> ampullæ.	<i>c.w.v.</i> circular water vessel.
<i>an.</i> anus.	<i>d.v.</i> dorsal vessel.
<i>ap.</i> aperture of gland.	<i>e.b.c.</i> epithelium of body cavity.
<i>arch.</i> archenteron.	<i>ect.</i> ectoderm.
<i>au.</i> auricula.	<i>ep.</i> epithelium of intestine.
<i>ax.sin.</i> axial sinus.	<i>ex.g.</i> external gills.
<i>bas.</i> basal plate.	<i>gl.c.</i> gland cells.
<i>blas.</i> blastopore.	<i>gl.s.</i> glandular sac.
<i>cen.pl.</i> central plexus.	<i>gon.</i> gonad.
<i>c.ep.c.</i> epineural canal.	<i>gp.</i> genital pore.
<i>c.p.h.c.</i> circ. pseudhæmal canal.	<i>hy.ent.</i> hydro-enterocœl.
<i>c.t.f.</i> canals of tube feet.	<i>inf.s.</i> inferior spiral of intestine.
<i>c.t.l.</i> connective tissue.	<i>int.alv.m.</i> inter-alveolar mus.

- int.pl.* interambulacral plates. *p.ven.a.* posterior ventral arms.
l.b.w.v. lat. branch water vessel. *rad.* radii.
lig. ligaments. *rad.pl.* radial plates.
l.n. lateral nerve. *rad.ep.c.* radial epineural canal.
l.t.f. cavity of tube-foot. *rec.* rectum.
mad. madreporite. *r.n.* radial nerve.
mad.amp. ampulla of ditto. *r.p.h.c.* rad. pseudhæmal canal.
mes.c. mesenchyme cells. *rot.* rotulæ.
m.f.l. muscular layer. *r.w.v.* radial water vessel.
m.g. muscular coat of gland. *seg.cav.* segmentation cavity.
mo. mouth. *si.* siphon.
m.p. pores of madreporite. *sk.r.* skeletal rods.
m.r. muscles of radii. *sph.* calcareous sphere of
nf. nerve fibres. sphæridium.
n.ph. nerve to pharynx. *sup.s.* sup. intestinal spiral.
æ. œsophagus. *sut.* suture.
op.m.t. opening muscles. *t.* test.
per. peristome. *to.* teeth.
ph. pharynx. *t.f.* tube-foot.
po. ambulacral pores. *t.f'.* buccal tube-feet.
pp. periproct. *t.t.* terminal tentacle.
p.pl. peristomial plate. *t.c.* tactile cushion.
pp.n.r. peripharyngeal nerve. *v.v.* ventral vessel.
P.v. polian vesicles. *w.t.* madreporic tube.

PLATE I.

- Fig. 1. The apical system of plates. $\times 4$.
 Fig. 2. One of the ten peristomial plates. $\times 10$.
 Fig. 3. Two plates from an ambulacrum. $\times 4$.
 Fig. 4. A single plate from an interambulacrum. $\times 4$.
 Fig. 5. A bihamate spicule from the connective tissue
 layer of a tube-foot. $\times 150$.
 Fig. 6. A cribriform plate from the connective tissue
 layer of an external gill. $\times 80$.
 Fig. 7. The mouth, peristome, and external gills. $\times 2$.

- Fig. 8. A rotula. Nat. size.
 Fig. 9. An alveolus, viewed from lateral faces. Nat. size.
 Fig. 10. An alveolus, viewed from outer surface. Nat. size.
 Fig. 11. A transverse section of an alveolus, to show the position of the tooth. Nat. size.
 Fig. 12. "Aristotle's lantern," after removal of two of the alveoli to show the pharynx. Nat. size.

PLATE II.

- Fig. 13. A tridactyle pedicellaria. $\times 20$.
 Fig. 14. A gemmiform or glandular pedicellaria. $\times 20$.
 Fig. 15. An ophiocephalous pedicellaria. $\times 20$.
 Fig. 16. Longitudinal section of the decalcified head of a small tridactyle pedicellaria. $\times 175$.
 Fig. 17. One of the blades of the head of a trifoliate pedicellaria. $\times 130$.
 Fig. 18. Vertical section of decalcified sphæridium. $\times 175$.
 Fig. 19. Head of a small ophiocephalous pedicellaria from the peristome. $\times 60$.
 Fig. 20. A small portion of the periphery of a decalcified spine. $\times 350$.
 Fig. 21. Longitudinal section of the decalcified head of a glandular pedicellaria. $\times 175$.
 Fig. 22. Transverse section of the decalcified head of a glandular pedicellaria. $\times 80$.

PLATE III.

- Fig. 23. Dissection to show the muscles and ligaments of the masticatory apparatus, and the principal canals of the water-vascular system. $\times 2$.
 Fig. 24. Part of a sagittal section of the apical system, showing the pores of the madreporite, madreporic ampulla, water-tube, axial sinus, and central plexus. Slightly diagrammatic. $\times 20$.

- Fig. 25. Transverse section of axial sinus, central plexus, and water-tube, seen under simple lens. $\times 8$.
 Fig. 26. Transverse section of a radial nerve. $\times 80$.
 Fig. 27. Longitudinal section of the distal end of a tube-foot. $\times 180$.
 Fig. 28. Part of a sagittal section of "Aristotle's lantern" and the adjacent parts. $\times 55$.

PLATE IV.

- Fig. 29. Diagram of a transverse section of an ambulacrum, showing the relation of the radial canal of the water-vascular system to the tube-feet and their ampullæ. Magnified.
 Fig. 30. Sagittal section of distal end of a radial nerve, showing the intercommunication of its fibres with the basal ends of ectoderm cells. $\times 180$.
 Fig. 31. Transverse section of the pharynx. $\times 20$.
 Fig. 32. Part of transverse section of œsophagus. $\times 180$.
 Fig. 33. Part of sagittal section of peristome, showing a lateral branch of a radial canal opening directly into the cavity of a buccal tube-foot. $\times 55$.
 Fig. 34. Part of transverse section of inferior coil of intestine, showing numerous gland cells. $\times 180$.
 Fig. 35. Part of the periphery of transverse section of central plexus, showing the densely packed nuclei of connective tissue and the rounded cells from which lymph corpuscles are said to be derived. $\times 400$.
 Fig. 35. Part of cortex of transverse section of central plexus, showing the loose meshwork of connective tissue. $\times 400$.

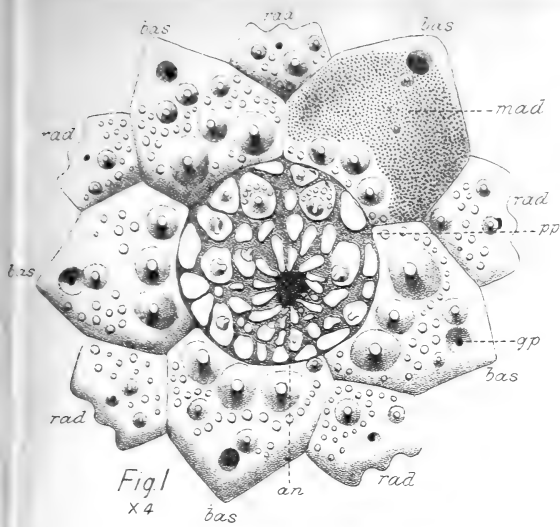


Fig 1
x 4

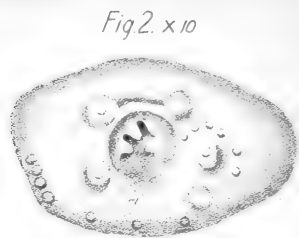


Fig 2. x 10

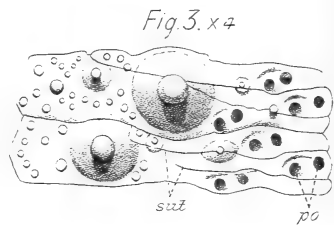


Fig 3. x 4

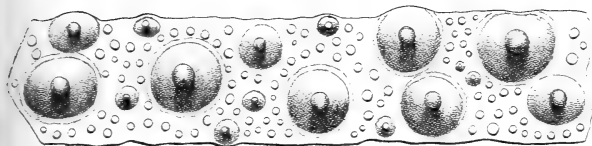


Fig 4
x 4

Fig 5. x 150



Fig 6. x 80

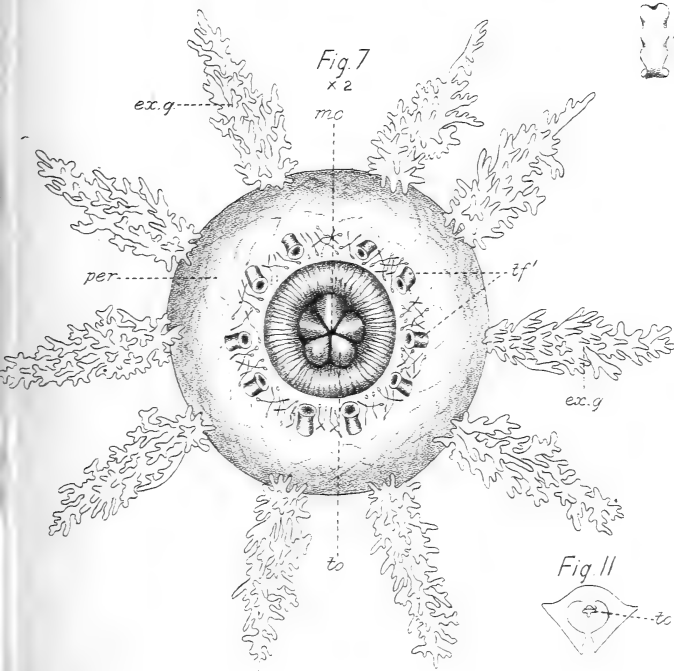
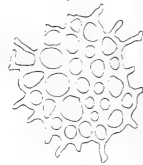


Fig 7
x 2



Fig 8



Fig 9



Fig 10

Fig 12

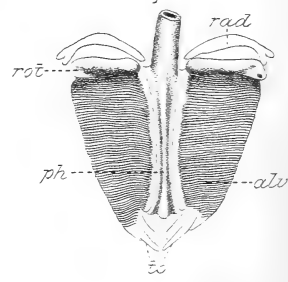


Fig 11



H.C.C. del.

S.B. lith.

ECHINUS.



Fig.13.x20



Fig.14.x20

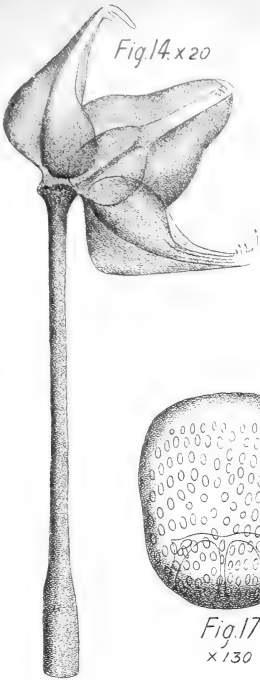


Fig.15.x20



Fig.16
x175

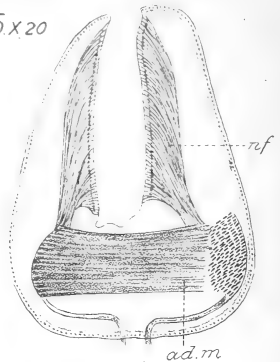


Fig.17
x130

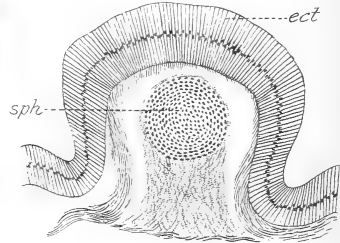
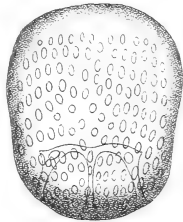


Fig.18
x175

ad. m.

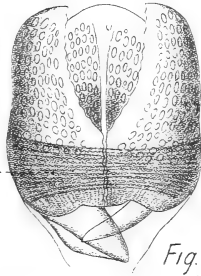
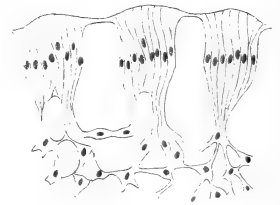


Fig.19
x60

Fig.20.x350



ap

Fig.21
x175

ap

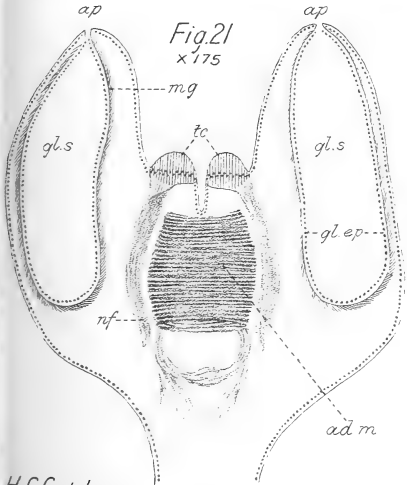
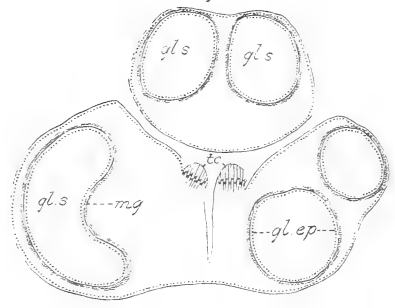


Fig.22.x80



H.C.C.del

S.B.lith.



Fig. 23. x 2

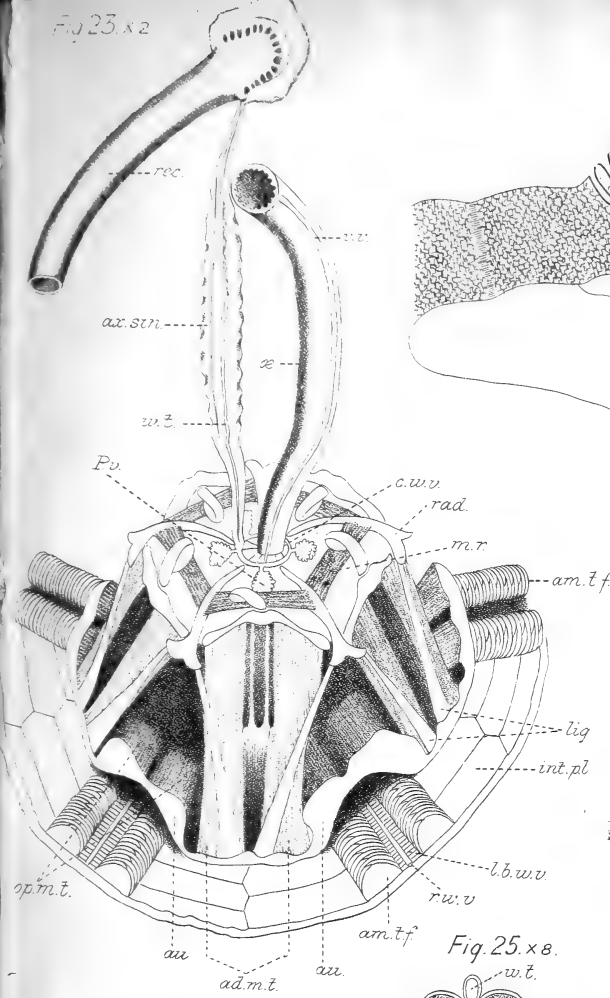


Fig. 24. x 20

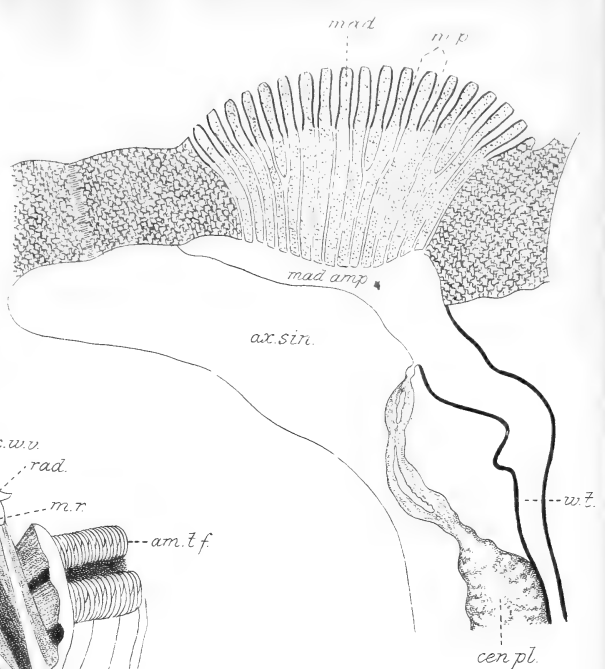


Fig. 26. x 80



Fig. 25. x 8

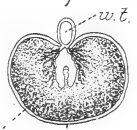


Fig. 28. x 55

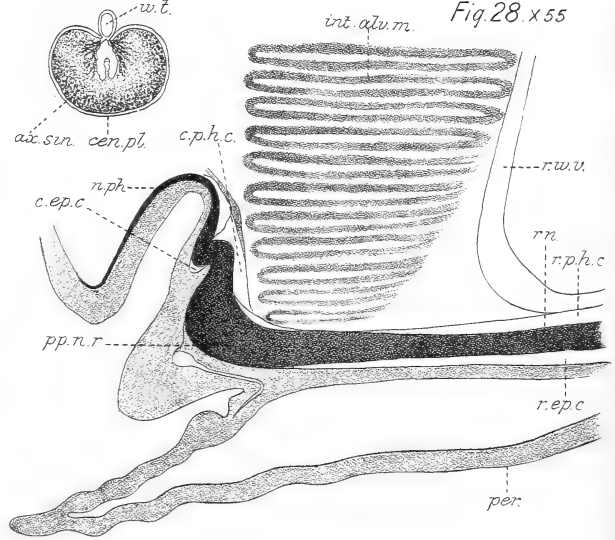
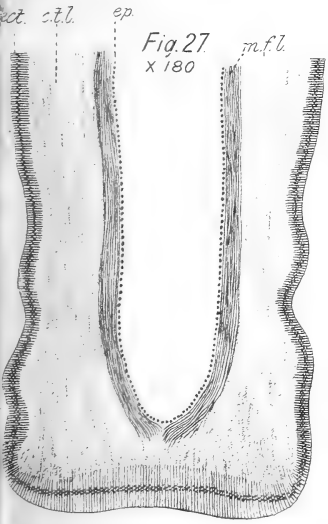


Fig. 27. x 180





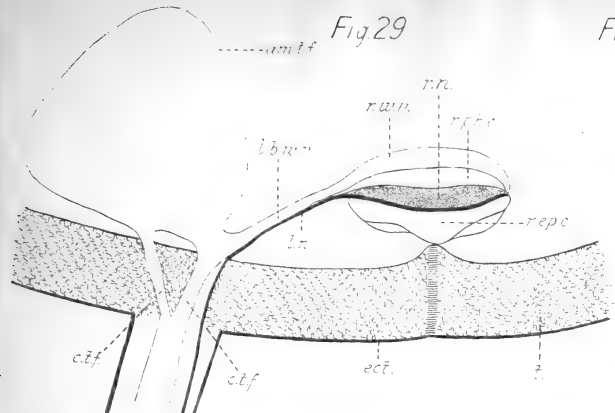


Fig. 29

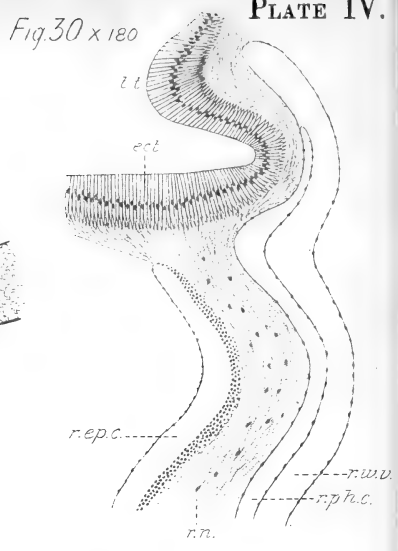


Fig. 30 x 180

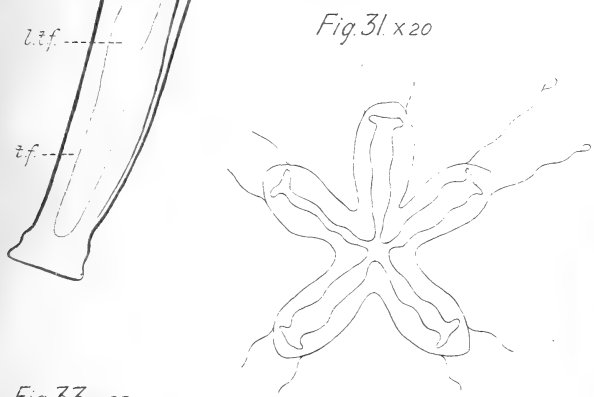


Fig. 31 x 20

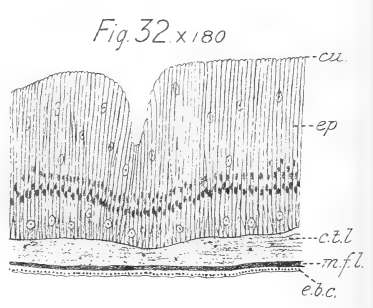


Fig. 32 x 180

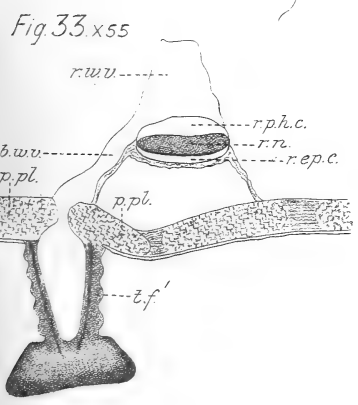


Fig. 33 x 55

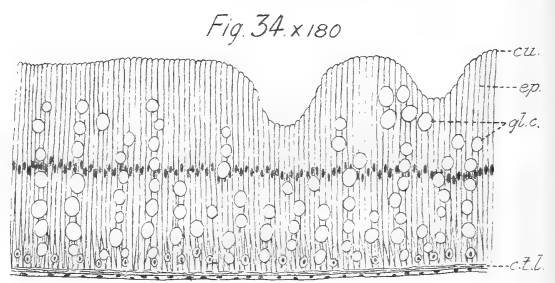


Fig. 34 x 180

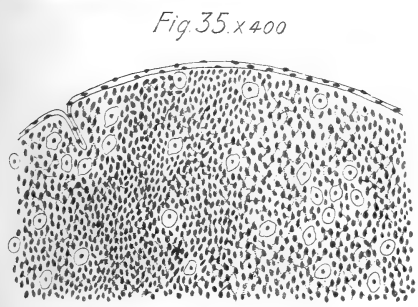


Fig. 35 x 400

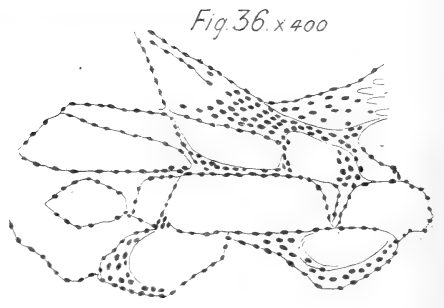


Fig. 36 x 400



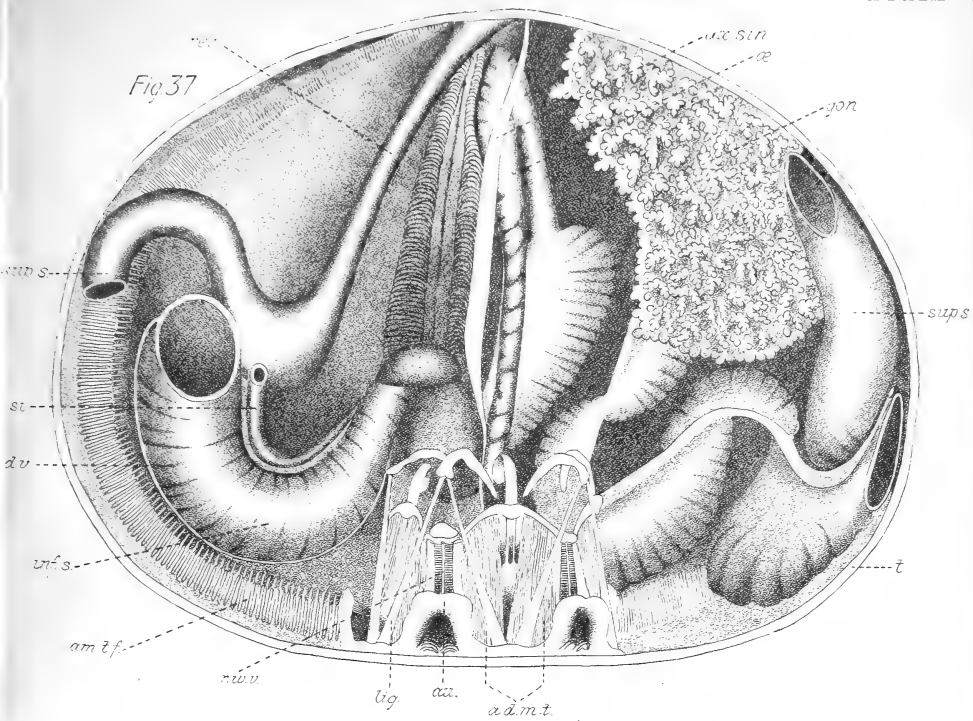


Fig. 38. x 210

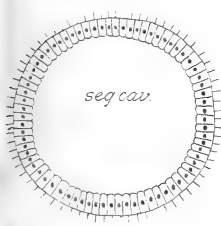
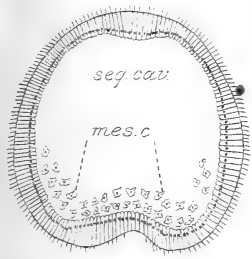


Fig. 39. x 210



H.C.C. del.

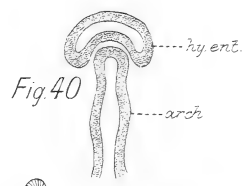


Fig. 42. x 170

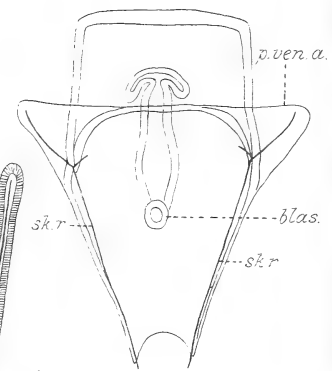


Fig. 41 x 100

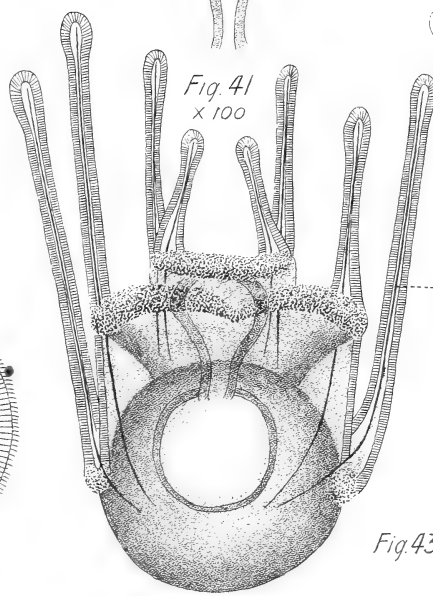
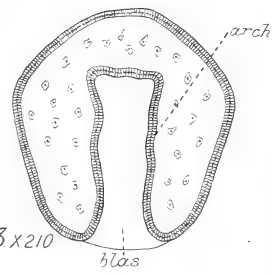


Fig. 43 x 210



S.B. lith.

ECHINUS.



PLATE V.

- Fig. 37. View of the interior of the test of *Echinus esculentus*. The three ambulacra shown are those forming the trivium. One gonad only is shown *in situ*. Nat. size.
- Fig. 38. A blastula of *Echinus*, in optical section. $\times 210$.
- Fig. 39. A blastula passing into the gastrula stage, showing the amœboid mesenchyme cells. $\times 210$.
- Fig. 40. Diagram showing the separation of the hydro-enterocœl from the archenteron.
- Fig. 41. A fully-developed but not full-grown pluteus of *Echinus*. $\times 100$.
- Fig. 42. A pluteus, two days old, showing the beginning of the formation of the hydro-enterocœl. $\times 170$
- Fig. 43. A fully-formed gastrula, passing into the pluteus stage. $\times 210$.

L.M.B.C. MEMOIRS.

No. IV. CODIUM.

BY

R. J. HARVEY GIBSON, M.A., F.L.S., and HELEN P. AULD, B.Sc.

INTRODUCTION.

AMONG the heterogeneous collection of Algæ, marine and fresh-water, known to Botanists as Chlorophyceæ, none, perhaps, are more interesting from the morphological point of view than the Siphoneæ. The interest attaching to them centres in the fact that the vegetative thallus, though not infrequently of immense size and complicated structure, is, in reality, produced by the extension, branching and modification of a single "cell" or cœno-cyte, possessed of an indefinite number of nuclei. In such forms as *Valonia*, the primitive spherical cell form is retained; in *Vaucheria*, the thallus becomes filamentous and sparingly branched; in *Caulerpa*, *Bryopsis*, &c., the branching is more extensive and symmetrical. In other types, again, the thallus consists of an aggregation of hyphæ, held together by a deposition of calcium carbonate, e.g., *Halimeda*, &c., by holdfasts of diverse form, e.g., *Udotea*, *Struvea*, &c., or by intimate interweaving of the filaments themselves, a mode of union illustrated by the subject of the present Memoir, viz., *Codium*.

Since the L.M.B.C. Memoirs are primarily intended for the use of "students of Biology in our laboratories and in marine stations," or "working privately at natural history," it may be advisable to summarise briefly the main features of the British marine Siphoneæ, and more especially the Codiaceæ, at the same time indicating the general distribution of the species on our shores.

The British representatives of the Siphoneæ include members of five different orders, viz.: Bryopsidaceæ, Derbesiaceæ, Vaucheriaceæ, Valoniaceæ, and Codiaceæ. According to Holmes and Batters (A Revised List of the British Marine Algæ, *Ann. of Botany*, V., 1890) four of these orders are represented in our flora by one genus apiece—in each case by the genus that gives the name to the order. In regard to the fifth, the Valoniaceæ, it may be noted that the genus inhabiting British seas, viz., *Halicystis*, had not been discovered at the date of the publication of Holmes' and Batters' paper.

I. BRYOPSIDACEÆ.

The thallus in this order is freely branched in a pinnate manner and anchored to the substratum by rhizoids which are extensions of the base of the chief axis. The branching of the thallus may be bi- or tri-pinnate. Multiplication is effected by the conjugation of dissimilar gametes. The female gametes are large and green, the male are small and brownish yellow. Both are provided with two cilia. The actual fusion of the gametes has not yet been observed. No other method of propagation is known in the order.

The Bryopsidaceæ include only one genus, *Bryopsis*, with about 25 species, chiefly inhabitants of warm seas. In British seas two species occur, *B. hypnoides*, Lamx., an inhabitant of the English Channel, and *B. plumosa*, C. Ag.,

which occurs in the same area but on the coasts of the Irish Sea also. *B. hypnoides* is recorded from the Isle of Man and Puffin Island, Anglesea, but requires confirmation; *B. plumosa* is fairly common in rock pools in the L.M.B.C. area.

II. DERBESIACEÆ.

This order also includes only one genus, *Derbesia*, with about 8 species, according to Wille (Engler and Prantl, *Pflanzen-familien*). The thallus is simple, irregularly or dichotomously branched, and produces spherical swarm-spores in lateral zoosporangia. Each zoospore is provided with a cirlet of cilia, surrounding the bluntly pointed hyaline apex.

Derbesia tenuissima, Crn., is recorded from the English Channel, but it has not as yet been discovered in the L.M.B.C. area.

III. VAUCHERIACEÆ.

This order also is represented by only one genus, *Vaucheria*, and embraces about 25 species, which are inhabitants of fresh or brackish water. Whilst vegetatively not unlike *Derbesia*, *Vaucheria* differs markedly in its methods of reproduction from the rest of the Siphonæ. In addition to considerable powers of vegetative multiplication, solitary zoospores (zoocœnocytes) are developed in sporangia formed by the abstriction of the terminal portions of vegetative branches. Sexual organs in the form of ovoid oogonia and filamentous antheridia also occur as lateral branches of the filamentous thallus. Fertilisation of the solitary ovum takes place within the oogonium, the oosperm developing into a new *Vaucheria* filament after a period of hibernation.

Five species, with several varieties, are found on British

coasts, but only two of these, *V. dichotoma*, Lyngb., var. *marina*, C. Ag., and *V. thuretii*, Woron., have been definitely identified in the L.M.B.C. area.

IV. VALONIACEÆ.

The thallus in this order retains its primitive cellular form or is branched, but shows no differentiation into axis and appendages. The sporangia are formed directly from portions of the vegetative thallus.

One genus only occurs in the British Algal Flora, viz., *Halicystis*, included by Wille (*loc. cit.*) under *Valonia*. *H. ovalis* was first discovered by Murray and Schmitz in Loch Goil, in the Clyde Sea Area, in 1892, but later it was found by Robertson at Lamlash, Arran (vide *Phycological Memoirs*, Pt. II., and *Journal of Bot.*, vol. XXXII., p. 345).

V. CODIACEÆ.

The Codiaceæ include 8 genera, viz.: *Chlorodesmis*, *Penicillus*, *Aurainvillea*, *Rhizocephalis*, *Callipsygma*, *Udotea*, *Halimeda*, and *Codium*. The last named alone occurs in English waters.

The thallus of the Codiaceæ is of varied form and organisation; some genera, e.g., *Halimeda*, being incrustated with calcium carbonate. The filaments of which the thallus is composed are profusely branched, and the branches are closely interwoven and bound together in such a manner as to form almost a definite tissue. Generally speaking, the filaments so woven together form a medullary region from which arise short swollen branches, standing at right angles to the long axis of the thallus, and forming a superficial limiting layer, the so-called "palisade layer" or "tissue." From the sides of these "palisade cells" arise the sporangia or

gametangia, from which are derived swarmspores or gametes.

Three species of *Codium* (out of fifteen) occur in British seas, but only one, *C. tomentosum*, occurs in the L.M.B.C. district.

CODIUM.

The genus *Codium* was first established by Stackhouse (*Ner. Brit.*, 1795—1801), to receive the type previously known as *Fucus tomentosus*. This name the same authority altered to *Lamarkea* in the second edition of his work, and included under it two species *C. tomentosum* and the plant now known as *C. bursa*. Lamouroux, in 1813, proposed the name *Spongodium* for the genus, whilst, later still, Cabrera re-christened these and other species by placing them in the newly constituted genus *Agardhia*. C. Agardh reverted to the name suggested by Stackhouse, and, at the same time, re-defined the genus. Decaisne subsequently sub-divided the then known species into two genera, one represented by *Codium tomentosum*, for which he retained the name of *Codium*, the other represented by *Codium bursa*, to which he gave the name of *Spongodium*.

An elaborate and authoritative account of the genus was, in 1885, published by the great Swedish Algologist, J. A. Agardh (*Till Algernes Systematik, Lunds Univ. Årsskr.*, XXIII.). In this monograph he includes all previously known species under the single generic heading of *Codium*, sub-dividing them, however, into tribes, which are, on the whole, co-extensive with the genera established by preceding authors.

The first tribe established by Agardh is that represented by *Codium adhærens*, Cabr., where the thallus is firmly fixed to the substratum in the form of a dark green, gela-

tinous expansion, with marginal lobes. This type naturally leads up to that of *Codium bursa*, Turn., where the thallus is globular, but fixed to the substratum by an extended base, the centre of the mass being filled with a loose network of filaments. The third series is represented by the species dealt with in the present Memoir, viz., *Codium tomentosum*, Stackh. In this series the thallus is cylindrical and elongated, and branched more or less dichotomously. Finally, Agardh establishes a series based on the species *Codium elongatum*, C. Ag., where the branches are flabellate.

The majority of the species of *Codium* are included in the third series, and these are by Agardh sub-divided again into two sections, dependent on the form of the lateral branches of the hyphæ, which form the superficial palisade layer. These lateral branches, named "utricles" by Agardh, are, according to him, either (*a*) smooth and rounded at their apices, or (*b*) furnished with an apical umbo or point. Under the former Agardh includes *C. tomentosum*. A careful examination of the palisade layer of that species will show, however, that this distinction cannot be rigidly maintained, for some of the palisade processes are smooth, whilst others are distinctly mucronate (see Pl. I., fig. 3).

Enough has now been said to indicate the taxonomic position of the species under consideration, and to define its general relationship to other Chlorophycæ.

DISTRIBUTION.

Codium tomentosum, the oldest known species of the genus, is widely distributed in the marine waters of the globe. If we accept Agardh's view, the species is a native of the shores of the Atlantic Ocean. On the west it occurs especially on the shores of Florida and the Antilles,

and on the east from the British Islands to the Cape of Good Hope. It is also found on the shores of the Mediterranean and Adriatic. Harvey (*Ner. Bor. Amer.*, III., p. 29, and *Phyc. Brit.*, vol. IV.), however, considers it to have 'a much wider range, by including under the species forms which are by other authors, and amongst these Agardh, ranked as distinct species. If we accept Harvey's view, then its distribution would be "all the shores of Europe, both Mediterranean and Atlantic. Dispersed also throughout the temperate and torrid portions of the Atlantic, Pacific, and Indian Oceans. New Holland and Tasmania. Auckland Islands."

Locally, so far as we have been able to find out, *Codium tomentosum* has been recorded from one situation only, namely, the south end of the Isle of Man. It occurs in shallow rock pools at or near low water mark, at Port Erin and at Fleswick Bay. From these regions our material was obtained fresh, and kept growing in salt-water tanks in the Laboratory. The plants are perennials, and fruit freely (at all events, in these localities) in winter. The time for fruiting is generally given as November. Plants sent to us in February had abundant fruit. We have not as yet had the opportunity of examining material collected at any other period of the year. Most of the sporangia had shed their contents by March.

GENERAL MORPHOLOGY.

Plants of *Codium tomentosum* most commonly grow in more or less dense clusters, arising from a basal expansion which is intimately connected with and attached to the substratum, rock, sand, or broken shell débris (Pl. I., fig. 1). The erect shoots are branched and cylindrical. The branching is usually dichotomous but occasionally monopodial. The branches vary in thickness, but in a well

grown plant average from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in diameter, narrower at the base and swelling out somewhat at the apex. The apices of the branches are obtuse and much darker in colour than the rest of the plant. Occasionally the fronds are somewhat compressed. In length they vary greatly. We have found, after examination of a large number, that a well grown plant (in this district) is on an average from 8 to 10 inches long, but Harvey speaks of them as sometimes reaching a length of 2 feet. The plant he figures, however (*Phyc. Brit.*, Pl. XCIII.), is under 8 inches in length, so that our plants may be taken as of normal size for the British Islands.

In colour *Codium tomentosum* is a rich dark green, intensely so near the apices of the branches—so dark, indeed, as to appear almost black. This will be found to be due to, first, the closer packing of the superficial palisade "cells" in these localities, and secondly, to the aggregation of the chloroplastids in the apices of the palisade "cells" themselves. The green is not so intense nearer the base. In substance the plant, when fresh, is fairly firm and rigid, and, externally, soft and slippery to the touch; but after preservation in alcohol it becomes soft and flaccid.

ANATOMY.

A. VEGETATIVE ORGANS.

The thallus consists essentially of densely woven branched hyphæ, forming a central core or medulla, from which arise very numerous short and thick branches, standing at right angles to the long axis of the branch and closely packed so as to form a velvety pile covering the entire surface.

The plant is attached to the substratum, as already stated, by numerous rhizoids. The rhizoids are branched

and contain a few chloroplasts and a delicate protoplasmic lining. They do not, indeed, differ from the general hyphæ, of which the main mass of the plant is composed. Each has a definite and fairly thick wall, and several nuclei in the peripheral lining of protoplasm. The rhizoidal, as well as the medullary hyphæ, are sub-divided at intervals by the formation of annular thickenings on the inside of the walls. The annulus gradually increases until the lumen is completely occluded. Such occlusion is figured at fig. 2, Pl. I.; figs. 10 and 14, Pl. II.; figs. 17, 18, and 19, Pl. III.

The chloroplasts in the plant generally are very minute and extremely numerous, and usually associated in strings or clusters, especially in the lateral palisade branches.

The nuclei, described first by Arcangeli (*Sul alcune Alge del gruppo delle Celoblastee, Nuova gior. bot.*, VI.), but not known to him as nuclei, have been the subject of investigation by Schmitz (*Sitz. d. natur. Gesell. zu Halle*, 1878) and Berthold (*Zur Kenntnis der Siphonien und Bangiaceen, Mitt. Zool. Stat. Neapel*, 1880). We have not ourselves followed the division of the nuclei, and so incorporate a brief abstract of Berthold's observations.

Berthold studied the division of the nuclei in the palisade "cells" where, in the basal region, owing to the small number of chloroplasts, they can be easily made out. He found them to be much flattened, oval or elliptical in outline, and sometimes pointed at one end. Each contains two or three nucleoli. The nuclei are usually about 15μ in length and 6μ broad, and each possesses a clearly defined nuclear membrane. Berthold was unable to study the very earliest stages in the division, but the phenomena observed from an early stage to the end of the division occupied from 3 to 4 hours. During the entire

period the nucleus remained clearly demarcated from the surrounding protoplasm. The nucleus is at first spindle shaped, a form which it retains for as much as half the period of division. The only alterations visible are at the apices of the spindle, which are at times blunter, at other times more pointed. Presently the spindle becomes flatter and shorter, the apices swell, and the central region contracts slightly. The nucleus has then a dumb-bell form. Later on the median part begins to swell, whilst the lateral parts adjoining the new nuclei become reduced to fine threads. Finally, the connection is broken in the neighbourhood of one of the new nuclei, but the connecting region is not absorbed into the other nucleus, as might be expected. On the other hand, a further separation between the second nucleus and the median connecting band takes place, and the intermediate region is thrown off and finally disappears. In the spindle stage, Berthold made out clearly filaments passing through the mass, having the nucleoli between them, and also certain granules which he considers as the equivalent of a nuclear plate. When the spindle elongates and the poles swell, the filaments thicken, and their substance is gradually transferred into the swollen ends. Berthold was unable to observe any movement in the surrounding plasma during division. (See also Zimmermann, *Die Morph. u. Phys. des pflanzlichen Zellkernes*. Jena. 1896.)

The rhizoids are continuous with the medullary region of the plant, which is composed of intimately interwoven branched filaments, forming a "tissue," not unlike a fungus mycelium. Numerous partitions, of the nature already described, occur in the course of the hyphæ, dividing the filaments up into multi-nucleate pieces, comparable to the segments of a *Cladophora* filament.

As the hyphæ become erect they proceed to give off

outwardly the palisade branches. These branches are several times the breadth of the hypha from which they arise. Each has a narrow base, its cavity sometimes separated from the hypha by a partition. More commonly the partition occurs on the hypha itself just before the palisade process is given off. The palisade "cell" rapidly thickens, and finally ends in a swollen rounded head (Pl. I., fig. 3), or more commonly, retains a uniform diameter for the upper third of its length, and ends in a bluntly rounded manner. The apex is in many cases quite smooth, but in other cases is distinctly mucronate. The wall of the cell at the apex is much thicker than elsewhere, especially so at the extreme tip. The palisade cell contains protoplasm distributed in a thin layer over the wall, with fine strands traversing the cavity. Towards the apex, however, the protoplasm is more abundant, and finally becomes aggregated in a non-vacuolated mass just at the apex itself. The chloroplasts, which are very numerous, are collected into a dense layer or mass, just at the apex, but occur also scattered in rows and clusters in the peripheral protoplasmic layer.

On teasing out a portion of a very young plant, one is able to see the relationship of the medullary hypha and the lateral processes more clearly. Figure 11, Pl. II., shows the terminal portion of a superficial medullary hypha, which has given off a lateral "palisade cell," now nearly mature, and which is forming two lateral processes acropetally, destined to become "palisade cells." It will be observed that the thickenings or septa are formed very early, and behind the point of origin of each process. Figures 10 and 14 show two septa in an older filament. The wall is double, and the septum is seen to be due to secondary deposit on the inner layer. For a long time protoplasmic continuity is maintained; indeed, it was

only in very old septa that we were unable to demonstrate the presence of stainable substance in the channel. Finally the lumen becomes completely obliterated.

B. REPRODUCTIVE ORGANS.

The reproductive organs of *Codium* have been the subject of investigation by several algologists.

Thuret (Recherches sur les zoospores des Algues, *Ann. Sc. Nat., 3e. Sér., Bot. XIV.*) showed that oval sporangia were formed from the upper parts of the swollen palisade "cells," each giving rise to biciliate swarmspores which, he affirmed, developed directly into new basal filaments.

Derbes and Solier (Mémoire sur quelques points de la physiologie des Algues, *Súpl. des Comp. Rend., 1856*) describe the formation of the sporangia and state that they become separated from the parent filament by a partition. The internal green mass resolves itself into zoospores which escape *en masse*, afterwards separating from each other, swimming actively apart. The authors were unable to determine the cilia, nor did they follow out the subsequent history of the zoospore. Schmitz (*loc. cit.*) added some notes on the nuclei of the zoospores.

In 1880 Berthold confirmed the occurrence of biciliate zoospores, but did not succeed in getting them to germinate. On the other hand, he affirms the existence of minute yellow biciliate swarmspores formed in quite similar sporangia, and he states that he succeeded in obtaining young plants only when both kinds of fructification were present.

Lastly, Went (Les modes de Reproduction du *Codium tomentosum*, *Vergad. der Ned. Bot. Vereen., 1889*) re-investigated the question and added new facts. He confirms Berthold on the question of the existence of large green zoospores and small yellow ones, but he states that, con-

trary to Berthold's observations, both kinds of sporangium occur on the same plant. He further states that he obtained young plants from the mega-zoospores alone.

Perhaps the most interesting point in Went's paper is his discovery of the fact that the sporangium may, instead of developing zoospores, germinate itself directly into a new filament, branching even whilst still attached to the parent "palisade cell." Went terms these "abnormal sporangia," and suggests the possibility of their being galls due to the presence and stimulating action of Rotifera, just as the Rotifer *Notommata* produces galls in *Vaucheria*. He admits, however, that he saw no evidence for the presence of any parasite.

Turning now to our own observations, we find that the sporangia are produced plentifully during the winter months, and are in the form of much elongated ovate bodies arising from the sides of the upper half of the "palisade cells" (Pl. III., figs. 15, 17, 18; Pl. II., fig. 5). Usually one sporangium is borne on each "palisade cell," but there may be a succession from the same cell, as is evidenced by the existence of scars indicating the points of attachment of older sporangia (Pl. II., fig. 5, and Pl. III., fig. 18). In other cases two or even three sporangia may occur together (Pl. II., fig. 5, and Pl. III., fig. 17). Each sporangium as it ripens becomes separated from the parent palisade process by an annular septum similar to those found in the vegetative part of the thallus. The wall of the sporangium is distinctly two layered, the outer layer being thin and well defined, the inner somewhat thicker and capable of swelling considerably. For the most part the two layers are in close approximation, but at the base and also at the apex they separate when the sporangium becomes mature. In fig. 15, Pl. III., a ripe sporangium is illustrated, where it will be seen that the inner wall is

distinctly separated from the outer at the base, leaving a small chamber between the plug-like septum and itself (compare fig. 20, Pl. III.). Similarly, at the apex of the sporangium, a like chamber is formed, and the inner wall itself, as shown in fig. 16, swells and exhibits very definite lamellation. The occurrence of these cavities at the base and apex of the sporangium was obviously noted both by Derbes and Solier and by Harvey, for their figures of the sporangium illustrate, though somewhat roughly, the peculiarity to which we draw attention. The sporangial cavity is from half to three quarters full of a dark green mass which, on careful focussing, is seen to be composed of spherical bodies, each crammed with chloroplasts.

Notwithstanding the fact that we examined hundreds of sporangia for long periods, and extending over three months, only once were we so fortunate as to see the zoospores escape. As described by Derbes and Solier, they escaped *en masse*, the apex of the sporangium rupturing suddenly, probably owing to pressure exerted from within by the swollen inner layer of the sporangium wall. The green mass gradually dissolved in the sea-water (in which, of course, the observations were made), and individual zoospores freed themselves and swam off. The zoospores were dark green, with a clear apex, and showed, in the apical region, a body which was doubtless the nucleus described by Berthold. Each was provided with two cilia. We were unable to keep the zoospores alive until germination had ensued, though we purpose repeating our observations in the hope of solving the question as to whether they are zoospores or gametes, as Berthold believes.

The sporangium is, early in its development, isolated from the palisade cell by an annular thickening in its narrow pedicel (Pl. III., fig. 20). This thickening becomes finally a complete plug, and after the contents of the

sporangium have been ejected, it suffers transverse rupture. The empty sporangium is cast off, and there is left a scar on the side of the "palisade cell" (Pl. III., fig. 18).

On the same plant we have found longer and narrower "sporangia" (Pl. II., fig. 7) with orange-green contents, which we believe to be the young stages of the microsporangia described by Berthold. This author gives no figure of these bodies, although he says they are quite similar to those containing the larger green swarm-spores. These gametangia (?) we found in all stages of development. They possess the same characters as the sporangia, save that they are much longer and narrower. We were, however, unsuccessful in determining the presence of the biciliate orange gametes (?) described by Berthold. This failure on our part, however, may be due to an entirely different cause, which we now suggest.

Berthold's view that the large, dark green swarm-cells are ova, and the orange swarm-cells sperms, seems scarcely conclusive, not only from the nature of his experiments, but also from Went's assertion that the larger cells can germinate alone. On the whole, the balance of evidence would seem to be in favour of the ordinary "sporangia" being asexual, whilst the "sporangia" containing the orange micro-spores are, in all probability, "gametangia," forming gametes. Why, then, the difficulty of obtaining cultures from these gametes? We suggest that the plant is becoming apogamous, and that, although the gametangia are formed, and although the gametes are developed in some cases, and may escape from the gametangia, still that they may be sterile. On the other hand, the gametangia may regularly, after reaching a certain stage in development, become vegetative and be transformed into adventitious buds. We have

never seen the larger sporangia so transformed, and venture to think that Went was in error in believing that that was the case. Certainly his figures lend no support to that view. Went considers this vegetative development of the sporangia as abnormal. We think, however, that the phenomenon is a perfectly normal one. It was observed by Went, in 1880, in plants obtained in the Gulf of Naples, and almost every plant which we examined from the Isle of Man, under different conditions, 20 years later showed these adventitious buds. On Pl. II., figs. 4, 8, 9, and 12, we figure some stages in the development of these vegetative buds, and at fig. 6, one of them isolated (naturally), evidently in the preliminary stages of forming a new plant. Further observations are, however, desirable on this point, observations which we hope to carry out later in the year. We may add that we never saw any evidence whatsoever of the presence of a gall-producing rotifer; in all cases the contents of the filaments and the sporangia were perfectly normal. Possibly it may be in the power of some worker at the Biological Station at Port Erin to follow out this subject, and, by determining accurately the fate of the mega-spore and of the hypothetical gametes, finally settle the problem, and so add the last chapter to the life-history of one of the most interesting of our British Chlorophyceæ.

EXPLANATION OF PLATES.

PLATE I.

- Fig. 1. A small plant of *Codium tomentosum*. Nat. size.
 Fig. 2. Rhizoidal filaments, in some cases attached to and enveloping grains of sand. $\times 350$.
 Fig. 3. One of the palisade "cells"—narrow mucronate type. $\times 350$.

PLATE II.

- Figs. 4, 8, 9, 12. Various forms of vegetative developments from the abortive gametangia (?). $\times 350$.
 Fig. 5. A "palisade cell" with one empty, one full ripe, and one developing sporangium. The same cell bears the scar of a fallen sporangium, or possibly, from its position high up on the cell, a gametangium. $\times 350$.
 Fig. 6. An adventitious bud after its isolation from the parent "cell." $\times 350$.
 Fig. 7. Gametangium (?) in process of forming a vegetative bud. $\times 350$.
 Figs. 10 and 14. Stages in the development of the plug-like septa. $\times 600$.
 Fig. 11. A medullary hypha of a young plant, showing mode of origin of the lateral "palisade cells." $\times 300$.
 Fig. 13. Apices of "palisade cells," (a) *C. galeatum*, (b) *C. mucronatum*, var. *tasmanicum*, (c. d.) *C. tomentosum*, (e.) *C. mucronatum*. c. d., $\times 550$; a. b. e., after Agardh.

PLATE III.

- Fig. 15. A ripe sporangium. $\times 350$.
- Fig. 16. Apex of ripe sporangium, showing apical cavity and lamellated inner wall. $\times 800$.
- Fig. 16a. Zoospores after escape from sporangium. The spot in the hyaline apex probably represents the nucleus. $\times 550$.
- Figs. 17 and 18. Palisade cells with lateral sporangia. $\times 350$.
- Fig. 19. Vegetative budding of one palisade cell from another. $\times 350$.
- Fig. 20. Base of a ripe sporangium, showing the plug, the basal cavity, and the mode of separation of the sporangium. $\times 350$.
- Fig. 21. Longitudinal section of the thallus, showing the relation of the medullary hyphæ to the palisade cells. $\times 60$.

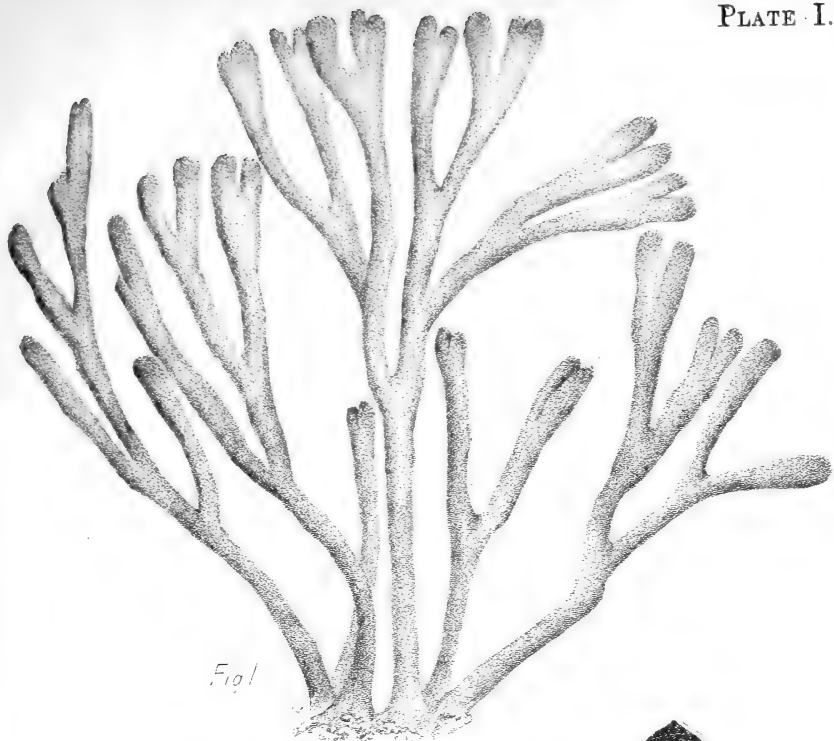


Fig 1



Fig 2

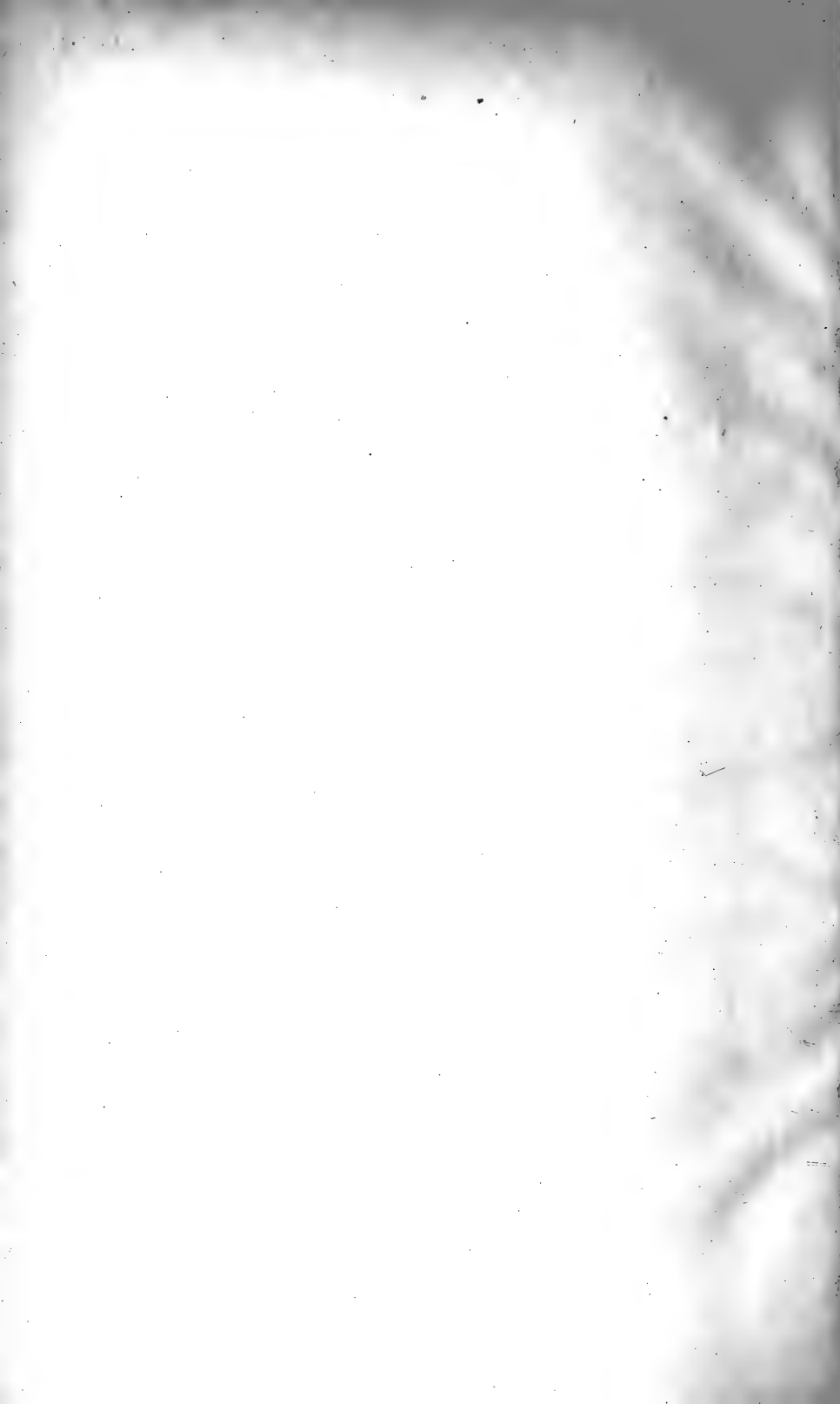


Fig 3.

HPA.del.

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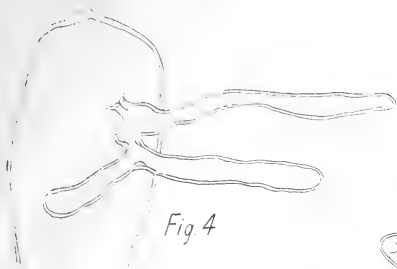


Fig. 4

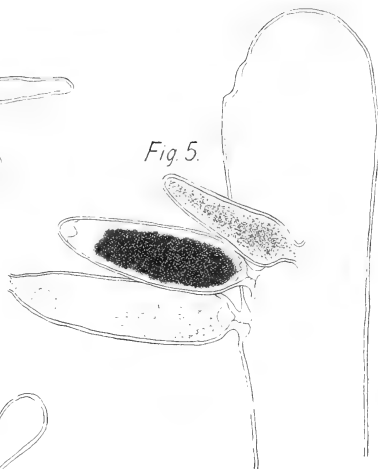


Fig. 5.



Fig. 6

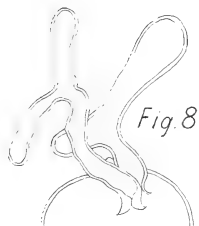


Fig. 8



Fig. 7.

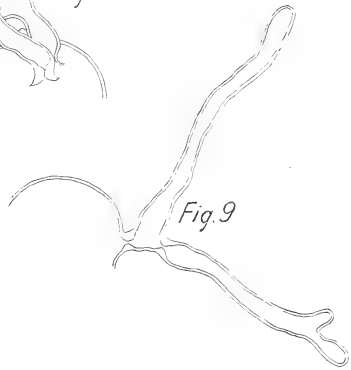


Fig. 9

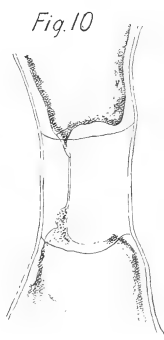


Fig. 10



Fig. 12



Fig. 11

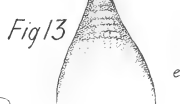
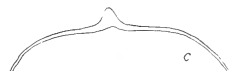
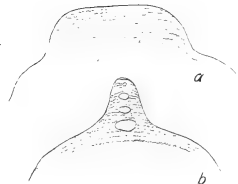


Fig. 13



Fig. 14.

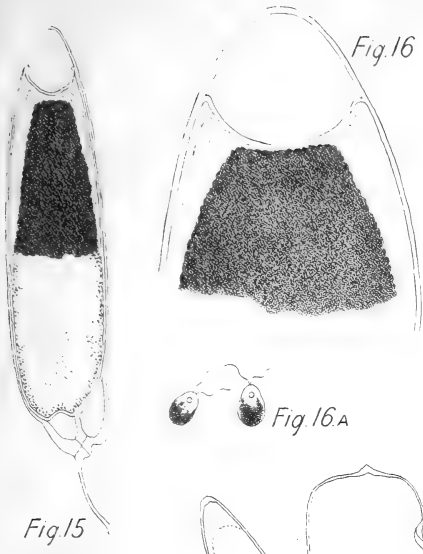


Fig. 17



Fig. 19



Fig. 18

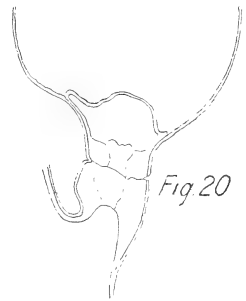


Fig. 20

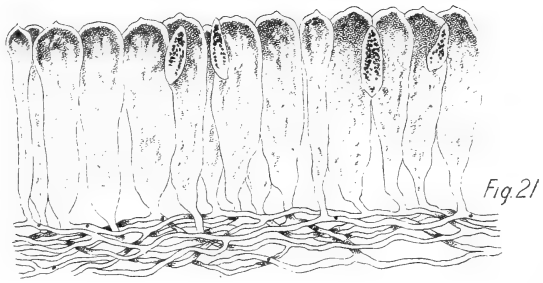


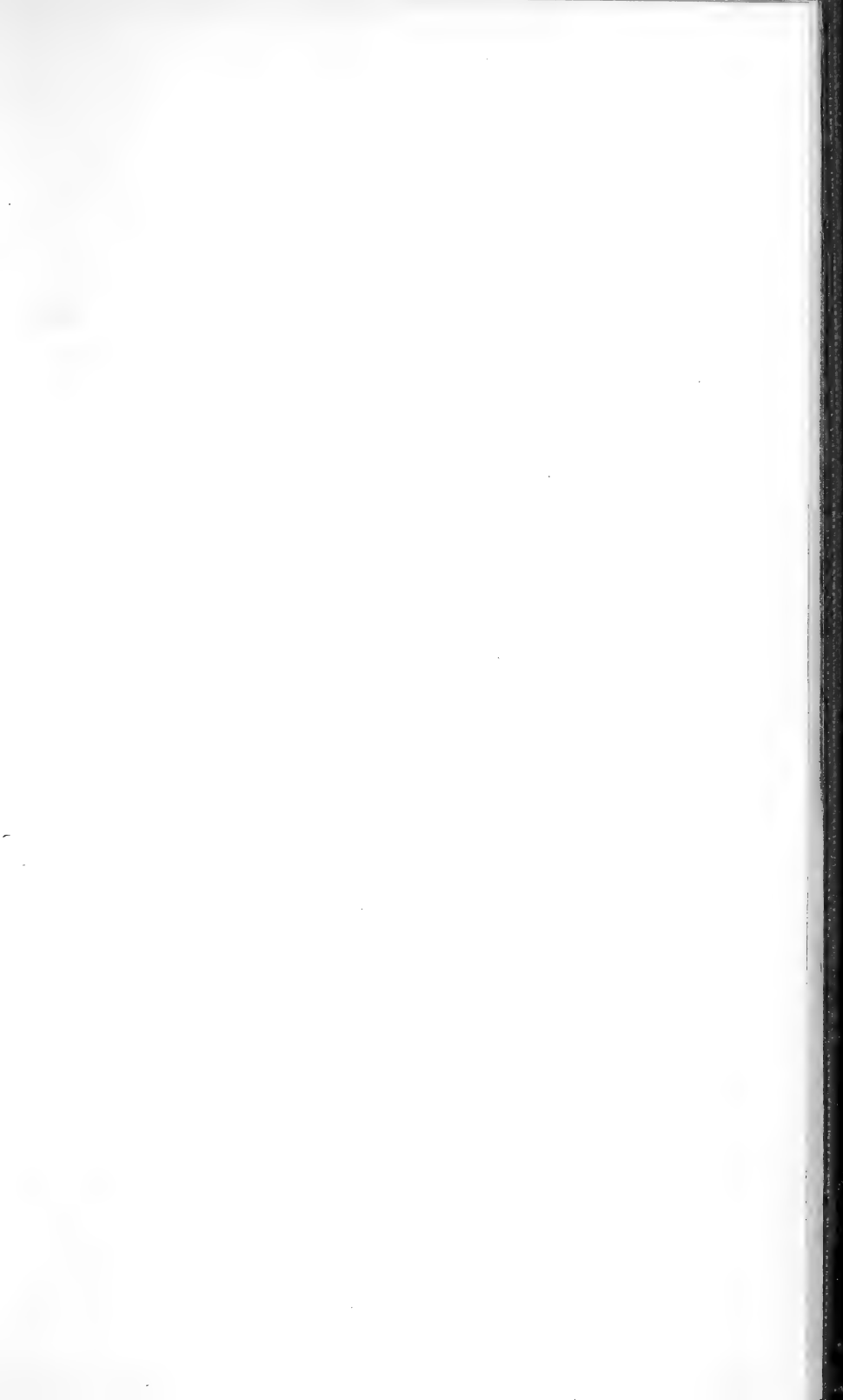
Fig. 21

H.P.A. et R.J.H.G. del.

S.B. lith.

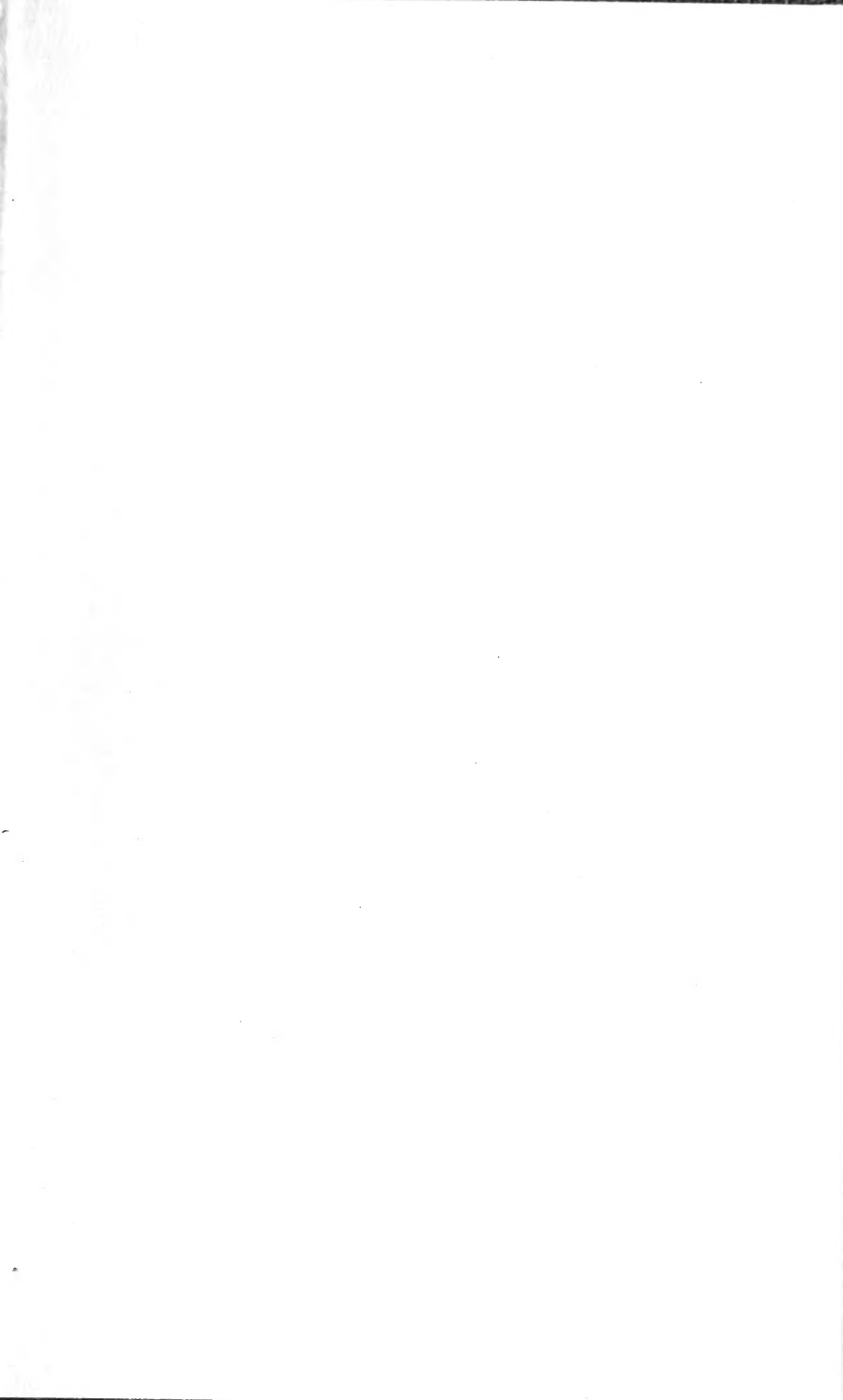
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