Liverpool Marine Biology Committee.

L.M.B.C. MEMOIRS

ON TYPICAL BRITISH MARINE PLANTS & ANIMALS

EDITED BY W. A. HERDMAN, D.Sc., F.R.S.

XIV.

LIGIA

BY

C. GORDON HEWITT, B.Sc.,

Demonstrator in Zoology, University of Manchester.

(With 4 Plates)

PRICE TWO SHILLINGS

LONDON

WILLIAMS & NORGATE

JANUARY, 1907

L.M.B.C. MEMOIRS.

XIV.

LIGIA.

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EDITOR'S PREFACE.

The Liverpool Marine Biology Committee was constituted in 1885, 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have been carried on intermittently since that time, and a considerable amount of material, both published and unpublished, has been accumulated. Nineteen Annual Reports of the Committee and five 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 accessible Station at Port Erin in the centre of the rich collecting grounds of the south end of the Isle of Man. A new and larger Biological Station and Fish Hatchery, on a more convenient site, has now been erected, and was opened for work in July, 1902.

In these nineteen years' experience of a Biological Station (five years at Puffin Island and fourteen at Port Erin), where College students and young amateurs form a large proportion of the workers, the want has been frequently 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 the Committee and of the workers at the Biological Station were at first chiefly faunistic and speciographic. The work must necessarily be so when opening up a new district. Some of the workers have published papers on morphological points, or on embryology and observations on life-histories and habits; but the majority of the papers in the 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 still further to the records of the Fauna and Flora. But the papers in the present series, started in 1899, are quite distinct from these previous publications in name, in treatment, and in purpose. They are called "L.M.B.C. Memoirs," each treats of one type, and they are 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 laboratories and in Marine Stations, and will be welcomed by many others working privately at Marine Natural History.

The forms selected are, as far as possible, common L.M.B.C. (Irish Sea) animals and plants of which no adequate account already exists in the text-books. 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 list shows those who have either performed or promised.

Memoirs from I. to XIV. have now been published.

Antedon, by Mr. Chadwick; Cancer, by Mr. Pearson: and Doris, by Sir C. Eliot, are now far advanced and ought to be out early in 1907. It is hoped that Cycloporus, Pecten, and the Oyster will follow soon.

Memoir I. Ascidia, W. A. Herdman, 60 pp., 5 Pls., 2s.
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,, XIV. Ligia, C. G. Hewitt, 45 pp., 4 Pls., 2s.
Cancer, J. Pearson.
Antedon, H. C. Chadwick.
Doris, Sir Charles Eliot.
Cycloporus, F. F. Laidlaw.
Oyster, W. A. Herdman and J. T. Jenkins.
Pecten, W. J. Dakin.
Ostracod (Cythere), Andrew Scott.
Buccinum, W. B. Randles.
Bugula, Laura R. Thornely.

Zostera, R. J. Harvey Gibson.
Himanthalia, F. J. Lewis.
Diatoms, F. E. Weiss.
Fucus, J. B. Farmer.
Botrylloides, W. A. Herdman.
Cuttle-Fish (Eledone), W. E. Hoyle.
Actinia, J. A. Clubb.
Hydroid, E. T. Browne.
Halichondria and Sycon, A. Dendy.

In addition to these, other Memoirs will be arranged for, on suitable types, such as *Pagurus*, *Sagitta*, *Pontobdella*, a Cestode and a Pycnogonid.

As announced in the preface to Ascidia, a donation from Mr. F. H. Gossage, of Woolton, met the expense of preparing the plates in illustration of the first few Memoirs, and so enabled the Committee to commence the publication of the series sooner than would otherwise have been possible. Other donations received since from Mr. Gossage, Mrs. Holt, Sir John Brunner, and others, are regarded by the Committee as a welcome encouragement, and have been a great help in carrying on the work.

W. A. Herdman.

University of Liverpool,

December, 1906.

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No. XIV. LIGIA.

BY

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Introduction.

The Isopod *Ligia oceanica* (Linn.) has been selected as the type for this Memoir on account of its comparatively large size, being the largest British Isopod, and also because it is one of the most interesting of the group, being mid-way between the aquatic and terrestrial forms.

The Isopoda, with the Amphipoda, form the sub-order Arthrostraca, and are characterised by being Malacostraca with seven distinct thoracic segments, each bearing a pair of limbs (except the Gnathiidae) and possessing sessile eyes; on account of the last character, they are usually classed together in the sub-order Edriophthalmia.

The Isopoda possess a dorsoventrally depressed body. The thoracic limbs do not bear branchial appendages, as in the Amphipoda, but respiration is carried on by means of the abdominal appendages, which are modified for that purpose, the modification varying in the different tribes. The terrestrial Isopods, the Oniscoidea, are the only members of the group which exhibit such a uniformity in the character of the thoracic appendages as to justify the name.

The following classification of the Isopoda is that given by Sars (1896), each tribe being defined by three characters—those of the first pair of legs, the uropoda, and the pleopoda or abdominal appendages:—

I. First pair of legs cheliform; Uropoda terminal; Pleopoda, when distinctly developed, exclusively natatory - - - 1. *Cheliferae.*

II. First pair of legs not cheliform. (1) Uropoda lateral. (i) Pleopoda for the most part natatory, forming a caudal fan with the terminal segment of the metasome - 2. *Flabelliferae.*

(ii) Pleopoda to a great extent branchial; the Uropoda valve like, inflexed, arching over the Pleopoda - - - - 3. *Valviferae.*

(2) Uropoda terminal. (i) Pleopoda exclusively branchial, generally covered by a thin opercular plate (the modified 1st pair) - 4. *Asellota.*

(ii) Pleopoda for air breathing - 5. *Oniscoidea.*

(iii) Pleopoda when present, exclusively branchial in the adult animal and not covered by an operculum - - - 6. *Epicarida.*

Ligia oceanica belongs to the tribe Oniscoidea, which are characterised by being terrestrial. This tribe includes all the so-called "wood-lice." Their abdominal appendages are fitted for air breathing, but in Ligia there is a very near approach to branchial respiration, as moisture is necessary. The body is oval in shape, and the seven pairs of thoracic appendages are similar in character. *Ligia oceanica* was first described in 1767 by Linnaeus as *Oniscus oceanicus.* Later, in 1798, the genus *Ligia* was created by Fabricius to include the *Oniscus oceanicus* of Linnaeus.

Biology.

Ligia oceanica (Pl. I.) has a wide distribution, and is recorded from the coasts of the British Isles, Faroe Islands, Norway, Denmark, Germany, Belgium, France, Spain, Morocco and America. At Plymouth* I have found *Ligia* most numerous, and of the maximum size, on Drake's Island. At Port Erin they occur in the cliff near the old biological station.

* I wish to express my thanks to the Council of the Marine Biological Association of Great Britain for the use of a table at the Plymouth Laboratory, during the Easter vacation, 1906. Other material for this memoir was obtained at the Marine Biological Station, Port Erin, during the Easter vacations, 1903-4.

They are terrestrial, but require a certain amount of moisture. On the other hand, they are unable to withstand prolonged immersion in sea-water, and still less in fresh water.

They are found just above high-water mark in a zone of varying width. The height of their habitat above high-water mark seems to depend on the nature of their surroundings, which is varied. The greatest number are found in deep narrow crevices in the rocks immediately above high water. Here they can be found in large numbers packed closely together. They also abound in crevices on the side of a quay, hence their name, 'quay-louse' or 'quay-lowders.' They are also known as 'sea-carpenters,' 'carpenter' being a local name of the wood-louse. They can be found between the wooden piles of a pier or under the loose stones and rubbish cast up by the tide, which have accumulated in small dark holes. The highest level is attained by those specimens which live in the loose clay and shale forming the cliffs on many parts of our coast, but the specimens living in these conditions do not attain the size of those living lower down in the rock crevices, and are generally of a darker colour.

In St. Kilda, I have found them in the crevices of the boulders on the top of a hill over 450 feet above sea-level. This high altitude may be explained by the fact that the sea spray often reaches that height. It is extremely improbable, however, that the animals go down to sea level to feed. Contrary to the usual rule, the majority of individuals found at this high level were females. I found large numbers of young individuals under rocks between tide marks, and none at the high level, these females probably go down to the sea level to liberate the young from their brood-pouches.

The colour varies from a dark greyish green to a light dirty brown. In young specimens two light-coloured patches occur on the median line of the dorsal side. The colouration has generally a mottled appearance, the dark portions being due to presence of closely packed chromatophores. In injected specimens a close connection is observed between the terminations of the fine capillaries and the chromatophores. In moulting, the cuticle of the posterior half of the body is shed first, and a short time elapses before the anterior half is shed, so that individuals are often found with the posterior half of the body lighter in colour than the anterior half.

Their food consists chiefly of decaying animal and vegetable substances, and from a study of the contents of their guts, the latter appear to form a large proportion of their diet. In captivity they prefer the weaker members of their own species, but there is not much evidence that this is a natural habit.

They are able to run with great rapidity, coming out from their dark retreats after sunset to feed, at which time they may be caught with the aid of a lantern. The best instrument for capturing them during the day is a fairly long wire, having the last half-inch bent at right angles; by means of this they can be extracted from their narrow crevices.

External Characters.

The body is oval in shape, broadest across the fourth thoracic segment, and gradually decreasing in size towards the posterior end. It is almost twice as long as it is broad. The males are larger than the females, the reverse being usually the case in Arthropods. They may attain a length of 32-34 mm., the width of the thorax reaching 18 mm. The females are more regularly oval in shape and may reach a size of 26 mm., their extreme width being 11 mm. The dorsal face of the body is moderately convex, and its surface is granulated. The body can be conveniently divided into four regions—1, the head segment or cephalon; 2, the mesosome or thorax, consisting of seven segments; 3, the metasome or abdomen, consisting of five distinct abdominal segments, together with a terminal segment, which is, 4, the telson.

The cephalon is sunk into a depression formed by the forward growth of the epimeral portions of the first thoracic segment. It is evenly convex in front; the posterior border is depressed, the edge being marked by a ridge. The dorsal surface is slightly curved transversely. A pair of large compound sessile eyes are situated laterally, each having a slight reniform appearance from a dorsal view. On the anterior face, which is almost vertical, the minute pair of first antennae are situated, one on each side the median line. To the outside of these are the large and robust second antennae. When moving, the animal holds the large antennae in a forward position, and constantly tests the nature of the surface over which it is proceeding with the very sensitive flagella, appearing to trust for guidance more by this means than by means of its sight. When at rest, they are folded back along the sides of the mesosome.

On the ventral side of the head the mouth-parts form a prominent projection. The mouth is bounded in front by a large transversely-hinged labrum. The sides are composed of the powerful mandibles and two pairs of maxillae. The posterior border is formed by the two maxillipedes, which are imperfectly fused together, forming an apparent lower lip; there is, however, internal to these, a lingua-like bilobed chitinous plate, deeply incised in the middle and having a small median plate;

this forms a true posterior lip. The maxillary excretory organ opens at the base of the second maxilla.

The seven segments of the thorax form the greater part of the animal's body. They are convex on their anterior margins and concave behind. The lateral portions form large epimeral plates, obtusely acuminate, and directed backwards. The segments slightly overlap, and the uniting membrane, which is not impregnated with calcareous salts, sinks into the hypodermal tissues. On the ventral sides, where the epimera join the body, the walking legs or pereiopods arise. The first three pairs of pereiopods are approximately the same size, the last four pairs gradually increase in size. The ventral wall of the thorax is thin and transparent, and strengthened by slightly curved transverse bars. On the ventral side of the thorax of the female, the brood-pouch full of ova is very conspicuous in the breeding season. It is formed by lamellae which arise inside the origin of the five anterior pairs of thoracic appendages and grow ventrally, overlapping the adjacent lamellae distally and laterally. The paired female genital apertures are situated on the inside of the fifth pair of pereiopods. The male genital products are ejected through a pair of styliform appendages on the posterior border of the last thoracic segment, immediately in front of the branchiae.

The metasome or abdomen consists of five segments and the telson, and is about a third of the entire length of the animal. The two anterior segments are narrow, and do not reach the margins, but are lodged in the concave posterior border of the seventh thoracic segment. The three posterior segments have their lateral margins produced into tooth-like backwardly projecting processes. Five pairs of uropoda, which are of the nature of branchiae, are borne on the ventral side of the abdomen.

Each of these consists of an outer 'opercular' lobe and an inner lobe. In the male the inner margins of the outer lobes of the first pair may, or may not, be produced into short spinous processes; the inner margins of the second pair are produced into two long slender styles for copulatory purposes.

The terminal segment or telson is composed of the last two segments of the metasome, which are fused to form a rather broad terminal segment. The posterior edge is evenly rounded; the lateral portions are acuminate and subtend a sinus in which the terminal pair of uropoda arise. Each of the terminal uropoda consists of a fairly stout basal portion, from which the styliform appendages arise. The anus is a longitudinal slit on the ventral side of the terminal segment.

The external apertures are—the mouth, the openings of the maxillary excretory organs on the protopodites of the second maxillae, the openings of the oviducts at the base of the fifth pair of pereiopods, or of the vasa deferentia at the posterior border of the ventral side of the seventh thoracic segment, and the anus.

Appendages.

The **first pair of antennae** (Pl. II., Fig. 1) may be truly called antennules, as they are extremely small, measuring a little over 1 mm. in length. They are situated internal to, and at the base of, the second antennae. They are triarticulate, the terminal joint being quite rudimentary and bearing two terminal groups of small setae.

The **second pair of antennae** (Pl. II., Fig. 2) are long, attaining a length of 25 mm. in the male and 14 mm. in the female; when folded back they extend to the posterior border of the fourth thoracic segment. The protopodite is composed of five joints, the fourth and fifth being the largest; the fifth joint equals in length the proximal five joints of the flagellum. The flagellum may have as many as 13 or 14 joints, which are setose, the setae being of two sizes.

The **mandibles** (Pl. II., figs. 3, 4) are very powerful and consist of a single protopodite. The point of attachment is D shaped, the curve being internal. From the anterior end of the external border, a powerful tooth-bearing process curves inwards, forming a quadrant-shaped anterior face. The curve of the quadrant is external; the lower side is partially attached and the vertical side bears the mandibular processes. Internally, on this vertical side, there are—a stout molar process, the flat extremity of which is covered with minute closely-set teeth; a small palpiform structure bearing setose bristles, and two stout mandibular teeth separated by a sinus, each being sub-divided into three smaller teeth. The ventral edge of the mandible is produced into a rounded keel, which gradually diminishes in depth towards the posterior edge.

The **first pair of maxillae** (Pl. II., fig. 5). Each maxilla is composed of two lobes. The outer lobe is calcified and much stronger than the inner, which is more flexible. The inner lobe is terminated by three deflexed setose bristles; the outer lobe has a terminal group of short thick spines.

The **second pair of maxillae** (Pl. II., fig. 6) are much modified, being thin and flexible. Each consists of a long protopodite, terminated by an oblique setose joint having internally at its base two setose bristles. The maxillary excretory organ opens at the base of the protopodite.

The **maxillipedes** (Pl. II., fig. 7) are closely approximated on their inner sides and joined at the base, so that they form an outer lower lip. Each consists of an inner rectangular plate spinose at its anterior margin, and an outer five-jointed palp. The joints of the palp are spinose, each of the four distal joints having on its inner side a setose pad. At the base there is a small lamella.

The **pereiopods** (Pl. II., figs. 8, 9) or ambulatory appendages. Each pereiopod consists of a basal protopodite and an endopodite, which is composed of five spinose joints (ischiopodite, meropodite, carpopodite, propodite and dactylopodite). In the posterior pairs of pereiopods, the carpopodite and propodite are long in comparison with the other joints. The dactylopodite bears two strong re-curved claws.

In the female each of the anterior five pairs of pereiopods (Pl. II., fig. 12) subtends a thin foliaceous lamella which curves downwards and inwards, overlapping the opposite and adjacent lamellae, and thus they form a brood pouch in which the eggs are carried. These lamellae are not out-growths of the limbs, but of the sterna.

Abdominal appendages. There are five pairs of abdominal appendages or pleopoda, and a terminal pair of uropoda. Each pleopod (Pl. II., figs. 11, 13) consists of a pear-shaped superior lobe covering a small inferior lamella. In the terrestrial isopods, the outer lobe is termed opercular and the inner branchial. In *Ligia* both are branchial, as will be shown later.

At the base of the outer edge of the superior lobe, there is a small lamella. The edge of the superior lobe is fringed with a border of setose bristles. The second pair of pleopods are modified in the male by having a two-jointed style arising at the base of the inner margin of the superior lobe (Pl. II., fig. 10). The style is long and grooved, and reaches to the fourth pleopod; its distal extremity is slightly swollen and finely pointed. It is for copulatory purposes. The superior lobe of the first pair of pleopods also may be modified slightly for copulatory purposes. The third, fourth, and fifth pairs of pleopods are very similar in character, the third pair being the largest.

The **uropoda** (Pl. II., fig. 14) are situated at the posterior edge of the sixth abdominal segment or telson, the pleural regions of which are produced posteriorly, thus forming a small sinus in which the uropods can bend laterally. Each consists of a stout basal joint which is widest in the middle and truncated distally. The middle region is thick, narrowing off sharply to the outer edge, and slightly to the inner edge, which is adjacent to that of its fellow. Distally, two setose styliform processes arise. These are about twice the length of the basal portion. During life they are carried in a diverged position, being separated vertically by a wide angle. The inner style has a well-developed terminal spine which is trailed over the ground, and is probably of a sensory nature, as it has similar nervous connections to the sensory bristles of the antennae.

Body Wall, Muscular System and Body Cavity.

The body wall consists of three layers, the outer cuticular layer, the hypodermis and the connective tissue. The cuticular layer is composed of a thin cuticula resting on a thicker layer of chitin, in which two distinct layers can generally be observed (Pl. IV., fig. 3). The chitin is impregnated with salts of calcium, which cause it to have a fairly resistant and brittle texture. Between the segments the chitinous layer is thin. In the middle region of the dorsal side the intersegmental membrane does not dip deeply into the tissues, as it does at the sides. The cuticula bears spines and setae in many regions of the body. The hypodermal layer is composed of a single layer of cubical cells. Underneath the hypodermis the chromatophores are found. The rest of the body wall is made up of connective tissue, in which groups of large adipose tissue cells occur. These last cells also occur in large numbers on the walls of the alimentary canal, and dorsal to the heart. (Pl. II., fig. 16, *ad. tis.*)

The body cavity (*b.c.*) is a haemocoel, the alimentary canal and other organs being in contact with the blood. A horizontal septum (*sep.*) divides the body cavity into a small dorsal pericardial cavity enclosing the heart, and a large sinus enclosing the other organs.

The muscular system, excluding the muscles of the wall of the gut, heart, &c., consists of three sets of muscles —1, those in connection with the gastric mill; 2, the muscles moving the segments of the body; 3, the muscles moving the appendages.

The muscles are composed of striated muscle fibres. The muscles controlling the gastric mill occupy almost the whole of the cavity of the cephalon and are very conspicuous on opening this. They are attached to the dorsal side of the cephalon, and most of them are inserted into the large lateral cardiac teeth. The muscles moving the segments of the body are also segmented, but the muscle segments alternate with the body segments. On each side of the dorsal line there is a series of longitudinal muscles (*d.l.m.*). The anterior end of each bundle of muscle fibres of this series is inserted immediately behind the anterior end of one segment, and the posterior end is inserted at the anterior border of the succeeding segment. In the lateral regions, where the cuticle dips into the body, a number of oblique muscle bands, which form a series of muscles on each side, have their posterior ends attached to the anterior wall of the cuticular invagination, and their anterior ends attached to the hypodermis of the middle of the preceding segment. In the lateral, and also the epimeral regions, the body cavity is almost entirely filled up with the muscles moving the appendages; these muscles are attached to the dorsal side of the animal in these regions (*ler. m.*). The longitudinal muscles of the ventral side (*v.l.m.*) have their attachments similar to those of the dorsal side. The joints of the thoracic appendages, like the appendages themselves, are provided with extensor and flexor muscles. The mandibles are provided with a powerful set of muscles, attached to the dorsal side. The proximal ends of the remaining mouth appendages have thickened skeletal rods, forming an internal framework, to which the muscles moving them are attached.

The Digestive System.

The digestive system consists of the alimentary canal and its glands—the salivary glands, and the hepato-pancreas or digestive gland.

The alimentary canal can be divided into four parts – the oesophagus, the stomach, mid-gut and rectum.

The **oesophagus** (Pl. II., fig. 15 *oes.*) opens by a slit-like aperture surrounded by the mouth appendages. Its course is almost vertical, and it opens into the anterior end of the stomach on the ventral side. The oesophagus receives the secretions of the salivary glands.

The **stomach** forms an efficient mill for triturating the miscellaneous substances upon which the animal feeds. It lies in the cephalic and first thoracic segments. The wall of the stomach, which is composed of columnar cells, is lined with chitin, and is folded in a complicated manner; thus a number of chitinous lamellae are formed, which project into the cavity of the stomach. The dorsal wall of the stomach is almost flat, and is continuous posteriorly with the mid-gut. The anterior end of the stomach is slightly oblique, and when seen from the upper surface is semi-circular. The plates and "teeth" which form the gastric mill are arranged in the following manner. On each of the lateral margins of the anterior end of the stomach a bilobed ampulliform triturating 'tooth' (Fig. 15, *l.c.t.*) arises, and meets its fellow of the opposite side above the opening of the oesophagus. These lateral cardiac teeth are the chief masticatory agents of the gastric mill. Between these, on the anterior wall of the stomach, three teeth fill up the space, a small median anterior tooth (*m.a.t.*) situated between two antero-lateral teeth (*a.l.t.*). Posteriorly, the closure of the entrance to the stomach is effected by a ventral transverse setiferous ridge, the ventral cardiac tooth (*v.c.t.*). In the preceding description, the word 'tooth' has been used to designate a chitinous protuberance of the wall of the stomach, which is covered with short, closely-set, re-curved setae. On the ventral side of the stomach, in the middle region, three tooth-shaped processes arise, their apices directed backwards: they are the median, ventral and ventro-lateral teeth (*v.l.t.*). On each side of the cardiac region of the stomach, a narrow lamella, the lateral cardiac lamella (*l.c.l.*) runs in an oblique direction from the antero-dorsal region to the ventral side, and terminates near the ventro-lateral tooth. In the pyloric region of the stomach, a deep invagination of the dorsal surface forms a broad dorsal lamella (*d.l.*), which extends across the dorsal side and half-way down the lateral sides. Between the lateral portions of the dorsal lamella and the wall of the stomach, two large lamellae (*v.l.p.l.*) have their lateral limits: these are the ventro-lateral pyloric lamellae. They arise on the ventral side immediately behind the ventro-lateral teeth. Their ventral edges almost meet along their whole length; their lateral edges extend in an oblique direction from behind the dorsal lamella to the ventral side at the anterior end of the mid-gut, where each ventro-lateral lamella terminates in a fine point.

The **mid-gut** (Pl. II., fig. 16 *mid.g.*) extends in a straight line from the posterior end of the stomach to the rectum in the posterior region of the abdomen. It is of uniform width throughout, except at the posterior end, where it narrows considerably, and is surrounded by a sphincter muscle. Three regions can be roughly made out, the arrangement of the epithelial cells of the gut being the means of demarcation. The wall is composed of three layers, an outer muscular layer, a median basement membrane, and internally the epithelium, which is covered by a chitinous intima. This intima is perforated and is shed when the animal moults. The muscular layer is composed of two sets of muscles, an outer longitudinal and an inner circular layer, but this only applies strictly to the anterior end of the mid-gut; further back the muscle fibres become separated by the bulging out of the epithelial cells. The epithelial cells of the gut are very large and contain correspondingly large nuclei. They form a syncytium, as they do not possess complete cell walls, but are separated by inter-cellular fibres, extending from the basement membrane to the intima, and probably of cytoplasmic origin. The arrangement of the epithelial cells varies in different regions of the mid-gut. In the anterior region, which is almost half the entire length of the mid-gut; the cells are irregularly arranged. On the lateral sides they extend in longitudinal rows; the two median ventral rows of cells extend from the anterior end of the mid-gut to the posterior end. On the dorsal side of the anterior region, in the median line, a typhlosole (*t.y.*) is formed by the floor of a groove being re-invaginated; posteriorly, the sides of the groove widen out into an elongate spoon-shaped structure. The function of the typhlosole is probably not, as is usual, to assist in the absorption of food, but to provide a channel along which the secretion of the hepatopancreas is able to flow to the middle region of the intestine. In the middle region of the mid-gut the epithelial cells exhibit a very regular arrangement. They are arranged in double rows, which run out in an oblique direction from the median line. The rows of cells project into the body cavity, so that grooves are formed between the double rows. In these grooves the muscle fibres are lodged, underneath the blood-vessels from the intestinal arteries. The posterior region is marked by the presence of the sphincter muscle, which separates the mid-gut from the rectum. In the sphinctal region the faecal pellets are formed.

The **rectum** is a short uniform tube opening by the longitudinal slit-like anus.

The **salivary glands**. There are two pairs of salivary glands situated in the cephalon, on each side of, and opening into, the oesophagus. Each is made up of a large number of rosette-like masses of gland cells, which are very similar to the mucous glands described by Allen (1892) in *Palaemonetes*. In section, they have the appearance shown in the figure (Pl. II., fig. 17). Each acinus is made up of a number of concentric cells, in which two regions can be recognised—a peripheral cytoplasmic region containing the nucleus, and a central glandular region. Each of the cells has at its internal apex an intracellular duct (*ic.d.*), which opens into a duct common to the mass of cells (*c.d.*). This duct is probably formed by a single cell, the nucleus of which can be seen near the centre of the gland (*n.c.d.*).

The **hepatopancreas.** This is also known as the liver, and the digestive gland; the last name describes its true function. In *Ligia* it consists of three pairs of tubules, which extend from the pyloric region of the stomach to the posterior end of the abdomen, where they gradually taper off, and are generally doubled back for a short distance. The three pairs are situated in relation to the intestine, dorso-lateral, ventro-lateral and ventral (Pl. II., fig. 16, *v. hep.*, *vl. hep.*). The muscles of the walls of the distal two-thirds of the tubules are so arranged, that a spiral appearance is produced. The spiral arrangement of the muscles no doubt aids their peristaltic contractions. The tubules of each side open into the pyloric region of the stomach by a single aperture, behind and below the ventro-lateral teeth. The two ventrally placed tubules of each side fuse and then open into the stomach. Anterior to the opening the dorso-lateral tubules curve ventralwards, and fuse with the anterior end of the ventro-lateral tubules. A small tube is given off from the front of the common hepatopancreatic duct, which runs forward for a short distance and ends blindly. The epithelial cells of the hepatopancreas are of two kinds—large secreting cells containing large nuclei, and smaller cells which may be either young secreting cells, or cells of an excretory nature.

The physiology of the digestive system of terrestrial Isopods has been studied by Murlin (1902). He finds that the secretion of the hepatopancreas, which may be liberated by the dissolution of the cell, fragmentation of the cell, or evacuation from the cell, contains ferments, which are able to act upon proteids, carbohydrates and fats.

Vascular System.

Delage (1881) has described the vascular system of *Ligia oceanica* in his Memoir on the circulation of the Edriophthalmia, and, except in a few details, my results confirm his account.

The **heart** (Pl. III., fig. 1, *ht*) is a fairly wide tubular structure, extending from the fifth abdominal segment to the anterior end of the fourth thoracic segment. This posterior position of the heart is correlated with a posterior position of the organs of respiration. Its walls are muscular, and are perforated by two ostia (*ost.*), which are oblique slit-like orifices provided with muscles and two small inwardly projecting flaps. They are situated in the anterior and posterior regions on the right and left sides respectively.

The **pericardium** (Pl. II., fig. 16, *p.c.*) extends from the anterior end of the heart to beyond the posterior end. It receives the efferent vessels from the branchiae, and is continuous with the venous lacunae in the anterior regions of the body. It is separated from the body cavity by a horizontal septum upon which the heart rests.

The heart is continued anteriorly as the median aorta. On each side four arterial thoracic trunks arise. The first pair may be termed the lateral arteries; the remaining three pairs are the fifth, sixth and seventh thoracic arteries, and they arise in the anterior half of the heart.

The **median aorta** (Pl. III., fig. 1, *med. ao.*) runs forward along the dorsal wall of the gut to the cephalic region. In the anterior region of the second thoracic segment two arteries arise from the dorsal side, and run a sinuous course in the hypodermal tissues towards the epimera. In the first thoracic segment a pair of large arteries arise laterally and run outwards at right angles. Each gives off a large branch which supplies the walls of the stomach, a branch running to the hepatic tubules, a few small arteries to the soft parts, and, after giving off another branch which runs into the epimeron (*ep. art.*), it unites with an artery (i) which is the anterior prolongation of the lateral artery. Immediately on entering the cephalic segment, a small median unpaired artery arises on the dorsal side, and bifurcating, runs in the hypodermis. In front of this the aorta gives off a pair of ophthalmic arteries (*op. a.*) which run outwards to the eyes, giving off many small branches to the soft parts. The aorta now bends down in front of the stomach, where it dilates somewhat, the dilation lying in a cavity on the anterior face of the stomach. This dilation serves as a kind of cephalic 'heart,' as it has on each side muscles connected with a pair of chitinous rods from the anterior face of the stomach. These muscles will aid in the contraction and dilation of the cephalic 'heart,' and so help to pump the blood into the rest of the vessels of the median dorsal aorta; the blood, on account of the posterior position of the heart, would not be driven into these vessels so effectively, if it were not assisted by the action of the cephalic heart.* At the point where the aorta bends, it gives off dorsally a small median artery, and lower down two median unpaired arteries, each of which bifurcates, the superior one supplying the posterior side of the cerebral ganglion (*cer. g.*), and the inferior artery the anterior side of the ganglion. The aorta then bifurcates. Each branch, besides giving off numerous small arteries, which can be better understood by reference to the figure (Pl. III., fig. 2), gives off a large antennary artery (*ant. art.*), and is then continued as the facial

* Contractile vascular sacs occur in the heads of certain insects. Pawlowa (1895) has described them in the heads of certain Orthoptera, and, according to Selvatico, they occur in certain Lepidoptera.

artery (*fac. art.*), which supplies the mandibles and the lateral regions of the face. Neither the injections nor the serial sections showed any oesophageal ring of the nature described by Delage. Several small arteries are given off from the posterior border of the antenno-facial arteries which supply the oesophagus (*oes. art.*) and neighbouring soft parts, as will be seen from the figure. The fact that in many cases these small arteries dilate to an exaggerated extent when injected, may account for the mistake.

The **lateral arteries** (Pl. III., fig. 1, *lat. art.*) run forward and outward from the anterior end of the heart, and in the first thoracic segment each anastomoses with the transverse artery from the dorsal aorta. On the external side of each lateral artery, four thoracic arteries arise (i., ii., iii., iv.), supplying the first, second, third and fourth thoracic segments. On the internal side of the thoracic artery a number of branches are given off which ramify on the walls of the gut (*int. art.*) and hepatic tubules (*hep. art.*). Close to the origin of the fourth thoracic artery a large branch (*gen. art.*) is given off, which supplies the terminal portion of the vas deferens. A number of arteries arise from the dorsal side of each lateral artery, and ramify in the hypodermal tissues.

The **thoracic arteries** (i., ii., iii., iv., v., vi., vii.).—The course of each of the thoracic arteries, with the exception of the sixth and seventh, is somewhat the same. Each runs directly outwards, and, when dorsal to the hepatic tubules, gives off a ventral branch which supplies these. Following the curvature of the dorsal surface the artery curves ventrally; a small artery arises which runs into the dorsal longitudinal muscles. When it reaches the insertion of the limb it bifurcates, the inner branch runs inwards and supplies the ventral surface, the outer branch soon bifurcates again, the dorsal branch supplying the epimeral (*ep. art.*) region, and the ventral branch is the crural artery supplying the leg (*cr. art.*). The inner branches of the first thoracic artery supplying the ventral surface of the first thoracic segment unite in the mid-ventral line at the base of the maxillipedes, forming a median artery (Pl. III., fig. 2) which runs forwards and gives off paired arteries to the maxillipedes (*mxp.*), second (mx'') and first maxillae (mx'), and terminates in the lingua-like lower lip.

The sixth thoracic artery soon after its origin gives off a branch which runs ventrally, and unites with its fellow of the opposite side in the mid-ventral line of the intestine; from the point of junction a median artery runs forwards and backwards, forming a sub-intestinal artery. From the sides of the sub-intestinal artery paired transverse branches arise in a very regular manner, and run on the walls of the intestine in the oblique grooves which have been described above.

The seventh thoracic artery, after running obliquely backwards for a short distance, gives off an artery which bifurcates and supplies the lateral regions of the intestine. It soon gives off from its posterior side a large artery, the abdominal artery which runs posteriorly; the rest of its course is similar to that of the other thoracic arteries.

The **abdominal artery** (Pl. III., fig. 1, *ab. art.*) of each side runs in an undulating manner, midway between the lateral margins and the median line; from it arise small arteries supplying the intestine, muscles and other tissues. In the third abdominal segment it gives off a ventral branch which supplies the three anterior branchiae and the body-wall. The fourth and fifth pairs of abdominal appendages are supplied by an artery which arises from the abdominal artery in the fourth abdominal segment. In the last segment an artery is given off internally to the intestine, on the ventral side of which it anastomoses with its fellow and the sub-intestinal artery. The abdominal artery finally terminates in the uropoda.

The **venous system** is lacunar. A large thoracic sinus runs into the abdominal sternal sinus, from which five afferent branchial vessels arise; each of these bifurcates at the base of the branchial appendages, supplying the superior and inferior lobes of the branchiae.

The **vascular system of the branchiae.** The branchiae are supplied by venous vessels from the abdominal sinus. The efferent branchial vessels open into the pericardium by way of the branchio-pericardial canals (Pl. II., fig. 16, *br.p.c.*). The circulation in the superior and inferior lobes of the abdominal appendages, both of which are respiratory, is different. The interior of the inferior lobe of the branchiae (*inf. lam.*) is fenestrated by an irregular system of lacunae, those of the outer side containing venous blood and those of the inner side arterial. On the other hand, the vascular system of the superior lobe (*sup. lam.*) is very definite and uniform throughout the five pairs. It consists of a venous portion (Pl. II., fig. 13, *a.b.v.*), which is ventral (looking at the gill from the anterior face) to the arterial system of vessels (*e.b.v.*). The individual arteries and veins interdigitate in a very complete manner, and the vascular supply is very rich, as will be seen by reference to the figure (Pl. III., fig. 3). On this account, the superior gills cannot be looked upon as beng merely opercular in function in this animal, but are certainly respiratory appendages of a very perfect nature.

The blood is colourless and contains nucleated corpuscles which vary in size. As in most anthropods, it is very coagulable.

Nervous System.

The nervous system (Pl. III., fig. 4) is composed of a series of paired ganglia, the ganglia of each pair being closely apposed; the ganglia are connected by distinct commissures.

The supra-oesophageal or cerebral ganglion (*cer. g.*) extends across the space between the eyes, anterior and dorsal to the gut. The ganglion cells have large deeply-staining nuclei, and the fibres arising from them decussate and connect the ganglia. In the supra-oesophageal ganglia several lobes can be distinguished. On the dorsal side there is a large pair of lobes, from the sides of which the optic stalks arise. Each of these optic stalks consists of a proximal lobe, connected by closely apposed parallel fibres with a distal lobe, from which the optic fibres arise and run direct to the retinulae. On the ventral sides of the superior lobes a small pair of median lobes is situated; these are anterior to, and connected with, a larger pair of ventral lobes, the olfactory lobes, from which the the large antennal nerves (*ant. n.*) arise. The supra-oesophageal ganglion is connected with the sub-oesophageal ganglion by a pair of peri-oesophageal commissures.

The sub-oesophageal ganglionic mass is perforated near the anterior end by a vertical muscle band. The mouth-parts are innervated by two pairs of nerves (*m.p.n.*), the first of which arises lateral to the perforation, and the second pair posterior to this, and latero-ventral. A pair of nerves (*g.n.*) arise posterior to these and run ventrally to the stomach.

The sub-oesophageal ganglion is connected with the ganglia of the first thoracic segment by a pair of cords, from the middle of each of which a bifurcating nerve arises supplying the muscles of the body.

There are seven pairs of thoracic ganglia (*th. g.*), the ganglia of each pair being closely connected. The pairs of ganglia are connected by commissures, those between the sixth and seventh pairs of ganglia being very short. Each pair of thoracic ganglia gives off a pair of stout nerves, which split into several parts, and supply the appendages. From the middle of the length of the commissures connecting the ganglia, nerves arise which innervate the muscles of the body.

In *Ligia* the abdominal ganglia are all fused into a single ganglionic mass (*ab. g.*) situated in the anterior region of the abdomen. In the Isopoda all stages are found, from the original separate condition of the abdominal ganglia to the fused condition occurring in *Ligia*. From the abdominal ganglion nerves arise, which supply the appendages and muscles of the abdomen; a large pair of nerves run from the posterior end of the ganglion to supply the uropoda.

A small median nerve runs between the commissures connecting the thoracic ganglia from the sub-oesophageal ganglion to the seventh pair of thoracic ganglia. It has been termed the 'sympathetic' nerve, but there is no evidence that it is of such a nature.

Sensory Organs.

The **eyes.**—As the eyes of the *Ligia oceanica* are different from the eyes of other Isopods, which have been described by Parker, Beddard and others, their structure will be given in detail.

They are compound and sessile, occupying almost the whole of the lateral region of the head. In the mature animal each eye consists of upwards of 500 ommatidia. The corneal cuticula is facetted. The corneal facets of the central ommatidia are plano-convex, with the flat side internal; those in the peripheral regions have the inner side slightly convex also.

In a single ommatidium (Pl. IV., fig. 1) the following parts can be recognised. The internal face of the corneal cuticular facet (*corn. cut.*) is covered with two thin cells, the subcorneal hypodermal cells (*s.c. hyp.*) The nuclei of these cells can be seen in the figure. Internal to these are the nuclei of the two cone cells. (*nuc. con.*). Each of the cone cells secretes a hemispherical transparent mass (*con.*), the two segments with their flat surfaces apposed form the cone. The cone cells surround the cone segments, and on the proximal side form two sub-cylindrical, transparent accessory cones (*acc. con.*), which is the most interesting and exceptional feature of this eye. The cone cells are surrounded by two pigment cells (*pg. c.*) which completely invest the upper half of each ommatidium. The retinula consists of six retinulae cells, and not seven, as stated by Beddard (1888). In this it agrees with *Idotea inovata*, which also has six retinulae cells (Parker, 1891). The retinulae cells (*ret.*) have fibrillar axes which are continuous with those of the nerve fibres. The six nuclei of the retinulae cells are situated at their proximal ends (*nuc. ret.*). The rhabdom consists of six individual rhabdomeres, each rhabdomere (*rh.*) remaining attached to the retinula cell which forms it, and separate throughout its length from the other rhabdomeres. There is a dense mass of pigment (*pg.*) between each of the rhabdomeres and its retinula cell. This may have been formed by the retinula cell, which also contains a large amount of pigment, or it may have resulted from an intrusion of a process from one of the pigment cells. The latter view is probably the correct one. The nerve fibrils of the retinulae pierce the basement membrane (*b. m.*); those of a single ommatidium fusing on the proximal side to form a single nerve fibre (*op. n. f.*), which runs direct to the distal portion of the optic lobe.

Sensory bristles.—On the flagellae of the large antennae there are a number of sensory bristles on each segment. These have been figured before by Němec (1895). Each bristle (Pl. IV., fig. 3, *s.b.*) is enclosed by a sheath (*sh*), which is continuous with the rest of the cuticula (*ctla.*). The thick inner layer of chitin is pierced by a canal, the lumen of which is continuous with that of the bristle. From the bristle, by way of the canal, a number of delicate fibres (*n. f.*) run and communicate with a number of nerve fibres lying beneath the hypodermis (*hyp.*). These sensory bristles are probably the most important organs of sense which the animal possesses, as the antennae are continually in use. Besides their undoubted tactile function, they may take the place of auditory organs.

The inner of the two styles of the uropods, as described previously, are probably of a sensory nature.

Excretory System.

The excretory system may be studied in two ways—by feeding animals on food mixed with ammonium carminate or indigo-carmine, and by injecting aqueous solutions of these substances into the body cavity. The latter method is the most satisfactory, but should be supplemented by the first. The injections are made with a hypodermic syringe (or a pipette drawn out to a fine point). The animal is injected on the ventral side, at the base of one of the appendages, and may be killed from 3 to 48 hours after the injection and fixed in absolute alcohol or Flemming's solution.

The excretory organs of Isopods have been studied by Bruntz (1904), with whose results my observations on *Ligia oceanica* are in agreement. There are four kinds of excretory organs, two of which are nephrocytes, either grouped or scattered; the third is a definite nephridium, or 'kidney,' and the fourth, certain cells in the hepatopancreas.

The maxillary kidneys, or nephridia, occur in the basal portion of the second pair of maxillae. They consist of two parts—the saccule and labyrinth. The saccule is a slightly convoluted tube, which Vejdowsky considers is a remnant of the obliterated coelom. It is blind at one end, and opens at the other into the labyrinth. The cells forming the wall of the saccule are large and of excretory nature. The labyrinth communicates with the exterior by an aperture at the base of the second maxilla.

The cephalic nephrocytes are situated at the bases of the first antennae. They occur along the ventral and lateral sides of the levator muscles of these appendages. These cells are fairly large; the protoplasm is homogeneous and contains a number of granules.

The branchial nephrocytes occur in the abdominal region, dorsal to the attachment of the branchiae. There are five pairs of groups of branchial nephrocytes. They are situated in two lateral lines, each line running above the points of attachment of the abdominal appendages, and their outer edges reach the bases of the epimeral plates. Each group borders on two segments, the first group bordering on the last thoracic and first abdominal segment. The nephrocytes lie on the sides of the branchio-pericardial canal (Pl. II., fig. 16, *br. neph.*). They are large cells, and the cytoplasm, which is vacuolated, contains many granules. Němec considers the branchial nephrocytes to be a syncytium, but the cell boundaries are very distinct, as Bruntz also noticed.

Bruntz found that certain small cells of the epithelium of the hepatopancreas, called 'Fermentzellen' by Weber, pass coloured solutions such as acid fuchsin from the body cavity into the lumen of the duct and are excretory in nature.

Reproductive Organs.

The reproductive organs of *Ligia oceanica* are simple in structure. In the male (Pl. IV., fig. 4) there are three pairs of elongate fusiform testes (*t.*), each being prolonged into a fine filament. They are situated dorsal to the intestine in the second and third thoracic segments. The three testes of each side are placed in series, and open into a vas deferens (*v. d.*) of uniform width throughout the greater part of its length. The vasa deferentia are usually white and extended. They are situated on the dorso-lateral sides of the intestine, and extend in a horizontal direction to the seventh thoracic segment. In this segment they narrow abruptly to form two narrow ducts, which curve ventrally round the hepatic tubules; each opens at the base of a styliform appendage (*st. ap.*) situated on the ventral side of the seventh thoracic segment, on one side the median line. The testes are divided by slight constrictions which indicate different regions of spermatogenesis in the interior. In the process of spermatogenesis the spermatids unite in varying numbers to form colonies, their cell walls disappearing. The nuclei elongate considerably, and very fine fibres are formed which may be attached to the nuclei, but on account of their extreme tenuity the writer is unable to be certain on this point. Miss Nichols found the same difficulty in the spermatogenesis of *Oniscus asellus*. The whole sperm colony, as it may be termed, together with the cytoplasmic fibres, is surrounded by a protoplasmic sheath. The anterior end of this is flagellate, and by contractions of the slightly muscular walls of the testis it is forced into the vas deferens. Here the sperm colonies are found bound together in masses (Pl. IV., fig. 5). The substance which causes this cohesion is probably secreted by a number of large cells which are situated in the anterior end of the vas deferens near the openings of the testes.

In the female the ovaries are very conspicuous in the breeding season, entirely filling up the dorsal part of the body cavity. They lie at each side of, and beneath, the heart, and extend from the first thoracic segment to about the fourth abdominal segment. They are usually filled with eggs of approximately the same size. A short distance behind the middle of the ovary a thin walled oviduct is given off. This opens to the exterior by a small longitudinal slit at the base of the fifth pair of pereiopods, immediately at the base of the brood pouch lamellae, these being the last pair of brood pouch lamellae.

The ova are large, oval in shape, and contain a large amount of yolk. In copulating, the male walks on to the back of the female and grasps the anterior thoracic segments with the first three pairs of pereiopods; copulation may last one or more days. After the eggs are extruded, they are carried about by the female in the brood pouch, where they develop; the young remain for a short time in the brood pouch.

Development.

The development of *Ligia oceanica* has been studied by Nusbaum. According to Nusbaum, the early cleavage is discoidal, although McMurrich has found superficial or centrolecithal segmentation in the Isopods which he has investigated. The first cleavage cell becomes separated from the rest of the yolk and lies on the periphery, where it continues to divide, and so forms a cap of blastoderm cells, no cleavage cells remaining in the food yolk. The starting point corresponds to the point where invagination takes place later, that being at the posterior end of the ventral side of the embryo.

After the formation of the blastoderm a thickening is formed, corresponding to the future ventral side. This thickening is the germ disc. Shortly afterwards, three divisions of the germ disc make their appearance. Two anterior paired portions (Pl. IV., fig. 6, *a.m.*) represent the formative region of the mesoderm; a median thickening (*end.*) situated posterior to, and between these, represents the fundament of the endoderm. The germ band is next formed by a probable forward growth of the mesoblast rudiments below the ectoderm, the ectoderm increasing in thickness. Three pairs of buds arise; these are the rudiments of the limbs, and this stage (Pl. IV., fig. 7) corresponds to the Nauplius stage. Behind these rudiments, and in front of the anal aperture, is a mesoblastic area, termed the formative area (*f.z.*), from which the remaining segments of the body will develop. The arrangement of the mesoderm cells in the formative area is extremely regular.

At the beginning of the formation of the mid-gut a number of cells (vitellophags) leave the endoderm and wander inwards; they do not take any part in the formation of the mid-gut, but assist in the disintegration of the yolk. The mid-gut is formed from two layers of cells which arise from the endoderm rudiment; these lie below the germ band, and gradually grow round the yolk, each being concave on its inner surface. By means of a ventral median piece they unite in the anterior region, and finally enclose the yolk by growing round to the dorsal side, so that the yolk becomes surrounded by mid-gut epithelium. Two flask-shaped vesicles are constricted off on each side of the anterior end of the mid-gut. These are the rudiments of the hepatic tubules, which are formed by their backward growth, and a longitudinal constriction and division of each rudiment into three parts.

The rudiments of the thoracic limbs are biramous (Pl. IV., fig. 8), a fact which is used in support of the theory that the Crustacea have descended from a schizopodous ancestor. In *Ligia* the inner limb (endopodite) alone develops, the exopodite being suppressed.

The nervous system arises as a continuous whole from the ventral thickening of the ectoderm between the limb rudiments. The thoracic ganglionic rudiments are paired, but those of the abdominal segments are unpaired. Three pairs of ganglia form the supra-oesophageal ganglion, namely the optic, first and second antennal. The sub-oesophageal ganglion is formed by the fusion of four pairs of ganglia—the mandibular, first and second maxillar and the maxillipedal. There are rudiments of seven ganglia in the abdomen; rudiments also of seven pairs of abdominal appendages are originally formed.

The heart is formed by the fusion of two dorso-lateral layers of cells, crescentic in section, and lying dorsal to the gut. The limbs develop successively from before backwards. In the earlier stages of development the embryo has a dorsal curvature, but later it becomes ventral. On hatching, the young isopod possesses six pairs only of thoracic appendages, which are imperfectly segmented, and not setose; the cephalic region of the young animal is large in proportion to the rest of the animal. It leaves the brood pouch of the female, and after several moults attains the adult form.

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Explanation of Plates.

Plate I.

Ligia oceanica (Linn.), dorsal view, × 4.

Plate II.

Fig. 1. First antenna seen from the side: much enlarged.
Fig. 2. Second antenna of left side seen from above.
Fig. 3. Left mandible seen from below.
Fig. 4. Teeth and molar process of mandible from the posterior side.
Fig. 5. First maxilla of left side.
Fig. 6. Second maxilla of left side.
Fig. 7. Left maxillipede.
Fig. 8. First pereiopod of male.
Fig. 9. Seventh pereiopod of male.
Fig. 10. Second abdominal appendage (or pleopod) of left side of male, showing copulatory style; anterior view.
Fig. 11. Fourth abdominal appendage (pleopod) of male, posterior view, showing the inner lamella.
Fig. 12. Third pereiopod of female, attached to the epimeral plate, showing one of the brood pouch lamellae arising from the sternum internal to the appendage.
Fig. 13. Fourth abdominal appendage of female, anterior view. The inner lamella can be seen by transparency; also the afferent (*a.b.v.*) and efferent (*e.b.v.*) branchial vessels.
Fig. 14. Uropod, showing sensory process at the tip of the inner style.

Fig. 15. Interior of the right side of the stomach. The stomach has been opened by a vertical section, a little to the right of the median line so that the median ventral tooth has been removed. The greater part of the cardiac region of the stomach is surrounded by a layer of connective tissue. (*a.l.t.*) antero-lateral tooth; (*d.l.*) dorsal lamella; (*hep.*) hepatopancreatic tubule; (*l.c.l.*) lateral cardiac lamella; (*l.c.t.*) lateral cardiac tooth; (*m.a.t.*) median anterior tooth; (*oes.*) oesophagus; (*v.l.t.*) ventro-lateral tooth; (*v.l.p.l.*) ventro-lateral pyloric lamella; (*v.c.t.*) ventral cardiac tooth.

Fig. 16. Transverse section through the abdominal region. The abdominal appendage of the left side is omitted. (*ad. tiss.*) adipose tissue cells; (*b.c.*) body cavity (haemocoel); (*br. neph.*) branchial nephrocytes; (*br. p. c.*) branchio-pericardial canal; (*d.l.m.*) dorsal longitudinal muscles; (*epim.*) epimeron; (*ht.*) heart; (*inf. lam.*) inferior lamella of gill; (*lev. m*) levator muscle of appendage; (*mid. g.*) mid-gut; (*p.c.*) pericardium; (*sep.*) septum forming floor of pericardium; (*sup. lam.*) superior lamella of gill; (*ty.*) typhlosole; (*vl. hep.*) ventro-lateral hepatopancreatic tubule; (*v. hep.*) ventral hepatopancreatic tubule; (*v. l. m.*) ventral longitudinal muscles.

Fig. 17. Transverse section of two of the rosette-like salivary glands. The left section shows the common duct (*c.d.*) of the glandular cells, formed by the uniting of the intracellular ducts (*ic. d.*); *n.c.d.* is the nucleus of the cell which probably forms the common duct.

Plate III.

Fig. 1. Dissection of the arterial system from the dorsal side. The main arterial trunks are drawn somewhat larger than they are naturally. For the sake of clearness, details of the anatomy have been omitted. (*ab. art.*) abdominal artery; (*cer. g.*) cerebral ganglion; (*cr. art.*) crural artery; (*ep. art.*) epimeral arteries; (*gen. art.*) genital artery; (*hep. art.*) hepatic arteries; (*ht.*) heart; (*int. art.*) intestinal artery; (*lat. art.*) lateral artery; (*med. ao.*) median aorta; (*op. a.*) ophthalmic artery; (*ost.*) ostium; (*vent. art.*) ventral artery; (i-vii) thoracic arteries.

Fig. 2. Arteries of the left side of ventral surface of head and first thoracic segments. (*ant. art.*) antennal artery; (*fac. art.*) facial artery; (*mand. art.*) mandibular artery; (*mx'.*) artery of first maxilla; (*mx''.*) artery of second maxilla; (*mxp.*) artery of maxillipede; (*oes. art.*) oesophageal artery. Other references as in the preceding figure.

Fig. 3. Afferent vessels of the superior lamella of one of the abdominal appendages injected with indigo-carmine from the sternal sinus.

Fig. 4. The nervous system, seen from above after the removal of the muscles and viscera. (*ab. g.*) abdominal ganglion; (*ant. n.*) antennary nerve; (*g.n.*) nerve to stomach; (*med. n.*) median nerve; (*m.p.n.*) nerves of mouth appendages; (*op. l.*) optic lobes; (*sub-oes. g.*) sub-oesophageal ganglion; (*Th'. g.*) first thoracic ganglion.

Plate IV.

Fig. 1. Longitudinal section of a single ommatidium. (Drawn with the camera lucida.) (*acc. con.*) accessory cone; (*b.m.*) basement membrane; (*con.*) cone; (*corn. cut.*) corneal cuticula; (*nuc. con.*) nucleus of cone cell; (*nuc. ret.*) nucleus of the retinular cell; (*op. n. f.*) optic nerve fibre; (*pg.*) pigment; (*pg. c.*) pigment cell; (*ret.*) retinular cell; (*rh.*) rhabdomere; (*s-c. hyp.*) sub-corneal hypodermal cell.

Fig. 2. Transverse section of ommatidium showing the six retinulae cells and their rhabdomeres.

Fig. 3. Longitudinal section through the cuticle of a segment of the flagella of the second pair of antennae to show a sensory bristle and its nerve supply. (*ch.*) thick layer of chitin; (*ctla.*) cuticula; (*hyp.*) hypodermal layer; (*n.f.*) nerve fibrils; (*s.b.*) sensory bristle; (*sh.*) sheath of sensory bristle.

Fig. 4. Generative organs of the male. (*t.*) testes; opening into (*v.d.*) the vas deferens, which opens externally by the styliform appendages (*st. ap.*).

Fig. 5. A collection of 'sperm-colonies' as they are found in the vas deferens, in the cohesive substance secreted by the latter.

Fig. 6. Early stage in the development of the egg, showing the cleavage of the germ disc into the two antero-lateral mesoderm fundaments (*a.m.*) and the median posterior endoderm fundament (*end.*).

Fig. 7. The 'nauplius' stage of the development of *Ligia*, showing the three naupliar appendages. (1.*a.*) and (2.*a.*) the first and second pairs of antennae, and the mandibles (*mand.*); (*end.*) endoderm fundament; (*f.z.*) formative zone; (*op.*) optic lobe.

Fig. 8. A later stage in the development, showing the elongation of the formative and the formation of appendages, also the rudiments of the ganglia. (*an.*) anus; (1. and 2. *mx.*) first and second pairs of maxillae; (*mxp.*) maxillipedes.

The last three figures are after Nusbaum.

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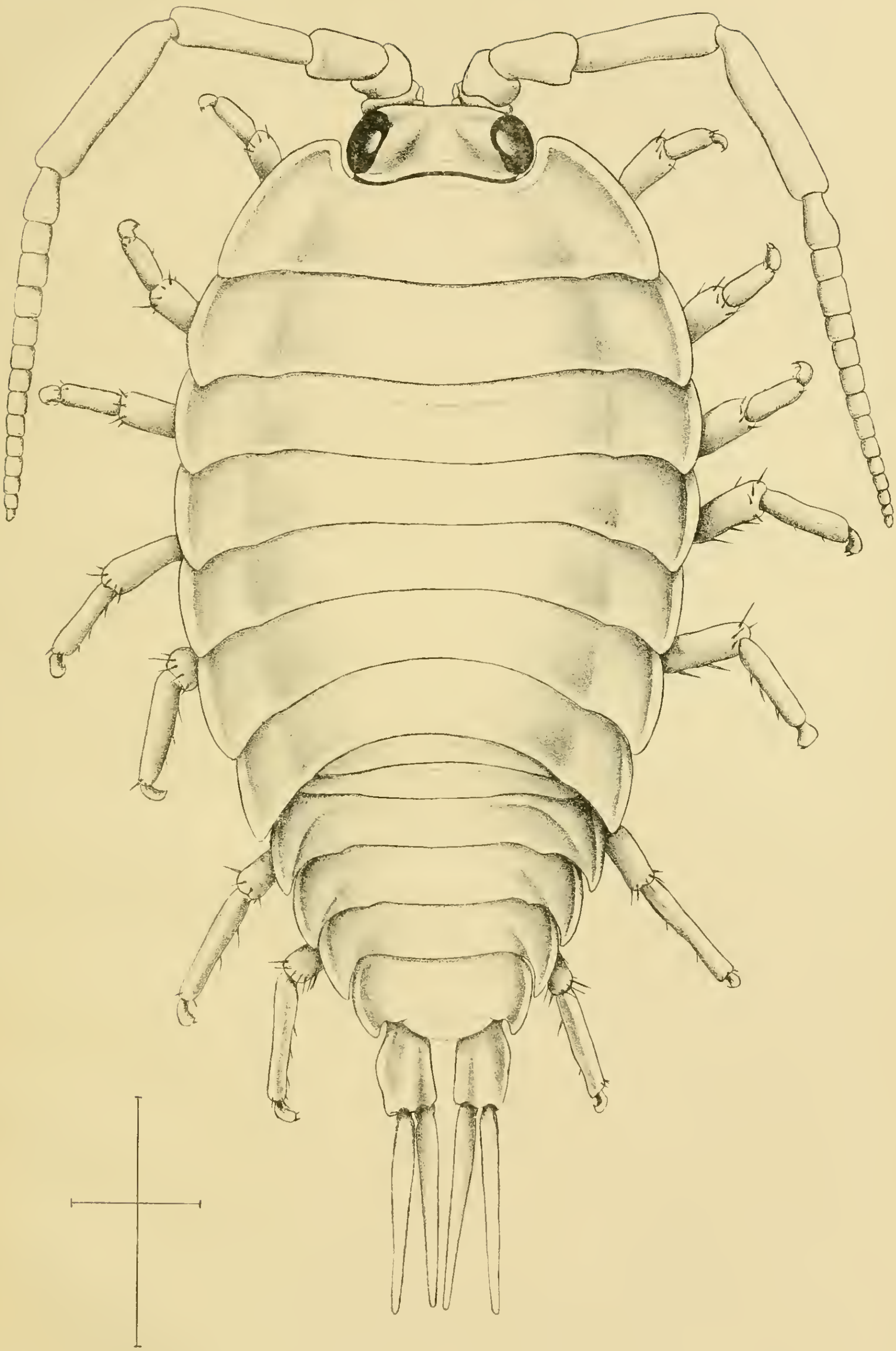

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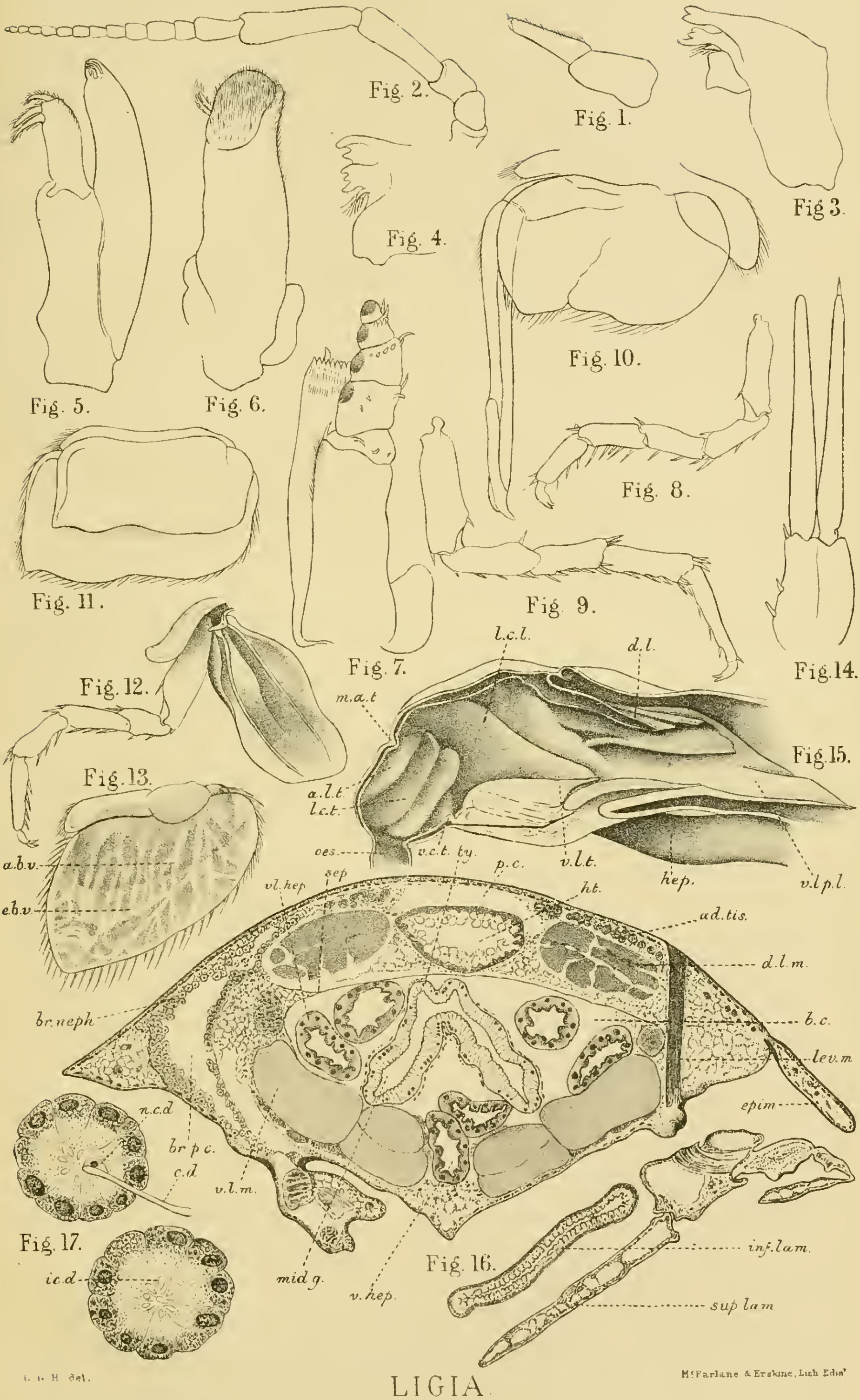

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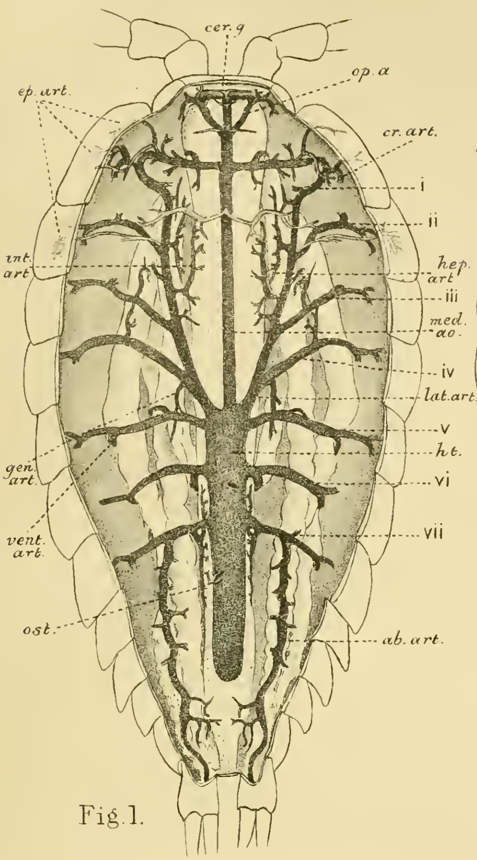

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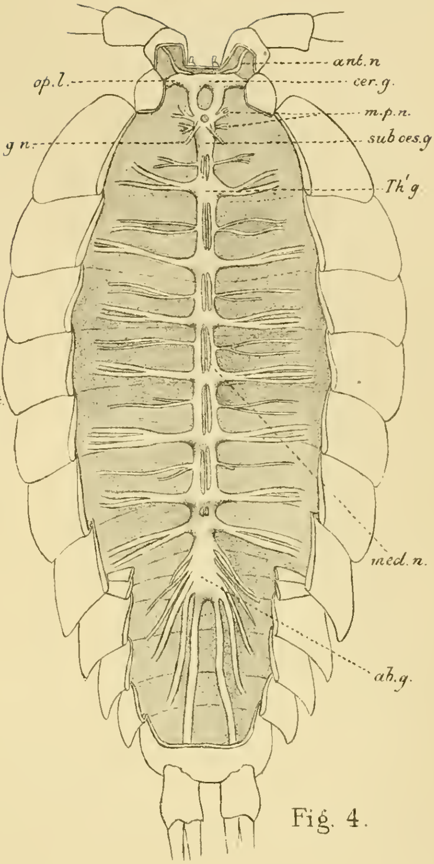

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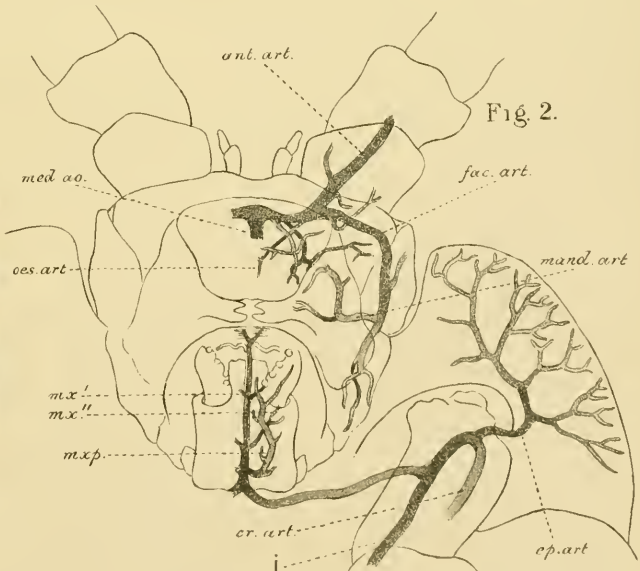

Fig. 2.

Fig. 3.

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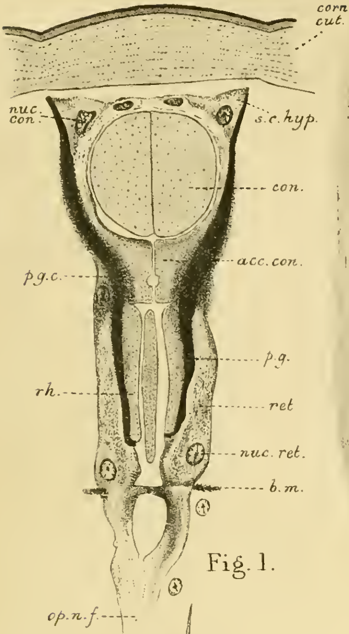

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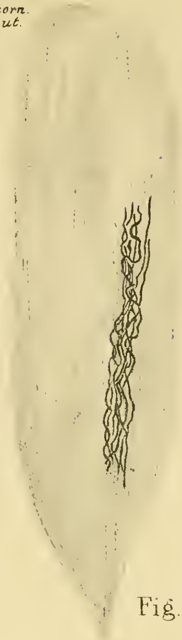

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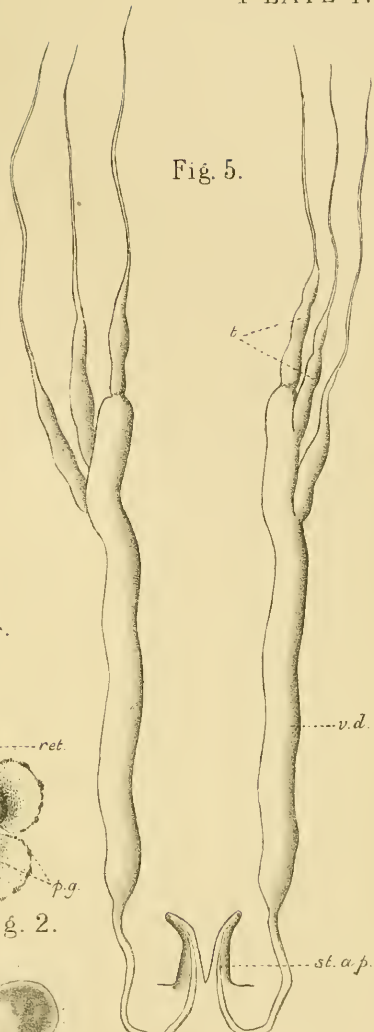

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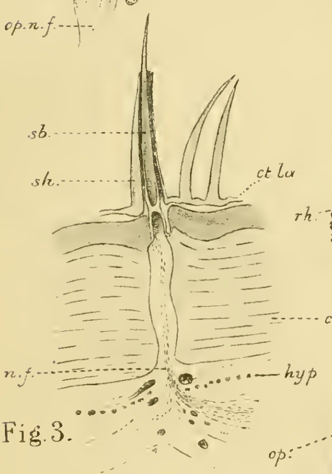

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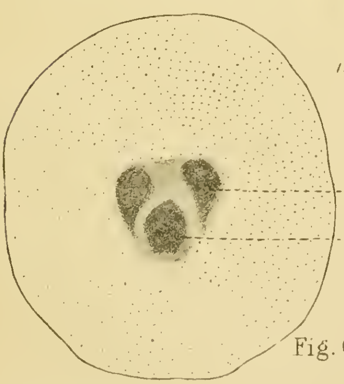

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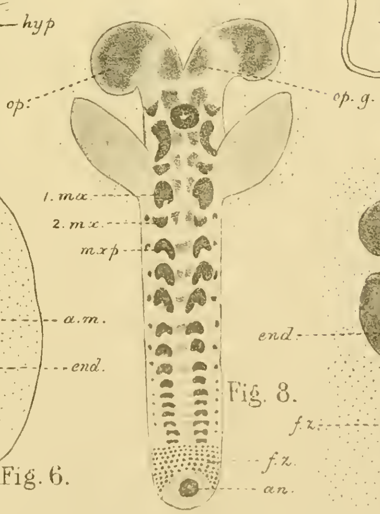

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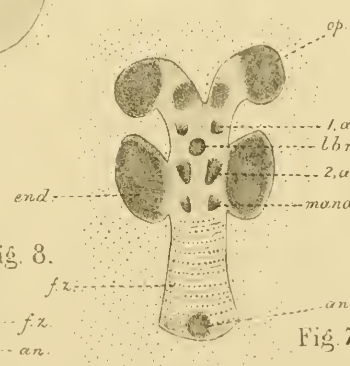

Fig. 7.

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