THE

JOURNAL

OF

MARINE ZOOLOGY

AND

MICROSCOPY:

A plainly-worded Biological Magazine.

EDITED BY

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VOLUMES I. & II.

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CORRECTIONS.

VOL. I.

On page 18, line 6, read "ovary" instead of "ovum."

In the article on "Variation in the Operculum of *Serpula*," pp. 57-60, *delete* all paragraph "C" on p. 60, also the whole of the last five paragraphs of the article from the words "so much for collateral evidence," etc. This is necessary as the dorsal processes, or "tentacles" of *Sabella*, are now known to be processes of the collar, and thus not homologous with the operculum of *Serpula*.

VOL. II.

In the explanation of Plate V., for "Figs. A to D, *Plumularia pumila*," read "Figs. A to D, *Sertularia pumila*."

Page 24. Note that the Pteropoda are now definitely merged with the Gastropoda and do not constitute a separate class.

Page 80. Let the 16th line from the bottom read "asserts that it will be only the effects of hatcheries such as this, that can prevent."

CONTENTS.

The Journal of Marine Zoology and Microscopy:

A PLAINLY WORDED BIOLOGICAL QUARTERLY.

VOL. I. NO. 1. NOVEMBER, 1893.

INTRODUCTORY.

WE scarce know whether or not apology is due for the appearance of this Journal in the long catalogue of Zoological periodicals. However, we believe a few words of explanation as to the inception of this project will suffice to justify its existence, and to arouse, we trust, sympathy with the undertaking.

When the idea first arose, it was in the narrow form of the issue of several pages of letter-press, descriptive of certain microscopical preparations of rare and interesting marine animals which were to be issued from the laboratory of the Jersey Biological Station from time to time. Gradually with further consideration the idea expanded, and we now ask for your support on the plea that this will be a journal wherein will be recorded general life-history notes, *for the most part original,* upon the Fauna of British Seas, together with descriptive articles and drawings of noteworthy points in the anatomy and histology of the animals from which the above-mentioned microscopic preparations are made. The greatest care will be taken to insure accuracy in the drawings. Being original these will have great value, not only to the amateur but also to the professed specialist. Not their least recommendation will lie in their being coloured by hand from the living animals.

Notes on current Zoological literature and progress will appear, while the microscopical portion will contain corresponding notes and hints upon the preparation of objects for the microscope. These subjects are in the present issue unavoidably crowded out, but this will be remedied in the future. We shall, we trust, substantially increase the bulk of the journal in succeeding numbers, but of course this will depend directly upon what amount of support naturalists accord us.

Every effort will be made to render the matter in good and lucid English. Technical terms will be avoided wherever great sacrifice of directness is not involved. All articles will be relevant and our efforts will be directed towards conciseness. The journal will be the organ of the Jersey Marine Biological Station, and will chronicle its progress, its struggles, and its encouragements, and thus afford to its many friends and supporters interesting record of the help it is rendering in a modest way to the cause of Natural Science.

The great majority of the present notes are furnished by the Station, and unfortunately the Editor and his pen are responsible for the whole of the present matter. Time has been too short to obtain for this issue any literary assistance from friends, but the Editor is able to promise that short notes will in future appear from several able writers in the world of science.

A first number is always beset by certain grave difficulties that however usually lessen with each succeeding issue. We are experiencing this in a great degree, and plead this as excuse for whatever blemishes disfigure the present pages.

But enough. Having asked your kind forbearance we must push off and venture out among the waves of criticism with what strength and courage and skill we can summon—

> "It may be that the gulfs will wash us down,
> "It may be we shall touch the Happy Isles,"

and whichever fate awaits us, we shall strive stoutly to deserve the more fortunate.

THE JERSEY BIOLOGICAL STATION. The hopes regarding the advantages that would accrue to Marine Zoological Science from the establishment of this Station, have been shown, by the past nine months' experience, to be well founded. Completed in March of the present year, work was immediately begun in the stocking of the aquarium tanks, and in the bringing together of representative specimens of the local Fauna. Much remains to be done, but there can be no doubt as to the suitability of the site chosen, and of the planning of the building.

In front, stretch for miles, immense areas of perhaps the finest collecting ground in Britain; the Station boats are moored within a stone's throw; high tide comes practically to the doors; the sea is pure and uncontaminated by sewage. The land surroundings are equally good, being the prettiest and quietest suburb of St. Helier; thus while having all the advantages of proximity to a large town, the Station is free from the close atmosphere and traffic noises of an urban situation.

The building consists of three floors: The first answers the purposes of an aquarium, while adjoining is a rough dissecting room, &c. The second contains the type museum and reference library, and serves admirably as a demonstration room. Finally upon the third floor, are partitioned compartments of ample size, for the use of students and research workers; several have already taken advantage of these facilities, and indications are that from next Easter onwards, there will be quite a numerous band of students and investigators at work.

NOTES ON ANIMAL COLOURATION.

(Series I.)

BY JAMES HORNELL.

I. On Lateral Independence in the Nervous Control of Colouration in the Octopus.

SELDOM have I been more surprised than when I first saw parti-colouration in the Octopus. I had been watching one of these creatures creeping slowly from point to point over the rock-work of the large tank which it inhabited in company with four others of its kin. In colour it was of the same dappled brown characteristic of the others. But suddenly, without apparent cause, the colour of the right side of the body as, too, that of the four arms appertaining to that side, paled almost to snowy whiteness. The division into coloured and uncoloured halves was absolute: had the median line been drawn with mathematical accuracy down the dorsal aspect, the division could not have been truer. This curious appearance lasted close upon five minutes, and though I took every opportunity of watching for its recurrence, nearly a week passed before I was successful. In this second instance it was not the same individual and the side that became deprived of colour was the left. The distinctness of the bipartite colouring was fully as well marked. Since then I have found by close observation that while by no means frequent, still this colour control was possessed by all the five specimens under observation.

Complete functional independence so clearly marked as this, is extremely unusual and it does not appear to have been noticed as voluntarily practised by the animal in question. It has however been observed as induced by artificial means during investigation by Klemensievicz* on the nerve centres controlling the pigment bodies or chromatophores of the Cephalopoda. These bodies—sacs full of pigment—are each provided with a radiating set of muscular fibres, which being excited, contract pulling the pigment sac into a

* "*Beiträge Zur Kenntniss des Farbenwechsels der Cephalopoden,*" Sitzungsber der Acad. Wien, 1873.

stellate form of much greater size that in the resting condition. When exciting cause is gone, the muscles relax and the pigment sac springs back to its normal spherical contracted state. What Klemensievicz found was that the innervation or nerve supply of these muscular fibres had its centres in the two peduncles or stalks of the optic ganglia, that issue, one on either side, from the coalesced ganglia functioning as the animal's brain. Moreover he discovered that irritation of one of these centres caused immediate change of colour in the corresponding side of the body. This implies a very close connection between the sense of sight and the chromatophores of the skin. Frequently have I seen an Octopus crawling among brown Fucus of a tint absolutely similar; anon as he darted away from this hiding place among the weed, he paled and grew grey as the sand over which the course lay. From what we know, the alteration of colour would here be a reflex result working through a visual perception of the alteration in the surroundings, passed inwards to the centre having control of the pigment sacs.* I believe the action to be purely involuntary, the adaptation being a process too complicated and delicately precise to be coordinated consciously.

In the same way the deep uniform chestnut-brown assumed by the animal under the excitement of combat—which I have frequently seen—is a reflex effect of the general nervous excitement aroused in the whole system; muscular contraction and not relaxation being well known to be one of the chief constant characteristics of strong emotion of this kind.

Again in swimming, more than usual effort is put forth by the Octopus—and this action characterised thus by vigorous muscular contraction is performed by the animal *always* in a colour guise of rich deep brown. When resting—which takes place usually during daylight—the colour is generally pale. Illness too is accompanied by great lack of colour.

In connection with the phenomenon of parti-colouration, it is interesting to note the following somewhat related instances. In Guernsey Museum is a lobster coloured of a pale pink down one side, but of the ordinary deep blue black upon the other. No special dissection was made, but there is obvious reason to believe the cause

* Since writing the above, it occurs to me that an alternative explanation can be given by supposing that the chromatophores act as *eye-spots*; that they themselves receive the impression of change in the colour surroundings, pass it back by their nerves to the controlling centres, which, upon this irritation, give out impulses bringing about alteration in the form of the chromatophores, and consequent change in the body hue. But I doubt this, principally because one would rather expect *local* colour change, than suffusion over the whole body as does normally happen. We would expect the alteration to occur only on that aspect turned towards the coloured objects of the environment, and this is not what does happen. To settle this point, I purpose carrying out some direct experiments, the results of which will be duly recorded.

was an injury to the nerves controlling the nutrition of the pigment cells upon one side of the body, as there remain signs of an old wound penetrating a little to one side of the median line right through the body.

The other case is one quoted by Dr. Lawrence Hamilton in "*Natural Science*" for Sept., 1893, to the effect that the Chameleon has been observed to be red on one side while of a green hue upon the other. The explanation has been hazarded that one side of the animal was asleep while the other was awake !

II. An Albino Lobster.

Before me as I write is a very unusual case of abnormal colouration, in the form of an all but white Lobster. Six weeks ago some fishermen brought it in, in good health. They told with much exultation how pleased they had been to find so curious a beast in one of their pots set in St. Aubin's Bay, on the south coast of Jersey. Never before had they taken or heard of such a curiosity, and experience and enquiry bear out the rare occurrence of such colouration, or rather want of colouration.

In size, this strange Lobster is fully adult, 14 inches long from rostrum to telson. When living in one of the large Aquarium tanks along with normal deep blue-black kindred, the contrast was wonderfully well marked. The one in question gave a definite impression of white, albeit rather soiled. Close and minute inspection showed this soiled appearance to be due to a very faint development of bluish pigment. On the carapace and limbs it was a pale and diffused hue that in no way could be said to mask the limy whiteness of the shell. On the abdominal parts the hue was somewhat better marked, the pigment blotches showing faintly but still traceably.

With its companions, it held its own. Appetite was good and apparently it was in perfect health. Whatever the cause of the colour may be, one fact was self-evident, its light hue rendered it extremely conspicuous. When its dark blue relatives were at rest in their nooks of retreat, they were difficult to discern. Their colour was not out of harmony with their surroundings, but the white one was so, most markedly.

If not pathological, this paleness of colouring is probably an instance of partial reversion in hue to that of some lighter coloured ancestor of different habit. The blue-black colour of normal Lobsters is certainly acquired. No other British crustacean boasts the same hue. Reds and browns predominate among the larger, while among the smaller Decapods, absence of pigment is very general. The swimming prawns *(Palæmon)* for instance, are marked by a nearly complete want of colour and by an allied transparency. The burrowing prawns *(Callianassa, Gebia and Axius)* on the other hand, are characterised by porcelain-like shell armour, either of pearly whiteness or else of coral pink.

III. Albinism among Marine Animals.

From the preceding note, the transition is natural to a consideration of albinism generally among the inhabitants of the sea.

At the outset we may well consider the characteristics of albinism among land vertebrates. There the phenomenon is seldom found among the Reptilia. It is among the divisions possessing feathery and hairy epidermal clothing (Aves and Mammalia) that it is met with most frequently. Lack of colouring matter in such cases, means albinism of snowy whiteness of plumage or pelt, *i.e.*, opaque whiteness. As every one now knows, when such is not an abnormal feature but is the settled hue during life or is regularly recurrent at one season, the possessing animals are, in a great majority of cases, inhabitants of snow-bound regions—polar or else above the snow-line in our great mountain ranges.

Albinism here may be assumed either as a method of protection or as a device to allow of unobserved stalking by carnivorous animals.

In the sea albinism in this narrow sense of opaque whiteness is seldom met with. There are no snowy plains beneath the waves—indeed in the dim light that reigns in the shallows and in moderate depths, whiteness would be a positive and very dangerous attribute. To the weak and ill-armed it would mean speedy extermination—so where it is present, either its employment will fall into the category of (*a*) warning devices, (*b*) lure devices to attract prey, or lastly (*c*) where the possessor has neither use nor fear for any particular colour.

It may here be convenient to place in tabular form the more common albino representatives yielded in British Seas by the various animal classes.

Protozoa :—*Foraminifera*, *e.g.*, the porcelain-white tests of *Miliolina*, &c. (calcareous).

Spongida :—*a.* The aspiculous *Halisarca* sometimes.
b. The calcareous sponges generally, *e.g.*, *Leucandra nivea*, *Ascaltis*, *Sycandra ciliata*, *S. compressa* and often *Ascetta (Leucosolenia) coriacea.*

Cnidaria :—*Actinoloba dianthus* ; *Alcyonium digitatum.*

Vermes :—Turbellaria, several.
Polychæta, *Nephthys* (burrowing), and the white plumes of a certain *Sabella*.

MOLLUSCA :—*Pholas, Lima, Cardium, Teredo,* and others, mostly burrowing.

CRUSTACEA :—The burrowing crabs *Corystes* and *Thia,* also the burrowing prawns *Callianassa* (white) and *Gebia* and *Axius* (pinkish).

ECHINODERMS :—*Cucumaria* (hiding).
Ophiura albida (calcareous).

TUNICATA :—*Circinalium concrescens* (calcareous spicules).

FISHES :—Under surfaces of Flat fishes—Plaice, Turbot, Soles; also of Ray fish and their relatives.

In our present obscure acquaintance with colour significance, it behoves us to proceed with caution in our speculations. Still two striking facts come out in perusal of the foregoing list; first, that white is associated in most cases with either the presence of a calcareous skeleton (Forams, Sponges, &c.), or with the habit of burrowing. In the latter case it does not seem to be the absence of light that prevents the development of colour—there are abundant instances of deep pigmentation developed in the dark. Cases in point are the burrowing purple *Spatangus,* the dark-green lug-worm (*Arenicola*), pigmentation of the nerve system of *Amphioxus,* of the mesentery of the Frog, &c.

Animal colouration has, I believe, always direct value to the possessor and is a developed attribute, being kept *in esse* solely by the continuation of the original exciting cause or causes. The principal of these are protection, warning, luring, sexuality and food supply. Take the exciting factor away and gradually the colouring having lost its usefulness will disappear. The production of colour must mean expenditure of energy; an allowable expenditure so long as it serves a useful purpose, but which becomes waste when it ceases to do so—a waste which natural selection is bound to dispense with in time. What does this lead to? Clearly that it is probable that the burrowing forms that are albino (worms, crustaceans, molluscs, &c.) may have dispensed with a former colouring because of a present non-requirement of such. The same explanation, I believe, applies to the under or white side of flat-fishes.

IV. THE COLOURATION OF SPONGES.

In the list given above of albino animals, the long list of white calcareous sponges is remarkable—no other order of animals is so consistently uniform in colour. The explanation I have to offer is that this is due (*a*) to the spongin or ground tissue of the sponge being reduced to a minimum, and (*b*) to the shape of the spicules being such that the optical effect produced by a dense closely packed mass of them is snowy white to the eye. Corroboration is furnished by the occasional occurrence of two exceptions in colouring, viz., in *Ascetta coriacea* and in *Alcyonium digitatum.* In the former case the sponge frequently varies from the normal white to a lemon yellow or orange, and even red, while in some rare cases *Alcyonium* is found of an orange hue. Examination microscopically, shows in both cases the new colour to lie in the ground tissue. Again, if we boil a piece of calcareous sponge in potash solution and get rid thus of all the animal matter, leaving spicules alone—the latter will be found to compose a snowy powder at the bottom of the vessel.

It is interesting to note that in marine animals, next to the primary white, comes yellow in various shades, grading easily into orange and then into red; an interesting fact when we remember that a similar colour series is made out in the acquisition of colour by flowers.

Another interesting point brought out by comparative examination of sponge colouring is that species with siliceous skeleton spicules are well advanced in the colour scale. Scarcely any have the primitive white.

How is this? It is not in all cases that siliceous spicules have such differences in form from the spicules of calcareous sponges as to lose the optical appearance of whiteness, because to take *Pachymatisma* as an example—even a small mass of its separated spicules appears of snowy whiteness, and yet alive, the sponge is not so coloured. The difference is certainly due in this case, to the optical whiteness of the spicules being masked by a superior development of coloured fleshy tissue. The other siliceous sponges have also this superior development of soft tissue, and this appears to have become pigmented through the action of certain of the following factors:—(*a*) a necessity for some colouring other than a dull greyness to act as a "warning" colour to predatory animals, (*b*) the greater ease in producing other pigments than white, *or* (*c*) the greater utility for this purpose of such alternative colours. The former of the two last mentioned is most certainly the more probable, for the white calcareous sponges are quite as immune from attack as any of the gorgeous scarlets and oranges of the siliceous division. What holds good of these sponges applies equally to the crusting compound Ascidians, which in brightness of colour rival, and at times outstrip the sponges.

OBSERVATIONS ON THE HABITS OF MARINE ANIMALS.

BY JAMES HORNELL.

SERIES I.—a. *The Octopus in captivity (cleaning of Suckers, strength and feeding habits).*

b. *Hunting-craft of the John Dory.*

I. THE OCTOPUS IN CAPTIVITY.

PERHAPS of no other animal have more fabulous travellers' tales been recounted than of this creature. Some have sought to identify it with the terrible Kraken—that superlative sea-terror of our viking ancestors. Others have figured it as the bona-fide sea-serpent, and then who is not familiar with the wonderful cuts in the old natural history books of the "colossal polypus" seizing a great three-masted ship and dragging it down to the depths.

In more recent years, Victor Hugo has, with poet's license, painted in sensationally gruesome detail, such an exaggerated and terrifying picture of the Octopus, that the true details of its really grim quaintness are apt to fall flat and appear trivial to those whose knowledge extends no further than the "Toilers of the Sea."

Quaint creatures indeed! Five of them are now restlessly crawling, swimming and climbing about the rockwork of a tank close at hand as I write. There, see the large fellow in the centre perched monkey-like on a boulder—what is his object in making an animated 'catherine wheel' of himself as he is doing? See how the pliant arms writhe and coil, in and out, over and under, intermingled, and upon themselves in supple twists and turns, as of a heap of lampreys in a bowl. See now the motion slackens and slowly the animal reverts to his sly slowly moving normal state. Frequently have I seen this performance, and it always appeared to give considerable satisfaction to the animal.

For a little while I was puzzled to account for such acrobatic movements, but soon I began to notice that these were accompanied by a throwing off of many disc-shaped cast-skins of suckers. The inference became plain that the process was a cleansing one, intended to get rid of this loose skin. After a period of activity, especially after a rough and tumble scramble for food, many suckers are seen with shreds of loose skin partly detached. As pneumatic organs the suckers must thus be much impared—hence the necessity for a frequent "rub-down," which is performed in the manner described.

STRENGTH. The strength and carrying power of the Octopus is—legends put on one side—really wonderful. When we had ours first, we planned out a picturesque arrangement of loose boulders to ornament the tank, but alas for earthly hopes and scenic display, our Octopus had their own ideas of how a tank should be arranged, and—we had three at first—piled the stones in ugly inartistic heaps in three corners. The route each boulder had taken was plainly graved by a deep rut in the loose sand and shingle that covered the bottom. Some of the blocks of stone were fully 9-in. in diameter, and our smallest Octopus—3-ft. 6-in. spread from tip to tip—could easily move them about like so many play things. Time after time this was done, to the woeful stirring up of all the sediment that in even a short space of time gathers in a tank. Indeed at last we were compelled to take away the sand and shingle, in which our friends had been so fond of blowing out nest-like lairs, and for sanitary reasons to leave them with but a few very large boulders and the thinnest layer of shingle in the bottom.

The overflow pipe in this tank is moveable and fits at its lower end into the opening of the low-level outlet. Being of lead, the weight of this pipe is considerable—to give the exact figures 9-lbs. 12-ozs. We are accustomed to lift it out bodily when desirous of emptying the tank completely. We never dreamed of such being liable to be moved by any force but our own, so our surprise may be judged when upon going down early one morning, we found the Octopus tank dried up; the overflow pipe wrenched out and lying prone on the bottom. Our concern was great and well founded—all the inhabitants were apparently dead, but the faintest play of colour in some argued a spark of life remaining. As quickly as possible we transferred the three that showed this to water, and soon had the satisfaction of seeing them recover. Two however we laid regretfully out on the floor, deploring their untimely demise—but to our unexpected pleasure one gave out a faint movement just sufficient to arouse hope—so we transferred both to the water with the other three, and were rewarded beyond our utmost hopes in soon seeing them make languid motion. The lapse of 24 hours saw them again in their usual healthy condition, but we had had our lesson. Ever since, we take care to wedge the overflow pipe firmly down before leaving at night.

We have also to take care to close the shutter securely above the tank, for twice we have found, after a short absence, one of the Octopus crawling excitedly about the floor like some monstrous spider.

Usually they are fed upon the common green Shore Crab (*Carcinus*), three or four daily—but they are far from being fastidious. If a few limpets be thrown in, they dart from their lairs and pounce upon them in a way which seems very like the turning of a somersault. Cockles, mussels, whelks—all are welcome and quickly devoured. As a rule the detritus of shells is thrown away within a couple of hours or less. In the case of Crabs, the carapace and endophragmal system are picked beautifully clean and are quite unbroken—the limbs too are separated and usually broken at the principal joints.

Limpets are the most badly cleaned, as there is generally a ragged ring of torn membrane left half-way up the inner surface of the shell.

Apparently any moving object—barring fish—is seized and tested for food. Several times I have thrown white pebbles in and in all cases, when hungry, the animals have darted out and drawn them to the mouth. It may be that this habit is not a natural one but is induced by the method of feeding by throwing the food into the tank—but whether or not this be so, I have little doubt that it is by sight and not by scent that the Octopus hunts.

The Octopus usually, but not invariably, darts out upon the prey. Often enough, if the object—say a crab—run within reach, the Octopus leisurely casts out one of its long arms—as a rod-fisher does his line—and lets the delicate tip touch lightly the carapace of the prey. Lightly it touches, but none the less securely is the crab caught. Some of the suckers have come into play. Often a second arm is then thrown out and some of the terminal sucking discs of this attached. Then the animal is slowly drawn to the mouth to be devoured at leisure, and strangely enough, the Crab almost invariably makes not the slightest resistance. It is as though stupefied and rendered helpless by terror—or is it that it feels powerless to resist? Once one of the Crabs thrown in, *did* elect to resist. It snapped viciously at the delicate arms, and surprised, the Octopus cowered down, letting go its hold. Instantly the Crab scurried away to climb up the tank side as far as possible out of reach of the foe. Several times in the course of succeeding days one or other of the Octopus tried to snare it, but with similar result as the Crab always made a stout resistance. At last one day it was mastered and we have never since seen a similar instance of fight on the part of Crabs.

II. Hunting Craft of the John Dory.

How like a consciously wise old vestryman is the Dory *(Zeus faber)* as he turns his great rotund solemn eye to survey the scene around him, and erects his great dorsal fin, with its few long rays so like the cherised and sparse hairs that ornament the afore-mentioned gentleman's polished bald cranium. A solemn and wise fish he looks, aye, but there is craft concealed beneath those smooth benevolent pecksniffian features. See, he moves stealthily along to within four inches of that Goby there on the bottom. See, with head directed downwards and just sufficient gentle, almost imperceptible motion of the fins to keep him in unchanged position, does he not seem bent upon hypnotising the Goby? But there, the latter is tired of being looked at. The Dory follows round to face him again, but does not try to diminish the distance. Thus 15 to 20 minutes go by, with alternate moves on the part of the two fishes, but with no alteration in the distance. At last any vague fears that the Goby had of his strange observer are lulled and he relaxes his vigilance. The Dory now sees his opportunity; the colour bands on his sides intensify and darken, the dorsal fin goes up—it had lain folded down till now. This martial bearing takes but a moment to put on—indeed it is really coincident with a lightning swift forward movement—a swift dash—a great telescopic mouth thrown out—the disappearance of the Goby and a satisfied gulping on the part of the Dory.

Thus it happened continually. Always a long stealthy stolid staring stalk, often unsuccessful it is true, but still giving a very satisfactory average, so the Dory appears to think. No doubt he counts upon occasional failure. He knows and appreciates his own large stock of patience, and is conscious that he can depend upon it for a comfortable competence in life. Gobies, Smelts, Wrasses and Grey Mullets have been fed upon in our tanks by the Dory.

Once recently the smaller of the two Dorys that we have, "negotiated" a 15-spined stickleback (*Gasterosteus spinachia*) quite 5 inches long. For a few seconds, the captor did his best to calm within his capacious stomach the flutterings of the 15-spined dorsal fin of the prey, but it was beyond his power. With sudden determination the Jonah was shot out, and like his great forerunner, seemed not one penny the worse. Away he swam after a moment's flurried hesitancy. There was a very obvious movement, what in a higher animal might be termed a shaking of himself together, and then a rapid return to every day humdrum existence.

The John Dory, we may add, lives very well in confinement. Our two we have had a long time. They are as can be seen from the above, very particular about having living food, but so long as it be small fish they do not mind what species.

ON THE METHOD OF DISPERSION

AND

FERTILIZATION OF OVA IN SOME SABELLIDS.

BY JAMES HORNELL.

PRINCIPAL among the tube building Sabellids that live in the Aquarium tanks at our Jersey Station, are a considerable number of the fine *Branchiomma (Sabella) vesiculosa,* so remarkable for well-developed eyespots at the tips of the filaments. This species, one of the commonest on these shores, builds a tube some 7 to 9 inches long in the *Zostera* banks, with the upper opening on a level with the surface, differing thus very markedly from the free or projecting tube-form of the allied *Sabella pavonia.*

Towards midsummer, dissection showed the genital products well advanced towards maturity, so seeing that this Sabellid does not depart from the usual characteristic of the Polychætes in having the sexes separate, I was induced to watch very carefully for the time when fertilization should take place. It is worthy of preliminary note that under natural conditions, the tubes are seldom closely set—usually they are from two to six inches apart. The plumes too have a very short radius and never make a broad far-reaching fan-circlet as in *S. pavonia.* When on July 5th the sexual elements appeared, the sight was most curious and worthy of the long and constant watch. First, a female *Branchiomma* was noticed passing up into the circlet of filaments, from—I believe—the median gutter that runs along the ventral side of the body, rather numerous large white ova. These gradually accumulated for some time in the cone-shaped hollow formed by the filaments; then rather suddenly the animal retracted its plumes with considerable force, such indeed that the ova by the impetus imparted were shot upwards and outwards to a distance of several inches. A minute's rest or less, saw the animal again with fully expanded plumes, passing up ova again from below in rapid succession. Then when the filaments were once more clogged, a similar sudden jerk dispersed them widely; so the process went on for nearly threequarters of an hour with more or less regularity—in fact until all the ova had been passed out. By this means the ova instead of accumulating in a heap around the opening of the tube were spread as a thin layer over quite a large circular area—not less than 10 inches across, in still water.

Very shortly after the beginning of the operation, a neighbouring individual began to manifest signs of a certain unusual excitement, and in a few minutes, from the centre of its filaments, there arose a thin greyish cloud, in appearance and form like smoke wreaths curling lazily upwards from some sleepy hamlet on a breathless summer afternoon. A male it was that had become aware of the call that was being made, and the cloud that was rising slowly was composed of a multitude of spermatozoa that were being ejected. Unlike the female, the dispersion was not aided by any sudden retraction, the reason being that on account of the minute size of the sperm elements they floated quite a considerable distance (6 to 7 inches) in even the calm water of an Aquarium, before settling to the bottom and there meeting and fertilizing the ova that had been ejected just prior. These two had not been busy for long when one after another the other individuals in the tank took up the tale in the same manner, and before the day was done all had finished. Apparently, in these animals, to avoid undue waste, the genital products are ripened nearly simultaneously, and experience some quickening or rather determining sensation when one among them begins to discharge, and which causes them to follow suit immediately. What this influence is would be very difficult to determine. We know so little of the psychology of the lower animals that we cannot even theorise on the subject with plausibility.

MICROSCOPICAL STUDIES IN MARINE ZOOLOGY.

BY JAMES HORNELL.

STUDY I.—HALICLYSTUS (LUCERNARIA) OCTORADIATUS.

THE pleasures of shore-collecting are many, and the one I fancy the most enjoyable, is trudging about among gay weed-decked pools and dyke-formed gutters in search of those delicate fern-like sea-sprays, the Zoophytes. Here on this coarse brown Fucus are numbers of serrate spikes of a Sertularian, bringing to memory Silurian graptolites, while in that pool tiny pinnate fronds anchored to the very rock itself, bespeak a Plumularian. *Coryne* too on this Jersey coast is not infrequent, twining its long clubbed branches among the finer weeds. But the vast sea-meadows or prairies as the French call them, are equally prolific and harbour many beautiful species never met with in rock pools. These meadows—where grows the strange *Zostera,* a true flowering plant that has entirely renounced fealty to its old home on dry land—are at times of spring tides frequently left uncovered for short periods, and then we must watch our chance. *Campanularia* and *Clytia* we may meet with, but by far most conspicuous are rather large brownish bells of exquisite outlines —that here and there are anchored to the long green blades of the *Zostera.*

Such are easily recognized as *Haliclystus octoradiatus,* in these parts the chief representative of the Lucernarians. In size these bells (Fig. 1) are about one inch in height by nearly the same across the oral face. The margin of this is drawn out into eight points, each furnished with a bunch of closely set and numerous capitate tentacles. In the centre is the mouth, standing up quadrangular and prominent. The four angles (of the mouth) mark the four primary radii that can be made out in these animals, and are usually known as the perradial lines or radii. In allied forms, *e.g.* the scyphistoma stage of *Aurelia,* these first radii are marked by the appearance of the first four marginal tentacles. The second four tentacles are alternate with the first and mark the secondary radii or interradials. In *Haliclystus* their positions are the radial lines beginning at points midway between the mouth angles. Thus they alternate with the perradials. Between each primary and secondary radius lies one of eight radiating genital bands. Their position is technically known as adradial. The margin of the bell just beyond the extremity of each genital band is marked by a great cluster of short capitate tentacles. The remaining external organs are eight conspicuous hollow bodies, each one lying midway between every two groups of tentacles. These are probably vestigial sense organs and have been termed colleto-cystophores. They will be referred to later as c.-c. Four must be interradial and four perradial. Looking to the internal anatomy, we find that the enteric or body-cavity is divided by four delicate radiating walls or septa into four gastric chambers—perradial in position. The septa—which by the way represent the mesenteries of the Anemones—are interradial. From their inner edges are given off numerous solid tentacle-like filaments —the gastral filaments.

Those unfamiliar with these animals are reminded that the Hydrozoa are divided into the two great groups, Scyphomedusæ and Hydromedusæ. The former includes, as principal order, those fleshy medusæ or Jelly-fishes—without a velum (membrane all but closing the mouth of the bell), with gastral filaments and with eight sensory organs (tentaculocysts)—known so well under the forms of *Aurelia* and *Pelagia* and termed collectively Discomedusæ. Normally the life-history of these animals is as follows:—A ciliated embryo (proceeding from the sexual or medusa stage), after a short period of pelagic existence, settles down and becomes attached to some stationary object. A mouth forms at the free end, and sixteen tiny tentacles appear. This form, $\frac{1}{16}$ to $\frac{1}{8}$-in. in height, is the *scyphistoma* stage and is often termed the hydriform phase from its likeness to the fresh-water polyp, *Hydra*. Soon transverse constrictions—*strobilation*—cut the body into a rouleau of discs, appearing thus as a tiny pile of sculptured plates. Each disc has eight arms, with a tiny tentaculocyst at tip. This is the *strobila* condition. The discs break off and begin a free swimming life, known at this period as *ephyræ*, rapidly take on the form of ordinary Jelly-fishes, develop sexual organs, and send out swarms of ciliated embryos to go through the same strange cycle of life.

The Lucernarians form another order of the Scyphomedusæ. Contrasting their life-history with that of the large fleshy medusæ just related, we find that the Lucernarians produce in the genital bands both ova and sperm masses. These give rise to ciliated embryos which settle down quickly and develop without metamorphosis into the adult bell-shaped form.

Until recently *Haliclystus* and the related forms were considered as being more or less unchanged descendants of the ancestral form of the Discomedusæ, *i.e.* prior to their adoption of the two well marked stages—hydriform and medusiform—that now characterise their life-history. Quite recently, however, Dr. C. Herbt. Hurst and the writer arrived independently ("*Natural Science*," Sept. 1893) at the novel conclusion that the connection between the Lucernarians and the Discomedusæ is much more recent and close. Thus we believe from the review of considerable evidence that the former are descended from a form having as well marked medusa-stage as *Aurelia* has, and with well developed marginal sensory organs. Then by abbreviation in the life-cycle, by a certain hastening of events, there were developed genital products in the hydriform or scyphistoma fixed form. This did away with the necessity for a free swimming sexual stage, and being found advantageous, was permanently adopted by some—the immediate predecessors of the Lucernarians of to-day.

Marginal sensory organs (*e.g.* tentaculocysts) can be only useful among swimming forms (Hurst "*Nat. Sc.*" vol. ii, part 16). Under the changed conditions they became useless in the Lucernarians and tended to become "vestigial." Such functionless organs are very subject to variation—and the writer has found such to a really extensive degree in these bodies in *Haliclystus*. It is well known that the origin of tentaculocysts is from ordinary marginal tentacles, and it is to this form that the marginal bodies (c. cystophores) of the species under description usually reverts. All gradations from the normal form of c.-c. up to the normal tentacle can be traced. The capitate terminations of the tentacles contain great numbers of nematocysts or stinging cells useful in paralizing prey, and the first stage in reversion is marked by the appearance on the apex of a c.-c., of a tiny wart containing numerous nematocysts (Fig. 4). The next shows a larger wart. In Fig. 5 this has a tiny stalk, while in Fig. 6 there is a well pronounced peduncle. Again in Fig. 7, is drawn a tentacle—one from a bunch of normal ones—where the stem is bellied out, in fashion approaching the most abnormal of the colleto-cystophores.

Explanation of Figs. 1 to 9, Plate I.

Haliclystus octoradiatus.

Fig. 1. Two individuals adhering in natural postures to a blade of Zostera. *n s.*

Fig. 2. Oral view:—*i s.* Interradial septum; *g b.* genital bands; *m f.* muscular fibres; *g f.* gastral filaments; *s.* sperm mass; *c c.* colleto-cystophore; *t.* group of tentacles, × $2\frac{3}{4}$.

Fig. 2*a*. Diagram of trans. section of body:—*m.* mouth; *i s.* inter-radial septum; *p c.* perradial chamber; *g b.* genital bands.

Fig. 3. Normal Colleto-cystophore, × 17.
Figs. 4, 5 & 6. Abnormal series of same, × 17.
Fig. 7. Abnormal tentacle, showing shortening and thickening of peduncle, × 17.
Fig. 8. Group of normal tentacles, × 30.
Fig. 9. Developing ovum, in optical section, × 25.

Study II.—The Pelagic Annelid Tomopteris.

Occasionally among the contents of the tow-net there appears this tiny paddle-propelled worm, active and sprightly in movement, and so glassy and colourless as to be well nigh indistinguishable from the water it moves in. The species figured on Plate I. averages scarcely $\frac{1}{4}$-inch long, but its breadth seems very great in proportion owing to the great length of the paddle-like feet or parapodia. The head is very distinct. At the front border are two stout gracefully-curved antennæ (*a*), while just behind these is a pair of very delicate processes (a^1) which have also been called antennæ. Next come the most conspicuous appendages in the body—a pair of enormously elongated tentacular cirri (*t c.*) In the centre of each one, and supporting it, is a stout bristle, seen under a high power to be septate (Fig. 13). Following these, about thirteen pairs of paddle-shaped parapodia entirely destitute of setæ, and consisting of a hollow cylindrical basal portion, expanding at the outer or distal end into two foliaceous blades—upper and lower—which represent respectively, the notopodium and the neuropodium of the typical annelid foot. Every foot is controlled by two principal sets of muscular fibres originating close to the median line in the body wall, one passing obliquely forwards to be inserted in the anterior border of the foot, the other backwards to the posterior border.

The mouth is situated between the tentacular cirri and leads into a rather muscular portion, capable of at least partial extrusion as a proboscis (Carpenter). This passes through a short œsophagus into a long and wide stomach, reaching nearly the whole remaining length of the animal. The body cavity is quite continuous. There are no internal septa and the interior of the parapodia communicates freely with the body cavity. The chief development of the nerve system consists of a large anterior ganglionic mass, seated upon which are two eyes, each composed essentially of a pigmented cushion bearing two crystalline cones. In front of each eye is a large vesicle of unknown function.

The sexes are separate. That depicted is a female and shows how the ovaries arise from the growth of certain cells on the inner surface of the peduncles of the parapodia. These cells grow to a very large size and then appear as very characteristic ova. Finally these break loose and pass into the body-cavity. It is probable that they normally pass thence to the water by rupture of the body wall of the parent, but whether fertilization takes place prior to this is uncertain. Curiously I have not lately met with the male form. Carpenter describes it as having a long tail-like prolongation bearing four or five minute appendages wherein are developed spermatozoa. The tail-like prolongation is indeed given as being present in both sexes of different species—but so far in the present species I have not seen any trace of it in the females. Of males, I have not been able to examine any.

The embryology is little known and we only become familiar with the animal in an advanced larval stage. The earliest one known to Dr. Carpenter belonged to a species having no posterior antennæ in the adult state, but in the larval it had no anterior developed—while the posterior were very obvious and bore each a distinct bristle, and were of comparative large size. The tentacular cirri (*t c.*) were short, and approached the form of the succeeding partially developed parapodia, saving that they (the tent. cirri) possessed stout setæ like the posterior antennæ. It is very interesting to note that the species figured here (Fig. 10), shows in each posterior antenna a distinct claw-like bristle, and this inclines me to the belief that these organs are not antennæ but are vestigial tentacular cirri. The large tentacular cirri in the larval stage approach very closely in form to the parapodia and differ principally in the presence of setæ. The secondary antennæ again approach closely in larval life to the appearance of the tentacular cirri, so the inference is clear. It is only with the attainment of maturity, that this organ becomes reduced and difficult to homologize, and even then, as seen in our figure, there can in some species be traced distinct setæ. In the larger *T. onisciformis* (Carpenter) this appendage however entirely disappears in adult life.

Rosette-shaped organs have been made out at the bases of certain feet; their function remains still obscure.

Explanation of Figs. 10 to 15, Plate 1.

Fig. 10. Entire adult *Tomopteris* (female); *a.* anterior antenna; a^1. posterior antenna (vestigial tentacular cirrus); *t c.* tentacular cirrus; *p.* a parapodium. × 17.

Fig. 11. Parapodium, *nt.* notopodium; *nr.* neuropodium; *ov.* ovary.

Fig. 12. Ovum. *nc.* nucleolus or germinal spot; *n.* nucleus or germinal vesicle; *v.* vitellus; *v m.* vitelline membrane, × 200.

Fig. 13. Seta from tentacular cirrus, showing septations, × 100.
Fig. 14. Eye showing two crystalline cones.
Fig. 15. Posterior antenna showing sickle-shaped vestige of a seta at *a*. × 100.

Study III.—Anatomy and Life History of Salpa.

The great heat of the past summer was apparently very favourable to the development of surface-life in British latitudes. Pelagic animals, usually rare, were this year sometimes abundant. Thus *Beroë*, *Medusæ* and *Copepoda* of southern species, *Tomopteris* and the pelagic Tunicates, were taken much more frequently than I have ever known before. For several days during August the tow-net was full of a transparent colourless barrel-shaped *Salpa*, which proved to be *S. mucronata-democratica*, Forsk. Most were adult—such as those figured on Plate II. were quite young, only a few hours severed from the parent and still showing remains of a placenta.

The large figures (16, 17 & 18) show this animal in various aspects. In all the most striking features are seven great hoop-shaped muscular bands. By comparing the three figures, the central four will be seen to encircle the body completely, while the two most anterior, together with the one most posterior, which lies in front of the exhalent aperture (*a*), fail to complete their respective circles, one upon the dorsal, two upon the ventral aspect (Fig. 17). On the dorsal side (Fig. 16) lying between and connecting the first two hoops, are a pair of band-shaped muscles whose function is to open the mouth. Another muscle of a ——< shape (Fig. 18) lies horizontally on either side of the mouth, performing the opposite function of closing its two lips. The remaining muscular bands are two strap-shaped ones, lying between the angles of the exhalent aperture (*a*).

The body wall possesses externally a thick, semi-gelatinous layer, which is the protecting tunic or test (*t*), formed originally of a glassy homogeneous secretion from the ectoderm or primitive superficial layer of the body. In this test are subsequently found numerous cells which have wandered in from the ectoderm. These are specially numerous in the extremities (*t c*). The mouth or inhalent aperture (*o*) lies at the anterior end of the body; the exhalent (*a*) at the opposite end on the dorsal aspect.

A great cavity is encompassed by the muscular hoops. An anterior and a posterior division is formed by the presence of a diagonal rafter or bar (*br*), stretching from a point behind the ganglion (*g*), backwards and downwards to the beginning of the œsophagus. This bar has been supposed to be the much modified remnant of the slit-perforated branchial pharynx, so well developed in the simple Ascidians, such as *Ascidia* and *Ciona,* the slits having gradually coalesced, and being now represented by the two great spaces which lie on either side of the branchial septum. Recent research (Brooks' "Salpa in its relation to the Evolution of Life," Baltimore, 1893), however, makes it probable that the ancestors of *Salpa* had never a complicated system of branchial clefts, and that the present represents the little changed primitive plan. At first, as Prof. Brooks points out, the ancestral Salp had an elongated digestive tube without pharyngeal clefts. The anterior part was distended and ciliated. Later on slime cells appeared, to retain food-particles swept in by the free current of water passing through the body. But this stream would also be liable to carry partially digested food particles away—so the appearance of one or more clefts in the distended pharyngeal part, allowing the water, after bathing the slime covered parts, to pass freely away without coursing through the intestine, would be a distinct advantage and would be retained by natural selection. The chamber anterior to the so-called branchial septum, therefore represents the pharynx—while the posterior chamber is the cloaca (*cl*), into which also empties the alimentary canal by the anus. On the ventral surface of the pharynx there stretches longitudinally a deep gutter with glandular walls, the upper edges of which join along the greater portion of its length. This appears optically to be a rod and is the endostyle (*end*); at its front extremity it sends off two diverging ciliated bands (*ac*)—the peripharyngeal bands or ciliated arc—which, arching upwards, join again and pass into the branchial septum. The cavity of the endostyle is ciliated, and the slime secreted by its glandular walls, is passed on by the cilia into the peripharyngeal bands, and thence to the ciliated surface of the branchial septum. At the posterior extremity of the pharynx is the short œsophagus, passing into a wide stomach; thence a short intestine leads to the cloaca (*cl*). This digestive tract in all pelagic tunicates is concentrated into a very small space, and forms the only opaque mass in the body, and is the so-called nucleus (*nc*). Water passing in at the mouth laden with food particles, has the latter arrested by the slime covered ciliated arc and branchial septum. Passing through the two gill clefts the water finds its way into the cloaca, whence it is discharged by the exhalent aperture. The food particles arrested are sent by ciliary action down the branchial septum and into the œsophagus.

The animals move through the water by repeated violent expulsions of water, due to contraction of the muscular hoops. According as the water is expelled from mouth or exhalent aperture, the movement is backwards or forwards.

The form figured was but a short time previous, attached to the parent. At *pl* is seen a mass of cells marking the unabsorbed remnant of the placenta; *el* is a collection of large cells which are believed to represent the urochord of the tail of an appendicularian-like ancestor. It would thus also be homologous with the cartilage-like cord of the tail of the tadpole larvæ of sedentary ascidians.

The nervous system consists of a central ganglion (*g*) above the anterior end of the branchial septum, with numerous nerves given off to the different organs of the body. Upon the ganglion is a rounded mass, the eye, containing dark pigment of horse-shoe shape. A little way in front, is a ciliated sac situated immediately above a tongue-shaped ciliated organ—languet—pendant in the pharynx and of sensory value.

A heart is present beneath the alimentary canal, giving off a large ventral longitudinal vessel. There is a similar vessel dorsally, and the two are united by lateral branches. Vessels ramify in the branchial septum. The peculiar blood circulation of Tunicates is well marked in *Salpa*—after beating a certain number of times in one direction, the heart remains still for a moment and then resumes pulsating, but in an opposite direction, thus reversing the blood-flow completely.

Life-history. The form under notice is asexual. The bud-shaped part *st* is the first indication of the stolon, which in the adult develops by growth and internal change into a long double-chain of tiny bud-like salps (Fig. 19). When a certain size is attained, the chain breaks free and swims away by rhythmic, and combined, alternate admission and expulsion of water. These chain salps (Fig. 20) have quite a different outward form, and a different—fewer—number of muscular hoops. Each individual in the chain is connected with four others by eight bars—two to each. Diagram Fig. 21 shows the method. The chain salps are fully sexual; both male and female organs are developed in each individual, but the female organs mature earlier than the male. A single ovum only is produced. It develops in situ—being fertilized by spermatozoa that enter through the mouth of the parent. It receives nourishment by the interposition of a true placenta between it and the parent. It possesses a circulation separate from that of the latter. When development is complete it breaks loose and swims away. This is the solitary asexual form we figure. In turn it again gives rise to a chain of sexual salps. Thus the life-cycle continually proceeds.

EXPLANATIONS OF FIGS. 16 TO 21.

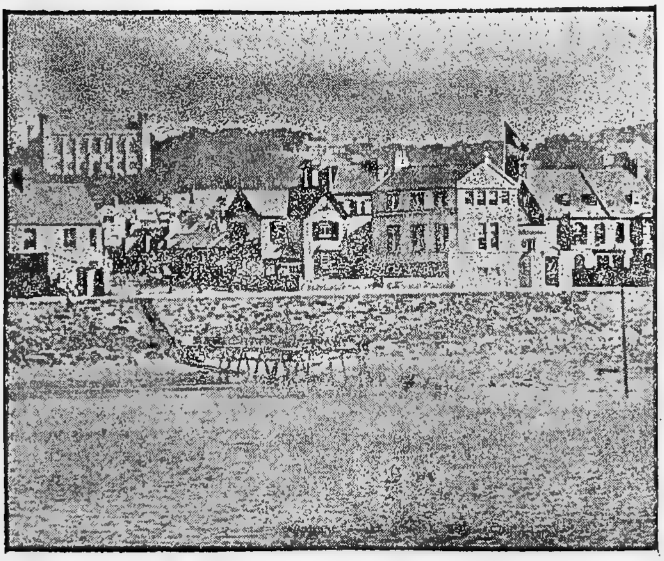
Salpa mucronata-democratica.

Fig. 16. Dorsal view; Fig. 17, ventral view; Fig. 18, lateral view. All solitary asexual form. *t.* test; *tn.* nuclei of test; *m.* mouth or inhalent aperture; *ph.* pharynx; *ac.* peripharyngeal bands; *end.* endostyle; *f.* languet; *br.* branchial septum; *n.* nucleus or gastral part of alimentary canal; *cl.* cloaca; *a.* exhalent aperture; *el.* eleoblast; *pl.* remnant of placenta; *st.* proliferous stolon; *g.* ganglion with eye seated thereon and nerves radiating. *Muscular bands are distinguished by brown colouring.* × 30.

Fig. 19. Posterior part of body of an adult solitary zooid, showing the development of the proliferous stolon *st.* into a chain of buds. *n.* nucleus. × 6.

Fig. 20. 3 chain salps showing method of connection. *emb.* embryo, *n.* nucleus. × 2½.

Fig. 21. Diagram of a double row of 8 salps, showing plan of attachment. Two connecting bars linking every two individuals.



View of the Jersey Biological Station from the sea.

IMPORTANT NOTICE.

The four microscopical preparations illustrated and described in the preceding pages, form the first quarterly instalment of a series of 14 subscription slides now in course of issue. There will be included fine mounts of entire organisms, *e.g.*, New Hydroids of great beauty, Medusoids, *Tomopteris*, larval annelids (*Polynoë, Nereis*), rare larval crustaceans, expanded Polyzoa, pelagic Tunicates (*Salpa, Doliolum*), &c., also type slides of British Sponges, anemones and the like. The remaining slides of the series will be treated in the same detail as are the four which have received attention in the preceding pages.

The slides will almost entirely be new to our lists—but should subscribers have a duplicate of any slide sent, we will willingly give an opportunity of allowing another slide to be chosen in substitution.

This opportunity will we think be required in only two instances, viz.: *Lucernaria* and *Plumularia*. Several subscribers who have these two slides, have requested us to include these two animals for illustration and description in the pages of the Journal, so if any subscriber having these will send a post-card naming another slide which he may wish substituted, we will arrange accordingly. A list of recent mounts will be found on the cover, and from among these a suitable substitution will probably be found.

The subscription, inclusive of the Journal and the 14 slides, is 21/- post free. Sample sets will be sent on approval if desired. Further particulars on application. The Journal may be had separately, and will be supplied *post free* for 6d. per number, or 2/- per annum. Address: Sinel and Hornell, Biological Station, Jersey.

EXCHANGES WANTED.

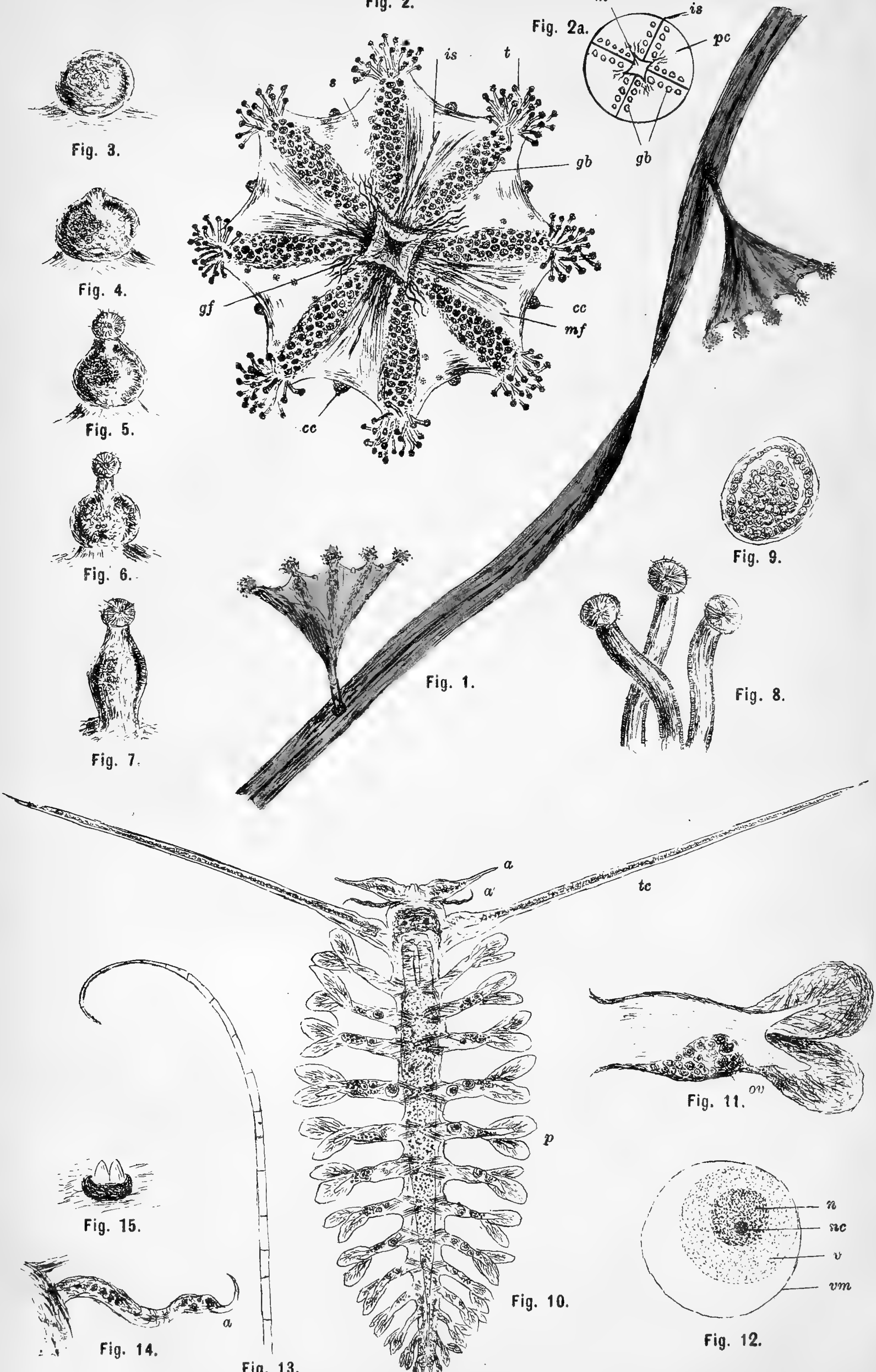
Literature upon the Hydrozoa and the Annelida; well preserved fossils (named); foreign echinoderms and crustaceans, also centipedes and scorpions in spirit. Exchange in micro. slides, zoological specimens, &c.

TO CORRESPONDENTS.

All communications for the EDITOR to be addressed to the BIOLOGICAL STATION, JERSEY.

Original notes on Marine Life are invited; while technically correct, they must however be written in an interesting style.

Advertisements to be sent to the same address.



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HALICLYSTUS AND TOMOPTERIS.

Fig. 16.

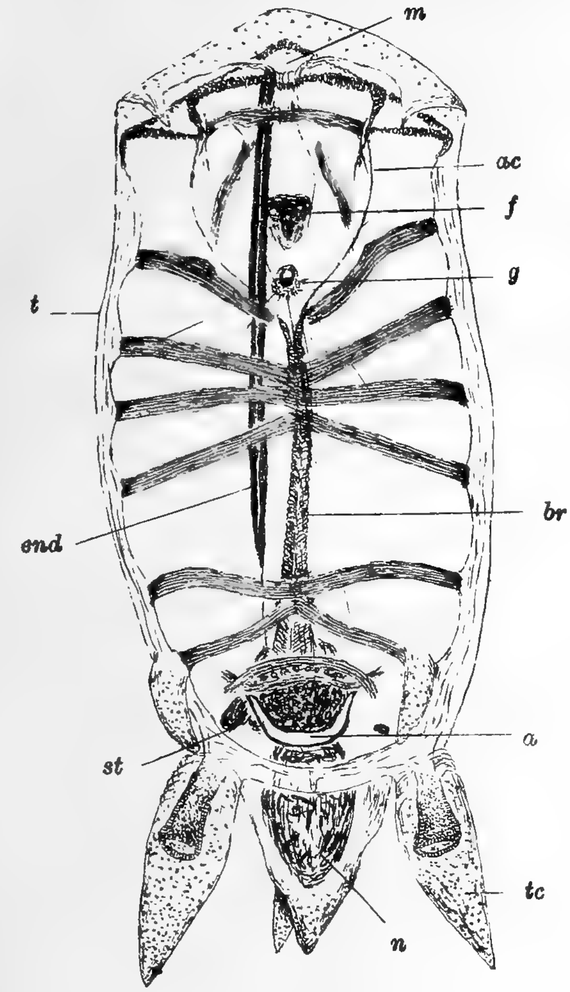
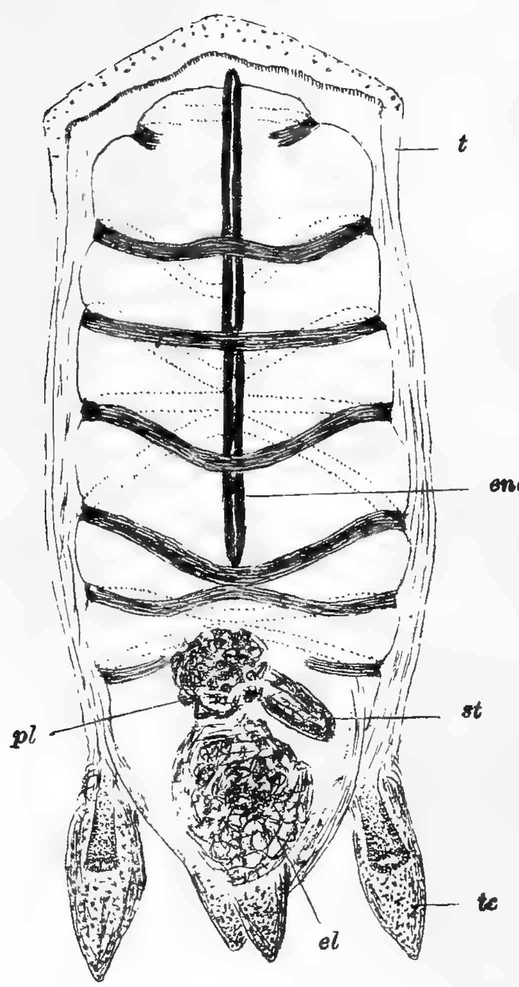


Fig. 17.



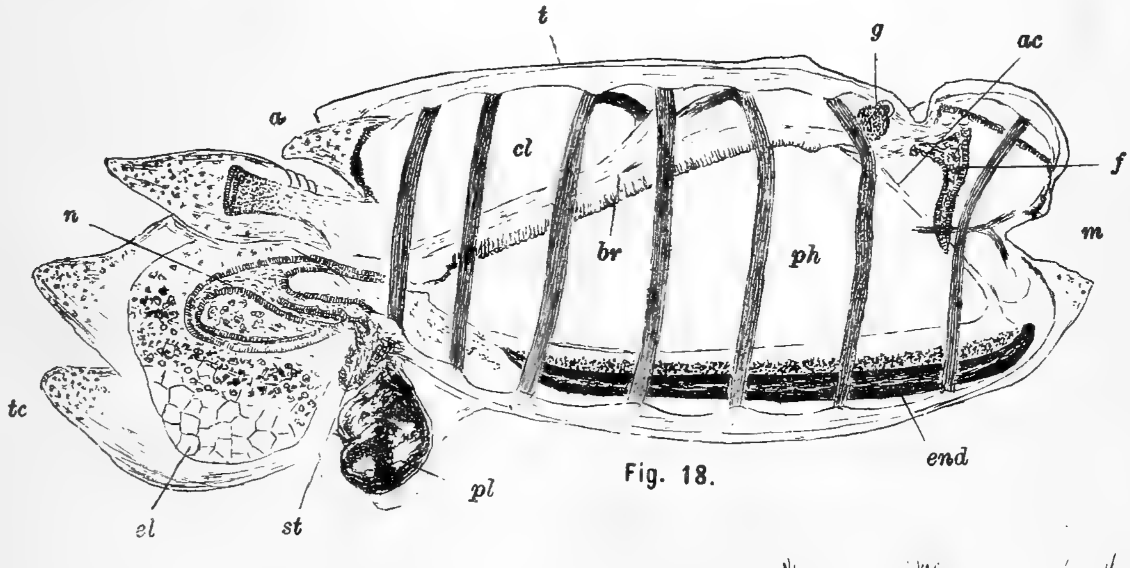
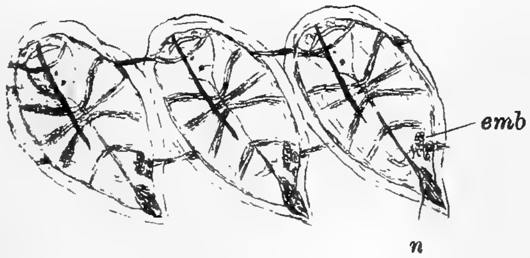


Fig. 18.

Fig. 20



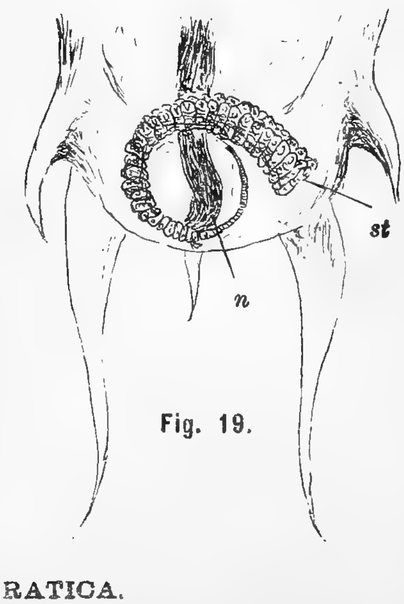
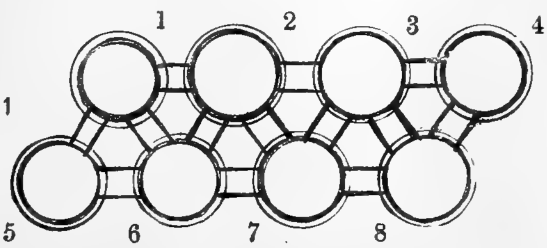


Fig. 19.

Fig. 21



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SALPA MUCRONATA–DEMOCRATICA.

The Journal of Marine Zoology and Microscopy:

A PLAINLY WORDED BIOLOGICAL QUARTERLY.

VOL. I. NO. 2. FEBRUARY, 1894.

THE REARING OF STARFISHES IN CONFINEMENT.

BY H. J. WADDINGTON.

PROBABLY of all the Echinodermata, *Asterina* is the most easily kept in small aquaria. The conditions for successful development are very simple, and the results more than repay the trouble expended.

In 1889, I commenced keeping a few *Asterina gibbosa* in a small bell-glass holding about 1 gallon of water. These were fed on small pieces of oyster every week, and remained in perfect health.

In May the ova were discharged, they rapidly rose to the surface of the water, coalesced and quickly decomposed.

The failure, in this instance, was no doubt owing to the seawater being above the normal density. In 1890, the ova from the same *Asterinæ* were again discharged, and although I succeeded in entangling a few among the filaments of some conferva, the remainder rose to the surface and decomposed as on the former occasion. It was evident that the conditions were unsatisfactory and must be modified. I placed the aquarium containing the *Asterinæ*, and which was covered with a piece of glass, close to a window with a S.W. aspect, and allowed it to have all the light possible. In a short time the aquarium was covered with vegetation which increased rapidly until May, 1891.

The ova were now deposited on the side of the aquarium, each ovum quite separate. In no case were two ova touching one another. The subsequent development was all that could be desired. I was equally successful in 1892 and 1893.

The ova are deposited towards the end of May (26th or 27th); in each of the years 1891-2-3 there has not been a variation of more than two days in the date of deposition. The ova are not all deposited at one time, as in 1892 from two *Asterinæ* were deposited 3 patches of eggs at intervals of a few hours.

The ova adhere to the vegetation on the side of the aquarium and show little motion for 2 or 3 days. They are very easily removed with a glass tube, and may be returned to the aquarium after microscopic inspection without any deterioration. The development may be watched under the microscope from the first day up to maturity.

For isolating the ova nothing is better than thin wine-glasses narrowing to the bottom, broken at the stem. These float readily in the Aquarium, and the small quantity of water they contain ($\frac{1}{2}$ to 1-oz.) remains perfectly good. In fact each becomes a miniature aquarium, the temperature of course being that of the larger aquarium in which they float.

For preserving the *Asterinæ* as permanent objects and at any stage of their development, the best method is to use Cocaine Hydrochlorate and to allow them to come under its influence very gradually. In this way they die without undergoing any distortion, and may be transferred to weak Alcohol of 30 or 35 %, and preserved in this fluid, or carried through higher percentages of Alcohol to oil of Cloves, this removed with redistilled Turpentine and then mounted in Canada Balsam.

A Handbook to the Copepoda.—We have before us "*A Revision of the Copepoda of L'pool Bay*," by Mr. I. C. Thompson, F.L.S., and find much to praise therein. It is indeed a happy idea to give small outline sketches of each animal dealt with, and to group those of related species on the same page, as is here done. Considered as a ready reference guide, it will be found extremely useful to all, and especially to the junior, students of this order. This paper appears in Vol. VII of the Trans. L'pool Biol. Soc., and we take this opportunity of suggesting to the Committee the desirability of adopting the plan pursued by the Royal Dublin Society, to wit, the selling of its more important essays separate from the main volume at a correspondingly lower price. The major publications of the Society would in this manner become much more widely known.

A New Biological Text-book.—Mr. H. G. Wells is to be heartily complimented on the completion of his useful *Text-book of Biology* (London: W. B. Clive, 1893). Part II, devoted to invertebrates and plants, is now before us, and in every way is a worthy successor to Part I (vertebrates), now so greatly esteemed in teaching circles. We feel sure Part II will quickly be received into equal favour, and we heartily recommend it to all students of "types."

The mode of illustration marks the trial of a novel experiment. Many folding plates are provided, and in order to prevent scamping of the practical work of dissection at first hand, the figures are of such a nature, that in most cases it is difficult for the tyro to gleam therefrom proper enlightenment of the text, except he be concurrently making the equivalent dissection, in which case the diagram will give him clearly the necessary information regarding the identification of parts. Such an arrangement spoils the artistic value of the work, but we appreciate the motive and believe the plan will answer admirably the purpose intended. The happy mean is struck 'twixt Huxley's too drastic "no illustration" and the over elaborate drawings of others, that by their completeness, delusively tempt the student to avoid the drudgery of dissection.

THE CLEANSING OF THE LITTORAL BY THE LUGWORM (ARENICOLA MARINA).

BY JAMES HORNELL.

WE are accustomed to admire the vast vivifying, or rather oxygenating, influence of the breakers. We watch them dashing and surging, frothed with the commingling of air globules, and then in full confidence of the purifying power thus imparted to the sea, we expel the noisome sewage of our cities by thousand mouths into the littoral. I do not dispute that results appear to justify this confidence, but I contend that the waves must not receive the entire credit. Granted that sewage and decaying matter can be brought to float and toss hither and thither with the waves, the transformation is wonderfully rapid. But in fact, much sewage laden heavily with organic matter soaks downwards into the sand and clay and gravel, after ejection from the sewer mouth. And not sewage alone. The sand of the shore has a natural tendency to keep on the surface. Throw upon it decaying matter and if not carried away, a day or two will find it buried well out of sight. Like too many of the conventional masks that we fit on as filmy covers to our social horrors, so the sand is apt to hide as a clean but thin crust, great deposits of noisome fœtid clay, black and malodorous with the concentration of ever present putrefaction. The purifying power of the waves fails to influence beyond the surface layer of sand and the accumulation would go on uninterruptedly, ever extending further down, if other cleansing power did not come into operation. Putrifying matter in solution we know tends like other watery fluids to percolate downwards. Hence a long period of quiet should show the clay at a considerable distance from the surface, more saturated with filth than the upper and newer layers. In reality, we find that the most evil smelling and blackest region is but a few inches from the top, and thence downwards the contamination decreases until a certain minimum is reached, which in all lower depths is fairly constant.

As I have pointed out, this is not what we would naturally be led to expect. The key to this apparent contradiction I owe to my old friend Mr. Isaac E. George, who suggested to me the influence of the common lug-worm (*Arenicola marina*, Linn.) This animal abounds on all the sandy and muddy stretches of our coast. Everywhere as the tide leaves bare the shore, its castings appear in myriads. On sandbanks well to sea, where decaying matter is scarce, *Arenicola* is found in small numbers, whereas along the shore, especially in the *higher* littoral towards high-water mark, its abundance is limitless. Here in Jersey is a region where after storms, vegetable matter in the form of sea-weeds (*Fucus, Laminaria, Chorda*, &c.), with a lesser though not inconsiderable amount of animal *débris*, is piled up along the farthest tide-reached limits, and a good portion of this soon becomes buried upon the beach.

Now *Arenicola* in habits, is the marine counterpart of the earth-worm. Like the latter, it is without any biting parts in the mouth. It has no means of capturing prey, and contents itself with swallowing the sand and mud it burrows in, extracting therefrom what organic matter it can. Within limits then, the more putrefied matter there is mixed with the mud and sand, the richer is the lug-worm's diet. This explains how it abounds in more than common number close to the outlets of rivers, in harbours and docks, and also high upon the littoral—these places being where much decomposing matter is deposited. Worm castings everywhere represent the sand and mud passed out of the worm's body in a purified state, freed from organic matter through such having been absorbed into the nutritive fluid of the worm's body.

Darwin astonished the world with his calculations of the magnitude of the cleansing operations carried on by the ordinary earth-worm. On my part, I cannot give figures, but considering how the castings of lug-worms are so numerous as practically to touch one another; that we see them renewed twice a day as the tide uncovers the sands, and that such visible renewals represent not one tenth of the work that goes on when the tide returns to give more congenial conditions, we may be certain their workings over areas of equal extent, are much more momentous than even those of the earth-worm. It must, too, be borne in mind that the average size of the lug-worm is greater than that of the earth-worm and that on the average, though great, there is less organic matter in sand and mud than in earth. Hence to obtain equal amount of food, the lug-worm must swallow a much larger quantity of matter than its land counterpart. As I have said, there is less organic matter in littoral sand and mud than in earth, yet what there is, is infinitely more evil smelling. The organic matter in earth is largely woody fibre—slow of decay—and besides, as gases are evolved, such are lost rapidly by diffusion in the atmosphere, to which the earth particles are freely exposed. On the other hand, similar diffusion is infinitely less rapid under water and indeed, the gases of putrefaction are in sand and mud virtually closely confined. Again, decomposing matter in the marine "soil" is without the slow-decaying fibrous matter so common in earth. Water plants do not require woody fibre, and they accordingly offer no resistance to decay. There is also probably more decaying *animal* matter in sea "soil" than in earth.

The full value of the cleansing operations of the lug-worm is not easily to be assessed. Without this humble worker, the littoral would in many places become a veritable cesspool, calling for costly human intervention, at least at those spots we dub as seaside health resorts. Left alone, the wrack or seaweed cast up by storms would putrefy, and whenever the thin covering layer of mud or sand were removed, noisome gases in horrid volume would arise to vitiate the erstwhile pleasant sea breeze. I do not draw a fancy picture. A few weeks ago, on a tramp along the west coast of our little island, searching for stray items geological, I tried to explore a little bay, perhaps the most used of any in the island by farmers during the wracking season, at that time in full swing. I write "tried to explore" advisedly, for the stench that rose from the bay was more than my nostrils were prepared to endure. I stayed just long enough to discover that the odours arose from the decay of *Fucus* and *Laminaria* dropped by the carts as they returned up the slip way, from off the shore. Some weed lay in forgotten corners above high water mark, but the main body of the stench arose from the pebbles, gravel, sand and pools. A greyish black slime enveloped and contaminated everything beneath foot. Landlocked as the little bay is, the air hung dense and heavy as that of a charnel house. One cannot exaggerate, strange as it may seem. In this instance, the accumulation on the beach of decomposable matter is too rapid for the lug worm to contend with.

While arguing the value of the cleansing of the littoral by this worm, I do not, however, wish to convey the idea that finally the whole of the decomposable matter is eliminated—only the bulk is removed. A certain residue is left, explainable by reason of the worm finding starvation conditions present, when the organic matter is decreased to a definite point; that reached, the worm removes to where more food matter is present mingled with sand and mud. Thus in a growing deposit, the progress of the lug-worm will be upwards. As the deeper layers are exhausted of their carbonaceous food supply, so the lug-worm gradually ceases to burrow down into these and if new layers are all the while being added at the top, so the dense black band which denotes the maximum presence of unexhausted organic decay does not remain stationary or spread downwards, but continuously ascends, the lower layers becoming cleared by the activity of the lug-worm while new layers are added above. Pale bluish-grey is the color of the sandy clay as left by lug-worms and here a curious point comes in. What but this color is the prevailing hue of our shales and marls? Worm tracks and castings of worms certainly closely allied to *Arenicola* are common fossils in rocks from very early times, *e.g.* the burrows of *Arenicolites* in the Cambrian strata. Their food supply must have been much the same—decaying vegetable matter. Thus the work they performed was similar, and to this ceaseless activity ever coping with the continuous accession of new decaying matter, we must look for the explanation of the very slight admixture of carbonaceous matters in the many sand-stones and shales of varied geological age, that by the associated castings and other evidence, are plainly marked as having once existed as the sandy and muddy shore lines of ancient seas; seas subject to the same storms as ours; seas where the jetsam of weed was thrown in piles upon the beach and where when covered up by surface sand it decayed and was purified by the life activity of the lug-worm, just as is happening continuously in the present. Truly, if the history of the past be written in the rocks, it is among the events of the present that we must search for the alphabet wherewith to decipher the words and sentences of the book.

PURE CHEMICALS.—Very often we are asked for the name of a firm supplying absolutely reliable Chemicals, or such as are in so little demand as to be difficult to procure in an ordinary way. It gives us, therefore, special pleasure in naming Messrs. Harrington Bros. of Cork—whom personal experience has shown us to be in every way worthy of confidence. What is also important, is that their prices are most reasonable.

BRITISH ECHINODERMS.—We are glad to welcome a goodly addition to our knowledge of British starfishes and sea-urchins, in the form of the latest British Museum Catalogue. Prof. Jeffrey Bell, who is the author, has here massed together the essentials of much important literature, and sorted out many tangled skeins of nomenclature. The task, weighty like all of its kind, has been conscientiously carried through, and without vain striving after effect. Intended primarily as a work of reference the book is without that fascination for the mere nature lover, present in such high degree in Forbes' classic volume. Hence we cannot advise any but the more earnest students of the group to add it to their shelves.

A few transcription errors occur. Thus on page 119, *Ophiura neglecta* is twice given as Forbes' name for *Amphiura elegans*, when in reality, Forbes, in both the cases referred to, wrote *Ophiocoma neglecta.* Again on page 171, Jersey is given as a habitat for *Echinocardium pinnatifidum.* To our positive knowledge, the island of Herm is the nearest point to Jersey, where this animal occurs. By the way, it would be a most useful plan, if authors of landmark works such as the one under notice, were to publish a pithy list of errata and corrigenda in some scientific periodical after the lapse of say a year from publication. Errors will creep in, be one ever so watchful, and for want of a simple safeguard such as the above, are needlessly endowed with, too often, a surprisingly long existence.

ON THE LOCOMOTION OF THE MOLLUSCA.

BY JOSEPH SINEL.

CONSIDERING the great variety of form assumed by the members of the group Mollusca, one is prepared for a corresponding diversity in their modes of locomotion, but perhaps few, except those who have made the group a special study, have considered how very varied these are, and what different parts of their organization are employed to this end.

For instance, the general reader may be surprised to hear of snails that jump, and of cockles that can proceed over dry land by bounds of several yards. In fact, so erratic are these animals in their modes of travel, that a general outline of such may not be void of interest.

Taking first the Lamellibranchs, or Bivalve Molluscs, and confining ourselves in all cases to the adult form, we find that while some are stationary, firmly cemented to rock or stone by one of their valves, *e.g.* some of the oysters, or moored by a tassel of strong threads (the byssus) after the manner of the common mussel, the majority have the power of slowly trailing themselves, over, or through, the sand or mud by means of the foot, the fresh water mussel affording a familiar example. Others, notably the Pectens, have the power of swimming. This is effected by the smart opening and closing of the shell, and in one member of this family, *Lima,* this faculty exists to such perfection as to be best described as a graceful undulating *flight* through the water, each closure of the shell propelling the little animal some eight or ten inches.

This faculty of swimming, combined with the beauty of the pearly striated shell, and the surpassing gracefulness of the long orange and vermillion fringe of its mantle which forms streamers behind, render this without a doubt the most attractive member of the Mollusca.

Then, at least one member of the class has very considerable leaping power, this is the marbled cockle, *Pectunculus glycymeris.* In Jeffrey's *British Conchology* (Vol. ii., p. 167) it is stated "This animal does not execute a direct progressive locomotion, but only turns the shell round on its disc or from side to side."

Very different from this has been the experience of the writer who, on several occasions when collecting at night at low tide limit on the great shell gravel reaches of La Rocque point, Jersey—where this mollusc abounds—has been fairly pelted with them as they leaped to meet the rising tide. These leaps ranged from three or four to six feet with a trajectory rising two feet or more—their course always seaward.

This phenomenon the writer has not observed by day, so cannot say how the movement is performed.

Then we have on these shores, one Lamellibranch, *Galeomma turtoni*, which takes up the mode of gastropod locomotion, and with valves set wide open, creeps over the rock with its flattened foot.

Next we come to the Gastropoda. Here the common land forms, snails and slugs, afford familiar illustration of the usual mode of travel—crawling by the alternate extension and contraction of the muscular foot. This mode is common to all except perhaps the pelagic Heteropoda, for even the pelagic *Ianthina*, that carries a float, has the power of crawling; but a few offer the following additional methods :—

Strombus, a cousin of the whelks can *jump*; some of the same tribe *Lachesis*, together with many of the Opisthobranchs (*Aplysia*, *Doris*, *Eolis*, &c.) have the habit of swimming foot uppermost on the surface of the water. Movement by this means is, of course, very slow and imperfect. A modification of this system, which is better described as a means of transport than of travel, the writer has frequently observed in *Eolis*,—this is its suspension by means of a thread of mucus, from a globule of the same, which, entangled with air, floats on the surface; the position of the animal when so suspended being always doubled up, hedgehog fashion, with the back downwards.

Next in order, we come to the Pteropods, or sea butterflies. These Molluscs are pelagic and their means of progression is by the flapping of their large wing-like fins.

Finally, in the Cephalopoda, we find the highest development of travelling power. The *Octopus* can propel itself swiftly backward by the expulsion of water from the mantle sac, an average size specimen (say one of two feet in length of body and arms) can propel itself by this means, at a rate of ten or twelve feet per second. It can also swim forward, by a spider-like movement of the arms, with considerable speed; it is in this manner that it usually darts on its prey from its lair. By means of the suckers on its arms it can crawl and climb nimbly over rocks and stones; and over smooth bottom, by the employment of the tips only of its arms, it can be said to walk.

Loligo, *Ommatostrephes*, *Sepia* and *Sepiola* dart backward in the same manner, and by the same means, as the Octopus, but yet more swiftly, and the two former, at least, swim forward with almost equal ease by means of their fins—the arms in this case being brought together to form a point.

THE COLOUR SCALE IN MARINE ANIMALS.

BY JAMES HORNELL.

IN a previous note on colouration (p. 8), I had occasion to chronicle the fact that a chromatic Scale similar to that found in the evolution of flowers, and with which Grant Allen and others have made us so familiar, can be made out in the colouring of marine animals. As the subject is interesting, I may be allowed here to amplify the statement.

The presumed order of evolution being from white, through yellow, orange, red, and purple to blue, we would expect the more primitive colours—white and yellow—to characterise the more simply organised species in each phylum or great division of the animal kingdom. As complexity in structure progresses, we may naturally look for corresponding advance in the colour scale. The advance will however not be made without purpose; some powerful reason—warning, mimicry, sexuality, &c.—must be present or the primitive colour will not be forsaken, and again through the working of the great law of atavism or reversion, so soon as the existing cause ceases or waxes faint, the advanced colour will in time be renounced, and the more primitive resumed.

Blue, the highest grade, is, as we are thus led to expect, seldom found in marine creatures. On our own coasts I can recollect only the sometimes lilac coloured sponge *Chalina montagui*; several purple sea-urchins, *Spatangus purpureus, Bryssus lyrifer, Strongylocentrotus lividus,* and *Sphærechinus granularis;* some partially blue Copepoda; the Lobster; several purple and blue compound Ascidians, and some partially blue fishes.

These animals are all among the most highly specialized animals of the groups or classes to which they respectively belong. Among the sponges, the Silicispongiæ, to which *Chalina* belongs, stands practically at the top—the great complication of the canal system, and the wonderful development of the mesoderm placing this order far in advance of the members of the other great sponge order, the Calcispongiæ. These latter, thus characterised by comparative simplicity, are all but entirely white. One only do I know of other colour, *Ascetta coriacea,* and then the hue, pale yellow or orange, is not even normal, being merely a varietal colouring.

The sea-urchins are among the most highly specialized of their phylum or indeed of any animals; the blue splashed Copepod, *Anomalocera pattersoni* is among the most highly organized of his order, and the Lobster, again, is in many respects the foremost of our macrourous (long-tailed) crustaceans. As to the Ascidians, there is no question that the species sporting blue and lilac colours are among the most special, for as such are counted the crusting compound Ascidians of the family Leptoclinidæ, of which on this coast I know a bright sky-blue species, and others of lilac and of purple in varying shade. Many fishes are striped (male of *Labrus mixtus*) or otherwise ornamented with bright blue; but only among the Teleostei, the most specialized of fishes. There are certainly cartilaginous fishes to which the term blue is affixed, such as the Blue Shark, but such colour is rather grey or drab and can only be termed blue by a stretch of courtesy.

All this is strong evidence, but we can obtain further confirmation by looking at the problem in a different light. Presuming blue to be furthest from the primitive colour, such hued animals must have passed through the scarlet stage at a later date than the yellow, and we should expect the species and genera nearest related to be of the scarlet hue rather than of the yellow. And it is so. The nearest relations—and less specialized too—of the lobster on our coasts, the Norway lobster *(Nephrops norvegicus)* and the two craw-fishes *Palinurus* and *Scyllarus* are all scarlet, not yellow. The star-fishes, more primitive echinoderm forms than the so frequently purple coloured sea-urchins, seldom or never in our seas get beyond yellow, orange, and scarlet. Regarding the Ascidians, the blue and lilac Leptoclinidæ have, as most closely related species, several of deep scarlet and blood red, a few of orange, and but one or two of yellow and of white.

The converse holds true. Such animals as cling with intensity to the primitive white, show in their nearest coloured relatives the light end of the scale, yellow and orange, rather than purple and blue or even scarlet. The sponge phylum being more homogeneous and showing less specialization than any other serves admirably as a test, and as already mentioned the only calcareous sponge I know to be ever coloured in our waters, viz., *Ascetta coriacea,* is normally white, occasionally canary yellow, and only rarely orange. The Plumose anemone *(A. dianthus)* normally white, has a pale orange variety, and again, the snowy *Alcyonium digitatum* is also occasionally orange.

To summarise these conclusions :—

I. White is the prevailing colour of the least specialized animals in the most primitive phylum of the Metazoa—viz. : the calcareous sponges.

II. Yellow and orange follow closely and are the characteristic colours of those coloured animals most closely related to white ones.

III. Blue and purple are characteristic of the most specialized among the most highly developed phyla—*e.g.* the sea-urchins among the Echinoderms, the lobster among decapod Crustaceans, and the crusting compound Ascidians.

IV. Animals most closely related to blue and purple species, are mostly scarlet, red, or deep orange in hue.

MICROSCOPICAL STUDIES IN MARINE ZOOLOGY.

BY JAMES HORNELL.

Study IV. Sponges; an Introductory Sketch.

THE Jersey shore between tide-marks is veritable "Spongeland." Scarlet, brick-red, orange, yellowish green, yellow, white, grey, and black patches clothe the rocks in chequered mantle, and with the vieing colonies of gaudy-colored compound ascidians, relieve in a pleasant manner the sombre brown of the fucus-covered rocks. Yet common though sponges are, they remained until comparatively recent years a puzzle group to naturalists. Grant is generally credited with having, in 1825, given the first great impetus in the right direction, by his observations on the passage of minute water currents into the sponge by numerous small pores and their emergence by a few large openings. The following extract from the third edition of the Encyclopædia Britannica, 1797, will, however, prove that our fine old pioneer naturalist, London merchant Ellis, should rather have the credit:—"Mr. Ellis, in the year 1762, was at great pains to discover these animals. For this purpose he dissected the spongia urens, and was surprised to find a great number of small worms of the genus of nereis or sea-scolopendra, which had pierced their way through the soft substance of the sponge in quest of a safe retreat. That this was really the case he was assured of, by inspecting a number of specimens of the same sort of sponge, just fresh from the sea. He put them into a glass filled with sea water, and then instead of seeing any of the little animals which Dr. Peysonell described, he observed the papillæ or small holes with which the papillæ are surrounded, contract and dilate themselves. He examined another variety of the same species of sponge and plainly perceived the small tubes inspire and expire the water. He therefore concluded that the sponge is an animal, and that the ends or openings of the branched tubes are the mouths by which it receives its nourishment, and discharges its excrements."

The same work describes "**Spongia,**" as "a genus of animals belonging to the class of *vermes*, and order of *zoophytes*. It is fixed, flexible, and very torpid, growing in a variety of forms, composed either of reticulated fibres, or masses of small spines interwoven together, and clothed with a living gelatinous flesh, full of small mouths or holes on its surface, by which it sucks in and throws out the water."

Now to trace something of the progress that has been made in the study of these animals during the last hundred years. By most authorities, sponges are granted a separate *phylum* or branch, in the genealogical tree of the division Metazoa or multicellular animals. They form the lowest or least specialized phylum ; the name applied to them collectively being **Porifera.** A short summary of the most important points in the anatomy of the chief types of sponges is however necessary to the intelligent understanding of such position in the scale of nature.

The most primitive form of sponge organization is well seen in the very simple sponge, *Ascetta primordialis*, so minutely described by Hæckel. In appearance, *Ascetta* is a tiny, thin-walled, goblet-shaped animal that lives anchored by the narrow stalk end to rocks and weeds. At the free end is a wide opening (Pl. iv. Fig. 1), the **osculum,** while minute holes, **pores,** pierce everywhere through the thin walls and open into the great central cavity or **paragaster.** These walls, thin as they are, are of considerable complication, for three layers of cells can be made out, an external, **ectoderm,** composed of a single thickness of more or less mosaic-like cells ; a middle, **mesoderm,**—here extremely thin,—and lastly an internal layer, **endoderm,** composed in this sponge of oval shaped cells, each provided at the free end with a well-marked circular upstanding collar, from within the centre of which a strong whip-like thread or **flagellum** arises. Such cells are termed flagellated collar cells or shortly, flagellated cells—technically choanocytes.

In the first four figures on Pl. iv, the outer black line represents both ectoderm and mesoderm, while the shaded layer stands for flagellated cells. In the living sponge, the activity of the flagella of the endoderm sets up minute currents of water flowing through the numberless pores into the paragaster where nutrient particles are picked up from the water and effete matter cast back. Hence these currents, now gathered into a strong body of water, are directed out through the great osculum at the summit of the sponge. Sponge circulation is always fundamentally similar, even in the most complex : ingress by very small openings, egress by a single large vent.

But to return to our *Ascetta.* Essentially its structure is a thin walled sac, with pores opening direct into a great paragaster lined with flagellated cells. This arrangement of water passages, technically **Canal System,** is the simplest known, constituting what Hæckel named the primitive **Ascon Type** (Fig. 1).

Complications are frequent, but the fundamental feature of flagellated paragaster remains stable. Thus in our common *Ascetta* *coriacea,* budding, and branching, and anastomosing long continued, produces a colonial network having a long ramifying paragaster with numerous oscula. An intermediate form, *Ascaltis botryoides,* helps us better to understand the change, for here the buds while remaining attached to the parent and with their paragasters in free communication with the parental one, have each a separate osculum. Thus in an old colony, we can trace distinctly of how many individuals it is composed, by counting the number of branches, for each possesses a single osculum, the sign of the sponge unit.

A foreign species furnishes another interesting complication shown in Fig. 2. The walls become pushed out into numerous radial tubes, into which the flagellated coating of the paragaster is extended, and into which the pores open. Thus the extent of flagellated surface and of the pore area is largely increased. The name Chambered Ascon is applied to this form.

The next sponge type given us by Hæckel, the **Sycon,** is a natural outcome of the Chambered Ascon, and in simplest organization has the same structure minus the flagellated lining of the primary paragaster. The cells of this become practically identical in form with those of the ectoderm by loss of flagella and collars. Thus the Sycon may be defined as a Chambered Ascon where the flagellated cells are restricted to the radial tubes. Figs. 3 and 4 graphically exhibit this change. These two types are practically restricted to the division of sponges possessing a skeleton of calcareous spicules, which is thus marked out as the lowest or most primitive division of the Porifera, and consequently also of the Metazoa.

The third and highest type of sponge canal system, called by Hæckel the **Leucon** from its being characteristic of the family Leuconidæ, and by Sollas the **Rhagon,** is accompanied, or rather caused, by a great development of the middle layer of the body, the mesoderm. This occasionally reaches immense proportions (see Fig. 8) and as the paragaster does not share in this increase, the rather dwindling, it is obvious that the pores must have, superadded, long canals to enable the water to pass through the thickened walls into the paragester, or even into its out-growing chambers. One origin of the Rhagon is probably from the Sycon, as shown by the hypothetical Figures 5 and 6; Fig. 5 is practically a thick-walled Sycon, the paragaster pushing into the mesoderm fairly large rounded chambers, henceforth to be called **ciliated chambers.** Narrow tubes, **incurrent canals,** connect these with the pores on the surface, and either one or several may serve each chamber. The flagellated form of endoderm is entirely confined to the chambers. The next step is where the mesoderm still thickening, the chambers lose their direct connection with the central cavity and become connected by a fairly long **excurrent canal.** The fresh-water sponge is organized essentially upon this plan.

In the Leuconidæ, *e.g. Leucandra nivea,* a further stage, Fig. 7, can be made out, where instead of the excurrent canal of each chamber pouring its tiny stream direct into the paragaster, those of large groups of chambers are collected, as a river on its journey to the sea gathers its tributaries, into a great and wide, but short stream emptying by wide outlet into the central cavity.

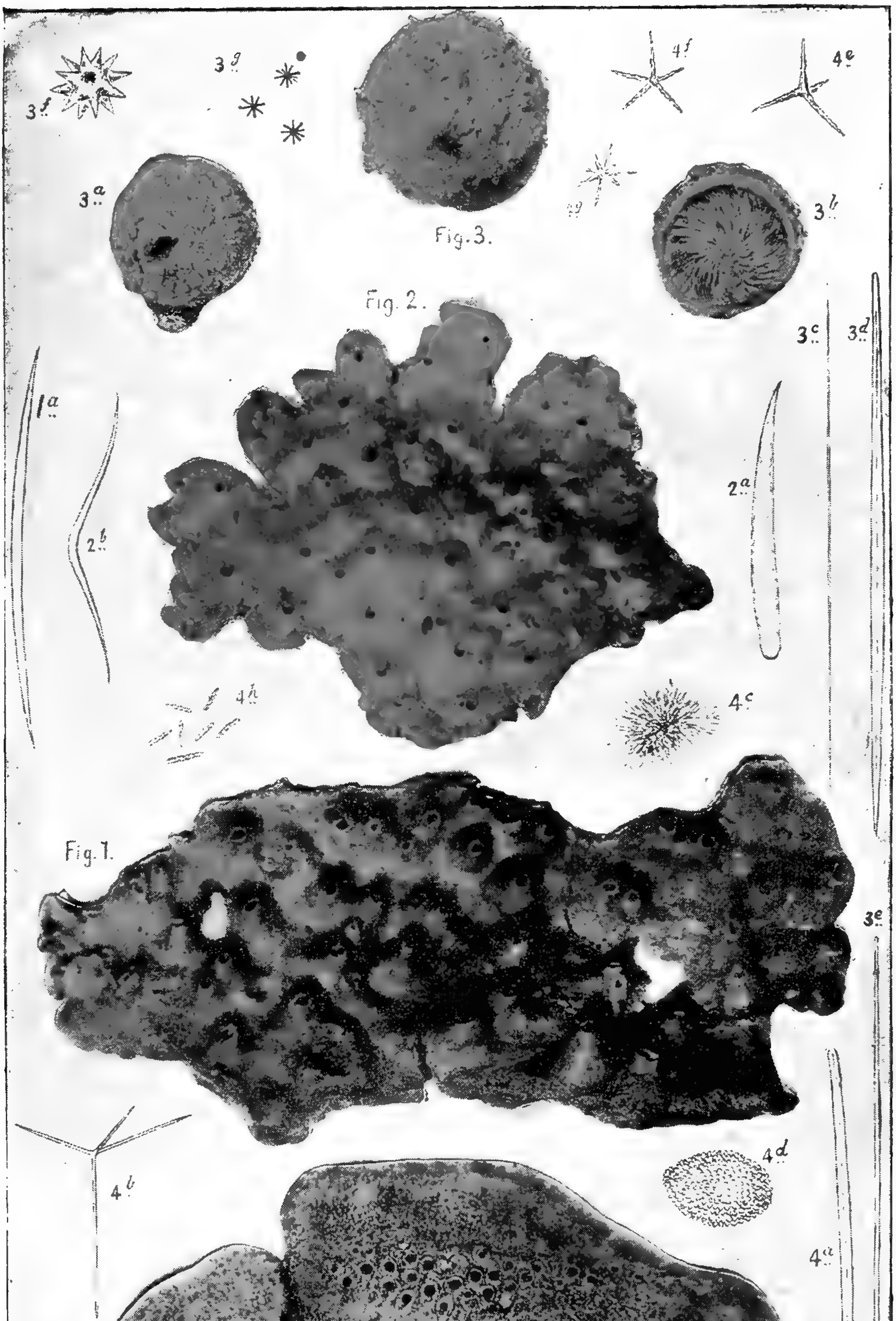
This, the true Leucon type, is what Sollas terms the **Aphodal** type of Rhagon. A further development, the **Diplodal** Rhagon, is reached when the incurrent canals, in this highest type usually restricted to one to each chamber, arise not singly and separately, but rather in the manner of the numerous branches into which a great river divides and sub-divides on its way through its delta. A large and wide tubular cavity, the sub-dermal chamber, penetrates the crust of the sponge, and from this, numerous wide incurrent canals lead inwards, throwing off at intervals still smaller tubules, each of which feeds a ciliated chamber. The excurrent canals remain the same as in the aphodal type. Often the sub-dermal chamber is arched over by a finely perforated membrane, the **pore area**, a natural filter against the entrance of enemies and coarse particles. A little below this filter membrane (inwards) is usually a well defined sphincter muscle, adapted by its power of contraction to completely or partially close the entrance to the water canals. The portion of the large chamber inward of the sphincter has received the name of **Subcortical crypt.**

A moment's consideration will show the great advantage that will accrue to the sponge if the soft ground tissue be laced with a network of intertwining fibres or supported by a cunningly arranged scaffolding of strong and rigid rods. Without some such support, the flagellated chambers would be apt to collapse and perform their function indifferently, if at all. Based upon the nature of this supporting skeleton, whether or not it is composed of calcareous spicules, we get our two first great divisions, the **Calcarea** and **Non-Calcarea.** The latter are by some termed Fibrospongiæ, because of a lacework of horny fibres more or less developed. But the majority of the Non-Calcarea have, superadded, spicules formed of silica (Silicispongiæ), while others again want both spicules and fibrous skeleton (Myxospongiæ). The Silicispongiæ are split up into three orders according to the shape of the principal spicules (megascleres), thus:—

Order I.—MONAXONIDA, megasclères simple, rod-shaped (Figs. 1*a* and 2*a*, Pl. iii).

Order II.—TETRACTINELLIDA, megascleres four-rayed (Fig. 4*b*, Pl. iii).

Order III.—HEXACTINELLIDA, megascleres six-rayed.



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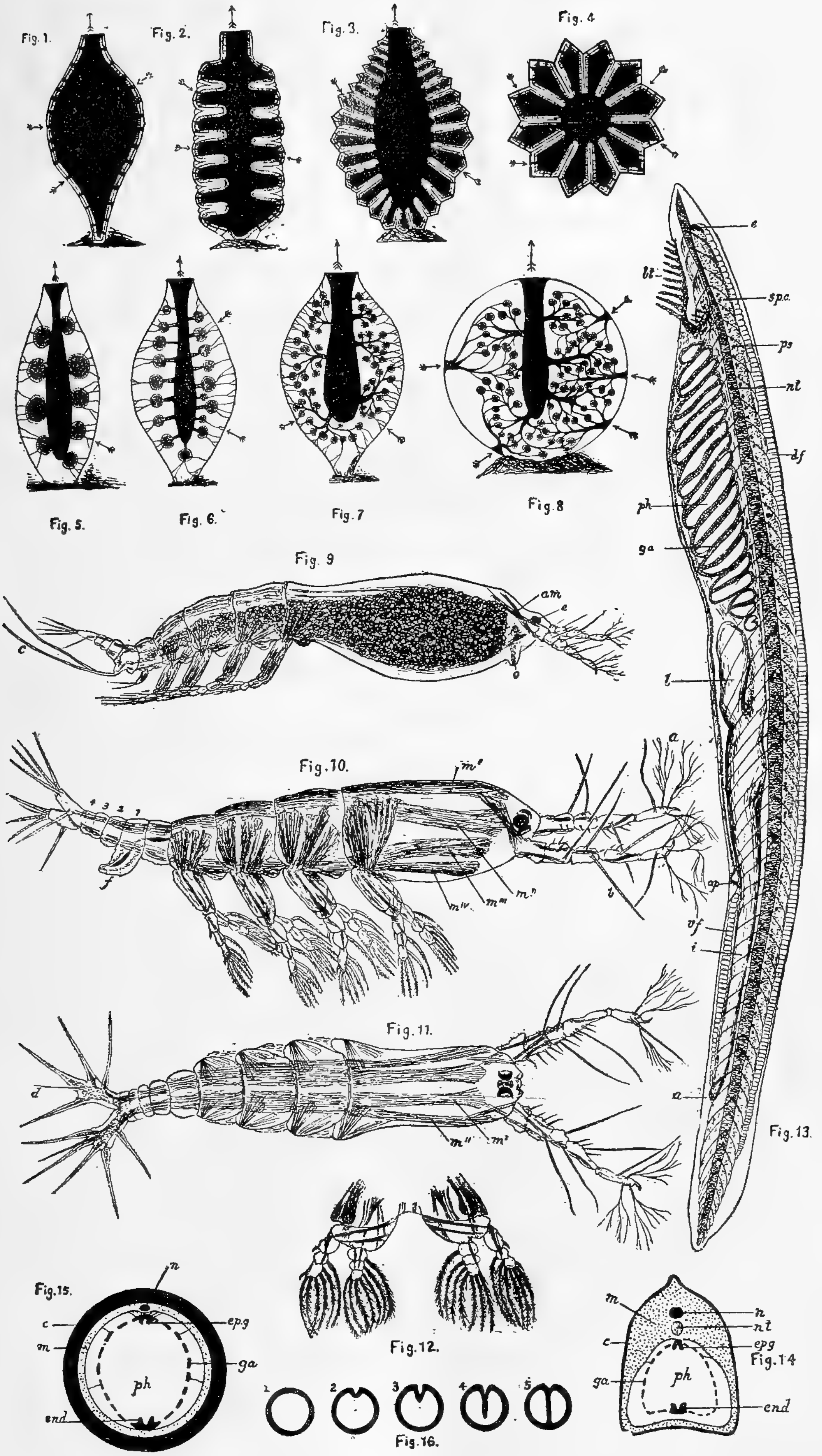
SILICEOUS SPONGES.



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SPONGES, MONSTRILLA, AMPHIOXUS.

We may tabulate the larger divisions of the Sponges thus:—

Phylum :—**Porifera.**

Branch A, **Calcarea.**	Branch B, **Non-Calcarea.**
Family I.—Asconidæ.	Class I.—(Skeleton siliceous) SILICISPONGIÆ.
" II.—Syconidæ.	Order I.—Monaxonida.
" III.—Leuconidæ.	" II.—Tetractinellida.
(Characterized respectively by the Canal system indicated by the name).	" III.—Hexactinellida.
	Class II.—(Skeleton fibrous) CERATOSA.
	Class III.—(Skeleton none) MYXOSPONGIÆ

Putting aside in the present article any consideration of the origin of the phylum as a whole, which is indeed bound up and identical with that of the entirety of multicellular animals, it seems most probable that the sponges arose independently by two main lines from a primitive stock, rather than that the Non-Calcarea were derived from the Calcarea or *vice versâ.* Were the question limited to the Calcarea, there would be little difficulty, for within the limits of the division, forms are found ranging from the very simple Ascon type, step by step up to the Sycon and thence to the complex Leucon or Rhagon. The Non-Calcarea are on the other hand nearly all of the Rhagon type, and were it not for the siliceous spicules in most, might easily be derived from some form of the Calcarea. But the nature of the spicules is a stumbling block. How derive a spicule of flint (silica) from one of carbonate of lime? Can we imagine the spicule forming cells to suddenly alter their selective power and to seize upon silica instead of lime? It seems too much to ask.

As to the Ceratosa, this difficulty is wanting and it is not improbable that their origin is due to the renunciation of the silica-secreting power in some ancestral siliceous sponge, while the ancestors of the Myxospongiæ may have gone a step further and have given up even the fibre forming power. But all is uncertainty as yet. Even fossil records help us not at all, for the most highly organized order, the Hexactinellida, are represented in our oldest fossiliferous rocks, the Lower Cambrian.

All the figures of entire sponges on Plate III are reproductions of photographs taken from living specimens, and show very clearly the outward form of four very prominent species of our Siliceous sponges—*Halichondria* and *Clathria* (Figs. 1 & 2) armed with rod-like spicules are typical forms of the Monaxonida; whilst the other two, *Tethya* and *Pachymatisma,* are representatives of the great group of the Tetractinellida. The third group, the Hexactinellida, familiar to us in the lovely Venus' flower basket (*Euplectella*), and the strange Glass-rope sponge (*Hyalonema*) is not met with in British waters. All belong to one or other variety of the Rhagon type of canal system, and except in *Tethya,* the widely open mouths of the oscula are plainly visible; situated in *Halichondria* at the apex of tall crater-like prominences; less marked in *Clathria*, where they crown low rounded swellings, and in *Pachymatisma*, peculiar as being collected into special elevated areas, and there arranged in serried, closely set rows. Details of histology must, for want of space, remain over to a future article, and with this reservation, I will now proceed to deal with the four species in question.

Halichondria panicea (Johnston), the Crumb of Bread, and also the Coxcomb Sponge of Ellis, varies much in colour, ranging from a greyish yellow to various shades of green. It is noteworthy that the higher up the littoral and the more exposed to light, the greener becomes this sponge. The yellow and ash coloured varieties are, conversely, found in the lower zones of the littoral or where matted curtains of fucus cause obscure shadowy light. In this sponge, the entire duty of keeping open the canals devolves upon the spicules, no fibrous tissue being present. The spicules (Fig. 1 *a*) are all of one form, curved pointed rods, arranged in a well ordered meshwork. Around the larger passages, the rows become much strengthened. Sub-dermal cavities are greatly developed.

Clathria seriata (Johnston), the *Ophlitaspongia seriata* of Bowerbank, shows more complexity in its skeleton. A well developed tough, square-meshed, horny network supports the sponge, beset, urchin-fashion, with numerous stout smooth rodshaped spicules pointed at one end only (smooth styli). The meshwork arrangement of spicules seen in *Halichondria* is absent, and apparently the horny skeleton is here used to keep open the canals—the spicules ceasing such function and limiting their benefit to defence against would-be enemies. A second and slender form of spicule, bow-shaped (toxon) can also be made out.

Pachymatisma johnstonia (Bowerbank) grows to immense proportions, and probably is the most massive of British sponges. The one photographed was 6 inches long, weighing just half-a-pound. Others we have had, have much exceeded this, *e.g.* one which is now deposited in the Guernsey Museum, weighed when alive fully 6-lbs., and measured 12-ins. × 7—9-ins., and 4 inches high. In section, this sponge shows many interesting points. An outer thick crust, cortex or **ectosome** is greatly developed by the massing of immense numbers of sterrasters—rounded and oval spicules thick set with spines radiating in all directions (4 *d*). Similar spicules are spread throughout the inner tissues of the sponge, the subcortical or **choanosome** region, but if examined carefully, it will be seen that these are much more sharply spinous than those of the cortex, which appear worn and battered. Probably these spicules are formed in the choanosome, and then pass outwards to accumulate in the cortex as a dense stony defensive layer. Other minute spicules (4 *e* – 4 *h*) are found scattered through the tissues. As to the larger spicules, the megascleres, the principal or four-axial ones peculiar to the order, are here disposed as a supporting scaffolding beneath the cortex. The form they take (Fig. 4 *b*) is known as the orthotriæne. Others of simple structure (4 *a*) are located in the inner tissues.

The water of circulation enters through sieve plates into large subdermal chambers, partitioned into two by a strong sphincter muscle, able thus to close the opening on necessity. From the inner chamber proceed the incurrent canals feeding the ciliated chambers.

Tethya lyncurium (Johnston) is in many respects a remarkable sponge. In appearance, it simulates perfectly a miniature tangerine orange in colour and in shape. Extremely spicular and furnished with a cortex—a true rind—as well developed as is that of *Pachymatisma,* no pores or oscula can be made out by the naked eye when the sponge is out of water, but in life in its native element, the oscula seem to be collected upon a slightly papillate prominence near the apex. Large canals are very sparse and it is at first difficult to believe this sponge to possess a complicated canal system as it undoubtedly does. The megascleres are strangely not four rayed as we should expect, but are long slender rods (3 *c* – *d*) gathered into great radiated bundles, quite obvious to the naked eye in a hand section (3 *b*). Microscleres, in the form of beautiful starry bodies, abound (3 *f* & 3 *g*). As regards ciliated chambers, I have to confess I have never seen any in either *Pachymatisma* or *Tethya.* But this is not to be wondered at perhaps, as the size of even the largest ciliated cells of any siliceous sponge is very small compared with that of those of the calcareous species.

Explanation of Plate III, Fig. 1 – 4 & Pl. IV, Figs. 1 – 8.

Sponge anatomy, &c.

Plate III, Fig. 1. *Halichondria panicea,* × $\frac{2}{3}$; *a.* megasclere.

Fig. 2. *Clathria seriata,* × $\frac{2}{3}$; *a,* megasclere ; *b,* micosclere (toxon).

Fig. 3. *Tethya lyncurium* ; *a,* another (smoother) specimen ; *b,* same split open to show cortex and radiating spicule bundles ; all × $\frac{2}{3}$; *c* – *e,* megascleres ; *f* & *g,* microscleres.

Fig. 4. *Pachymatisma johnstonia* × $\frac{2}{3}$; *a* & *b,* megascleres ; *c* & *d,* sterrasters ; *f* & *h,* other microscleres.

Plate IV, Fig. 1–8. Diagrams of the types of Canal System. f. 1. Ascon; f. 2. Chambered Ascon; f. 3 & f. 4. Sycon; f. 5. simplest possible Rhagon; f. 6. Eurypylous Rhagon; f. 7. Leucon or Aphodal Rhagon; f. 8. Diplodal Rhagon. All these are shown in vertical section, saving Fig. 4 which shows transverse section. In the Rhagon diagrams, the white portion represents the greatly developed mesoderm. The shaded portion denotes where ciliated cells occur. Arrows denote the direction of the water currents.

Study V.—A contribution to our knowledge of the Copepod Monstrilla anglica.

This species is for many reasons extremely interesting. A single specimen, a male, was captured in 1857 by Sir John Lubbock (1) at Weymouth, and at the publication of the concluding volume of Prof. Brady's fine monograph on the British Copepoda (2) in 1880, no further record had been made and the original specimen had been lost. Just about this time the record was resumed by the capture off Jersey, of a few specimens by Mr. J. Sinel, who however did not identify his interesting find till the publication, by Mr. I. C. Thompson, of the description of a specimen of the same animal taken off Anglesey in the autumn of 1887. Mr. Thompson at first believing the animal to be new to science, named it *Cymbasoma herdmani* (3) but later on, having more material to examine, he recognized his animal to be of the same species as Lubbock's. Since 1880, *Monstrilla anglica* has appeared pretty regularly every year off Jersey during Aug. and Sept., in sparing numbers. Mr. Thompson has also recorded a second specimen from the Irish sea (5), and another from off Malta, while one or two more have been taken on the south coast of England. Apparently then, here in Jersey, we have been the most successful in obtaining this rare animal. Indeed of late years we have been specially so, for out of a small number of tow-nettings taken in Aug. and Sept. of the last two years, we have picked out nearly 80 specimens.

Normal Copepoda may be defined as minute crustaceans of simple organization, having an elongated body clearly divided into numerous rings or **somites,** and without the shield-like shell or **carapace** that covers the anterior part of the body being double or bivalve, having an anterior pair of **antennæ** or feelers (properly antennules): *a posterior pair (the true antennæ); 3 pairs of mouth organs (1 pair mandibles, 1 pair maxillæ, and 2 pairs of maxillipedes),* and five pairs of two-branched, **biramous,** swimming feet attached to the anterior part of the body or **cephalothorax.** The hinder end of the body consists of an **abdomen** of 5 somites bearing no organs and terminated by a forked tail.

With such definition *Monstrilla* closely agrees if the italicized part be omitted. Every vestige of the usually well developed and complicated mouth organs is absent; the posterior antennæ have shared a like fate, and further, no trace of alimentary canal can be made out, though a very short tubular proboscis is apparent. This however leads nowhere, and I am inclined to hazard the suggestion that these animals may live during the greater part of life as **suctorial parasites** upon or within some larger animal, but that at breeding time (Aug. and Sept.) they leave their hosts and seek for mates, free-swimming in the surface waters of the sea. Certainly many species of copepoda do live as parasites, *e.g.* the whole family of Notodelphyidæ affect some or other of the simple Ascidians, while others live within the cockle, pecten (6) and other shell-fish. Regarding the assumption that *Monstrilla* forsakes the host at the breeding time, and that stomach and intestine become absorbed coincidently, such would not be without parallel among other animals. Thus those small free-swimming worms, the Syllidæ, forsake their homes among the corallines as the time for reproduction approaches, and are found among the surface life of the sea with alimentary canal reduced to a mere cord or else entirely atrophied, and the cavity of the body wholly filled by masses of ova or of sperm. Reference to Pl. iv, Fig. 9, will show how the ova in *Monstrilla* is similarly disposed. Mr. I. C. Thompson has indeed (5) considered and condemned the view that this animal may be a sucking parasite—but apparently he has overlooked the probability now suggested, of its regularly abandoning such habit and altering its anatomy at the breeding season. He adduced the fact that all specimens of *Monstrilla* have been recorded as free-swimmers near the surface—but considering that a copepod, common in, and peculiar to the cockle, was only discovered in 1892, there is plenty of chance of this supposed parasitic habitat of *Monstrilla* to have been overlooked. Hence I cannot without positive evidence agree with Bourne (7) in the possibility that "the adult may be preceded by a predaceous larva supplied with mouth parts and an alimentary tract, which, after a succession of rapid ecdyses, develops into the mature sexual form, whose only function is that of reproduction." But we have no record of such a larva having been seen—and as such would be less easily overlooked than would a parasitic adult in some perhaps obscure host, I think the suggestion I mention is the more probable. A great deal of work has yet to be done ere the parasitic copepoda are even fairly well known, and I would therefore draw the attention of workers to what assuredly is a promising field for research.

The few appendages possessed by *Monstrilla* are all exceedingly interesting when viewed under a high power. Thus if we examine the antennæ of the male, we will find each to be five jointed, and furnished with a most curious variety of spikes and sensory hairs. First there are numerous short stiff spines, next a few much longer ones with a row of regular dots along each margin. Some of these hairs are equal in length to half that of the antenna itself. Of about equal length are three strange much branched slender hairs set around the apex of the terminal joint. Into these hairs, branch nerves can readily be traced. At the apex of the last joint is a claw-like spine. These spines and hairs are very definite in position and number, thus the 1st joint bears 1 short spine,

the 2nd has 5 spines and 1 long hair,
" 3rd " 1 spine and 2 long hairs,
" 4th " about 5 spines and 1 long hair, while
" 5th " 1 stout claw spine, 2 slender ones, 3 branched hairs, 1 long straight hair and a short slight apical thread-like process.

Between the 4th and 5th joints is a strange hinge arrangement, peculiar to male copepods, and of use in holding on to the female.

The antennæ of the latter are shorter and less deeply jointed than those of the male; the ratio being as 8 to 11. The 4th and 5th joints are practically fused into one, so that the antenna seems to consist of 4 joints only. The spinous hairs are more strongly marked in the female, while the branched and the long hairs are less developed. Apparently then, these being sensory, it falls to the male to search for his mate. In arrangement, the hairs, &c., are much the same in both sexes—except that in the female the part that answers to the 4th joint bears 5 spines and 3 long hairs, while what represents the 5th, in addition to having a stout apical claw spine has two others equally well developed and which are equivalent to the two slender spines in the male. It has been said that the claw spine of the male is for use in seizing the female but, seeing that the latter is even better equipped, it seems to me more likely that these are primarily of use in anchoring as parasites to some host.

The cepalothorax to which the swimming feet are attached, is, in its front part, covered by a great shield, the **carapace.** On the under side, at the hinder edge of the region thus marked out, is inserted the first pair of feet. Behind the carapace are four distinctly marked off body rings, each bearing in the female a pair of feet on the under side. In the male the fifth pair of feet are suppressed. In structure the first 4 pair of feet are very much alike. The fundamental plan of the typical crustacean foot can be traced clearly. A stout basal part of two stout joints articulating to the body represents the **protopodite.** To the joint away from the body are joined two branch limbs, one directed inwards, the other outwards, respectively **endopodite** and **exopodite.** Each again is divided into 3 short joints, bearing *setæ* or stout hairs definitely placed (Pl. iv, Fig. 12). The 1st pair differs from the others in possessing one hair less on the distal joint of the exopodite. All the setæ of the feet are finely plumose. The fifth pair of feet, present only in the female, is very different, as each foot consists merely of two short weak joints, bearing at the termination a couple of slender hairs.

The abdomen consists of 4 joints (Fig. 10, 1, 2, 3 & 4), ending in a forked tail. Each fork bears 1 slender and 5 stout bristles in the position shown in Fig. 11. Lubbock erred in writing "upon the fourth candal seta (counting from the outside) is another, rather smaller than the other five." In reality it arises from the tail fork in the same way as its fellows, but being very slender, a mistake is very liable to occur. Mr. I. C. Thompson has apparently overlooked this slight hair in his diagnosis of the species as he says "5 setæ to each furcal segment" (6).

Muscular System.—By selective staining, I have been fortunate in being able to make out very clearly the principal arrangements of the muscles. A glance at Figs. 10 and 11 will show how immensely powerful this tiny creature (female 3 mm. long; male 2·25 mm.) is in proportion to its size. This is apparently against the idea of the generally parasitic life of this animal, for such life in general leads to partial atrophy of the muscles. Still it does not dispose of the suggestion—there may be compensating causes.

To return. The largest muscles are found within the carapace, lying longitudinally; four pairs arranged as in Figs. 10 and 11. The two upper or dorsal pairs are used in straightening or extending the body, **extensors;** the other two pairs for bending or flexing, *i.e.* **flexors.** Each of the following body rings or segments possesses but one pair of extensors and the same number of flexors, modified however in the abdomen by the extensors of the first and second segments, and both the extensors and the flexors of the third and fourth being respectively wholly or in great part coalesced. Thus these segments lose more or less their independence of action, the first and second acting in concert in extension, the third and fourth in all movements. To understand well the action of these body muscles we must remember that the axis of movement between adjoining body rings lies transversely across the body a little above the articulation of the feet, so it is obvious that a pull *below* such axis, will bring the rings together on the under side, producing flexion; conversely, if above, the opposite, *i.e.* straightening will be produced. Hold a coin between finger and thumb, pull on the uppermost point of the edge and the movement that produces extension in crustaceans, is simulated; if the lowermost edge be pulled, then flexion is imitated. The anterior end of all these muscles is attached well forward to the inside of the chitonous shell that forms the protective skeleton in these animals; the hinder end being inserted on the front edge of the body ring next following, and which is governed in action by the muscle so placed.

The swimming feet are each governed in their larger movements by two great fan-shaped muscles which pass upwards from the thigh joint along the sides of the body. The smaller movements are co-ordinated by a very complex series of small muscles which space forbids the enumeration of. The antennæ are each governed by two strong muscles passing backwards close to the eyes. In both sexes the muscular development of the antennæ is great, particularly in the male, and is of great assistance to the animal in swimming, being, in this sex, virtually equivalent to the addition of another pair of swimming legs.

Sense Organs.—These seem practically limited to eyes and sensory hairs. The former are well developed, three in number, each possessing a large crystalline lens. They lie somewhat in triangular fashion, two paired ones on the upper surface of the head between the bases of the antennæ, and a third, the unpaired one, being beneath these on the under side of the head. The structure is essentially that of a convex glassy lens set in a mass of pigment and connected by a stout nerve with the brain.

It is interesting to notice that the paired eyes look sideways, while the unpaired one looks downwards and forwards, just the best possible optical arrangement for the animal when it betakes itself to free life at the surface of the sea. To pelagic animals there is no above. Their world lies around and beneath, and there alone do they require to cast inquiring glances, if indeed their modest optical equipment will so permit me to phrase it.

In the females full of ova, the eyes are frequently much reduced and apparently more or less absorbed and functionless.

As to sensory hairs, there are apparently two kinds, one having a much branched form (Fig. 10, *a*), the other straight and unbranched (*b*). It may be that *a* is olfactory and *b* tactile, but this rests entirely upon supposition.

Respiration.—No organs adapted to this end. The general surface of the body seems to function.

Reproduction.—The sexes are always separate; the difference expressing itself plainly in the outward form. The male is smaller (2·25 mm.) than the female (3 mm.); he has more powerful antennæ (ratio 11 to 8); the hinge between the 4th and terminal joints of his antennæ is absent in those of the female; he is without the rudimentary fifth pair of swimming feet present in the female, and the sexual orifices which open in both sexes on the under side of the 1st abdominal segment, are in the male situated on stout low prominences (Fig. 10, *f.*); in the female when mature, these are produced into long tubes reaching backwards considerably beyond the ends of the caudal bristles. Internally both ovaries and testes lie as two great paired glands in the cephalothorax. Both sexes have in this species two distinct efferent ducts whereby the genital products are passed downwards and obtain egress at the openings already mentioned. The function of the long tubular genital processes of the female (*c*) is probably to give attachment to the ova after being extruded, as Mr. I. C. Thompson has observed ova adherent to them in an allied species (4).

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EXPLANATION OF PLATE IV, FIGS. 9—12.

Monstrilla anglica (Lubbock).

Fig. 9. Side view of a female full of ova (size 3 mm.), *am* antennary muscles, *e* eye, *o* proboscis, *c* genital tubes. (*Note*—No definite articulation should be shown between the fourth and terminal joints of the antennæ. Such is shown here by a slip in drawing.

Fig. 10 & 11. Lateral and dorsal view of a male (size 2·25 mm.), *a* branched sensory hairs, *b* straight tactile (?) hairs, m^{i} & m^{ii}, the extensors muscles of the segment next behind the carapace, m^{iii} & m^{iv} flexor muscles of same, 1, 2, 3 & 4 abdominal segments, *f* genital prominence, *d* the 6th or slight seta of the caudal fork.

Fig. 12. View from behind, of the third pair of swimming feet.

VI. The Main Facts concerning the Lancelet (Amphioxus lanceolatus).

Few animals are cosmopolitan. Changes of climate, food, and habits, brought about by life in other latitudes, alter, directly or indirectly, sooner or later, some features of the body, and the migrant becomes a new variety, and even in course of time may have this variation so indelibly impressed upon it, as to constitute a new species. Even migrant civilised man, with all his special advantages of constant inter-communication with his original stock, is affected appreciably in comparatively a short time. The American—our *Brother* Jonathan—has not *our* features, but bears a physical trade-mark solely his own; our cousin, too, in New Zealand—a really nearer relative than he from the U. S. A.—is developing "points" alien to ours. Naturally however, the land is less likely to present cosmopolitan types than the sea. Under the waves vicissitudes of climate are reduced to a minimum. But even there, we but seldom find a species stable over widely extended areas; those known to be world-wide may practically be counted on the fingers.

Thence, when we find that perhaps the most curious of living animals, the strange Lancelet, most lowly among the vertebrates, is found without appreciable change of form or structure in the seas of Europe (around Britain and in the Mediterranean), along the North American coast, in the West Indies, Brazil, Peru, Tasmania, Australia, and Borneo, we seize one of the many noteworthy facts concerning this animal.

Spread thus universally, *Amphioxus lanceolatus* is not only the sole species in its genus, but also the only representative of the family, and even of the group to which it belongs. Curiously enough, the first example known, was caught off Cornwall, and passed into the possession of the early Russian naturalist Pallas, who indeed saw so little affinity with the vertebrata, that he described it (1774) as a slug, *Limax lanceolatus*. Some fifty years passed ere we have note of a second specimen being caught (1831). This again was taken on our English coast, at Polperro, Cornwall. It was well described by Yarrell, who bestowed upon it the name we are now so familiar with, *Amphioxus lanceolatus*. Yarrell recognised its relationship better, and placed it at the bottom of the list of fishes, where it has ever since remained.

The growth of the systematic study of marine life has of late years shown *Amphioxus* to be both widely spread and frequently numerous, so that now it may aspire to join the select circle of martyrs to science, already adorned with the names of the frog and the dogfish.

The anatomy and description of few animals are better known, hence I have little or no excuse for occupying space with details here. Any zoological text-book will provide such, as for example Marshall and Hurst's "*Practical Zoology*," which is specially commendable, from its clearness and accuracy. I will therefore now give what is intended as merely a running commentary upon the figures as drawn on Plate IV.

External Characters.—In life, the Lancelet is a small, nearly transparent fish-like animal, pointed at either end—of some two to three inches in length. No scales are present, the body being clothed in a thin transparent cuticle. Along the entire dorsal region, and along the ventral from atrial pore to the end of the body, the skin is raised into a fold or ridge best marked both dorsally and ventrally in the part of the body posterior to the anus, and which we may term the tail. The dorsal ridge of skin is strengthened, except at the ends, by a row of cube-like compartments forming a supporting skeleton, answering to the fin rays of true fishes. The ventral ridge is strengthened by a similar skeleton between atrial pore and anus, and this part is the ventral fin (*vf.*); the fold running along the dorsal and ventral sides of the tail being the caudal fin, while the dorsal fold anterior to the tail constitutes the dorsal fin (*df.*)

Alimentary Canal.—The mouth is a large oval aperture placed anteriorly on the ventral aspect, and bordered on either side by a line of tentacles (*bt*). The mouth leads into an elongated dilated chamber, the **pharynx**, which functions also as the organ of respiration (*ph*). Its walls are supported on either side by a framework of cartilaginous arches set obliquely, the **gill arches** (*ga*), along which course the branchial blood-vessels. Between every two arches is a long narrow perforation, the gill cleft. Through these openings, the water, brought in through the mouth by the action of the cilia that line the pharynx, is directed into a cavity all but surrounding the pharyngeal tube. This, the **Atrial Chamber,** corresponds closely to that of similar name in the Ascidians, and indeed, the respiratory plan is altogether exactly conformable in the two animals. The water passing into the atrial cavity from the pharynx is conveyed out by an opening, the **atrial pore** (*ap*), situated at the front end of the ventral fin. As in the Ascidians, an **endostyle** is present in the ventral wall of the pharynx. It is however flattened in the anterior part, but posteriorly it has the deeply grooved form characteristic of Ascidians. The epibranchial groove found in Ascidians is also well marked as a dorsal counterpart of the endostyle. The pharynx leads into a straight intestine ending in an anal opening (*a*) placed on the left side of the ventral fin.

Immediately above the alimentary canal is a tough elastic rod, the **Notochord** (*nt*), reaching from end to end of the body. Above this again, lies the **Spinal Cord,** a cylinder having slightly less diameter, marked along the under side by black pigment cells. No brain is apparent, but the more anterior part is slightly thicker than posteriorly. Branching nerves are given off at intervals to the various organs.

Sense Organs are rudimentary; a pigmented patch at anterior end of the spinal cord, serves as "eye," while a ciliated pit at the same point may be olfactory in function.

The Muscular System is well developed and enwraps the various organs as in a sheath. Its elements are composed of striated fibres, arranged principally in peculiar < shaped bundles or **myotomes** numbering 61–62 on either side of the body. On the ventral surface are subsidiary muscles running transversely whose function is, by contraction, to expel water from the atrial cavity.

Blood System.—No definite heart is present. Impure blood from all parts of the body is collected into a ventral vessel, the cardiac aorta, which by the contractility of its walls is able to propel this blood into paired vessels, aortic arches, that pass along each alternate (primary) arch. The blood, purified in these vessels by intimate exposure to the water passing through the gill slits, is emptied into a right or left dorsal aorta according as it comes from right or left side of the pharynx. The right and left dorsal aortæ unite to form, at the hinder end of the pharynx, a single vessel which passes backwards on the dorsal side of the intestine. From the dorsal aortæ the purified blood is distributed to the organs of the body.

Reproductive Organs.—The sexes are separate—ovaries and testes have the same outward appearance, that of two rows of enlargements along the body-wall, external to the atrial cavity and parallel with the pharynx, a row on either side of the body. The products escape by rupture of the atrial wall, into the atrial cavity and escape by the atrial pore, or it may be by the mouth, by passing through the gill clefts.

Want on Internal Symmetry.—It is a remarkable fact about Amphioxus, that the internal organs do not show bilateral symmetry, that is, are not arranged in balanced pairs. Thus any particular gill cleft on one side is opposite a gill arch on the other side instead of opposite another cleft. The aortic arches necessary partake also of this asymmetry. The muscle segments or myotomes, nearly all the nerves arising from the spinal cord, and the reproductive glands are also alternate on the two sides of the body. The liver too is asymmetric, being turned to the right side, while the anus opens on the left side.

Development of Gill Arches.—These are of two kinds; half are forked at the ventral ends, others which alternate are unsplit. The cleft in front of, and that behind each unsplit rod originally formed together a single opening which, by secondary growth downwards of a portion of the wall, become divided into two in the manner shown in Fig. 16, Plate IV. The down-growing rods may be therefore termed secondary arches, the others primary. In adult individuals connecting bars cross the clefts so as to join more intimately the primary and secondary arches, an arrangement reminding us of that in the Ascidians.

A comparison of Amphioxus with a typical Ascidian is extremely interesting and suggests such a closeness of relationship that were it not for the emphatic developement of a central skeleton, there would be more reason in classing it as a highly developed free-swimming Ascidian, than as a little developed ancestral fish.

The points of similarity are well brought out by glancing at the comparative diagrams of the two, shown in figs. 14 and 15. The section shown in both figures is transverse. In the Ascidian, the section is just posterior to the mouth and through the nerve ganglion that serves as brain. That of Amphioxus is through the pharynx. Examination shows how, except in minor details of relative thickness and arrangement of the tissues, the fundamental similarity (homology) is absolute, saving for the presence in the lancelet of a central skeleton, or notochord (*nt*). In both the body is encased in a more or less structureless cuticle. Within this is a ring of muscular fibres, and more or less sunk in this muscular layer is the central nerve-mass (*n.*) Suspended from the muscular band at a point just beneath the nerve centre, is a perforated pharyngeal tube shown in figs. 14 and 15, by an interrupted line (*ga.*) intended to represent the sections of alternate gill arches and gill clefts. Top and bottom of this pharyngeal tube are two grooves, respectively the epibranchial groove and the endostyle.

The minor differences as seen in such a section are:—In the Ascidian the cuticle is immensely thickened to form a protective test; but the muscular hoop is infinitely less developed than in the Lancelet, due to the want of much muscular effort in the sedentary life led by the former. In the Lancelet again, the pharyngeal tube is only attached dorsally. In the Ascidian, it is, at the points shown, attached both dorsally and ventrally.

In both animals the mechanism of respiration and feeding is alike; the muscular arrangements are strictly comparable; the reproductive products are in both expelled from the genital glands into the atrium and leave the parent by either the atrial pore or mouth. In both is the same lowly development of sense organs, and want of any defined cephalic or head region.

The points of divergence are essentially the presence in the Lancelet, of a notochord, of an elongated central nerve-mass, and of a higher type of blood system.

Finally it is noteworthy that a series of minute tubules, probably excretory, open into the upper portion of the atrial cavity on either side of the pharynx. There can be but little doubt that these represent the paired excretory tubules (nephridia), so characteristic of the worms. Hence, as no kidneys of any vertebrate pattern are present, the Lancelet exhibits in the structure of its renal organs, the most unmistakable of its many plebeian characteristics.

Explanation of Figs. 13–16, Plate IV.

Amphioxus lanceolatus (Yarrell).

Fig. 13. View of a young specimen $\frac{3}{16}$-in. long; from the left side.

Fig. 14. Diagram of a transverse section of same through pharyngeal region.

Fig. 15. Diagram of a transverse section through the anterior end of the body of a typical Ascidian, *e.g. A. mentula.*

Fig. 16. Diagrams showing the mode of formation of a double gill slit from a single.

Lettering the same in all figures, viz.:—*a p.* atrial pore; *a.* anus; *b t.* buccal tentacles; *c.* cuticle; *d f.* dorsal fin; *e.* eye; *end.* endostyle; *ep g.* epibranchial groove; *ga.* gill arches; *i.* intestine; *l.* liver; *m.* muscles; *n.* nerve system; *nt.* notochord; *ph.* pharynx; *p c.* pigment cells; *sp c.* spinal cord; *v f.* ventral fin.

A PROGRAMME FOR THE EASTER HOLIDAYS.

 (See also page 3 of cover).

TO CORRESPONDENTS.

All communications for the Editor to be addressed to the Biological Station, Jersey.

Original notes on Marine Life are invited; while technically correct, they must however be written in an interesting style.

Advertisements to be sent to the same address.

Jersey Marine Biological Station. Interior View of Portion of Aquarium Floor.

The Journal of Marine Zoology and Microscopy:

A PLAINLY WORDED BIOLOGICAL QUARTERLY.

VOL. I. NO. 3. MAY, 1894.

OUR PROGRESS AND OUR PROGRAMME.

NOW that six months have elapsed from the inception of our venture, we are in a fairly good position to assess the measure of success that has rewarded our efforts. In the number of subscribers gained, our expectations have been immensely surpassed, and we are proud to say that our little Journal penetrates everywhere in Britain where Zoology and Microscopy find votaries. In size, the Journal has expanded from the 16 to 24 pp. promised in the prospectus, into a minimum of 28 pp. which too we shall expand to 32 or more, if each of our subscribers will but help us by prevailing upon a friend to remit us the sum of 3/4 as one year's subscription. And in this connection we may point out that increase of size has necessitated the raising of the price to 10d., including too, the back numbers—but then we make no additional charge for postage on any numbers forwarded from the Jersey office.

We wish also to bring before the notice of our friends, the fact that we have further aims than simply to produce a useful scientific magazine. Through the medium of our Marine Biological Station at Jersey, we have certain public duties to perform, in the facilitating of the practical study on the spot, of marine life. Our laboratories, established last year, have had considerable measure of support. The following, among others, have rented compartments for longer or shorter periods, or have had instruction in the preservation of marine animals, viz :—

Miss EVA HOOPER, London.
Miss WARD, Ladies' College, Jersey.
Mr. F. BORROW, Medical School, St. Bartholomew's Hospital.
Mr. H. BURROWS, Medical School, St. Bartholomew's Hospital.
Mr. E. S. GOODRICH, Dept. of Comp. Anatomy, Oxford.
Mr. D. HOUSTON, Director of Biological Instruction, Essex County Council.
Mr. R. PAULSON, Sec. Toynbee Hall Nat. Hist. Soc. and several members of same Society.
Mr. W. G. RIDEWOOD, Br. Museum (Nat. History).
Dr. E. MARETT TIMS, Medical School, Westminster Hospital.
Mr. E. H. L. SCHWARZ, Royal College of Science, London.
Mr. HY. SCHERREN, F.Z.S., London.
Mr. W. H. UNTHANK, Birkbeck Institute, London.

Several of the above have followed out a wide course of dissection with the view to qualifying in the higher exams in Zoology of the London B.Sc. syllabus, and it is most satisfactory to us that all have expressed themselves extremely gratified with the accommodation and material provided for their work. In these cases a full supply of all the living types required, is provided free to all renters of laboratory compartments, and as the rent of these, inclusive of the full use of reagents, microtomes, dissecting dishes, library, &c., varies between the modest sums of 7/6 and 12/6 per week, we scarcely require to emphasize the great boon our Station is to those who elect to make use of it. Undoubtedly the facilities we offer, are more extensive and lower priced than any to be had elsewhere in this country. We have, at the very doors, a fauna immensely richer and more valuable than that available to any other British Zoological Station.

A vital necessity to such an establishment as ours is a good reference library, kept well up to date. And this keeping up to date is a weak point with us. Our means—unsupplemented by the Government and local grants so freely given to marine stations well nigh everywhere else but in this belated island of Jersey—are quite inadequate to this strain, and we appeal earnestly to friends to help us in this respect either by the gift of books or pamphlets, or by donations to the library fund. Several gentlemen have been extremely kind in this way. Thus among others—to all of whom we beg to tender our most sincere thanks—Mr. W. Hatchett Jackson has, within the last few days, sent his extremely valuable revision of Prof. Rolleston's "Forms of Animal Life"; while Mr. Theo. T. Groom has contributed his monograph "On the Early Development of Cirripedia," and the Smithsonian Institution contribute their "Proc. of the U. S. Nat. Museum." To the Editors of "The Journal of Malacology," "The Naturalist," "The British Naturalist," "Knowledge," "Science Gossip," "Neptunia," and several others whom space prevents naming, we have also to return thanks for the favour of exchanges.

As to the future—we have pleasure in announcing that Mr. Theo. T. Groom, our foremost British authority on the Cirripedes, will contribute to our next number a very interesting article of original observations upon the development of the Barnacle *(Balanus)*, while Mr. Ernest H. L. Schwarz will be responsible for an equally important paper on the ancestry of the Octopods, and the close relationship of the fossil Ammonites with this group. "A Naturalist's Year" will, it is hoped, also be commenced either in this or the next following issue. In this will be recorded the breeding times, and occurrence of notable marine animals upon the Jersey coast, with such items of investing interest as may from time to time crop up.

CONTRIBUTIONS TO THE STUDY OF VARIATION.

BY JAMES HORNELL.

SERIES I.—a. *Sexual colour divergence in Labrus mixtus.*
b. *Duplication and origin of the operculum in Serpula.*
c. *Anastomosing of muscle bands in Salpa.*

I. SEXUAL COLOUR DIVERGENCE IN LABRUS MIXTUS.

THE *Labrus mixtus* of Linnæus, and the *L. trimaculatus* of Pennant, are by no means rare on the Jersey coast. Yearly a fair number are caught during the warmer months, especially in the more deeply sunk lobster pots. Apparently they do not come so close inshore as the other Wrasses.

These fishes differ so immensely in colour that they are recorded as different species, while at the same time, the fact that they agree closely in size, habits, contour, and anatomy, has given rise to the strong suspicion that they, in reality, represent the different sexes of the same animal. Dr. Günther, among others, has formulated this opinion, and undoubtedly it is correct, for the sole divergence—colour—I have recently noticed to vary in a manner calculated to remove all doubt as to such relationship being the true explanation.

Than *L. mixtus*, called here " coucou " universally by the native fishermen, there is probably no more gorgeously bedecked British fish. So bizarre and gaudy is it indeed, that the taxidermist, who, with scrupulous fidelity, reproduces the crude and glaring tints in their full brightness, is apt to have his work eyed askance, and to receive as scant courtesy as did the traveller's tales of Bruce on his return from that memorable pioneer Abysinnian journey. Bright orange red predominates, streaked by some three longitudinal vivid blue bands; several blue or purplish markings and blotchings adorn the head, in which glistens—a very jewel—the bright crimson eye. The large dorsal fin is orange and red in varying patterns—sometimes a margin of blue specially strong at the hinder end—more rarely the anterior part blue, the hinder orange. Then the tail is a marvel of colour, the blue usually disposed as a sharply defined edging.

The so-called, *L. trimaculatus,* called here "*Le Roi,*" is normally of a bright vermilion orange, with from three to five dark blackish patches along the back, close to, and sometimes even encroaching upon the dorsal fin. The most well marked spots are usually just at the hinder end of this fin.

Now the evidence I have to offer is briefly stated thus:—These fishes being brightly coloured, we used our best endeavours to procure a good number for the aquarium tanks of the Station, and as they are extremely resentful of handling, being usually half dead, spite of all care, when brought up from the fishing boats, we, unfortunately, had an opportunity of examining quite a considerable number ere we succeeded in stocking the tanks. Of such as were brought up, most of the *L. trimaculatus* were of the colouring noted above; two, however, showed unmistakeable signs of the *L. mixtus* relationship. Thus one showed dark markings on the head in just the position of the blue streaks of *L. mixtus,* while similar dark bands were along the sides of the body, and the tail, too, showed a faint but decided blue border. The other specimen was almost without the characteristic black spots, and showed besides, faint blue marking on both tail and dorsal fin.

On the other hand, a very fine example of the blue striped, or *L. mixtus,* type, which we were successful in keeping for several months, gradually faded as November ran its course. From being the gay coloured Cuckoo fish, its bright blue and purple streaks and bands slowly paled till in parts they were all but lost. At the same time two distinct black patches appeared on the back just in front of the tail fin. One was situated a little behind the dorsal fin, the other a little in front and spreading slightly on to the membrane of the fin. Trace too of a third spot could be made out about an inch in front of the last mentioned.

It is difficult without the help of coloured plates to show the full cogency of these abnormal colourings, but what I have stated will suffice to finally prove the good grounds of Dr. Günther's surmise—a surmise, which in common justice, I must however say, had been years ago anticipated by the Jersey fishermen, who have been, from time immemorial, in the habit of applying the term "coucou" indiscriminately to both the *L. mixtus* and the *L. trimaculatus* type; the term "*Le Roi*" (*ut sup.*) applied to the former, being only used by the more particular of the fishers.

We may therefore count these two colours as representing respectively the male and the female of one species—for which the name *L. mixtus,* L. will be the more appropriate cognomen to retain.

Dissection has also shown the sexual organs to conform to this view.

II. Duplication and Origin of the operculum in Serpula.

It is of frequent observation that certain animals are characterised by more or less mutability, either as entire organisms or else in some particular organ. Such mutable species are, however, greatly in the minority—the vast majority being so remarkably stable in all save trivial degrees, as really to be cause for wonderment, considering the diversity of environment that most species must encounter in life's struggle. Accordingly the forms exhibiting marked mutability, are of the greater interest. These variations fall naturally into three categories; *a*, where the mutation is due to an atavistic cause, *i.e.*, recalling some phase in the past history of the race to which the animal belongs; *b*, where it is spontaneous or original, and usually limited either to one individual or to a few nearly related ones—a variation often pathological; lastly, *c*, where the change is due directly to altered environment and altered habits—a change which will probably become fixed, and therefore producing a distinct and permanent variety—liable to become sufficiently stable to constitute finally a new species.

The following instances fall, I believe, to be explained by the first of these causes:—

I. **Serpula.*** Having recently occasion to examine a large number of that most beautiful Serpulid, *S. (Hydroides) pectinata*, Philippi, to my surprise, I found 25 % of the examples—which be it noted were not all from the same cluster of tubes or **vermidom,** but from several—affected in more or less degree with abnormality in the antenna.† The proportion was very constant; out of two large batches, the variation was not more than 1·6 % viz., 8 abnormal out of 32, and 14 out of 60. Others I have examined since, have shown a like proportion.

In the present note, the two antennæ are distinguished for convenience under the terms respectively of antenna and of operculum; the former term being applied to the process which, while homologous to the long filament modified to form an operculum, is normal short

* For those unacquainted with the Serpulinæ, I may here explain that they are those tube-building worms, whose sinuous limy tubes are frequently seen upon old and sea-worn shells—oysters, scallops and the like. Attached to the head in these animals, are two half circlets of delicate bipinnate plumes, useful as breathing (gills) and touch organs, while close to the first gill-filament on either side on the dorsal aspect is a non-pinnate organ—on one side, long stalked and stopper-like, the operculum; on the other, short and weak and nearly aborted. Serpulids have the power of withdrawing entirely within their tubes, and of stopping the entrance with the plug-like operculum.

† I adopt here Quatrefages' nomenclature, viz., call the appendages that belong to the prostomium, antennæ; and reserve the term tentacles for the appendages of the peristomium. (Peristomium = mouth somite; prostomium = region anterior to such).

and slender. Neither the right, nor the left antenna is permanently responsible for the furnishing of the opercular stopper, for out of 92 specimens examined, in 50 cases the right antenna—*i.e.* that one belonging to the right branchial fan—performed the opercular duty, having the stalk elongated and the extremity swollen into the usual opercular plug. In the remainder, viz. in 42, the left antenna was become the functional operculum.

This fact that in practically equal number of cases, the operculum is devoloped indifferently from either the right or the left antenna, is obviously of extreme importance in any attempt to trace the story of its origin and subsequent history. Before making this attempt, we will proceed to notice the more important of the aberrant forms of antenna and contrast them with the normal form, and with its homologue, the functional operculum.

The Operculum:—The normal form is doubly infundibuliform, fairly well figured by Johnston (1) for his *Serpula reversa,* which I am convinced is the same species as the present.* The upper cup is beset with 12 to 17 bipinnate spinous processes, while the lower has a multiserrulate margin, the serrations being continued as grooves for some distance downwards on the inside as well as on the outside (Pl. v, Fig. 11).

The form is subject to not inconsiderable variation within certain limits. Thus the larger specimens count more pinnate process than the smaller, and the relative proportions of the two cups are inconstant.

One case was however very remarkable, for the lower cup was absent, and represented solely by a large elongated swelling as shown in Fig. 14, while the processes which represented the pinnate spines of the normal upper cup, were merely rather deep crenulations with smooth margins. Fig. 12 and 13 show intermediate stages in this variation, showing in Fig. 12 a great swelling of the lower cup and a decrease in size in the pinnate processes above, while in Fig. 13, these spines are still further reduced and all trace of the crenulated margin of the lower cup lost. In this case also, the part representing the lower cup is much swollen. Figs. 12, 13, and 14 are therefore perfect gradational steps in the retrogression in shape of a normal operculum (Fig. 11).

The Antenna:—The normal form is $\frac{1}{4}$ to $\frac{1}{5}$ the length of the operculum. The average length of those of adult specimens of

* The only differences I can trace are that *S. reversa* is solitary and has more branchiæ and more lateral teeth on the spinous processes of the opercular cup; *S. pectinata* occurring in colonies and being on the average smaller than *S. reversa.* But I have traced all intermediate grades, so that the differences are not great enough to constitute more than a variety. Fig. 15 shows typical form of operculum of *S. reversa.*

15mm. long is ·75mm. The apex is swollen into a somewhat conical bulbous form, and beneath this is a narrow constriction, followed by another slight swelling, which passes gently into a short cylindrical stalk (Fig. 1).

Of abnormal antennæ, there was a perfect series grading from the normal form as described, to one that could scarcely be distinguished either in size or shape from that of a perfectly formed normal operculum. These gradations are outlined in Figs. 2 to 10. Fig. 2 represents a form common to several specimens. In it the equator of the terminal swelling is scored by shallow vertical grooves. The next stage (Fig. 3) is where the equator besides being grooved, is slightly raised into a serrulate and grooved rim. In Fig. 4, is a form where this is accentuated, while the constriction beneath the terminal swelling is much more emphatic. Another specimen had the antenna (Fig. 5) one-third the length of the operculum, the terminal knob being modified into a miniature of a true opercular upper cup, and hiding entirely—for the first time in the series—the conical apex of the organ.

In all these instances, the lower swelling was nearly normal.

Following on Fig. 5, we have a form such as Fig. 6, where, with as well developed an upper cup as in the preceding, the lower has also started to develop, taking the form of an obscurely serrated collar at the base of the upper cup.

Finally in Figs. 7, 8, 9 and 10 we have a number of cases where both cups are well developed, and closely approach the form of the normal operculum. Keeping pace with this series of gradations in development, was the growth in length of the stalk of the pseudo-operculum. That shown in Fig. 2 was rather stouter, but not much longer, than the normal form of antenna, 4 was rather longer, 5 was one-third the length of the operculum, while the remainder varied from one-half to all but equal length with the same organ.

The forms shown in Figs. 2, 7, 8, 9 and 10—those at the beginning and the end of the series—were the most common.

Summing up the foregoing facts we find that :—

a. The operculum is developed on either the right or the left antenna inconstantly.

b. The non-opercular antenna is normally cirrus-like with two slight swellings towards the further end.

c. The same organ in 25 % of instances is abnormal, showing all manner of degree of approximation to the form and size of the functional operculum.

Before considering further the meaning attaching to the variations as above set forth, let me enumerate the principal points already known concerning the homologies of the branchiæ and the operculum in Serpulids and their near neighbours, the Sabellids.

A. Firstly, from an examination of the nerve supply to these organs, Quatrefages (2) found "that in the Sabellinæ as in the Serpulinæ, the branchial nerves arise directly from the cerebral ganglia as antennary nerves" (*i.e.* in the position which such nerves have in such forms as *Nereis*) "and among the Serpulids a slender branch springs, on each side, from the principal trunk and leads to the base of the two opercula, as well to the rudimentary one, as to the one completely developed. The branchiæ and the opercula therefore correspond to antennæ." Pruvot (3) further shows that the antennæ modified into gills in *Serpula,* are the second pair, those large organs that in *Nereis, Polynoë,* &c., are known as palpi.

B. Embryology shows that very early there appear *(Sabella)* two ciliated wing-like processes on the dorsal aspect, which shortly after divide each into two slender lobes which constitute the first four branchial rays, their number augmenting rapidly by budding on the ventral side (4).

C. Next examining the near relatives of *Serpula,* we find in *Sabella* no opercula, but in place, there are two slender, simple dorsal processes occupying the same relative position and having the same innervation or nerve-supply as the opercula of Serpulids—whence we may justly infer that they had similar origin.

In some Sabellids *(Othonia)* these simple antennæ are wanting, as is the case too with a number of the Serpulids. Thus *Apomatus* and *Filigrana* possess only branchiæ and to make amends for want of a true operculum as in the more typical species, in these the summit of one or more of branchiæ—which are of the usual bipinnate style—is enlarged in a bulbous manner into a pseud-operculum.

D. Finally Fritz Müller (5) has described a Serpulid which when first observed had but three pairs of pinnate gill-filaments, but which in a few days time, he found had developed a clavate operculum at the extremity of one of the filaments. In the course of three days more a new pair of branchial filaments had sprouted forth and the *opercular peduncle had lost its lateral filaments.*

So much for collateral evidence. Now let us see if we can gather the threads together, and make a web of fairly good strength.

From the frequent assumption of opercular shape by the ordinarily non-functioning and simple antenna in *Serpula,* and from its inconstancy to one particular side, we may justly infer that this variation is atavistic, and therefore that at one time, *Serpula* possessed two functional opercula. Then, from the corresponding relative position of the organs, we have already inferred that the opercular processes of *Serpula* are identical with the simple antennæ of *Sabella.*

Now in the latter animal, we have evidence (**B,** *ut sup.*) that in the course of development, the branchial filaments are at first simple and *antenna-like,* so as we know by **A** that the branchiæ and the antennæ are in reality homologous—having the same innervation—we may conclude that *the antennæ in Sabella are the unaltered first dorsal pair of organs that result from the splitting of the wing-like processes of the very young larva,* while the other two lobes of this winged organ and the others that arise by budding on the ventral side, become bipinnate and function as gills.

Now in *Serpula,* I believe the course of evolution was probably as follows :—First came a *Sabella*-like stage with simple antennæ, but probably these were *larger* proportionately than those now seen in this animal. Next the ends of the antennæ became swollen to act as stoppers and to close the tube against intruders. Finally one aborted, and being useless, was reduced to an insignificant filament, which occasionally reverts to its former well developed condition. By this explanation I avoid Fritz Müller's supposition of a *Filigrana* and *Protula* ancestry, and this seems to me advisable, as there appears no record, save Müller's own very incomplete and vague observation, of the opercular filament ever being pinnate, either in variation or in larval development.

I incline to the belief that *Filigrana, Protula,* &c., had independent evolution to *Serpula*; probably by the development of *all* the processes of larval " wings " into pinnate gills, and the subsequent formation of false opercula on the summit of one or more of these.

References :—

1. **Johnston, Geo.** —*Cat. of Worms in Br. Mus.,* 1865, p. 270, Pl. xx, Fig. 6—7.
2. **Quatrefages, A. de.**—*Hist. Nat. des Annelés,* 1865, Vol. ii, p. 401, also Pl. iii.
3. **Pruvot.** —*Archiv. de Zool. Expérim. et Gen.,* 2nd Series, t. iii, 1885.
4. **Claus, C.** —*Traité de Zoologie,* 1884, p. 601.
5. **Müller, Fritz.** —*Facts for Darwin,* 1869, p. 113.

Explanation of Pl. V, Figs. 1—15.

Serpula pectinata.

Fig. 1.—Normal antenna; Figs. 2—10.—Abnormal forms of the antenna.

Fig. 11.—Normal form of Operculum; Figs. 12—14.—Abnormal forms of same.

Fig. 15.—Operculum of *S. reversa*. Note:—All the figures are drawn to the same scale.

III. Abnormalities in the muscular bands of Salpa.

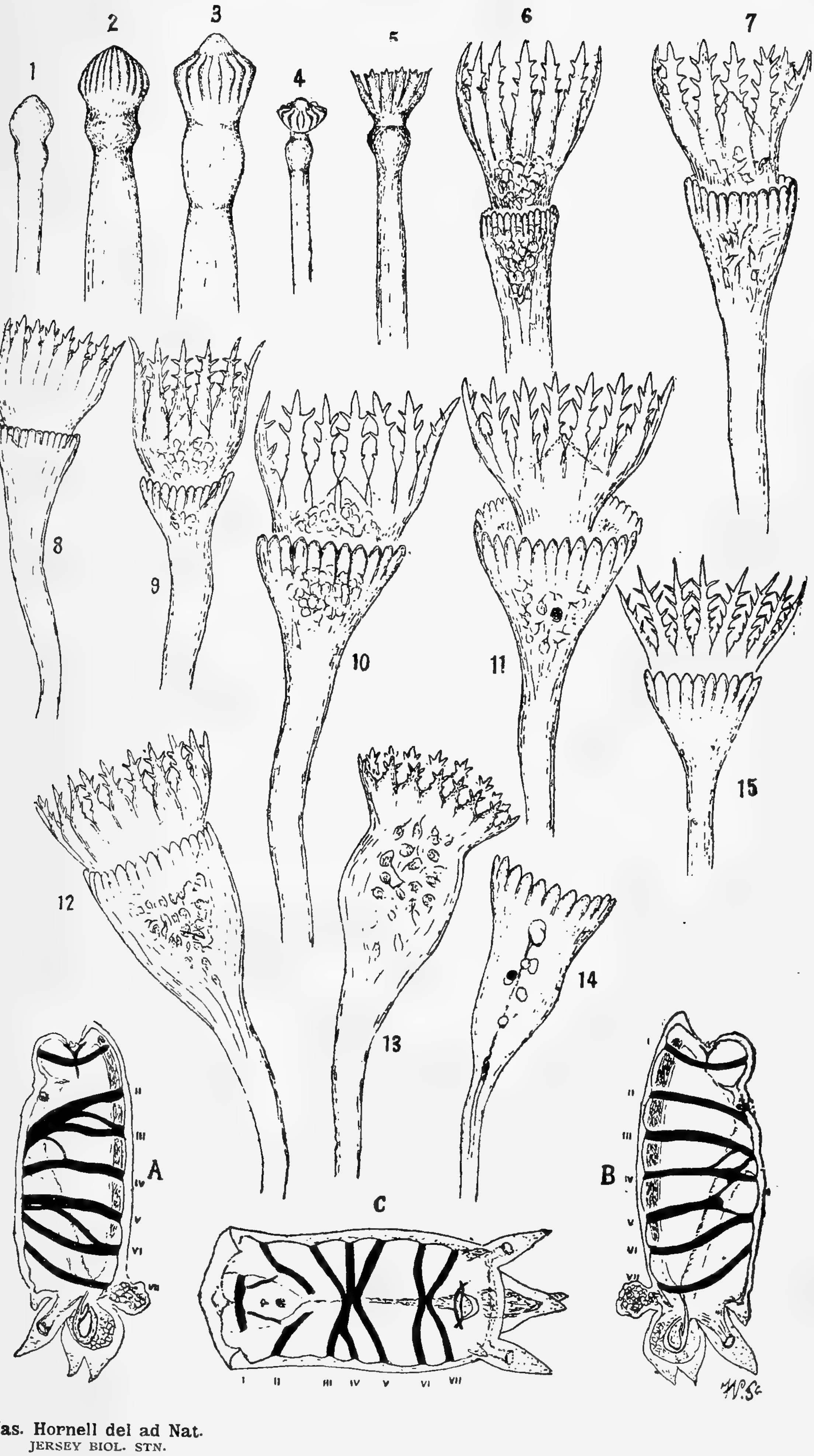
Of over 200 specimens of larval *Salpa mucronata-democratica* (solitary form) that I recently examined one by one, only some three shown any marked sign of abnormality. Of these, two are figured Pl. v, Figs. A, B, and C. The first two figures, A and B, represent the two lateral views of the same animal; C, the dorsal view of another.

In every respect saving in that of muscle arrangement these individuals were quite normal, but C showed a blending of bands iii and iv for a short distance, as shown, and this case is of comparatively little importance. The other example, figured in C and D, is a much more curious instance, and is of high value to the student of variation. Therein all the muscle bands save the 1st and the 7th, branch and anastomose in an extremely complicated manner—rendered clear however, by reference to the drawings.

Without entangling ourselves in the rival theories as to the primitive character or otherwise of the pelagic Tunicates, the variation I now record can be used as one link in the chain of true evidence that will some day be forged explanatory of Ascidian descent. Probably the variation is atavistic, and if so, points directly to a state when the musculature was not a nearly regular arrangement of more or less encircling bands, but was continuously, or at least irregularly, disposed over the whole body, perhaps much in the manner now to be seen in the muscle arrangement of *Ascidia mentula*.

Gegenbauer (*Comp. Anatomy*, 1878, p. 395) from reasoning based on other foundations, arrived at the same result, stating that in the Thaliacea, " the hoop-like formation arises from the differentiation of a primitively continuous muscular layer. Gaps arising in this, became gradually larger until the breaking up of the layer into separate hoops is brought about ";—a statement that receives very important direct confirmation from the instances of irregular banding that I have figured.

I may add that the abnormal specimens, described in the above note, as well as in the preceding one dealing with the Serpulid operculum, are carefully preserved in the permanent collection of the Jersey Marine Zoological Station.



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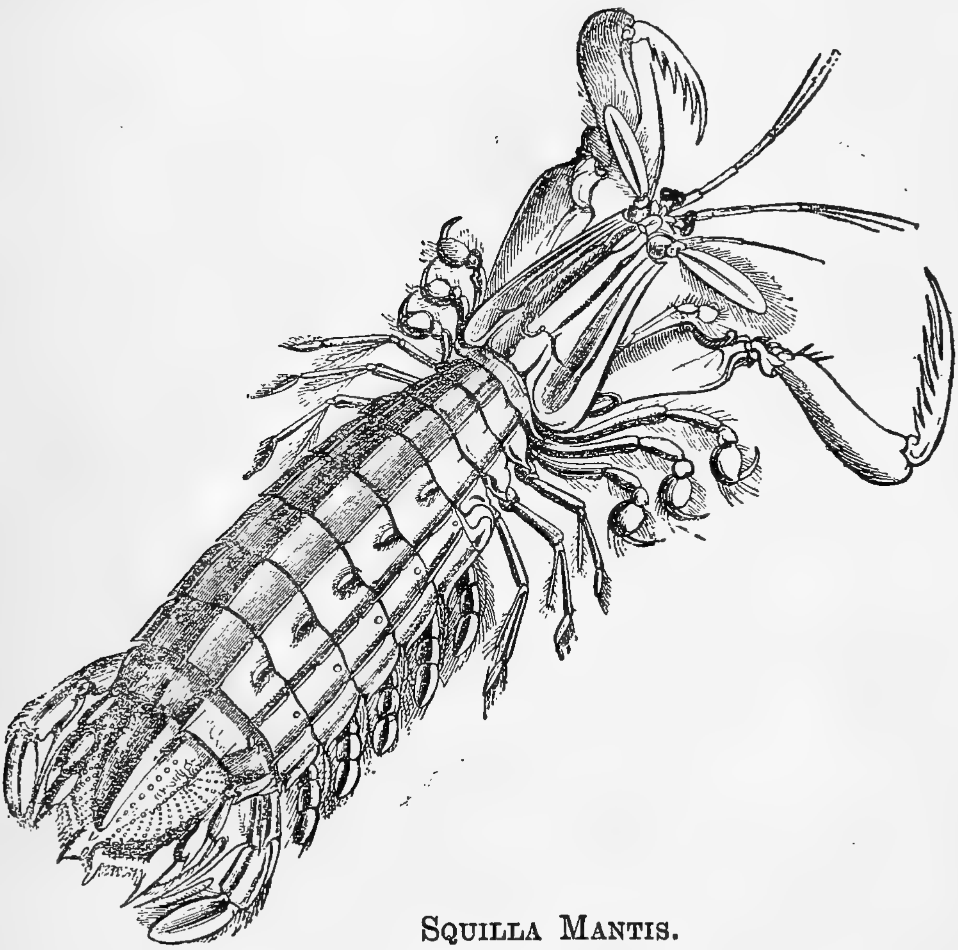
JERSEY BIOL. STN.

ABNORMALITIES IN SERPULA AND IN SALPA.

MICROSCOPICAL STUDIES IN MARINE ZOOLOGY.

BY JAMES HORNELL.

Study VII. The Metamorphoses of the Mantis Shrimps or Squillidæ.



Squilla Mantis.

The Mantis Shrimps, the Squillidæ, are among the least known of the larger crustaceans found on our shores. Essentially a southern type, the two species of this family that occur in British waters, have been met with on the southern coast only, and if we were to judge from the few captures reported, we should account them extremely rare. In reality, one of the two,—*Squilla desmarestii*—is not uncommon along the shallower shores of Jersey, but as it takes up habitation in deep burrows among the roots of the sea-grass (*Zostera*) in a zone never uncovered by the tide, one can understand how rare in appearance it may be—how abundant in fact in some favourite localities. On several occasions, immense numbers have been cast up on the Jersey coast after great storms. Their homes in the Zostera beds of the Laminarian zone had been devastated by heavy surf due to the bursting of storms coincident with the furthest receding tides of the year, and the Squillids forced or frightened from their burrows, and helpless to withstand or get clear of the dashing breakers, had been buffetted to and fro, to be finally thrown in multitudes upon the beach.

The Squillidæ, the sole members of the order Stomatopoda, are distinguished from the other order of *large* Crustaceans—the Decapoda (Lobsters, Crabs, &c.)—by a different arrangement for breathing and by a different function to which certain of the anterior limbs are put.

For the purpose of comparison, let us take the Lobster as type of the Decapoda. In it, the three divisions of the body of an ideal higher crustacean—head, thorax and abdomen—are reduced to two, by the fusion of head and thorax to form the **cephalothorax**. This, protected by a great shield, the **carapace**, is furnished with 14 pairs of appendages. Taking these in order from before backwards, we have one pair of stalked and moveable compound **eyes**; two pairs of sensory organs, the **antennæ**; one pair of stout jaws or **mandibles**; two pairs of weaker jaw organs, **maxillæ**; followed by three pairs of appendages which in structure are midway between that of the walking limbs and that of the maxillæ, and as they share in the work of preparing food and closely surround the mouth, they have received the name of foot-jaws, or **maxillipeds**. Next come five pairs of large walking or ambulatory limbs, **pereiopods**. Of these, the anterior pair are enormously enlarged and form the **chelæ**, or pincers, powerful organs for seizing and tearing prey. The second and third pairs have also small pincer terminations, but the third and fourth end in simple claws.

The abdomen consists of five well-marked rings or **somites**, bearing each a pair of two branched (**biramous**) swimming feet or **swimmerets**, followed by another somite bearing much enlarged flattened swimming feet. A large, strong plate, **telson**, forms the hinder extremity of the body and with the plate-like limbs of the preceding somite, constitutes a powerful flapping tail—the so-called **caudal fin**. In all probability, the telson represents a true somite once provided with swimmerets, for the anus opens on the under side of it, and further, minute moveable points, esteemed to be vestiges of swimmerets, have been observed upon the telson of the common prawn, *Palæmon serratus*.* If this be so, the abdomen consists of seven somites; and as each pair of limbs attached to the cephalothorax is believed to indicate an original somite, we arrive at 14 as the

* Bell, *History of Br. Stalk-eyed Crustacea*, p. xx., London, 1853.

number of somites composing this part of the body. But several weighty reasons point to the eyes as not representing a somite, and this reducing the number to 13, we find the entire body to consist of 20 somites. And this number not only characterises the Decapods, to which the Lobster belongs, but equally the whole of the higher crustacea. In some species, indeed, the thorax is distinctly jointed after the fashion of the abdomen, emphasizing clearly the primitive segmentation of the former region.

In the Lobster as in all Decapods, the breathing organs consist of lancet shaped gills composed of innumerable closely packed plates or lamellæ, connected with the ambulatory limbs and some of the maxillipeds, and lodged in a special champer on either side, formed by the down-turned edges of the carapace.

If we now turn to *Squilla,* we have to note the following radical differences from the Decapod type. Most are apparent in the accompanying drawing of *Squilla mantis,* the larger of the two British species.

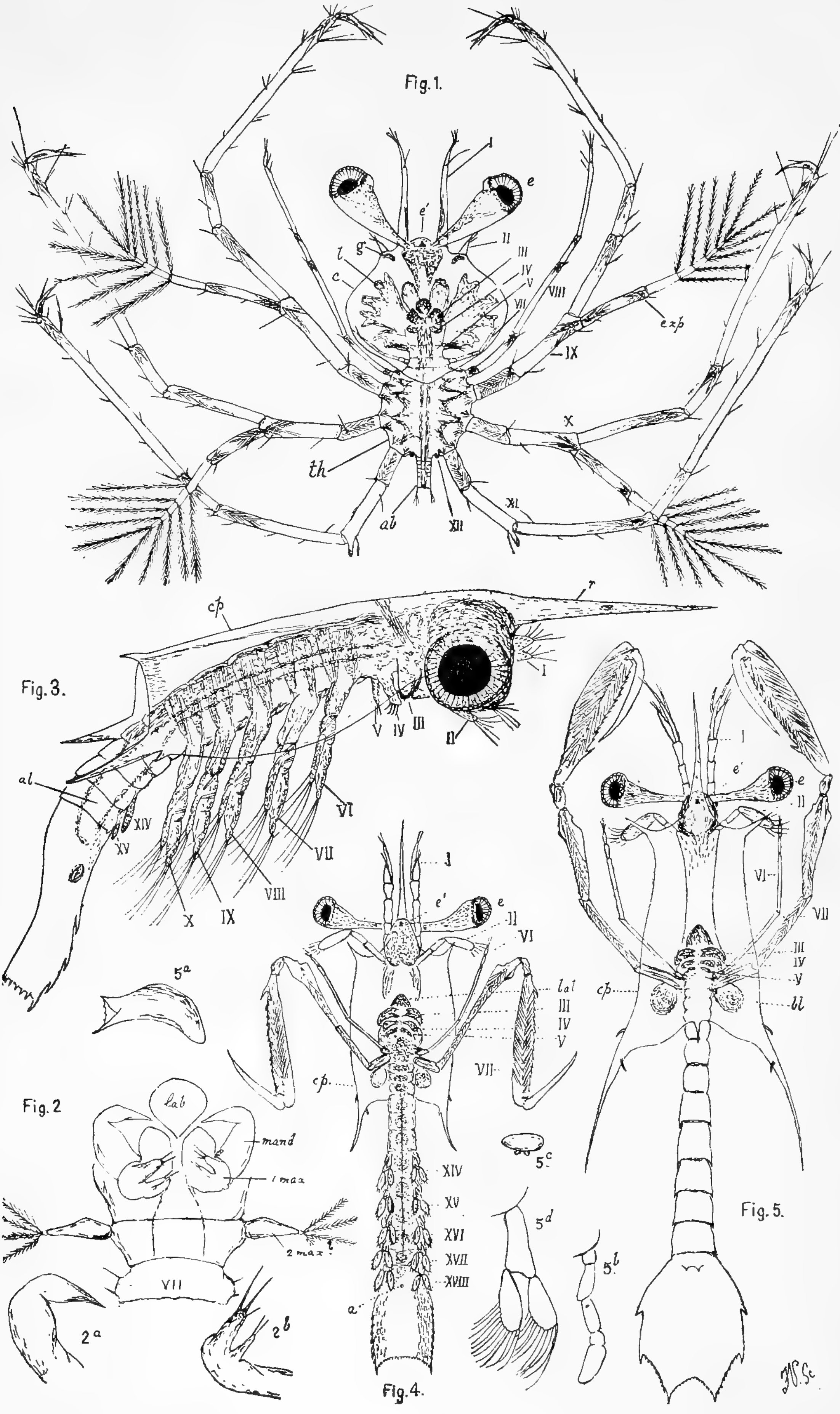
This animal is much more active and lithe than the Lobster, by reason of the fusion of the head and thorax being less complete. The carapace leaves uncovered the last three somites of the thorax, and the shortened ones bearing the hinder maxillipeds are also not fused with this shield. Apparently then, *Squilla* shows a more primitive form of structure than does the Lobster—for undoubtedly the architypal crustacean had a body composed of a number of somites of which none were fused together—all being separate and independent. As to the appendages, the eyes are extremely curious in shape, expanding at the summit in a broad bilobed fashion that arrests the attention at once. Then follow two pairs of antennæ, the outer bearing a broad oval scale or squame; next a pair of strong mandibles and two pairs of maxillæ, just as in the Lobster. But here the similitude ends, for instead of three pairs of foot-jaws, there are five pairs,—the first weak, the second formed into strong and greatly developed prehensile claws,—with toothed terminal joint capable of folding down into a groove on the inner side of the joint preceding, while the succeeding three are weakly organs, with rounded penultimate joint, bearing a tiny spine-like claw. Next, instead of the five pairs of walking limbs characteristic of Decapods, there are in *Squilla* but three pairs, and in structure they differ also, being weak and styliform and bearing a delicate outer branch (**exopodite**), which disappears entirely in the Decapods—one of several reasons stamping the latter group as more modified, more distant, from the primitive co-parent, than the Mantis Shrimps. As to the abdomen however, the form of the appendages remains essentially the same, saving that in *Squilla* the first five bear gills—beautifully tufted or feathered, and kept constantly in movement by the incessant paddling of the limbs wherefrom they spring. No gills belong to the anterior part of the body; hence the carapace is small as it does not require to bend down laterally to form gill chambers as in the Lobster.

Good as the drawing given above, in life *Squilla* would scarcely be recognised by it. No great seizing claws are visible, indeed none of the maxillipeds are in evidence. I remember how, when I found my first specimen, my heart sank very low—my capture was but a sorry one—the great claws were gone! And then as I little by little examined more carefully, my spirits rose again—for there, snugly folded up beneath the shelter of the projecting margins of the carapace, were the two *lost* limbs, and equally safe were the other foot jaws hidden closely away between the bases of the great claws. A moment's thought will show how necessary it is for animals living in a narrow burrow to have means of packing away, in small compass, great limbs that are of no service except in procuring food, and which otherwise would be getting in the way continually. In leisurely swimming, the abdominal limbs—the swimmerets—are used as paddles—but they by no means do all the work for the large oval squame of each of the second antennæ paddles assiduously and must be of great assistance.

The **development** is singularly interesting. Unlike the Decapods, the Mantis Shrimps do not carry their spawn about till hatched, attached to the swimmerets, but deposit it in their burrows in the Zostera meadows—a great difficulty in the way of the study of the embryology of this animal.

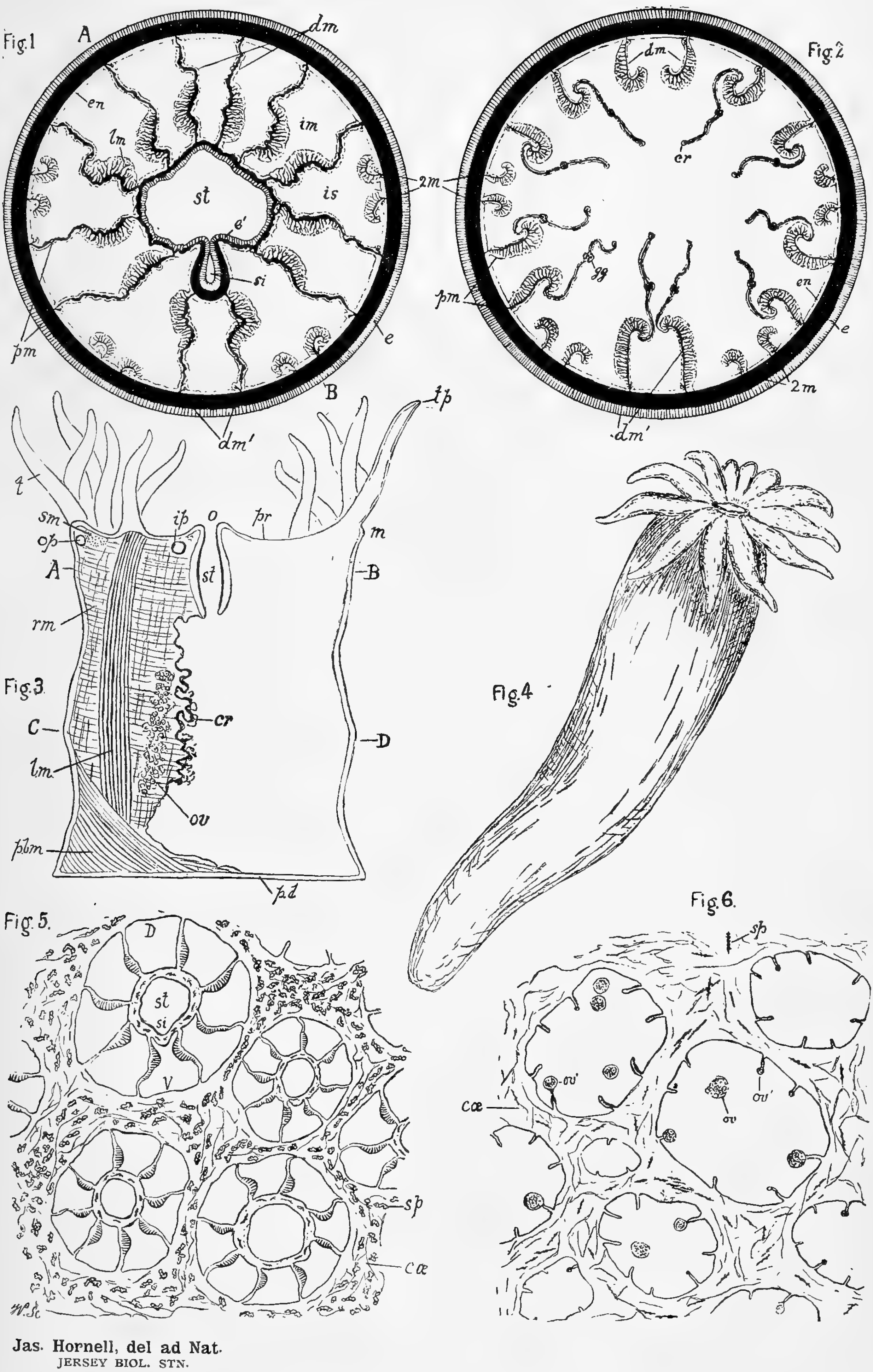
Upon emerging from the egg, the larva is very simple in structure, soon assuming the form shown in Pl. vi, Fig. 3. A great shield covers nearly the whole of the body. In front, this carapace is drawn out into a long spine or rostrum; behind, into two other but smaller spines, with a third tiny one midway between these two last. The eyes are very large and show no trace of any stalked condition. Indeed this sessile form characterises the early larval stage of all the higher crustaceans when normal, and clearly points to an ancestry with unstalked eyes. Two pairs of tiny antennæ, two mandibles and two pairs of maxillæ are present, together with five powerful biramous maxillipeds, co-equal in size—saving the second pair, which in their slightly stouter form, forshadow the great clawed prehensile second maxillipeds of the adult.

The three succeeding somites of the thorax are clearly seen from the first, but without sign of any appendages. In the very early stage a large spinous-edged telson articulates with the hindmost of



Jas Hornell, del ad Nat.
JERSEY BIOL STN.

METAMORPHOSES OF CRUSTACEA.



Jas. Hornell, del ad Nat.
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STRUCTURE OF ANEMONES.

[illegible]

these limbless thoracic somites, and as time goes on, the true abdominal somites appear at this point of junction and simultaneously tiny limbs sprout out from these newly formed parts. In Fig. 3 two pairs are shown in an early sprouting stage. This, the *Erichthus* or Glass Shrimp stage, was long mistaken as representing a separate animal, and before going further, let me point out why it does not receive the name of *Zoëa,* as the young larvæ of the Decapods are so well known by.

If the newly hatched young of the Common Shore Crab (*Carcinus*) be examined they will be seen to possess apparently the same body parts as the Squilla *Erichthus.* A large carapace covers the fore part of the body, and a tail unprovided with limbs follows, ending too in a broad telson. Yes, but here most curiously, the hinder part of the thorax is not yet in any way recognizable, and the tail portion is true abdomen and not thorax as in Squilla; seven pairs of appendages are present; the two pairs of antennæ, the mandibles, two pairs maxillæ and *two* pairs of maxillipeds. The third pair of the last named organs and the whole of the ambulatory limbs are absent and when they do appear, they sprout out from the point just anterior to the junction of thorax with abdomen. The swimmerets appear about the same time as paired buds from the segments of the tail-like abdomen. Thus there is a wide divergence between the *Zoëa* and the *Erichthus.* In the one, the abdomen is present from the first, while the hinder part of the thorax is absent—in the other, the cepalo-thorax is present in full segmental number from the beginning, but the abdomen is wanting, saving for the telson.

Advanced Zoëa of a Crab.

After several moults the *Erichthus* loses entirely the three hinder maxillipeds, while synchronously the tiny abdominal somites that have just appeared, develop their bud-like limbs into large biramous swimmerets or **pleopods,** while each of the second maxillipeds increases in size quite disproportionately to its neighbours and becomes a huge somewhat chela-like limb—differing however from the true chela or pincer form (seen so well in the Lobster) in that the terminal joint is not opposable to an outgrown, huge finger-like spine of the second, but instead folds down *upon* the second, fitting when at rest, into a deep groove running along the inner margin of this penultimate joint. In the adult the edges of this groove are beautifully sculptured with most delicate serrations, and in the larvæ show also, but in a coarser form (Pl. vi, Fig. 4).

The larvæ have now passed into what is known as the *Alima* stage. The paired compound eyes now become stalked, and the unpaired simple eye more easily distinguishable as a tiny **X** shaped black speck, set at the base of the rostrum and between the bases of the stalked eyes. As a point of interest, it may be noted that a connection has been suggested between it and the pineal eye of vertebrates.

In Pl. vi, Fig. 5, a later alima stage is figured—just prior indeed to the assumption of adult form. Here the three suppressed maxillipeds are reappearing, but extremely short (Fig. 5*b*). In it also, the three biramous walking limbs of the adult are beginning growth—tiny buds on the underside of the three hinder thoracic segments (Fig. 5*c*), which until the present have from the time of hatching been free from any sign or trace of appendage.

During all these larval stages, the tiny animal leads a pelagic free-swimming life, and is occasionally taken in the tow-net in the sunny waters of the Channel Isles. Like other pelagic animals it is glassy and colourless and a powerful swimmer.

Explanation of Figs. 3—5, Plate VI.

Metamorphoses of Squilla.

Fig. 3. The recently hatched animal in the *Erichthus* or Glass-shrimp stage; actual size 4 mm. (inclusive of rostrum).

Fig. 4. Early *Alima* stage of another species, ventral view; actual size $4\frac{1}{2}$ mm.

Fig. 5. Advanced *Alima* stage, dorsal view; actual size 11 mm. (In this figure, the rudimentary three hinder pairs of maxillipeds—5*b*; the bud-like ambulatory limbs—5*c*; and the well-developed ambulatory limbs—5*d*, are not figured for clearness sake).

5*a*, a mandible; 5*b*, one of the three hinder and rudimentary maxillipeds, × 55; 5*c*, Section through the hinder part of the thorax, showing the first appearance of the ambulatory limbs as buds, × 18; 5*d*, a swimmeret, × 13.

Lettering the same in all figures, viz:—I. anterior antennæ; II. posterior antennæ; III. mandibles; IV & V. 1st and 2nd maxillæ; VI, VII, VIII, IX & X. maxillipeds; XIV—XVIII. swimmerets; *e.* paired compound eyes; *e'.* unpaired simple eye; *lab.* labium; *bl.* branchial plate of maxilliped; *cp.* carapace; *r.* rostrum; *al.* alimentary canal; *a.* anus.

Note.—Probably the two *Alima* forms figured, belong to the same species of *Squilla,* viz., *S. desmarestii.*

VIII.—The Phyllosoma or Glass Crab larva of Scyllarus.

Pelagic animals are, without exception, of the highest beauty, but, saving for the wondrous loveliness of the pelagic Cœlenterates—the elfin-locked Medusids, the glassy Cydippe, and the phosphorescent and elaborate Siphonophores,—what can compare with the quaint "Glass Crabs" of the older writers. These, long known by the name of *Phyllosoma,* were considered a separate group of animals, till Couch in 1857 hinted vaguely to the British Association that they were in reality the larval forms of certain Decapod Crustaceans, notably of *Palinurus vulgaris,* the Common Crawfish. Couch had been studying for some years the development of the larger Crustaceans, and the pity is, that through inadequate training he was unable to utilize to full, or even moderate advantage, the opportunities that the practically unexploited field of this study then afforded.

Couch's figures were anything but accurate, and his work did little but point the way. Indeed not till so long after as 1870, was the full value of the relationship definitely traced and worked out, and the achievement is one of the many that Biology owes to the indefatigable perseverance of that prince among naturalists—the veteran Dr. Dohrn.

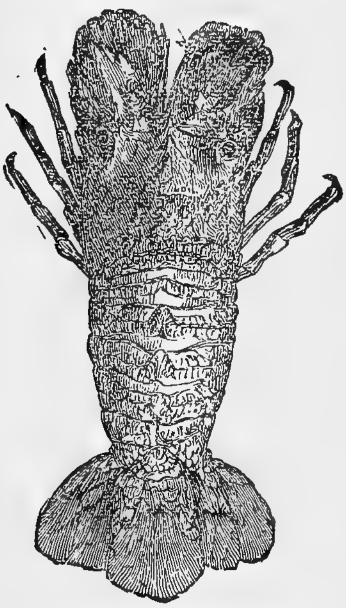
In that year Dr. Dohrn detailed the development of a very near relative of Palinurus, viz. of *Scyllarus arctus,* while in the egg, and also during a short period in its free swimming life, showing that there is absolute identity between the hatched larva and a certain form of Phyllosome.

Other naturalists have extended these observations, and to-day the only points requiring much elucidation, are the final metamorphoses just prior to the period when the Phyllosome larva changes to the adult. A limit seems to be set to the age to which the larvæ can be reared in confinement. For a while all goes well, then the captives begin to find some necessary condition of life to be wanting, and rapidly decrease in numbers, till not one survives.

But before describing the larval form, let us glance at the chief points in the anatomy of the adult. *Scyllarus arctus* is one of the rarest of the large Crustaceans living in British waters, and like the Squillidæ, found only in the English Channel; just on the northern boundary of the great Mediterranean zone—just where this zone grades into that of the northern regions. Its captures on the English coast can be traced in paragraphs in scientific journals, and only in the Channel Islands is it frequently enough met with to receive a vernacular cognomen. In these islands the fishermen speak of it indifferently as the Bastard Crawfish and the Square-nosed

Lobster; sufficiently graphic epithets—strong in the descriptive name-power that lurks so often in the rough harvesters of the sea.

Scyllarus is a strange mingling of the uncouth and the beautiful. His form is clumsy; short squat body with weak legs and with disproportionate development of the second antennæ. These, which in the Lobster and the Crawfish *(Palinurus)* are elegant, long, gently tapering rods equal and exceeding in length that of the body—dwindle in *Scyllarus* into short broad plates very evident in the figure drawn beneath.—But the coloring! That is superb: In general tint a rather light chestnut brown, the depressions and deep lines of the closely covering fine sculpturing are of deeper tone, almost black; in striking contrast to this the anterior portion of each of the abdominal rings is of a brilliant scarlet. The short eye-stalks are also scarlet, giving these organs, with the black pigment disc showing distinct through the transparent cornea and retina, a striking resemblance to those little scarlet and black beans *(Abrus)*, which bottled up, form such familiar objects on the mantel-shelves of our seafaring men's homes. Undoubtedly *Scyllarus* is the most beautifully coloured of our large Crustaceans.



Scyllarus Arctus.

The number and arrangement of the limbs are the same as in the Lobster, but unlike the latter animal, all the five pairs of ambulatory limbs are formed on the same pattern—each terminating in a short sharp claw—none pincer-like as in the Lobster.

A very different creature issues from the egg. Instead of a short legged, stout body, an elegant glassy-transparent and colourless, leaf-like organism appears, delicate, fragile, with four enormously long, six-jointed limbs, freely armed with spines. And two of these spider-like limbs give off branches ending in delicately plumose hairs.

Further and minute examination shows the body to consist of three distinct divisions—a broadly oval flattened head, larger in size than the remainder of the body; a thorax, rounded and likewise flattened leaf-like, and of about half the size only of the head; lastly the abdomen, least developed of the three parts, narrow, elongated, and without appendages.

Head: From the anterior margin of the head spring two pairs of simple antennæ, the posterior extremely small, only some fifth the length of the anterior ones. Between these lie two great facetted eyes, borne on long stout peduncles; while in the median line just between the bases of the eyestalks, is a tiny X shaped mass of dark pigment representing the unpaired simple eye, of the same structure as that of the *Squilla* larvæ.

The mouth is situated on the under side of the head, midway between the front and hinder edges, and is surrounded by an upper lip or labium (Pl. vi, Fig. 2), two stout mandibles, and two pairs of maxillæ, the first large, with two appendages—and working inwards in the same plane as the mandibles; the second pair, on the contrary, are small and rudimentary and appear not to function.

Of the maxillipeds—the first pair is non-existent, showing not the slighest trace : a very peculiar fact and characteristic of *Scyllarus*, distinguishing from the youngest Phyllosome of *Palinurus* where this appendage is just visible as a tiny cylindrical process.* The second however, though slender, can be easily resolved into six joints, while the third is more than thrice this length and proportionately stouter. Behind this are three enormously elongated spider-like limbs, the true ambulatory legs or pereiopods; each is six jointed—the terminal one claw-shaped and reminding one sharply of the similar appearance of this joint in the adult. The first and second ambulatory limbs are biramous, for there springs from the further end of the second joint in each, a paddle-functioning jointed and plumose appendage which represents the exopodite. The third is unbranched, but a knobbed projection on the second joint indicates where the exopodite is about to sprout forth. In older larvæ the third maxilliped also develops a plumose branch. Four pairs of limbs,—the third maxillipeds, and the six pereiopods are the only appendages of the thorax at this stage, but as age advances and repeated moults take place other pereiopods appear at the point between the base of the abdomen and the third pereiopod; these in turn assuming the biramous character of the first formed.

* In this statement I give the accepted view (Dohrn, *Zeitschr. für wiss. Zool.* 1870). My own examination of the young larvæ, points rather to the missing appendage being the second maxilla and not the first maxilliped. Undoubtedly one or other is missing, for between the first maxilla and the second maxilliped, there is but one organ, and the reason why I think this to be the first maxilliped is that the somite it belongs to, is clearly defined and shows no trace of having another somite between it and the equally well defined somite bearing the second maxilliped (see Fig. 2). On the other hand, the region in front of the somite bearing this uncertain appendage, and between the latter and the first maxilla, is extensive, and bears no appendage. The shape too, of the uncertain limb, is in favour of my view; it consists of a stout, rather fusiform basal joint, bearing a tiny terminal joint from which spring four long and highly plumose hairs. Now in the Phyllosome of *Palinurus* which possesses *both* second maxillæ and first maxillipeds, Cunningham (*Journ. Mar. Biol. Assn.*, New Ser., Vol. II, No. 2, p. 147) describes the former as rather large and foliaceous and gives the figure of a distinctly biramous limb; while the latter he speaks of as being each a simple, small but distinct conical stump, a description much more fitting the organ in the *Scyllarus* larva, than that of the second maxilla, for it is in nowise foliaceous, nor yet biramous. Not having examined the embryo nor yet any advanced Phyllosomes of *Scyllarus*, I cannot however give my view as more than an opinion.

The third part of the body, the abdomen, is trivial and shows no signs of the importance it will attain to in the adult condition. No limbs are present, not even a caudal fin—the intestine can however be traced, traversing the entire length, and opening by the anus at the extreme end. A few very faint transverse markings can be made out, indicating the limits of future somites.

Now what is the significance of this most peculiar larval form ?

Only *Scyllarus* and *Palinurus* among the Decapods possess it. Of the others, the vast majority, especially the solid phalanx of the Crabs, leave the egg in a totally different condition, viz., in the Zoëa form, *i.e.*, with head and abdomen well developed but without thorax and abdominal limbs. On the other hand the larvæ of the Lobster are never so primitive. Thorax and thoracic limbs are present from the first though abdominal limbs are at first absent. A few others have still further abbreviated metamorphosis, *e.g.*, the Fresh-water Crayfish is hatched practically in adult form, while conversely a few prawns *(Peneus)* leave the egg in the curiously primitive *Nauplius* condition that characterises specially the Entomostracans and Cirripedes and pass through numerous other stages ere reaching the adult.

To either of the last two, *Phyllosoma* bears no relation, and analysing the other couple, it is at once seen that the Zoëa form is also inadmissable. This one has no thorax developed, while in *Phyllosoma* such is of great importance. We are thus left with the Lobster larva (early stage), a form at first sight nowise resembling a Phyllosome. But stay ; both show distinct head, thorax and abdomen ;

Advanced Larva of the Lobster.

in both, limbs are developed on the first two divisions, and both are without appendages on the abdomen. All parts bear comparison in the two forms, and the differences which, first sight, appeared so great as to forbid thought of any probable fundamental similarity until arrived at by analysis, are after all but comparatively trivial differences of proportion. But if the larval forms of the Palinuridæ be so closely akin in fundamental structure (homology) to those of the Lobsters *(Homarus)* how did the present striking divergence in the form of the respective regions arise ? The answer must be sought in the different habits of these animals during the larval life. And the chief determining habit centres in the different mode of progression adopted by the two. The Lobster larva moves largely by a jerky movement or flapping, produced by the muscular contraction of the powerful abdomen: the Phyllosome on the other hand swims entirely by the paddling action of the thoracic legs. In the one case, the animal chooses a mode of progression requiring a well developed and muscular abdomen—in the other, *Phyllosoma* elects a method that dispenses with the need for such a strong tail, hence the non-development of that during such period when indeed it would be an encumbrance and a danger. Then as to the change in form of the rest of the body—such is probably the outcome of the greater pelagic habit of the Phyllosome. The latter has a much longer surface-swimming larval life (so far as my observations go) than larval lobsters, hence the necessity for a greater or more perfect, defensive transparency. Such, obviously, can be better attained in a thin flattened body, than in a thick muscular one.

Surely this study of individual development is without superior in fascinating interest among Zoological problems—its interest, too, enhanced by the great light it sheds upon the past development of the race. But while its importance in this sense is so great, let us beware of blind acceptance of that present day biological shibboleth "Ontogeny recapitulates Phylogeny," meaning that the history of the development of the individual sums up and points out the various stages passed through by the particular race in the course of its evolution. Such a theory I doubt not is useful to work by, but it must have intelligent and reasoning and ultra-careful handling, or further false pages will be added to the already too many that have of late years been inserted in our scientific journals by hasty and theory-ridden writers. The harm done in this way is incalculable and unfortunately difficult to cope with or to stem. Every such wildly reasoned generalization or inference is a false finger post upon the scientific highway. Therefore let us beware of setting up even one more.

Explanation of Figs. 1 and 2, Plate VI.

The Phyllosoma larva of Scyllarus.

Fig. 1. Early Phyllosome larva seen from the dorsal surface; actual length (tip of rostrum to end of abdomen) 1·5 mm.; *e.* paired compound eyes; *e'.* unpaired simple eye; *c.* head; *th.* thorax; *ab.* abdomen; I. anterior antennæ; II. posterior antennæ; III. mandibles; IV & V. 1st and 2nd maxillæ; VII & VIII. 2nd and 3rd maxillipeds; IX, X & XI. 1st, 2nd, and 3rd ambulatory limbs; XIII. 4th ambulatory limb beginning to sprout; *exp.* exopodite; *g.* rudiment of green gland; *l.* largely lobed liver.

Fig. 2. Enlarged view of mouth organs; *lab.* labium; *mand.* mandibles; 1 *max.* & 2 *max.* 1st and 2nd maxillæ; 2*a,* stout limb of mandible; 2*b,* a 1st maxilla—both further enlarged.

Study IX. The Structure of Anemones.

Ever since that comparatively recent period little more than a century ago, when, for the first time, men's eyes were opened to the beauties of the smaller marine creatures, the sea-anemones have held perhaps the foremost place of honour in this artistic appreciation. Their very name—the implied resemblance to the gorgeous scarlet-rayed, black disc'd anemones that give such wealth of colour to our old-fashioned gardens—suggests this thought. And our German cousins vie in doing similar honour, a higher one if possible, by calling them after the queen of flowers, for they name them Sea-roses *(Seerosen).* Even the learned and usually strictly practical framers of our scientific nomenclature have experienced the same spell, for is not Anthozoa—one of the terms applied to the Anemone group—merely the Greek rendering of "Flower-animals"? Few marine animals are nowadays better known. Everyone who has started even the smallest of small aquaria—if only in the form of a big pickle-jar or an earthenware pan—has begun by stocking with some common species of anemone; mayhap the brownish-red Beadlet *(Actinia)* with its necklace of lovely blue beads; or perhaps the stout fleshy *Tealia,* with body covered with strange warts, each holding firmly some fragment of shell or pebble; or yet again, he may have started with the medusa-locked *Anemonia sulcata (Anthea cereus).* Their hardiness, as well as their beauty, conduces to this popularity.

If we take any typical anemone, we find it to be of extremely primitive structure. Usually the body consists of a short, stout, hollow cylinder (**column**), attached at the base to some rock or boulder, by a sucker-like **pedal disc,** often spoken of as the foot. The opposite or free end, the **peristome** or mouth disc, bears the mouth, slit-like in shape, and surrounded by several concentric rows of hollow, finger-like tentacles, the older towards the centre. At the point where the peristome merges into the column, is a distinct ridge, the **margin** (Pl. vii, Fig. 3, *m.*)

No anus is present. The mouth, *o,* leads into a short **œsophagus** or **stomodæum** (*st*), not continuous with a stomach and intestine as in the higher and more familiar animals, but ending in a free, pendant margin, opening direct into the great body cavity, the **cœlenteric space.** The fundamental form of this simple alimentary arrangement can be at once understood if we take a hollow india-rubber ball, cut a small slit at one end, and then push the edges of the slit well down into the interior of the ball; the short tube thus formed will represent the stomodæum.

Each of the two angles that bound the extremities of the mouth slit are continued downwards along the œsophagus as a deep, richly ciliated groove—the **siphonoglyph.** Most anemones have two of these grooves but some *(Peachia, Cerianthus)* have but one.

The siphonoglyphs remain open, even when the animal is greatly contracted, and they appear to be useful in keeping up a constant flow of water through the œsophagus.

Numerous vertical partitions, ingrowths of the body wall—the **mesenteries**—join the hanging œsophageal tube to the outer wall of the body, and serve to break up the great body-cavity into a number of radial longitudinal chambers; an arrangement clearly shown in Fig. 1, representing a transverse section through the upper part of an anemone. The section of the œsophagus appears as a small inner circle, connected to the large outer circle of the body wall by twelve radial lines, the sections of the mesenteries. But in the lower part of the Anemone's body—below the level of the œsophagus, the mesenteries form incomplete partitions, and show as in Fig. 2, as though a cart wheel had had the hub broken out leaving the rim with the broken spokes projecting inwards. The free edge of each mesentery is swelled out distinctly into three longitudinal lobes, the middle one crowded with nematocysts and gland cells, the lateral ones clothed with strong cilia.

The mesenteries are arranged in pairs. Some reach across to the œsophagus—the **primary**; others fall a little short of it—the **secondary,** and yet others may be still shorter—the **tertiary.** Of these the primary are the first to appear. The secondary appear next in succession, in pairs between every two pairs of primary. In Fig. 2, four pairs only of secondary mesenteries (2 *m*) are present, while the full complement of primary, six pairs, is obvious. Each mesentery has a very pronounced longitudinal ridge on one face running from peristome to base (*lm*), and except in two pairs, the ridges in each pair face one another. The two exceptional pairs are on opposite sides of the œsophagus. In them, the ridges, in the members of each pair, face outwards, and the presence of these *directive mesenteries* (*dm*) serves to divide the animal into a right and a left half, and in certain cases, even into a dorsal and a ventral division. When two siphonoglyphes are present, each gives attachment to the inner margins of one of these two pairs of special septa.

The chamber enclosed by the members of each pair of mesenteries is the **intraseptal** (*im*); that between the outer members of adjacent pairs, the **interseptal** (*is*). Some slight direct communication with the exterior, is usually provided for these chambers, by a pore (*tp*) at the tip of each tentacle, which are simply hollow outgrowths of the peristome. Intercommunication is also allowed by the presence of one, sometimes of two pores piercing the mesenteric walls just beneath the peristome (*ip* and *op*).

Examining a transverse section with the microscope, we can resolve the wall of the body and of the œsophagus (a mere downgrowth of the mouth disc), into three well differentiated layers. The most obvious is the middle one—**mesoglæa** or **supporting lamina**—consisting of a thick layer of a clear, fibrillated tissue, approaching somewhat the texture of tendon, denoted in Figs. 1 and 2 by black bands and lines. Outer to this is the **ectoderm** or epidermal layer, containing in certain regions, glands and stinging cells or **nematocysts.** This is the seat of what poorly developed nerve elements there are in these animals.

On the inner side of the mesoglæa, is the thin but important layer of the **endoderm,** lining the entire body cavity in all its chambers with a coating of ciliated cells, which give off strong muscle fibres on the side in contact with the mesoglæa. The principal functions of the endoderm are those of digestion and the provision of muscular movement.

Most anemones have great powers of contraction, being able in many cases to reduce their bulk to less than one-seventh of that when fully expanded. The principal muscles employed are strong longitudinal ones running in the ridged surface of each mesentery. The supporting lamina is much folded at this point, forming in section, a beautiful arborescent pattern, and along these multiplied faces run from base to peristome, great numbers of muscle fibres, whose duty it is to pull down the tentacles and mouth-disc, and so shorten and retract the animal. On the other face of the mesenteries the muscle fibres run transversely; so that we may describe the disposition of the mesenteric muscles as usually longitudinal on the intraseptal surface, and as transverse on the interseptal. The latter towards the base of each mesentery alter their course so as to run obliquely from the wall downwards to the base—the parieto-basilar muscle (*pbm*). In the walls, the peristome, the œsophagus, and usually also in the base, the muscular processes of the endoderm cells are arranged in a circular direction.

No animal is more ravenous. Crabs, molluscs, and small fishes wandering incautiously close, are entwined and pulled inwards by the long tentacles, the while that cruel stinging cells are conveying into the poor quivering body, a poisonous, numbing juice through innumerable thread-like barbs. Still struggling, the prey is passed into the œsophagus and thence downwards. At this stage, nervous excitement brings about a remarkable occurrence. The free edges of the mesenteries close together and form an improvised stomach by the approximation of the lateral lobes. If death has not yet occurred, the powerful stinging-cells that load the central ridge of the mesenterial filaments complete the work, while the associated gland cells provide digestive fluid in plenty. It is surprising how powerful and rapid this is in action. A few hours, three to four, secure the complete digestion of a fish or a crab nearly as large as the anemone itself. As the prey dissolves, this nutrient fluid is permitted to leave the improvised stomach, and flows freely into the various septal chambers, even too, into the tentacles; the cells in contact taking up what quantity they can. Any hard undigested parts are ejected by the mouth.

The sexes are usually separate. Both ova and sperm arise from similarly placed glands lying a little way from the free edges of the mesenteries (Figs. 2 and 3, *gg* and *ov*). Many species are viviparous, the young undergoing their early development within the septal chambers, and only when their tentacles are just long enough and sufficiently provided with sting cells to capture prey, are they cast out from the mother, by way of the mouth. Often have I obtained these baby anemones by gently squeezing the parent's body, when, one by one, minatures of the parent popped out through the mouth. The Gem *(Bunodes)*; the Beadlet *(Actinia)*; and the Sand-Anemone *(Sagartia bellis)* are examples in point.

Classification. The anemones belong to the phylum Cœlenterata, consequent upon having no definite tubular alimentary canal, the mouth and œsophagus leading into a great bag-like cavity without anal aperture. No cavities are developed within the walls of the body; neither is a ganglionic chain present, only an irregular loose network of ganglia and nerves.

The Coelenterata are subdivided into two classes; a simpler, without œsophagus or mesenteries—the Hydrozoa; a more complex, with well marked œsophagus, and numerous mesenteries—the Anthozoa or Actinozoa, and it is to this latter division that the animals we are now dealing with belong, and here I must remark, that I am using the term Sea-anemone, in a wide sense, as equivalent to the whole of the Anthozoa.

Within the bounds of this class, many very divergent forms are found. These are ranged in two sub-classes:—

I. The **Hexactinia** or **Zoantharia** and

II. The **Octactinia** or **Alcyonaria.**

The first contains the true Anemones, most generally simple, rarely colonial in habit, and which have their mesenteries in pairs in multiples of **six,** and with usually two siphonoglyphs. The Octactinia on the contrary, are all but entirely colonial, growing usually in masses of many hundreds of associated individuals; the mesenteries are some multiple of **eight;** only one siphonoglyph is present, and the longitudinal muscle ridges of all the mesenteries face towards it (Fig. 5). For convenience, I shall call these the colonial anemones, in contrast to the true or simple ones.

Let us now examine briefly the special points about the types chosen in our plates to illustrate the characteristic features of these two divisions.

Siphonactinia (Peachia) triphylla (Gosse), which we use as type of the true anemones, is in many ways remarkable. Its body is cylindrical, tapering to the base, which unlike that of other anemones, is not broadened into a flat attachment disc but is narrowed to a blunt point, and still more remarkable, is perforated by a small opening. Around the mouth are set twelve stout swollen tentacles, beautifully marked with dashes and lines of chocolate as is too, in rather more irregular manner, the whole surface of the body, on a ground tint of very pale pinkish brown. A stranger to the strange convergence of outward form wrought upon animals of different groups by similarity in environment and in habits, would never guess the true relationship of these animals living in the shell-sand gravel that here and there accumulates in patches along the shores of the Channel Islands; he would surely presume them to be some queer coloured sea-cucumber—some Holothurian not figured by Forbes.

In habit *Siphonactinia* burrows down several inches into the sand when the tide goes down, cautiously ascending and spreading its tentacles level with the surface as the sea returns.

Fig. 1 shows what is seen in a transverse section close under the mouth disc. Notice the single siphonoglyph (*si*) giving attachment to the ventral pair of directive mesenteries. The mesoglaea forms the central layer in all the threefold walls and mesenteries of the body. In the section from which this is drawn, the mesoglaea has absorbed most of the stain used and has become very conspicuous by reason of its bright crimson and glassy appearance. Fig. 2 represents a section below the level of the œsophagus, and shows the swollen free edges or **craspeda** of the primary mesenteries, as well as a swollen region (*gg*)—the ovary—some distance from the edge.

Few anemones are so useful to use for a due understanding of the general anatomy of the class, and the pity is, that this species is becoming extremely rare. The trouble connected with the commoner species, is that they all combine in the possession of so many and so well developed subsidiary mesenterics that in section the apparent complication becomes bewildering and confusing beyond measure to the student to understand, to the teacher to explain.

The representative used to illustrate the second sub-class, is the common *Alcyonium*, a colony of polyps cemented together by a gelatinous or semi-cartilaginous matrix strengthened by calcareous spicules. On some parts of our coasts it is plentiful, forming when living and with tentacles fully expanded, an exquisite feathery mass of life—strangely contrasting with the woeful, gruesome appearance it takes on when dead, and battered, and cast up, a sea-waif, upon the beach. Fishermen give it all sorts of names expressive of their loathing, "Deadman's fingers," "Deadman's toes," "Cow's paps," and the like.

The colony is formed of tiny, anemone-like polyps,—each with a row of eight **pinnate** tentacles,—united together by a wonderful development of the mesoglaea; indeed a distinctive name is now applied to this tissue—**coenosarc**—and it adds a great defensive device against predatory enemies, by the development within its substance of curiously warted spicules of carbonate of lime. And these tiny flesh-spines are not only found in the connecting matrix, but even in the thin layer of mesoglaea of the œsophagus are some smaller ones.

Note the different number and arrangement of the mesenteries. Instead of being in pairs, they occur in two series, a right and a left, and the muscular swellings face downwards (towards the siphonoglyph) in each series. Fig. 6 shows a section cut low down in the stalk of the colony, a region equivalent to that of *Siphonactinia* shown in Fig. 2; here the mesenteries are reduced to low folds or ridges.

Reproduction is rather different; the ova and sperm masses are not produced in special glands in the substance of the mesenteries, but arise singly in bud-like fashion on the edge of the mesenteric ridges (*ov'* and *ov*).

Besides *Alcyonium*, there are several other and diverse representatives of this class found on our shores. There is the lovely, light-emitting Sea-Pen *(Pennatula)*; the equally curious if less elegant *Virgularia*, and the grand Sea-Fan or rather Sea-Bush, *Gorgonia verrucosa*. The organ-pipe Coral *(Tubularia)* and the true red Coral *(Corallium rubrum)* are also members—their ultimate structure being identical with that of *Alcyonium* as described and figured, and differing almost solely in the method of spicule arrangement: in the one, loosely scattered; in the other, densely packed and soldered intimately together.

Explanation of Plate VII.

Structure of Anthozoa.

Fig. 1. Trans. sec. of *Siphonactinia triphylla,* through region of œsophagus, *i.e.,* cut along the line indicated by the letters A—B in Fig. 3. × 3½.

Fig. 2. Trans. sec. of same, at a lower level, *i.e.,* along line indicated by C—D in Fig. 3. × 3½.

Fig. 3. Diagram of anemone structure, shown by a vertical section along the plane indicated by letters A—B in Fig. 1. A mesentery is cut through longitudinally on the left side; on the other, the section passes through an interseptal space.

Fig. 4. *S. triphylla,* actual size.

Fig. 5. Surface section through a colony of *Alcyonium digitatum,* the polyps retracted wholly. For the sake of clearness, the tentacles which are retracted within the œsophagus, are omitted from the section. D, dorsal region; V, ventral region. × 9.

Fig. 6. Trans. sec. thro' portion of stalk of a colony of *A. palmatum.*

Lettering:—*cœ,* cœnosarc; *cr,* mesenterial filament or craspedon; *dm,* dorsal directive mesenteries; *dm',* ventral ditto; *e,* ectoderm of body walls; *e',* ectoderm of œsophagus; *en,* endoderm; *gg,* genital gland; *im,* intraseptal chamber; *is,* interseptal chamber; *ip,* inner pore; *lm,* longitudinal muscle band; *m,* margin; 2 *m,* secondary mesenteries; *o,* mouth; *op,* outer pore; *ov,* ovary; *ov',* loose ovum; *pbm,* parieto-basilar muscle; *pm,* primary mesenteries; *pr,* peristome; *rm,* radial or transverse muscle fibres; *si,* siphonoglyph; *sm,* sphincter muscle; *sp,* spicules; *st,* stomodæum or œsophagus: *t,* tentacle; *tp,* tentacle pore.

EXCHANGES WANTED.

Handbook to the Channel Isles. We have pleasure in directing the attention of those interested in the natural science of our islands, to the revised edition of Ansted & Lathom's "*Channel Islands,*" 8vo., 476 pp., which has been issued by Messrs. W. H. Allen & Co. Special Chapters are devoted to Zoology, Botany, and Geology; 40, 16, and 48 pages respectively, and all facts have been brought up to date. The work is profusely illustrated, and it is due to the courtesy of the publishers that we are enabled to use their block of adult *Scyllarus arctus* upon a preceding page. The published price is 7/6, and at this we will send it post free to any part of the United Kingdom.

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THE LIFE-HISTORY OF THE ROCK BARNACLE, (BALANUS).

BY THEO. T. GROOM, F.Z.S.

(PART I).

EVERY visitor to the sea-side is familiar with the appearance, if not with the names of the "Barnacles" and "Acorn-shells". The spar cast up by the waves, with its forest of strange-looking stalked shells, has often provoked the curiosity of those unacquainted with the secrets of Natural History. Almost anywhere along our rocky shores the countless myriads of small whitish conical shells firmly fixed on the rocks between tide-marks, give quite a distinctive appearance to the landscape. These small creatures apparently so rigid and still, have a wonderful life-history. In mediæval times it was seriously maintained that the barnacle was only the young of the barnacle-goose. One observer desirous of handing down his name to posterity as an original discoverer, actually saw the young bird inside the shell of the Crustacean, and records his observations in the following words:—"In every shell that I opened I found a perfect sea-fowl, the bill like that of a goose, the eyes marked, the head, neck, breast, wings, tail, and feet formed, the feathers everywhere perfectly shaped and blackish coloured, and the feet like those of other water-fowl to my best remembrance."—(Quoted in J. V. Thompson's "Zoological Researches").

The young Barnacle, however, leaves its egg-shell in a much less highly organized form than that of a young bird. It hatches as a typical **Nauplius,** a larval form characteristic of the Entomostraca or lower Crustacea. The Nauplius of the ordinary rock Barnacle *(Balanus)* after throwing off its first cuticle is shown in Pl. viii, Figs. 1 and 12. It has a shield-shaped carapace, and is so transparent when living that most of the internal organs can be easily made out. The anterior angles of the shield are prolonged, as in nearly all Cirripede Nauplii, into a pair of horns, which are tubular and emit a secretion formed by two unicellular glands (fronto-lateral glands, Fig. 6; *cf.* also Fig. 16) on each side. Articulating with the hinder end of the carapace is a caudal spine (*c. s.*), which is moved by means of a muscle (*t. f.m.*) in a vertical plane together with the tail or rudiment of the thorax and abdomen, and helps to steer the larva. On the lower side is seen another characteristic organ of the Nauplius—the huge labrum or upper lip (*lbr.*) This projects below the mouth (Fig. 9), and is furnished at the apex with four unicellular glands (Fig. 5) which emit minute secreted spherules. In front of the labrum is seen the black Nauplius-eye, another characteristic Entomostracan feature, rarely seen in the higher Crustacea or Malacostraca. At the sides of the Nauplius-eye are seen a pair of delicate frontal or olfactory filaments, also found in forms belonging to other groups of Crustacea. Behind and hidden by the labrum is the small mouth (Fig. 9).

The posterior end of the larva is formed by a broad-based forked spinous process (*t.*), representing the thorax and abdomen of the later stages. The large size of this region is a feature characteristic of the Nauplii of Cirripedes. The appendages (Figs. 2, 3 and 4) as in Nauplii generally, are three in number; the antennules (Fig. 2) are simple, and the antennæ (Fig. 3) and mandibles (Fig. 4) biramous, as usual in Nauplii. The figures show sufficiently the characters of these appendages. There is in every Nauplius a perfectly definite arrangement of the various hairs, spines and other processes.

The alimentary canal shows three distinct regions:—a bent œsophagus (*œ.*), a rounded stomach (*s.*), and a straight intestine (*i.*) leading to the anus, which is situated, as in Entomostraca generally, on the dorsal side of the tail; in the Cirripede Nauplius it lies just beneath the caudal spine (Fig. 9).

The brain (Fig. 8) consists of a supra-œsophageal ganglion, on which the eye rests, and from which the olfactory filaments are directly given off; behind, the brain gives off two circum-œsophageal nerve cords, which unite below to form a sub-œsophageal ganglion.

The Nauplius swims about actively and feeds and grows rapidly, a definite series of moults taking place.

A curious fact often misunderstood by naturalists is the way in which, just after moulting, the various spines and hairs are at first telescoped. This is a direct consequence of the mode of formation of a larger organ within a smaller; thus for the long tail to arise within the cuticle of the newly hatched Nauplius, it is necessary that it should become folded and telescoped within the corresponding part of the younger larva: after the moult it gradually becomes everted (Fig. 10).

In *Balanus* there are altogether exactly six stages, and the most ready way to distinguish these is by measurement. Figs. 11—16 show the form of the carapace at each stage, and at the same time the relative size, and certain other characters. We see, then, that the last Nauplius stage is between three and four times the length of the first, and whereas the newly hatched Nauplius is only just visible to the naked eye, the oldest are easily recognisable. During this growth highly important changes take place in both internal and external organization. These lead up to the last larval condition known as the Pupa or Cypris-stage. The Nauplii of the sixth stage (Fig. 22) are beautiful and instructive creatures. One can see already the compound eye of the Cypris-stage, at first red and showing the retinulæ (Fig. 23), later black; the six pairs of thoracic legs are visible but still lie within the cuticle, and can be seen to take their origin in a series of paired spines on the ventral side of the larva.

An exceedingly interesting feature about the Nauplii of some Cirripedes is the effect of light on the direction of their movements. At some times the Nauplii move towards the light, and at others away from it. In one species *(Balanus perforatus)* upon which the author, in conjuction with Dr. Loeb has experimented, the Nauplii performed daily migrations in the vessels; in the early morning they commonly sought the light, while a little later on and during the greater part of the day they avoided it. Beautiful experiments can be made on these little creatures, they can, for instance, be made to follow a candle all round a glass vessel. There can be little doubt that we have here a partial explanation of the daily oscillations performed by a great number of the animals living at the surface of the sea. When they have been sufficiently long exposed to the light, they retire to the depths. Whether this is done for the purpose of concealment or for some other object, it is difficult to say.

The **Cypris-stage** or last larval condition, is another exceedingly interesting form. The larva attains this stage, so utterly different in appearance from the Nauplius, in a single moult. In some forms, the Cypris-stage immediately after the moult shows curious transitional features between it and the Nauplius (Figs. 24 & 25); these intermediate forms are important for the understanding of the structure of the fully formed Pupa. In the latter (Figs. 26—28) the shield-shaped carapace has assumed the form of a bivalved shell, open below for most of its extent. The caudal spine and the horns are quite lost, and the antennules have suddenly become transformed into a most remarkable pair of prehensile organs of curious shape (a^1), provided with a complex series of muscles (Fig. 27) to enable them to perform a variety of movements. They are usually seen completely withdrawn within the shell. The labrum is lost, as also are the great antennæ, while the mandibles are reduced to a pair of small jaws (*mn.*) All the thoracic appendages have become external, and are each provided with a pencil of long bristles, and perform swimming movements by giving sharp jerks in unison. A good deal of the internal organization is obscured by the presence of a considerable number of oil drops (*o. g.*), but many points may be made out in living and in Canada balsam specimens. One can still distinguish the Nauplius-eye (*Np. e.*), while the compound eyes (*c. e.*) are now well developed, and can sometimes be seen to have a continual twitching movement. The shrivelled stomach (*s.*) appears as a red spot (bleached in mounted specimens) in the front part of the thorax. A powerful adductor muscle (*ad. sc.*) runs from one valve of the shell to the other, and just in front of this is seen a kidney-shaped glandular structure (*rn. gl.*), the function of which is not clear; the same may be said of a transparent oval sac on each side of the body near the Nauplius-eye (Fig. 26). The thorax (*th.*) can now be completely withdrawn within the shell by an important muscle (Fig. 24); when protruded, the thoracic ganglionic chain (*t. g. c.*) can be seen as a conical mass just above the bases of the appendages. The Cypris-stage no longer feeds, and shows little or no reaction to light, and seems to pass its time chiefly in sporting at the surface of the water.

The Cypris-stage of *Balanus balanoides* (Figs. 27 & 28) can be distinguished by a number of points from the corresponding stage of other Barnacles. Among the most readily recognized features are the large size (1·11 mm. in length), and the pitted markings on the shell (Fig. 18). The shape, too, differs from that of other species found on our coasts. The anterior and posterior portion of each half of the mantle are reddish and marked by a number of minute chocolate coloured spots, and towards the hinder end on each side of the thorax, is usually (if not always) found an accumulation of minute greenish yellow oil droplets (*o. g.*) The apertures of the fronto-lateral glands are very small. (Compare Figs. 24 & 25 representing the immature Cypris-stage of another species of *Balanus* which was obtained along with the other by Messrs. Sinel and Hornell off Jersey). This Pupa is smaller (0·7 mm.) and more transparent than that of *B. balanoides*, and has no markings on the shell; the fronto-lateral apertures are tolerably prominent. Another British species is shown in Fig. 26. It was obtained in the surface waters of Plymouth in May, 1892: I am unable to name even the genus of this form; it may perhaps belong to *Chthamalus stellatus*, which is excessively common in that district. It has an elongated shape and undulating contours, and is almost colourless; it has a number of small reddish brown spots principally on the dorsal side in front and behind. It measures on the average about 0·7 mm. in length.

After swimming about for a certain length of time the larva becomes attached to the rock between tide-marks, and undergoes a very remarkable series of changes which result in the production of a form totally different in appearance from the Pupa. The appearance of the young Barnacle when some time after fixation is shown in Fig. 29; the shape and colour of the carapace has altered considerably; the changes during this transformation are very considerable, and when the moult has taken place, and the cuticle been finally thrown off, give the young Barnacle almost the form of the adult (Fig. 20). The shell is marked by the same punctures (Fig. 21) as were seen in the Cypris-stage. Further growth in size and some change in the proportion of the parts gradually lead the young form up to the adult.

(To be continued).

Note.—The Plate illustrative of Part II of this paper will comprise Figs. 21 to 29, references to some of which are made in the text.

Explanation of Plate VIII.

Nauplius-stage of Barnacle.

Fig. 1. Side view of Nauplius of Stage II of *Balanus perforatus*. Behind the brain (*br.*) are seen the circum-œsoph. connectives and the sub-œsoph. ganglion.

Fig. 2. Antennule of same.

Fig. 3. Antenna of same, with (*gn.*) gnathobase moved by a powerful muscle (*gn. m.*)

Fig. 4. Mandible of same.

Fig. 5. Distal lobe of labrum showing the four unicellular glands (*ax. gl.*)

Fig. 6. Fronto-lateral glands of one side of same.

Fig. 7. Striated muscular fibres of appendages, showing the muscle corpuscle.

Fig. 8. Dorsal view of brain of same.
br. brain; *br. a. l.* accessory lobes of brain; *br. c. l.* central lobe of brain; *c. o. c.* circum-œsophageal connectives; *f. f.* frontal filaments arising from spherical bases within the brain; *Np. e.* Nauplius-eye imbedded between two cushions of special sensory cells.

Fig. 9. Diagrammatic sagittal (median longitudinal vertical) section through Nauplius belonging to Stage II; *int.* intestine suspended by contractile fibres; *gt. l. m.* longitudinal

muscular fibres joining intestine with hinder pocket of stomach; *st.* stomach with hinder pocket projecting below intestine, the hind part of the stomach composed of high striated deeply staining glandular cells; *œs.* œsophagus suspended by contractile fibres and projecting into stomach; *lbr.* labrum projecting below mouth.

Fig. 10. Hinder part of tail (thorax-abdomen) of *Conchoderma virgata* soon after first moult, to show telescoping of this part.

Figs. 11—16. Ventral views of the six Nauplius-stages of *Balanus perforatus*, drawn to scale, and showing some of the most important differences. The appendages are omitted, though their sockets are shown in Fig. 16.

Fig. 11. Newly-hatched Nauplius (Stage I).

Fig. 12. Stage II of same.

Fig. 13. Stage III of same.

Fig. 14. Stage IV of same.

Fig. 15. Stage V of same, showing segmenting thorax.

Fig. 16. Stage VI of same. The position of the mouth shows by the transparency of the labrum (*lbr.*) The first pair of thoracic legs alone are shown in this figure, the remaining ones being omitted for the sake of clearness.

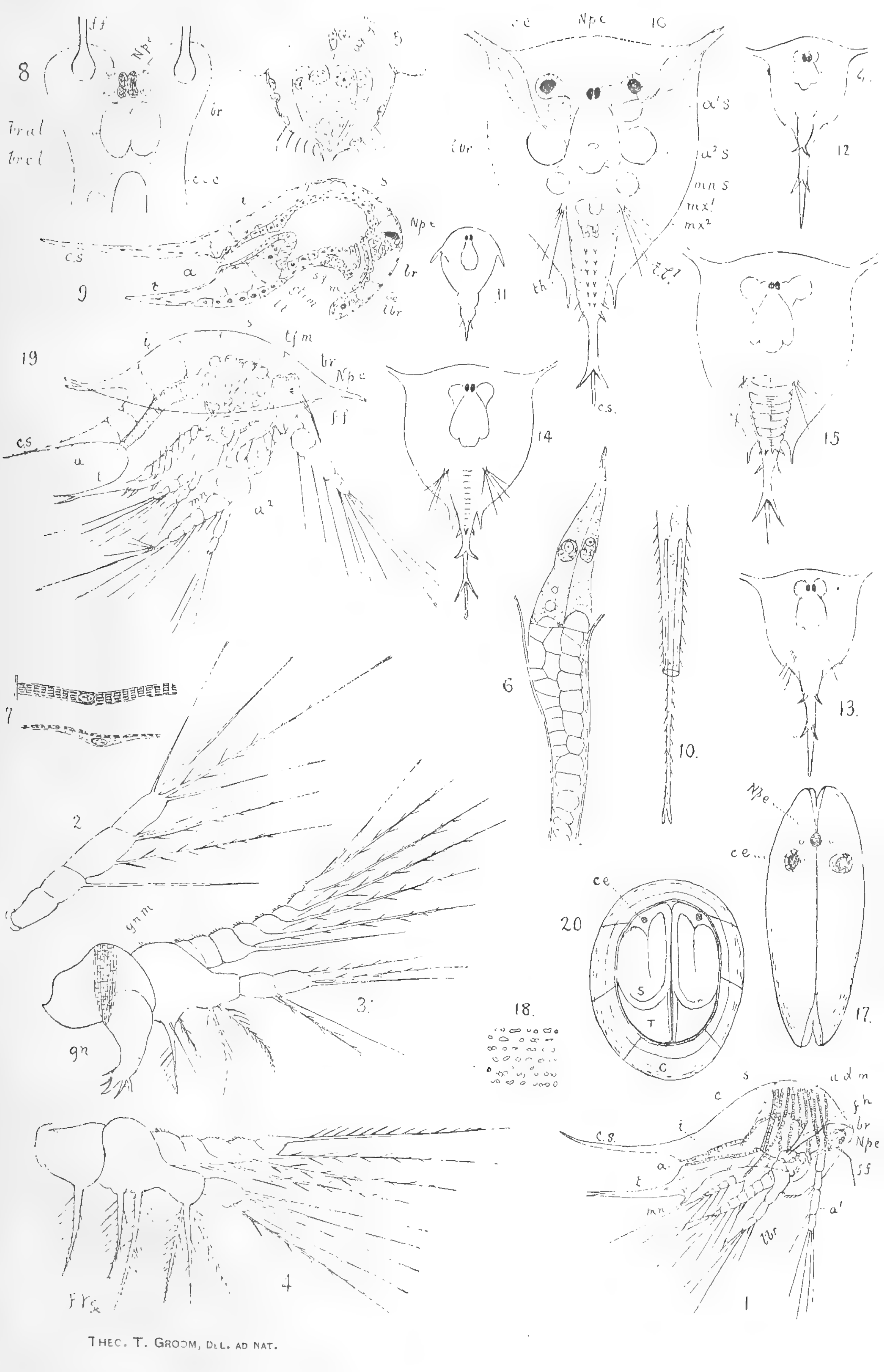
Fig. 17. Cypris-stage of *Balanus perforatus*, ventral view; drawn on same scale as Figs. 11—16.

Fig. 18. Portion of shell of same greatly magnified.

Fig. 19. Side view of Stage V of Nauplius of *Balanus perforatus*. Behind the brain (*br.*) are seen the circum-œsophageal nerve cords and the sub-œsophageal ganglion. The stomach shows numerous oil drops imbedded in the wall and is suspended like the œsophagus and intestine by contractile fibres.

Fig. 20. View of very young adult form of *Balanus balanoides* from above, showing valves of shell; *s.* scutum; *t.* tergum.

Lettering the same in all figures, viz:—*a.* anus; a^1. antennule; a^2. antenna; a^1. *s.* socket of antennule; a^2. *s.* socket of antenna; *a. d. m.* dorsal muscles to appendages; *br.* brain; *c.* carapace; *c. e.* compound eye; *c. o. c.* circum-œsophageal connectives; *c. s.* caudal spine; *f. f.* frontal filament (olfactory); *f. h.* fronto-lateral horn; *i.* intestine; *lbr.* labrum; *m.* mouth; *mn.* mandible; *mn. s.* socket of mandible; mx^1. 1st maxilla; mx^2. 2nd maxilla; *Np. e.* Nauplius-eye; *œ.* œsophagus; *o. g.* oil globules; *s.* stomach; *s. g.* sub-œsophageal ganglion; *t.* tail (thorax-abdomen); *th.* thorax; *t. f. m.* flexor muscle of tail; *t.* l^1. first thoracic leg; *t. t.* enlarged ectodermal cells of tail (ventral plate).



Theo. T. Groom, Del. ad nat.

THE DEVELOPMENT OF BALANUS.

THE DESCENT OF THE OCTOPODA,

A Contribution to a more Natural Classification.

BY E. H. L. SCHWARZ, A.R.C.S.

The Cephalopoda are usually now divided into the **Tetrabranchiata** and the **Dibranchiata,** terms which, though relying on a character, viz. the number of gills, which must always remain hypothetical in the vast majority of forms, nevertheless, till lately, divided this group of Mollusca into two divisions, apparently separated by a great gap.

The former group, except for a very few (3 or 5) species of Nautilus, is extinct, and includes the animals of the camerated shells. These are structures which, beginning from an embryonic protoconch, are built up of a series of gradually enlarging chambers separate one from another, except for a tube running uninterruptedly through the whole, called the **Siphuncle,** which, according to Zittel,(1) is the remains of the visceral sac drawn out and now functionary as a conveyor of nutriment to the distal parts of the shell.(2) In the **Ammonoidea** the protoconch is inflated and calcified, and is usually to be seen in carefully removing the matrix from the centre of well preserved specimens: in the **Nautiloidea** on the other hand, it appears to have been membranous, for no corresponding structure is found except in rare cases of *Orthoceras*,(3) but we infer that it must have once been present by the occurrence of a scar or cicatrix on the apex of the shell, showing the place where the embryonic shell opened into the first true chamber.(4) Besides this distinction in the protoconch, the Ammonoidea are distinguished from the Nautiloidea by the complex folding of the wall or **Septum** separating two adjacent chambers, and which forms the suture line on the exterior, being always bent away from the mouth on the external (ventral) side, forming a median lobe; and also by the siphuncle being placed on the external margin of the shell, a character however which is broken in *Clymenia,* which has the siphuncle internal.

The Nautiloidea are first met with in the lower rocks of the Baltic Cambrian, occurring in a sandstone round St. Petersburg, together with *Olenellus,* Cystideans, &c.,(5) in the form of a small *Orthoceras,* (*Volborthella*). In the Ordovician, a great number of

(1). This has recently received fresh support from the work of Dr. G. Holm on *Endoceras.* Dames and Kayser's *Palæont. Abhandl.* Vol. III, 1885.

(2). Edwards and Wood, Eocene Mollusca, *Pal. Soc. Mon.*, 1849, p. 12.

(3). Hyatt, Arietidæ, *Mem. Mus. Comp. Zool.*, Harvard, 1889, p. 10.

(4). Hyatt, Embryology, Foss. Ceph., *Bull. Mus. Comp. Zool.*, Cambridge, Vol. III, 1852.

(5). Schmidt, *Quart. Journ. Geol. Soc.*, Vol. XXXVIII, p. 516.

genera and species spring into existence; while in the Silurian this division reaches its maximum developement; in the Trias, the straight *Orthoceras* forms become extinct, while the coiled forms continue in decreasing numbers through the succeeding strata to the present day.

The Ammonoidea are first found in strata which Barrande correlated as Silurian, but Kayser has recently made these beds equivalent to the Hercynian, or lower Devonian.

The early forms belong entirely to the Goniatites; in the upper Devonian the puzzling Clymeniadæ appear, only to die out soon after. In the Permian beds of the Artinsk region in the Urals,(6) the Salt Range of India,(7) and Texas, Nebraska, &c., the last of the Goniatites and the first of the true Ammonites appear. In the Trias the latter become important constituents of the world's fauna; and by their apparent sensitive natures, unable to withstand alterations in their surroundings, form not only important zone fossils, but have even been used as tests of Climate(8): thus we get in the Jurassic rocks on either side of the equator, the delicate *Phylloceras* and *Lytoceras* in great abundance; in the northern latitudes, however, these two genera are never found, while sturdy forms like *Cardioceras,* take their place. In the Cretaceous, many of the Ammonites become curiously modified as if trying to withstand the new order of things by taking fantastic shapes, such as the hooked *Hamites,* the straight *Baculites* and *Ptychites,* the loose spirals like *Pictetia* and *Crioceras,* &c., while some of them returned to the ancestral Triassic types, such as *Buchiceras.* A similar story occurs in the Juvavian province of the Trias, whose beds were probably laid down in a sea gradually drying up; here there occur the aberrant *Choristoceras, Rhabdoceras,* and *Cochlioceras,* paralleling respectively *Crioceras, Baculites,* and *Turrilites* of the Chalk. In the uppermost Chalk (Danian), the Ammonites cease, though an Ammonite and a Baculite from Chico Creek in California have been referred to the Eocene.(9)

The Dibranchiata first appear in the rocks as the Belemnoidea, recently traced as descending from *Orthoceras* through the Triassic *Aulacoceras.*(10) These consist of a "**phragmacone**" similarly

(6). Karpinsky, Sur l'Amm. Fauna Artinski, *Mélanges géol. et paléont. tirés du Bull. de l'Acad. des Sci.*, St. Petersburg, Vol. I, 1890.

(7). Waagen, Salt Range, Fossils. *Mem. Geol. Surv. India*, 1879.

(8). Neumayr, Ueber Climat. Zonen der Jura und Kreide, *Denkscrift Akad. Wien*, Vol. XLVII, 1883.

(9). Trask, An Ammon. and Baculite from Chico Creek, California, *Acad. Nat. Sci. Proc.*, Vol I, p. 92, 1856; also Heilprin, Ammon. in Tertiary Rocks, *Philadelp. Acad. Nat. Sci. Proc.*, Vol. 34, p. 94, 1882.

(10). Mojsisovics, Mediterran. Trias Prov., *Abh. der K. K. Geol. Reichs,* Wien Bd. X, 1882.

shaped to a brevicone *Orthoceras*, round which is deposited a strong calcareous "**guard**" prolonged backwards as a cylindrical rod and enclosing and preserving the naturally caducous protoconch (hence Bather's suggested name "Coleoidea" for the Belemnites and their derivatives).(11) In front, the sheath of the phragmacone rises up to form the thin **pro-ostracum,** which probably held up the mantle. The Belemnoidea commence in the upper Trias of the Alps, and cease in the top of the Chalk, attaining their maximum in the Lias.

Representatives of the Sepiadæ and Teuthidæ are first met with in the Lias, but owing to the fragility of their shells, they are only found under exceptional circumstances. The shell of the ordinary Cuttle-fish is possibly a modification of the Belemnite structure(12); the phragmacone becomes hypertrophied, and instead of a succession of well marked septa there arises a spongy tissue of innumerable fine calcareous lamellæ; the pro-ostracum remains as before; and the guard dwindles away to a small peak. In *Loligo*, all calcareous matter has disappeared from the shell, and only a chitinous structure occurs. Then, till recently, the shell sac was supposed to abort completely, and the Octopoda arose without any calcareous skeleton whatever.

Everything would fit in nicely if the female of one of the Octopoda, viz., *Argonauta*, the paper Nautilus, had not an external shell. This structure was regarded merely as an accident; was formed by the arms and not by the body at all; and was considered in no way homologous with the external shells of the Ammonites and Nautili, because it was not camerated. But Hyatt(13) has shown that half of it is formed by the body-mantle; Süss(14) and Steinmann(15) have shown that it closely resembles some of the Cretaceous Scaphites in outer shape; while the consideration of how the chambers of the latter are formed, shows that the absence of these is no essential at all. For the shell of all Ammonites and Nautili is formed of an outer porcellanous or granular layer, and an inner nacreous or prismatic one, the latter also forming the septa. To produce this nacre, it appears necessary that the mantle should be wholly occupied with that function; but in the Argonaut the mantle surface bears chromatophores, and hence is used for other purposes than secreting the shell; therefore, all the parts represented in the

(11). *Ann. Mag. Nat. Hist.*, 1888, p. 302.

(12). Voltz, *Mém. Soc. Hist. Nat. de Strassbourg*, Vol. I, p. 1, 1830; see also F. A. Bather, *loc. cit.*

(13). Embryology, *Bull. Mus. Comp. Zool.*, Vol. III.

(14). Ueber Ammon., *Sitz. ber. der Wien Akad.*, Bd. LII, p. 71, 1866; *ib.* LXI, p. 305, 1870.

(15). Vorlauf. Mittheil. u. d. organiz. der Ammon., *Ber. Naturforscher Gesell.*, Freiburg, Vol. IV, 1889.

true camerated shells by the nacreous layer, must necessarily be absent, though the design of both is the same. Again, the complex foldings of the Ammonite septa show that they were formed from a very loose mantle, and being curved forwards instead of backwards, as in the Nautili, the membrane must have been blown out from behind while it was depositing the shell: also where the siphuncle passes through the septa, the little funnel around it there, is turned forwards, as if sticking into the animal. Hence we must conclude that the mantle, before it secreted the septum, must have been distended with something which at the time of the secretion had disappeared, and the mantle was blown forwards to take up its space, for useless superabundance of mantle is inconceivable. The only suggestion that can be offered, is that this something was eggs,[16] which, accumulating in the hinder portion of the animal, forced it forwards; when the full complement was laid, and they became extruded, the mantle secreted gas on its outer surface, which blew it out to take the place left empty; but where the internal organs had once pressed firmly, the mantle adhered to the shell, and a series of festoons were formed which ultimately became translated into the lobes and saddles of the particular species of Ammonite.

The animal cannot have moved forwards merely to obtain more body space, for in *Arcestes*, for instance, the rate of increase is so minute, that each living-chamber is inappreciably larger than the one before. Also there would in that case be a drag on the fleshy Siphuncle, which, when the shell was secreted around the proximal part must have formed a backwardly directed funnel; but on the supposition that the animal was forced forwards by the eggs, the siphuncle would have time to permanently stretch, and the gas would then be able to press it up to its insertion in the body wall and a forwardly directed funnel come to be secreted.

No such structure as these complicated suture lines could be found in a male, whose spermatozoa do not take up anything like the space that ova do, which in the Cephalopoda generally contain an enormous amount of yolk.

Thus we get an additional probability that the Argonaut is closely allied to the Ammonites, since the shell in both is only possessed by the female. Munier-Chalmas[17] and Haug,[18] however, have discovered series of Ammonites of which one is characterized by their large size and simple mouths, and another consists of small

(16). Tate and Blake, *Yorkshire Lias*, p. 263, 1876.

(17). Munier-Chalmas, Sur la possibilité d'admettre un dimorphisme sexuel chez les Ammon., *Comptes-Rendus Sommaires*, *Bull. Soc. Géol. France*, 1892, p. clxxiv.

(18). Haug, Etudes s. l. Ammon. Juras., *Bull. Soc. Géol. France*, Vol. XX, 1892.

forms with lateral ears to the mouth, while in other characters they are similar, suture line, ornaments, &c.; hence they conclude that the large ones are the females, and the small, males. But since the lobings of the Septa must be determined by the position of soft parts, and it is impossible that the female with her complex sexual apparatus should produce the same septa as a male with his comparative simple one, it seems inevitable that we must call these forms different genera, as Zittel does,(19) such as *Oekotraustes* and *Oppelia.*

If this view be true that Argonauta is closely allied to the Ammonites, (and it has been gaining sensibly in favour in the last few years, for we find the Ammonites set down as Dibranchs in the "Zoological Record,") then Owen's group Dibranchiata includes a direct "mutation" (to use Prof. Blake's term)(20) of the Ammonites, and highly specialized "divergents" of the Nautili (Belemnites, &c.); so that the division has now become artificial and strained. And not for this reason alone.

In the Dibranchiata, the skin is richly supplied with blood vessels, and a considerable amount of cutaneous respiration goes on, so that the least possible number and size of gills is required to keep the blood in its normal condition; but in animals enclosed on all sides with a shell, a greater gill-surface will be required. This may be obtained either by increasing the number or size of the gills. Since the only living Nautilus has done the former, it is probable that the Ammonites did the same, and, possibly to a larger extent. In *Arcestes,* for instance, we get a body chamber over one whorl in length, and in some cases approaching two, the aperture is very narrow, and the chamber low and flat; here there would not have been room for two large gills of the requisite size, or even four, but there might easily have been a row of several pairs of small branchiæ. Therefore there seems as much reason to class the Ammonites and Nautili with long chambers as Multibranchiata, as the conventional Tetrabranchiata.

However, the number of gills must always remain hypothetical in these extinct forms, and a new division with new names seems desirable. Foord(21) and Blake(22) have taken Mr. Bather to divide the Cephalopoda into the Ammonoidea, Nautiloidea, and Coleoidea, though he himself seems to restrict his new name to the Belemnites. However the two first groups are bound together by so many bonds of similarity, that it seems unwise to separate them, especially as

(19). *Handbuch der Palæontologie,* Bd. II.
(20). Presidential Address, Geol. Assoc., 1893.
(21). *Brit. Mus. Cat. Cephalop.,* Vol. I, 1888, p. 10.
(22). *Ann. Mag. Nat. Hist.,* 1888, p. 377.

long custom has united them under the old term Tetrabranchiata. Hence I propose the division of the Cephalopoda into the **Endocochlia** and the **Ectocochlia**[(a)]; the first including the Belemnitidæ, Sepiadæ, Teuthidæ, and Spirulidæ; while the second includes the Nautiloidea, the Ammonoidea, and the Octopoda. This division not only agrees with the trend of recent investigation, but also has the merit of relying on a character which can be actually examined in fossil, as well as recent animals.

P.S.—Since the above was written, my attention was called to a paper by MM. Perrier and Rochebrune, (Comptes Rendus CXVIII, p. 770), in which they describe a new Octopus (*O. dignati*) from California, which deposits its eggs within the shells of bivalves (*Cytherea* and *Pecten*) and not only so, but itself gets into the shell and remains there during incubation, and possibly longer. This may be taken merely as a specialization of the ordinary habit of European Octopi which utilize in like manner the crevices of rocks, and any other hollow, as has been described by Aristotle, Lee, &c. But it seems more likely to be a return to former habits. The Octopus in the process of loosing its ammonitic shell, passed through a stage in which some retained their original covering while others were free; some of the latter, then, during the sexual period, would feel the loss of the shell which their near relatives possessed, and like the hermit-crab, would take to their cast off shells if they could find them, or, in default, any shell that came handy. From these are descended the Californian species. Others, under peculiarly luxurious surroundings lost the habit of covering their body altogether, and when harder times set in, only a vague reminiscence of the instinct remained, and they sheltered their eggs in any convenient hollow. On any other hypothesis than the derivation of the Octopoda from the Ammonites, the incubation of the Octopus is an inexplicable mystery.

(*a*). ἔκτος, without; ἔντος, within; κόχλος, a shell.

Ponds and Rock-pools.—Under this attractive title, Mr. Hy. Scherren has gathered together, in pleasant form, many valuable notes on the smaller life that swarms in tiny tidal reservoirs and among the weeds of country ponds. The book is just what such a work should aspire to be, and will be read with thorough enjoyment by all true Nature-lovers. And while popularly written, the author sacrifices no scientific truths, and draws upon personal experience in all things. The price of this little work, which is published by the Religious Tract Society, is extremely moderate.

MICROSCOPICAL STUDIES IN MARINE ZOOLOGY,

BY JAMES HORNELL.

Study X.—Typical Alcyonaria.

The general characters of the central or typical form of these colonial Anthozoa, have already been dealt with in outline in the preceding note, and it therefore only remains to fill in some details.

Two species of *Alcyonium* are found comparatively plentiful in European seas; the one, *A. digitatum,* stout and massive, with few or no branches; the other, *A. palmatum,* slender, arborescent, and with fewer, but larger polyps. Normally the colonies of both species are found attached by an extended base, but instances are known where *A. digitatum* occurs in free, ball-like masses.

The latter species is usually snowy white, but occasional pale orange coloured varieties are found, the tint being due to the diffusion of colour throughout the cellular tissue. *A. palmatum* on the other hand, has very frequently a well marked variegated rosy hue, extremely pretty and not affected at all by the extractive action of alcohol. Curiously this is due to certain of the superficial spicules containing iron oxide. The bright red tints of the fiery *Pennatula* (Sea-pen) are due to a similar cause, and more important still, to this is also due, the colour that gives commercial value and beauty to red coral.

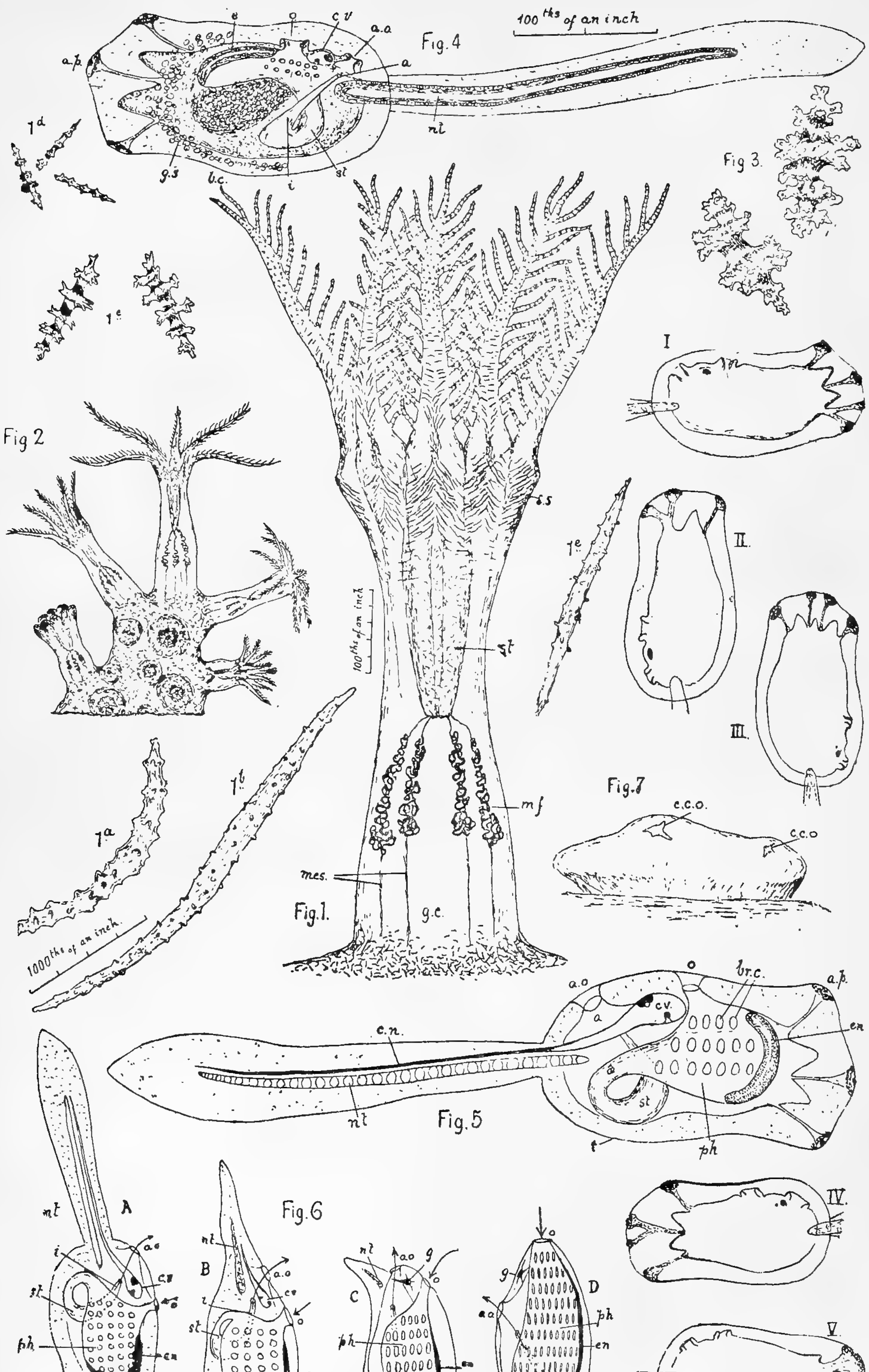
In many ways these spicules are of great interest. Their shape and arrangement, in conjunction with the form of the colony, furnish the principal guides to the classification of the group. In *A. palmatum* there are five principal forms: (*a*) those of ruddy hue and the largest in size ($\frac{7}{500}$-in. long), are arranged in eight bundles at the bases of the tentacles. The spicules in each of these bundles converge from right and left, and form a strong framework support for the free extremity of the polyp. The shape of each spicule is that of a stout bent rod, tapering abruptly to a rough point at either end; warted too, but much less prominently than any of the others to be mentioned. The foregoing pass at the apex of each bundle into those (*b*) that act as the supporting skeleton of the tentacles. Their general shape is rather more irregular, they are colourless, shorter, and the warting is much stronger. Size $\frac{4}{500}$-in. (*c*) A dense irregularly disposed layer crusting the general surface of the colony, consists of small, strong-spiked straight rods $\frac{2}{500}$-in. long. Most peculiar forms are sometimes assumed, due to the great and irregular development of the spines; being sometimes broadly bilobed, sometimes even trifid. (*e*) In the interior of the colony, in the stiff mesoglæa that divides and yet joins the different polyps, scattered spicules, very slightly spined, and nearly straight, occur; while a fifth form of spicule (*d*) occurs in the thick wall of the œsophagus. These last are the smallest of any in the colony and barely measure $\frac{1}{500}$-in. long.

In *Alcyonium digitatum*, the spicules differ very characteristically from all the preceding, in their much greater profusion, in their greater massiveness, and in their peculiar shape. The rod-like form, so closely adhered to in *A. palmatum*, is here nearly obliterated, and the spicules are often irregularly branched, and all the limbs beset by enormous wart-spines. (Fig. 3).

In the Organ-Pipe Coral (*Tubipora*) the spicules of the mesoglæa surrounding each individual, become locked firmly together by numerous minute serrations, and form perfect calcareous tubes. In the Red Coral of commerce, (*Corallium rubrum*), on the other hand, a strong central stony axis is formed by an even more intimate association of the spicules of the axis of the colony, due to an actual cementing together of these tiny limy rods. In *Tubipora* the polyps can retract within their protective tubes, but in the Red Coral there is scarcely any provision for the retraction, for safety, of the polyps.

As in the Anthozoa generally, so in Alcyonium the sexes are separate; indeed even the sexes of different colonies are distinct; the individuals in any one commonwealth are thus either all males, or else all females. The ova and the sperm masses are borne on little stalked capsules upon the free edges of the mesenteries, and development takes place outside the parent. The embryos are free swimming by means of a complete investment of lashing threads or cilia; a little while they sport thus amid the waves, and then affix themselves to some rock, and by continued budding produce extensive colonies.

Note the very large size of the hollow pinnate tentacles, and the thickness of the walls of the œsophagus (*st.*) Below the latter, the upper parts of the mesenteries are very apparent because of their greatly convoluted and thickened margins (Pl. x, Fig. 1, *m. f.*); from this point downwards, the mesenteries decrease rapidly in prominence, and soon show us very slight ridges only. The two dorsal ones are of greater length than any of the others, *i.e.*, descending lower down the gastric cavity, and whereas their thickened edges or **mesenterial filaments (craspeda)** are composed of strongly ciliated



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ALCYONIUM AND LARVAL ASCIDIANS.

Explanation of Plate X.

Figs. 1 to 3, Alcyonaria.

Fig. 1. Single polyp of *Alcyonium palmatum*, greatly magnified.

st. Stomodæum or œsophagus; *mes.* mesenteries; *m.f.* mesenterial filaments or craspeda; *g.c.* gastric cavity; *s.s.* supporting spicules.

1*a*, a spicule from lower end of a tentacle; 1*b*, a supporting spicule; 1*c*, some of the superficial-lying spicules that form the protecting cortex of the colony; 1*d*, spicules from the supporting lamella of the stomodæum; 1*e*, a spicule from the deeper parts of the mesoglæa.

Fig. 2. A branch of *Alcyonium*, with polyps in various stages of expansion. × 2.

Fig. 3. Spicules from mesoglæa of *Alcyonium digitatum.*

Figs. 4 to 6, also A to D, Larval Ascidians.

Fig. 4. A tadpole larva of *Aplidium elegans* (Giard), just freed from the parent. Viewed from left side.

Fig. 5. Diagram of the structure of a similar larva, seen from right side.

Fig. 6. Diagram showing stages in the metamosphosis of a tailed larva into the adult sessile condition.

Fig. 7. A colony of *Aplidium elegans,* when in adult stage; natural size; *c.c.o.* common cloacal orifices.

Figs. A to D, Larvæ where the papillæ are abnormal in number or in arrangement.

Lettering the same in all figures, viz:—*a.* atrium; *a.o.* atrial or cloacal orifice; *a.p.* adhesive papillæ; *c.v.* cerebral vesicle; *c.n.* candal nerve; *br. c.* branchial or pharyngeal clefts; *en.* endostyle; *g.* ganglion; *g.s.* cells homologous to the rudimentary gemmiferous tubules of other species, which give rise, by growth and budding, to new individuals, when the larva becomes attached, and proceeds to form a colonial mass (*fide* Giard); *o.* mouth; *oe.* œsophagus; *nt.* notochord; *ph.* pharynx; *st.* stomach.

Explanation of Plate XI.

Polynoë propinqua, one of the higher Annelida.

Fig. 1. Optical section of an individual viewed from above, the elytra having been removed.

Fig. 2. Appearance of the animal with elytra in place—life size.

Fig. 3. View of head and its appendages.

Fig. 4. Anterior portion of body showing the extruded proboscis, bearing at the extremity a ring of papillæ, and having four pairs of horny jaws (2 only visible here) just within the orifice.

Fig. 5. An individual showing regeneration of the hinder end, after a breakage that had taken place at the point marked *.

Fig. 6. Diagram of a transverse section of a somite bearing dorsal cirri.

Fig. 7. Diagram of a similar section through an elytra-bearing somite. These two figures are useful in the understanding of the possible origin of elytra from dorsal cirri.

Fig. 8. A parapodium or foot.

Fig. 9. A dorsal or notopodial bristle.

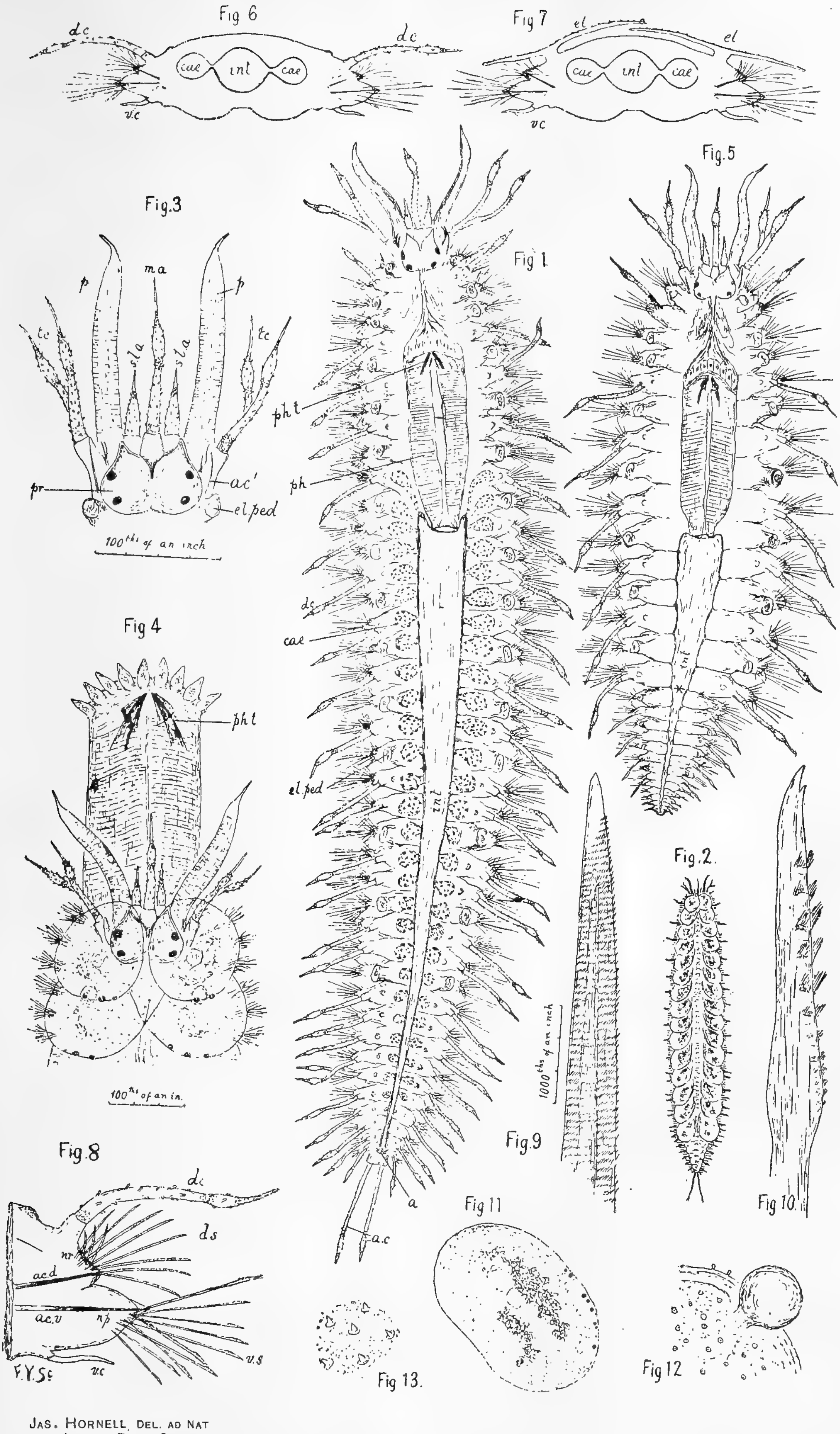
Fig. 10. A ventral or neuropodial bristle.

Fig. 11. An elytron or scale, showing the row of globular tubercles around the outer margin.

Fig. 12. Edge of same highly magnified, to show one of these tubercles.

Fig. 13. A portion of an elytron still more highly magnified, to show the fine papillæ of the surface.

Lettering the same in all figures, viz:—*a.c.* anal cirri; *ac.*[1] aciculum of 1st somite; *acd.* aciculum of notopodium or dorsal branch of foot; *acv.* aciculum of neuropodium or ventral branch; *cae.* caecum of alimentary canal; *d.c.* dorsal cirrus; *el.* elytron; *el. ped.* peduncle of elytron; *int.* intestine; *m.a.* median antenna; *nr.* notopodium or dorsal branch of foot; *np.* neuropodium or ventral branch; *ph.* pharynx; *ph. t.* pharyngeal teeth; *p.* palp; *pr.* prostomium; *s.l.a.* supero-lateral antenna; *t.c.* tentacular cirri; *v.c.* ventral or neuropodial cirrus.



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THE ANATOMY OF POLYNCË PROPINQUA.

cells derived from the downgrowth of two lines of cells from the lining of the œsophagus (ectoderm cells*), the thickened edges of the remaining mesenteries are less ciliate and their cells are endodermal in origin. By the combined action of the cilia of the two dorsal mesenterial edges, an ascending current of water is kept in motion.

The gastric cavities of the zooids are sometimes very long, extending downwards along the axis of the colony for several inches. Those of adjoining zooids are put into communication by a network of fine ramifying tubes, buds from whose walls produce the fresh zooids of the commonwealth.

The group Alcyonaria is of some importance geologically. Thus *Syringopora* of Palæozoic times was probably allied to the Organ-Pipe Coral (*Tubipora*). The common fossil *Favosites* was also an Alcyonarian, while *Corallium* has been found in the Jurassic rocks.

STUDY XI.—THE LIFE-CYCLE OF OBELIA GENICULATA.

A few weeks since, a friend in the North of England was good enough to send me some living specimens of a Zoophyte not found in Jersey waters. Confined in a comparatively small jar, the somewhat unnatural conditions had apparently hastened the birth of the developing reproductive buds, and these were swimming freely in the water as so many rythmically pulsating salver-shaped jelly fishes of the most wondrous transparency and delicacy of form. A circlet of regular and rather short thread-like arms stood out from the margin, while upon the disc could just be made out, with the aid of a lens, two intersecting lines with a handle-like stalk pendant from the point where these two lines crossed. And the tiniest pin's head was not larger in size. Some were born before my eyes from ovate sacs in the branch axils of the Hydroid parent.

Very generally the Hydrozoa, to which the subject of our sketch belongs, present well-marked instances of that many phased strange phenomenon, known familiarly as Alternation of Generation. At one period living attached to rocks, or weeds, or shells, under the form of tiny anemone-like animals, they often form by a continued process of budding, a shrub-like colony of many individuals. This is termed the **Hydroid Stage,** from which arises by budding and fission, free-swimming individuals or **Medusæ**—the true sexual

* Ectoderm and endoderm are terms of extreme importance. The embryo very early in its history consists of two layers of cells, an outer ectoderm and an inner endoderm, between which develops quickly a third, the mesoderm. All succeeding tissues owe origin to one or other of these, and roughly we may take it that epidermal tissues have ectodermal origin; the alimentary canal and its offshoots being lined with endoderm, while muscle, connective tissue, &c., are of mesodermal origin.

stage. The sexes are separate, some producing ova, and some spermatozoa. The resulting embryos—tiny things that progress by rhythmic lashing of cilia—attach themselves after a short period of activity to some fixed object and soon develop into tiny *Hydra*-like creatures, to circle once more with absolute fidelity through the strange alteration of stages gone through by innumerable multitudes of progenitors.

Seldom are these two great Life-Phases at all equal in size-importance. One is nearly always magnified at the expense of the other. One usually sinks into insignificance, slurred over and frequently even entirely suppressed. And according to which phase is magnified, have we one of the principal points characteristic of one or the other of the two sub-classes of the Hydrozoa. If the free-swimming sexual or Medusid-stage be the chief life-form, and the Hydroid be all but suppressed, then we have the division of the **Scyphomedusæ**—the **Acelephæ** of some writers. Herein are included all the large Jelly-fishes so familiar in summer time on our coast, during warm weather, and moving at times in shoals of immense numbers. The other division is that where the Hydroid-stage is exaggerated and usually colonial, and where the Medusid or swimming stage is tiny or even eliminated. Such constitute the **Hydromedusæ** which are further distinguished from the Scyphomedusæ, in that the Medusæ of the former have the edge of the bell turned horizontally inwards forming a delicate veil, the **velum,** partially closing the mouth of the bell. This character constitutes a **Craspedote** Medusa, as contrasted with the **Acraspedote** form of the Scyphomedusæ, where the velum is absent.

The Hydroid Zoophytes, or **Hydroidea,** constitute the central order of the Hydromedusæ, and possess the typical life-history. In passing it is well to remember that besides the Hydroidea, there are two other orders, viz., the Trachymedusæ and the Siphonophora, both characterised by pelagic habit, and the fact that they never have a fixed or stationary hydroid phase.

The Hydroidea show much variation in the form of their Hydroid stage and in the completeness of their life-history. *Obelia* is very typical of unabbreviated life-cycle, so is specially useful to use as an introductory type for study. The colonial stage is remarkably beautiful, its delicate zig-zag branches forming dense miniature forests on the broad brown oar-weed. An old writer speaking of a nearly related and not more beautiful species, says, "Delicacy, transparency, and grace pervade the entire structure; the spirit of beauty has thrown itself into every curve and line: the eye rests with full satisfaction on the little cups, so perfect in their form;

and hardly less beautiful are the ringed and twisted pedicles that support them."

The colony is protected in all its parts by a delicate transparent horny substance—the **perisarc,** and consists of a zig-zag stem, jointed at each curve, and giving off on alternate sides, a short ringed pinna, bearing aloft a tiny crystal cup **(hydrotheca** or **calcycle),** wherein lodges an equally tiny **polypite** or **hydranth** (Pl. ix, Fig. 2, *p.*), armed with a well-marked proboscis and numerous tentacles. To the polypite is delegated the sole duty of capturing prey. The whole organism is the truest of commonwealths; each polypite captures not for its own sustenance only, but equally for the whole colony, for the base of the body of each individual passes into a tubular prolongation, **cœnosarc,** continuous with a similar tubular tissue in the main stem. If one polypite capture food, part of the products of digestion pass into the tubular cœnosarc, and is conveyed to neighbouring parts of the colony for purposes of nutrition. And upon this unselfish mutual help, depends the power of the colony to set free from the purely nutritive (vegetative) function, certain individuals or zooids, charged specially with the reproduction of the species. These specialized zooids are developed in the axils of the branches and are elegant elongated urns in shape, **gonothecæ** (*g*), wherein the cœnosarc breaks up into granular bud-shaped masses that gradually evolve into transparent delicate swimming-discs. Their gracefulness has to be seen to be understood. One has to watch them as, so many streamer-decked bells, they sink slowly through the water, of a sudden to regain activity and pass upwards by a series of vigorous jerking pulsations, to cease after a number of strokes and become inert, slowly-sinking parachutes once more.

Medusæ are generally bell-shaped, with the true edge turned horizontally inwards to form the *velum* (Fig. 5, *v.*), but in the form under notice, the shape is nearly that of a flattened disc, and the velum in consequence of this difference is all but absent. From the apparent edge of the disc proceed a number of tentacles beset with stinging cells, while from the centre depends a tubular process, the **manubrium** (*m.*), having the mouth at the free extremity and a slightly dilated cavity, the **atrium** (*a.*), at the attached base. From the atrium proceed four radial canals (*rc*), while around the edge of the disc, just inside the ring of tentacles, is a **circumferential canal** (*c.c.*), into which the radial canals empty. All these cavities are lined with ciliated endoderm, which shows little divergence in form in the various regions. The ectoderm forming the exterior coat of the Medusa exhibits much more differentiation; while on the upper surface it consists of flattened cells, on the under it developes radially disposed muscle fibres, and on the manubrium, longitudinally disposed ones. Between the ectoderm of the upper surface of the disc, and the endoderm of the atrium and radial canals, is the intermediate body layer, the **mesoglæa**. In *Obelia*, it is thin, but in some species it is often enormously developed as a thick jelly-like substance (*Aurelia, Pelagia*, &c.), that gives cause to the popular name of the Medusæ. The term **umbrella** (*u.*), is bestowed upon this layer. The **sub-umbrella** (*s.u.*), another layer of the same tissue, but quite thin in even the best developed instances, is found between the endoderm and the lower surface of the animal. A point sometimes overlooked is that the radial canals are joined together by a horizontal layer of endoderm cells, so that where the umbrella and the sub-umbrella are not separated by an endoderm-lined space (atrium or canals), they are by a solid layer of endoderm cells.

The tentacles are here solid, consisting of a single row of large endoderm cells encased in a layer of small ectoderm ones, which develop numerous stinging cells.

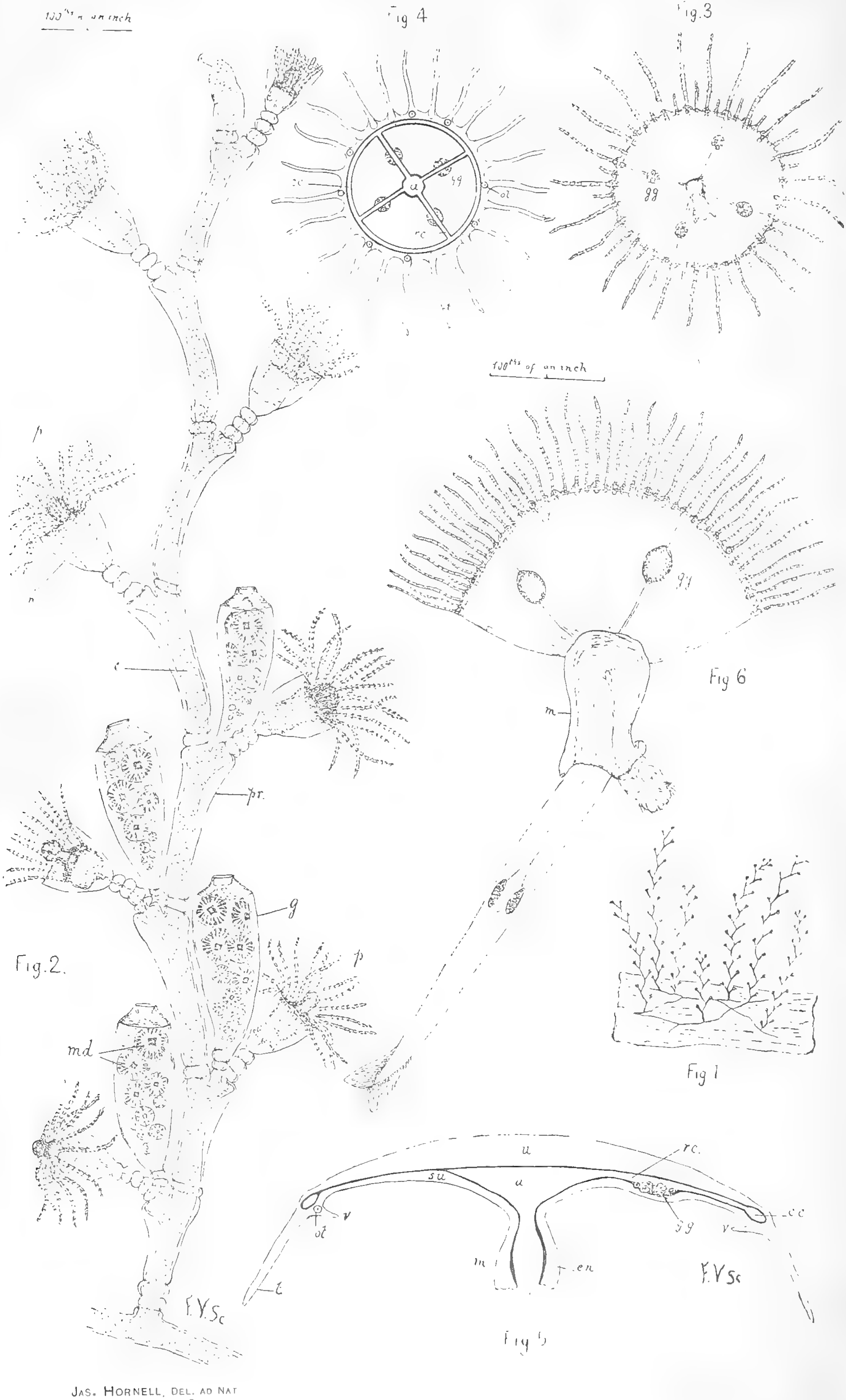
Eight so-called "**otocysts**" (*ot.*) are found on the inner side of the bases of certain of the tentacles. Each consists of a sac containing an **otolith.** The function has long been supposed to be auditory, but Hurst (*Nat. Sc., June, 1893*) has with much plausibility argued for their true use as organs designed to give warning of approach to an unquiet, wave-disturbed region, in the turmoil of which their frail anatomy might suffer. (The thick umbrella of some contains up to 95% to 98% of water !)

The sexes are separate. In *Obelia*, the genital glands (*gg.*) are developed as four masses upon the radial canals, one for each midway between manubrium and margin. The ova after fertilization become ciliated embryos, which soon affix themselves and develop into hydroid colonies.

It is painful to have to record that these tiny marvels of Nature's excellence of workmanship, are sordidly greedy and voracious. The power of the sting-cells has great paralysing action and comparatively large animals are easily captured, and sucked into the mouth. Fig. 6 shows how an Arrow-worm (*Sagitta*) had been captured and partly doubled in two and so partially swallowed. Copepods, notably *Temora*, form another common food.

Obelia, save in the slight development of the velum of the Medusa, and the form of the latter being rather that of a disc than bell-shaped, is thoroughly typical of the form and development of that division of the Hydroidea where the polypites are borne in cups—the Calyptoblastic Hydroidea.

Endless and complicated modifications exist in other species, and some of these I hope to illustrate and explain before long.



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THE LIFE-HISTORY OF OBELIA GENICULATA.

Explanation of Plate IX.

Life-History of Obelia geniculata.

Fig. 1. Natural appearance of the fronds of the Hydroid-stage, as they grow upon the surface of *Laminaria*. Life size.

Fig. 2. A single frond of the same much enlarged. *pr*, perisarc; *c*, cœnosarc; *h*, hydrotheca; *p*, polypite; *b*, bud developing to form a polypite later on (note that the perisarc covers the entire surface of the bud; as growth goes on a thinning takes place at the apex, and finally gives way to permit of the extrusion of the polypite's tentacles); *g*, gonotheca; *m*, medusid buds in different stages, within the gonotheca.

Fig. 3. View from below of a freed medusa.

Fig. 4. Diagram of same.

Fig. 5. Diagrammatic vertical section through same. The section follows the course of a radial canal on the right side, while on the left, an interradial portion of the disc is sectioned.

Fig. 6. A Medusa, considerably older than that shown at Fig. 3, seen reverted and from the side. It had just captured an Arrow-worm (*Sagitta*), which is doubled up, the bend being within the digestive cavity of the Medusa.

Lettering the same for Figs. 3—6, viz:—*a*, atrium; *c.c*, circumferential canal; *en*, endoderm; *g.g*, genital glands; *m*, manubrium; *o*, mouth; *ot*, otocyst; *r.c*, radial canal; *s.u*, sub-umbrella; *t*, tentacle; *u*, umbrella; *v*, velum.

Study XII.—On Polynoë propinqua as typical of the Higher Annelids.

Polynoë propinqua (Malmgren) is an elegant marine annelid, short and slender in its proportions, rapid and lively in its movements. When the tide recedes, its haunts are to be found wherever boulders litter the shore, and many a weary backache have I had through a course of such stone-turning. It is easily recognized by reason of two rows of oval overlapping brownish scales that lie upon its back, and from under which project, oar-like, on either side, serried banks of lovely translucent paddling-bristles. A pretty creature, but loath to be captured. Alarmed at the approach of the forceps, it squirms and makes desperate effort to escape, and indeed if it be lifted roughly and by force, instead of being taken by some gentle snare, lo! it breaks into pieces and is to you but a worthless capture.

A cursory examination suffices to show that except for the two extremities, the body is divisible into about 41 ring-like portions, all broadly or obviously of the same value one with the other—formed fundamentally upon the same plan, though some are either internally or externally modified in particulars for special functions. The typical form of these equivalent body-rings, or **somites** as they are termed, possesses on either side a fleshy two-branched lobe, the **parapodium,** in which are implanted bundles of finely sculptured bristles or **setæ.** The upper branch, the **notopodium,** is considerably smaller than the ventral or **neuropodium,** and its setæ are shorter and of a different pattern to those of the latter. The drawings on Pl. XI sufficiently illustrate the general arrangement and the details of divergence. Besides the ordinary setæ, each branch of the parapodium contains a single stout spine, **aciculum,** buried, all but the point, in the flesh.

The form of the parapodia—often termed rather loosely the feet—and of their bristles, is remarkably stable throughout the whole length of the body, excepting only in the case of the first somite, the peristomium, the one bearing the mouth. Here each parapodium is reduced to a long slender lobe, obscurely divided into rudimentary upper and lower branches, and with but one aciculum and two or three tiny setæ.

The tactile appendages garnishing the various somites show much divergence. Thus the somites 2, 4, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 26, 29, 32, bear each one pair of the characteristic scales, or **elytra,** while the remaining ones bear on either side a long filiform appendage, the dorsal or **notopodial cirrus,** arising from the base of the notopodium. Reference to Fig. 1 will explain this arrangement and show how, in the major part of the body, these two organs roughly alternate, giving place in the last ten somites to cirri only, thus leaving this short portion naked. The neuropodium bears also a short **ventral cirrus,** but this shows no variation except in the peristomium, where it is greatly elongated.

In structure, the elytra are thin membranous two-layered plates, borne on broad low peduncles, and so loosely attached, that it is extremely difficult to obtain a preserved specimen with the full number present. This extreme looseness is peculiar to this species. In others, such as the common *Lepidonotus squamatus,* they adhere with such firmness that they frequently tear rather than lift off, and between these two extremes, there is every intermediate degree. The surface of the scale is prettily marbled, while around the exposed edge is a row of all but globular tubercles, very diagnostic of this species. Occasionally I have noticed the elytra to be distended in a bladder-like manner. Some observers have supposed this to be an incubatory device, as they have found them filled with ova. This however does not necessarily follow, for the ova when freed, find their way into all the spaces of the body-cavity, and of this, the hollows of the elytra are but offshoots.

Probably elytra are modifications of certain dorsal cirri—the two never being found co-existent upon the same somite in *Polynoë*, though in *Sigalion*, a scale-covered worm of great length, they do exist together. In the latter case however, the common phenomenon of duplicative variation (see Bateson's "*Materials for the Study of Variation*") has probably been at work; if so, then *Polynoë* shows regular modification from a form possessing dorsal cirri to every somite, while *Sigalion* shows such modification with duplication superadded.

The head, the prostomium, consists of all to the front of the mouth-somite, and indeed is apt to be confounded in part with the latter, as its upper surface is bent back and lies partly obscuring it. Viewed from above, after the concealing first pair of elytra are removed, it appears sharply defined and roughly heart-shaped, with two pairs of black eyes set widely apart (Fig. 3). Long appendages of sensory function, borne on separate peduncles, are given off from the fore edge. Four are in pairs, while a median unpaired one, the median antenna, is given off, rostrum-like, from the central point. On either side of this is a rather short, almost conical process, the superior-lateral antenna; while attached immediately beneath each is a stout, very extensile organ, the inferior-lateral antenna or palp.

In addition to these, the dorsal and ventral cirri of the peristomium have to be considered as supplementary head appendages, as they are specially elongated and are directed forwards at the side of the true appendages, acting in unison in sensory duties. They receive the distinctive name of **tentacular cirri.**

From the paired nature of the prostomial organs, it has been suggested that, as happens among the Crustaceans and the Insects, the head has resulted from the coalescence of several somites, which in losing locomotive duties have been profoundly modified to subserve sensory uses. But a very serious objection to this is, that all the prostomium results from one particular part of the larva, known as the præ-oral lobe, and which at no period of its history shows any suggestion of segmentation.

Turning now to internal arrangement, we find that the mouth leads into a well-marked pharynx, the anterior portion of whose walls lie in puckered folds capable of being everted like the finger of a glove, and thus allowing of the protrusion of the hinder portion, so as to form a proboscis. This hinder portion has walls of great thickness and muscularity, and the anterior end when protruded, is crowned with a circlet of conical transparent papillæ, each containing a dark pigment spot. Just within this ring are four horny beak-like teeth, that bespeak plainly the essentially carnivorous nature of the Polynoinæ. Indeed one has but to keep a number of them together for some time to find proof of their cannibalism, in the bitten and torn parapodia of the weaker individuals, and undigested bristles can frequently be traced in the matter contained within the intestine of newly captured ones.

From the pharynx, the alimentary canal passes direct in a straight course to the anus. As in the closely related *Aphrodite*, it gives off in each somite to the rear of the muscular pharynx, a right and a left glandular pouch or cæcum, whose function we are yet uncertain of. Curiously enough, the anus is not terminal, but, as in the Copepoda, is found upon the dorsal surface of the penultimate segment.

A definite respiratory, or pseud-hæmal system, was long denied to the Aphroditidæ, but Salenka and others have demonstrated in *Aphrodite* and other species, a highly developed series of fine closed tubes containing fluid apparently respiratory in use, but almost invisible because of its all but entire lack of colour.

These vessels are in no way concerned with the diffusion of digested nutriment. That duty is taken charge of by a corpusculated fluid filling the general cavity of the body **(Coelome)**, and which circulates readily through the whole length of the body by reason of gaps being present in the septa that break the coelome up into numerous chambers.

Each of the septa here mentioned is a vertical partition wall or rather transverse membranous mesentery, parting the coelome of adjacent somites throughout the greater part of the body, but suffering modification in the anterior portion of the animal, where the evertible pharynx requires special freedom of movement.

The nerves consist of a large cerebral mass above the mouth, connected by a commisure passing on either side of the pharynx, with a chain of ganglia in the ventral wall of the body. In reality this chain is double, but is so far coalesced as to appear single. Each somite possesses one of these double ganglia. From the upper and anterior edge of the cerebral nerve mass, nerves are given off to the median and to the superior lateral antennæ, while the palps are innervated from the ventral surface. Segmental organs, excretory in function, are also present, but extremely minute.

Reproduction. The sexes are separate, but no special ovaries or testes are present; the genital products being developed as cellular masses from the internal surface of the body walls. The products ripen and are set free in the coelome, whence they obtain egress, either by rupture of the body-wall, or by way, perhaps, of the segmental organs in some cases.

The embryos have the characteristic Polychæte form, being **trochophores,** that is, they are rounded bodies with an encircling band of cilia immediately in front of the mouth, the portion in front of the band, forming the præ-oral region already referred to as the precursor of the adult prostomium.

Adult form is soon assumed, but for some time after so doing the young pursue a pelagic existence, swimming freely on the surface of the sea, and frequently falling victims to the snare of the tow-net. Like the adults these larvæ are brightly phosphorescent upon irritation—the luminous areas being the elytra.

The Polychætous Annelids, or Polychætes, to which *Polynoë* belongs, include nearly all the marine bristle-bearing worms. Very few (only some half-dozen rarities) are inhabitants of fresh water; whereas, on the contrary, the Oligochætes (the few-bristled annelids), extremely rare in the sea, have in fresh water and upon the land, practically the entire monopoly.

Polynoë is very closely akin to the lovely iridescent Sea-mouse (*Aphrodite aculeata*), so often dredged in sandy estuaries. Both belong to the same family, Aphroditidæ, but to different tribes, namely to the Polynoinæ and the Hermioninæ respectively. The former comprises a great number of species, marked off from one another chiefly by differences in the number and ornamentation of the scales, and in the sculpturing of the setæ.

I might have chosen a much simpler type whereby to illustrate the anatomy of the Polychætes, but on the principle of the axiom that the greater includes the less, I chose *Polynoë,* as in it, complexity of anatomy reaches its highest development and if we become familiar with its general features, we need not be afraid of being puzzled to understand the modifications seen in other forms.

The present species, *P. propinqua,* is dominant in the Channel Isles between tide-marks, but in the Irish Sea I found it extremely rare, its place being taken by the stouter *P. imbricata.* Both these are prowling robbers, without home or sojourning place, but many species take up uninvited lodging with some of the larger tube-forming worms, or with Echinoderms. Thus two species live with the strange *Chætopterus* in his great parchment tube, one with the giant *Eunice sanguinea,* one with *Terebella,* and another in the ambulacral groove of the starfish *Astropecten,* while a tiny one lies sometimes among the tube-feet of *Echinus,* and yet another, one of the most beautiful, finds safe dwelling among the spines of the purple heart urchin *Spatangus.* Such are termed **commensals** or messmates, but the mutual relations subsisting between the host and the guest are obscure and little understood. It may be that the annelid frequents the host for protection only, sallying out in quest of food when hunger presses, but that there is something more seems argued by the fact that each species is always found with its own particular host. If it were a question of protection only, would not the tube of one worm be as good as that of another ?

Another curious point about these worms is the great power possessed of reparation of injuries. If in danger, it is the invariable habit of *P. propinqua,* in common with many allied species, to break up into two or three fragments in the hope of the head part being able to escape under cover of the consequent confusion. If it be able to do so, in a very short time a number of rudimentary somites appear sprouting from the broken end, and these grow and increase until finally the full and complete size be once again attained. I have seen individuals in all stages of this regeneration, but have never seen the hinder or tail fragment of a ruptured worm reproduce a fresh head, as has been recorded by some writers. Such however would, I believe, be likely to occur were the fracture close to the head, but usually it occurs much nearer to the tail than to the head, and in such cases I feel sure that the tail portion dies.

Study XIII.—The Tadpole Larvæ of Ascidians.

The Tunicates or Ascidians, may be either fixed or free ; simple or colonial. The central type of the free is seen in the Appendicularïæ, transparent tadpole-like animals that sport in the surface waters of our seas, in profusion, at certain seasons. In size these are extremely minute, the British species averaging only $\frac{1}{5}$-in. to $\frac{1}{4}$-in. in length, tail included, while the length of $1\frac{1}{2}$-in. which a foreign species reaches, is altogether exceptional and monstrous. In this type, the tail is supported and strengthened by a firm central rod, the **notochord,** believed to be a similar structure to the first supporting stiff axis of the embryos of vertebrates, and which in them is subsequently usually obliterated by the encroaching growth of the vertebral column. Another curious point is that two openings communicate between the pharynx and the exterior, and serve as gill slits.

These tiny ocean wanderers are never colonial, always free and simple. The fixed Tunicates, the Ascidians proper, are, on the contrary, very frequently colonial, or as some writers term it, composite or compound. In such latter, there is usually a certain amount of federation, such for example in those where the anal apertures of a circlet of individuals open into one common atrial or cloacal chamber, to be expelled by a centrally place atrial opening.

In size, the colonial individuals are usually very much smaller than the simple, but in structure the two are essentially similar, having the anterior portion of the alimentary canal distended into a large chamber, with walls perforated by numerous gill slits, a nervous system reduced to a single rounded mass (ganglion) between mouth and cloacal aperture, a blood system of much simplicity and an enveloping case of nearly structureless semi-cartilaginous or gelatinous tissue, the **tunic** or **test.**

July and August is the breeding season of many species, and if one of these animals be then dissected, eggs and embryos in various stages of development will be found.

Taking one of the most advanced, the following points can be observed. The body is a tiny oval, slightly flattened from side to side, while from the one end is given off a long broad tail, containing centrally a clear rod of a cartilaginous substance. Both the body and the tail are invested in a thick coat of gelatinous material, equivalent to the test of the adult fixed animal. Turning the animal on to one side (when the tail is found to be now on edge) one can, by staining, make out clearly the thick investing test, in which lies the darker stained kernel-like body. At five points the test is broken through; three of these are where, at the anterior end, there pass an equal number of tiny rod-shaped papillæ spreading into wide heads on their emergence. These are glandular in function, secreting a tough glutinous cement whereby the larva when tired of a free life, attaches itself to a rock or weed. The other two points where the test is pierced, are upon the dorsal side, and in the larva of *Aplidium elegans* are situated far back. The anterior is the opening of the mouth (*o*), and is separated by only a short interval from the posterior, which is a depression indicating where the atrial aperture breaks through. The mouth opens into a wide pharynx occupying a great part of the larval body space. In the stage figured, the stomach is just beginning to be apparent as a thick walled canal in a ventral position towards the hinder part of the body, and connection is just being made between the atrial cavity and the intestine. In the advanced larva several openings pierce the pharynx and allow water entering through the mouth to pass into the atrial cavity without having to traverse the stomach and intestine. Such openings are obviously the same as are so numerous and so apparent in the adult. In Fig. 4, Pl. x, they show as two rows of disc-shaped thin places in the pharyngeal walls.

The nervous system, of the most extreme simplicity in the adult, has in the larva a complicated and highly developed arrangement. As in the Vertebrata, it takes its origin as an open furrow stretching longitudinally along the dorsal side of the body. The edges gradually grow upwards and inwards to meet, and thus form a tube which now constitutes the central nervous system of the animal.

The anterior end gradually swells into a large vesicle, while from the hinder end of this, there runs a rapidly narrowing tube which is prolonged into the tail as the caudal nerve. The large anterior vesicle contains two peculiar sense organs, an eye, and an otolith perhaps of auditory value. These can readily be made out in mounted specimens, as both are darkly pigmented and show conspicuously, rendering easy the location of the cerebral vesicle lying between the mouth and the atrial opening. Of the two, the eye is much the more complex, for it possesses a cup-shaped retina in which is placed a projecting and complex lens. It is placed at the posterior upper corner of the vesicle and projects downwards towards the centre of the cavity. The otolith on the other hand, rises upon a stalk from the floor of the vesicle more to the front end. It is noteworthy that both are *within* the vesicle.

The after history of the animal is quickly told. The larva affixes itself by the glutinous secretion of one or all of its three papillæ to some object; the tail with its contained notochord, as well as the three anchoring papillæ become absorbed; the test becomes enormously thickened and strengthened, and the perforations of the pharynx become multiplied greatly, and most significant of all, eye and otolith vanish utterly, the well developed nervous system being reduced to a fairly large ganglionic mass occupying the position of the cerebral vesicle of the larva, *i.e.* midway between the mouth and the atrial opening. Radiating nerves to the various organs are thence given off. The course of these changes brings about a certain alteration of placing of the two external apertures, as may be seen in the diagrams; thus the mouth in the fixed larva of *Aplidium* is at first not terminal, but gradually becomes so, thus necessitating a corresponding travel of the atrial opening. There is, however, no real travel of these parts, simply a more rapid growth than of the opposite side, of that part of the body wall and test lying below the mouth, *i.e.* between it and the point of attachment to the rock. This naturally pushes the mouth upwards, and finally places it in a terminal position, at the point of the body furthest removed from the point of fixation. Budding produces a cake-shaped colonial mass of a general pink colour, flecked with white points indicating the position of the mouths of the various individuals or ascidiozooids.

With the assumption of adult form by Simple Ascidians, the genital glands develop, but among the Compound, a frequently long-continued course of budding, takes place prior thereto. All species are hermaphrodite, but as a rule the male and female organs do not ripen at the same time. The young produced are the tadpole larvæ we have above described.

Only within the last 28 years have the Tunicates bulked with large importance in scientific ken. Until 1866, when the Russian naturalist Kowalewsky published his famous researches and speculations upon the embryology of the group, they occupied a position of comparative isolation, with ill-understood affinities, and were generally treated as aberrant forms of little importance. Some were for placing them among the Mollusca, largely upon the count of their acephalous (headless) condition; others from the peculiar looped form of the alimentary canal would have that they were peculiarly developed relatives of the Polyzoa. The lowly development of the venous system favoured alike either of these views.

But Kowalewsky's researches altered all that, and gave the Tunicates a status of great importance. He pointed out how the adult Appendiculariæ and the tadpole larvæ of the fixed Ascidians bear many close resemblances to the lower vertebrates, especially to the Lancelet (*Amphioxus*), such for instance as the presence in both of a stiff central axis, the **notochord,** and the occurrence of a central nervous system expanding into a large cerebral vesicle at the anterior end. Finally he pointed out the perfect concordance of the perforations of the Ascidian pharynx, both larval and adult, with the gill clefts of the Lancelet specially, and of fishes generally.

Huxley and Haeckel warmly espoused this view so carefully and logically put forward, and now it reigns as the orthodox opinion. Prof. W. K. Brooks, who has within the last few weeks published an extremely valuable monograph upon the *Salpæ,* a group of much modified and altered pelagic Tunicates,* after a fresh and independent investigation from new stand-points and with many new facts to put into witness, fully endorses the same view, and states his belief that a simple pelagic form, of which *Appendicularia* is the nearest living representative, is the common ancestor of all the Chordata, *i.e.* alike of the Tunicata as of the Lancelet and all the Vertebrata.

Of course such theory can never be proved with mathematical certainty. It is at best a plausible probability, the most probable explanation of the mode of descent of the higher animals we at present know of. But there are, and have been, capable investigators who cannot bring themselves to accept it. Thus Prof. Giard, who as the first occupant of the chair of Darwinism at the Sorbonne, cannot be considered in any way a scientific reactionary, in 1872, after elaborate investigation of the Compound Ascidians, refused to endorse this opinion. He then could see nought but a convergence or coinci-

* "*The Genus Salpa,*" Baltimore, 1893.

dence in general form between Ascidian larvæ and lowly vertebrates, due he believed to a similar mode of life, *i.e.* free-swimming. He thus considered the adult as the true or fundamental form of the Tunicate group, and the larvæ not as a reminiscence of ancestral freedom, but as a larval form that for its special and temporary needs, assumed through like requirements of mechanical stresses, due to the adoption of a similar mode of progression, swimming, a form akin to that of a lowly vertebrate.

If we want to go astray in reasoning, it is often easy enough with the exercise of a little ingenuity or else of some obtuseness to sink deep in the mire of false deduction. Anyone not thoroughly master of an intricate subject may easily mistake cause for effect, and conversely, and I remember once when considering this Ascidian problem, thinking what a grand opportunity exists in the life-history of Appendicularians for such an one to go astray. Among these tiny tailed swimmers, the habit exists, at certain times, of forming a gelatinous envelope in which the animal lies enveloped for a short time—the " Haus " this has been termed ; and it is obviously homologous to the test of the fixed Ascidians. Now a very probable line of descent of the latter is from Appendicularians that have taken this " haus " stage as a permanent adult condition and so have deserted the free-swimming life—evidence being that the fixed Ascidians recapitulate very closely, in their larval condition, the general form, together with many of the essentially characteristic internal features of adult Appendicularians. But the student not thoroughly on his guard against the pitfalls of evolutionary reasoning, might easily deduce that the Appendicularians are arrested larvæ of fixed Ascidians ; that is, that certain larvæ instead of performing the full life-history of their race, retained the tailed form all their adult life, and that the occasional formation of the " haus " is the atavistic recollection of the fixed Ascidian condition ! !

In reality such conclusion is easily refuted, and there is really no reasonable doubt that the tadpole larvæ show the ancestral form fairly clearly. To mention one argument only, why should they have a nervous system infinitely superior to that of the adult, formed too on a plan entirely different from any to be found among invertebrates, but characteristic of vertebrates ?

Correction. —On page 18, line 6, read " ovary " instead of " ovum."

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THE LIFE-HISTORY OF THE ROCK BARNACLE, (BALANUS).

BY THEO. T. GROOM, F.Z.S.

(PART II).

THE question of the meaning of the various larval forms known, has, for many years, engaged the attention of naturalists, and, thanks to the writings of Darwin, Haeckel, Fritz Müller, Hatschek, Lang, Lankester, Balfour, Sedgwick, and others, we are gradually getting some idea of the true meaning of the facts of development. In the following pages, I do not pretend to set forth anything essentially new, but merely to illustrate some of the points which arise when one considers the development of animals belonging to such a group as the Cirripedia.

In comparing the anatomy of two animal forms, zoologists very commonly restrict themselves to a consideration of the adult forms alone. It is found, however, that in some cases the adult of a certain form resembles the larva of another form more than the final or adult stage of the latter, or more frequently that two forms widely different in adult structure have very similar larvæ. The structure and development of the curious parasitic Cirripede *Sacculina,* bears out these statements. The adult differs greatly from such a form as *Balanus,* though the Cypris-stages of the two show great agreement. In order to ascertain the true points of agreement of two forms, it is necessary, then, to compare not only the adult but also the young forms: hence the importance of embryology from a morphological point of view.

We may represent an animal form by the symbols A B C D, D being the adult, and A, B, and C successive stages in its development: now in the production of a higher form from a lower, we may suppose that all the stages of the lower form are passed through and a further condition reached. Thus we may get a new form E which shows in its development the stages A, B, C, D and E. Were the course of evolution as simple as this we can readily see that "the development of the individual would be a recapitulation of that of the race." Species, however, arise by the modification of old ones in more than one way. We may distinguish :—

(1) Species which have advanced in organization.

(2) Species which have retrograded.

(3) Species which are simple transformations of old ones, not higher or lower in organization, but possessing new characters.

In the two first-mentioned groups we may suppose a species A B C D E to have arisen from an older one A B C D, E being either a more complex, or a more simple form than D : in these cases the development (in the later stages at any rate) indicates the source of the race. In the third case, however, instead of the series A B C D we should get a new series A B C E, the stage D being omitted, owing to the selection of variations which appear as entirely new characters, and not merely as higher or lower conditions of the characters seen in the stage D. In this case, it is clear the development is only an incomplete recapitulation of the phylogeny.

In spite of this, were the adult the only variable stage, the task of tracing the ancestral history of a form would be much easier than it actually is. As a matter of fact, however, variations affect not merely the adult, but also the earlier stages.

If we compare the larvæ of two very similar animals, we shall not unfrequently find considerable differences; these can only be explained by supposing the larvæ to vary. It would, indeed, seem true that any variation in the adult, must, to a certain extent, be represented by a corresponding difference in all earlier stages, for each of the latter must possess all the potentialities of the adult; but independently of this the variations are considerable. One can readily convince oneself of this by comparing the very different kinds of larvæ seen in any one of a number of animal groups, such as the Insecta, Crustacea, Mollusca, &c. We may, then, represent a species derived from a form A B C D, not by the symbols A B C D E, but as A_1 B_1 C_1 D_1 E (supposing for the sake of simplicity that all the stages become thus modified): we might, however, get such forms as A_1 B_1 C D_1 E_1, A_1 B_1 C_1 D E, the stages C or D being supposed to remain unaltered. Further modification would lead to the successive forms A_2 B_2 C_2 D_2 E_1 F, A_3 B_3 C_3 D_3 E_2 F_1 G and so on. The later phylogenetic history of the last-mentioned form is D E F G : but D_3, for example, may be quite different from D, and E_2 from E. When modification in the development has proceeded so far, we might represent the new form by such a symbol as A B C P Q R G, the three earlier stages being supposed in this case to have remained unaltered, whilst the stages D, E, and F have become so much modified that new symbols P, Q, and R are required to indicate them; where the adults have changed little we might get such formulæ as A Q C D, P Q R D, &c. In such cases the development will only to a very limited extent express the history of the race. This "falsification" of the record was recognised many years ago, and Haeckel showed that in considering the development of any animal we must distinguish characters which were *palingenetic*, or ancestral, and characters which were *cenogenetic*, or acquired.

A further set of disturbances may be, and very commonly actually appear to be, set up in the development by the early or precocious appearance in the young form of characters belonging to the adult. Thus we may get sequences such as the following:—**A B C D**, A_1 B_1 d D_1, and A_1 d_1 d_2 D_2, the larval forms B and C being replaced by d_1 and d_2, which already show many characters originally confined to the later stage D.

The problem as to the value of a given larval form is thus a very complicated one, and we have to face the question as to how we can eliminate the cenogenetic or acquired larval characters. In the case of relatively rapidly acquired characters this can sometimes be done by comparing the development with that of remaining members of the group: if the embryos and larvæ of a form show characters which differ widely from those seen in the young forms of the rest of the group, we may reasonably believe that the development has been modified, especially if we can point to special features in the environment which would be likely to bring about such changes, or if we have reason to believe from the structure of the adult that we are not dealing with one of the most primitive forms of the group. Much may be learnt of the primitive mode of development by seeing which characters are common to the embryos and larvæ of the various members of the group, and valuable clues may be obtained by studying the development of the form to which adult anatomical structure points as the most primitive; for supposing all stages to vary equally in a given length of time, we may reasonably conclude that the adults which have been least modified will have the least modified larvæ.

Let us suppose that we have succeeded in eliminating many of the cenogenetic characters from the development, say, of the Barnacle, and have an idea of the series of young forms passed through by the immediate ancestor of the Cirripedia, we must still bear in mind that the development is not necessarily a recapitulation of the phylogeny. This point was overlooked by Fritz Müller in his classical work " For Darwin." This philosopher, seeing that the typical development of the Crustacea was by means of a Nauplius, concluded that the Nauplius represented an ancestral form of the group. To make this clear we may suppose that we have two Cirripedes, A_1 B_1 C_1 D_1 and A_2 B_2 C_2 D_2 : the close resemblance of the stage A_1 to A_2, of B_1 to B_2, &c., may at first sight seem only explainable on the view that A, B, and C represent ancestors. Thus if B_1 and B_2 represent Nauplii of two species D_1 and D_2 of the group, the resemblance between B_1 and B_2 is so striking (extending even to the minute character of the numerous hairs and other processes shown on the appendages) that we can only conclude that similar characters were possessed by the ancestral form; one might then jump to the conclusion that the Nauplius must represent an ancestor of the group: such a conclusion is now known to be unjustified, for the characters, though necessarily present in the ancestor at some stage in the development, were by no means certainly found in the adult condition; in fact so far as we can tell from the development of the two types, it is clear that they did not belong to the adult of the immediate ancestor, for the two adults present an equally great resemblance to one another in a totally different way, comparatively few of the striking characters of the Nauplius being found at this stage: the resemblances in the case of the adults are of such a character that we can only conclude that the similar characters in their case also, are due to inheritance from a common ancestor: the same may be said of each of the other stages, and it clearly follows that all we can conclude from the similar development of the two forms A_1 B_1 C_1 D_1 and A_2 B_2 C_2 D_2 is that the common ancestor had a stage corresponding to each of foregoing stages, and that the development may be represented by the formula A B C D. It does not, then, follow from this alone that B, for instance, is an ancestor of D_1 or D_2; at the same time nothing disproves this view: the question must be decided upon other evidence.

If the modification of forms leading to D has been a progressive one, C will represent an ancestral form, and its life-history will be A B C: the discovery of such a form would appear to furnish the only satisfactory evidence as to the ancestral history of D. Judged by this standard, the trochosphere or larva of many annelids, molluscs, &c., has great value, for we find a number of adult animals which are either practically in the trochosphere condition (Rotifera, Polyzoa, &c.) or are but little removed from it. The same may be said of the embryo of Birds and Mammals with its gill-slits, for we find more primitive forms (Fishes, &c.) which in their adult condition have functional gills, and share many other features with the higher vertebrate embryo. On the other hand, we find no adult forms at all like a Nauplius; the comparison, too, of the anatomy of adult Crustacea lends no support to the view that the ancestor of the whole group had the simple structure of a Nauplius, the common characters of the adult members of the group giving us a picture differing considerably from that of such a form. Many characters of this larva are, however, so strikingly like those of adult members of the group (e.g. presence of carapace, labrum, jointed appendages of special character, Nauplius-eye, caudal furca, dorsal anus, &c.) as to suggest that it is merely a form which has acquired early the characters proper to the mature form.

The study of embryology is, indeed, replete with questions of this kind. We may at first be inclined to chafe at the difficulties we meet, and to wish that the life-history presented us with a perfect picture of the history of the race, but it must be remembered that the reconstruction of the genealogical tree is not the only task of biology. The study of the special adaptations of larvæ to their surroundings is one of great importance: the adaptive relations of the adults have, indeed, formed a branch of natural history, but comparatively little has been done in viewing the young forms from this teleological point of view. We ought to have as accurate a knowledge of the use and adaptation of the parts of larvæ, as we aim at getting in the case of the adults. Interesting results have, indeed, been obtained in this direction, and amongst these I may specially mention Prof. Miall's late investigations on aquatic Insect larvæ, but a great field is still open to anyone who will undertake it.

Explanation of Plate I, Vol. II.

Life-History of Balanus (Part II).

Fig. 21. Tergum of young *Balanus balanoides* considerably magnified to show the punctures on the shell.

Fig. 22. Last Nauplius-stage (VI) of a species of *Balanus* obtained, together with the Cypris-stages of *B. balanoides*, from Jersey. In addition to the three pairs of Nauplius-appendages and first pair of maxillæ, the remaining appendages can be seen beneath the cuticle. The compound eyes can be seen through the antennules on each side of the Nauplius-eye: through the basal part of the labrum can be seen the œsophagus suspended by simple unstriated muscular fibres. The position of the gnatho-

base, or movable jaw-piece of the antennæ just behind the mouth can be clearly seen. Inside the antennules can be seen the developing prehensile antennules of the Cypris-stage, the newly-forming shell of which (Cypr. sh.) can be seen retracted from the carapace. The first pair of maxillae can be likewise seen retracted some distance forward from the external processes in which they were formed.

Fig. 23. Developing compound eye of a somewhat younger Nauplius of the same species, showing the polygonal retinulae, with their red pigment (which at the stage shown in Fig. 22, has become black).

Fig. 24. Side view of the Cypris-stage of the same species just after the moult, showing certain transitional features—a^1. prehensile antennule; a^2. relic of antenna; *cp. edge,* edge of carapace (not yet closed); *f. f.* frontal filament; *fr. l. ap.* aperture of fronto-lateral gland, marking former position of horn; *lbr.* labrum; *mn.* mandible; mx^1. first maxilla; mx^2. second maxilla; *o. gl.* oil globules; *rnf. gl.* reniform gland; *th.* thorax; *th. ret.* retractor muscle of thorax-abdomen.

Fig. 25. Ventral view of similar stage. Letters as in Fig. 24, also *th.* app^1. first pair of thoracic appendages.

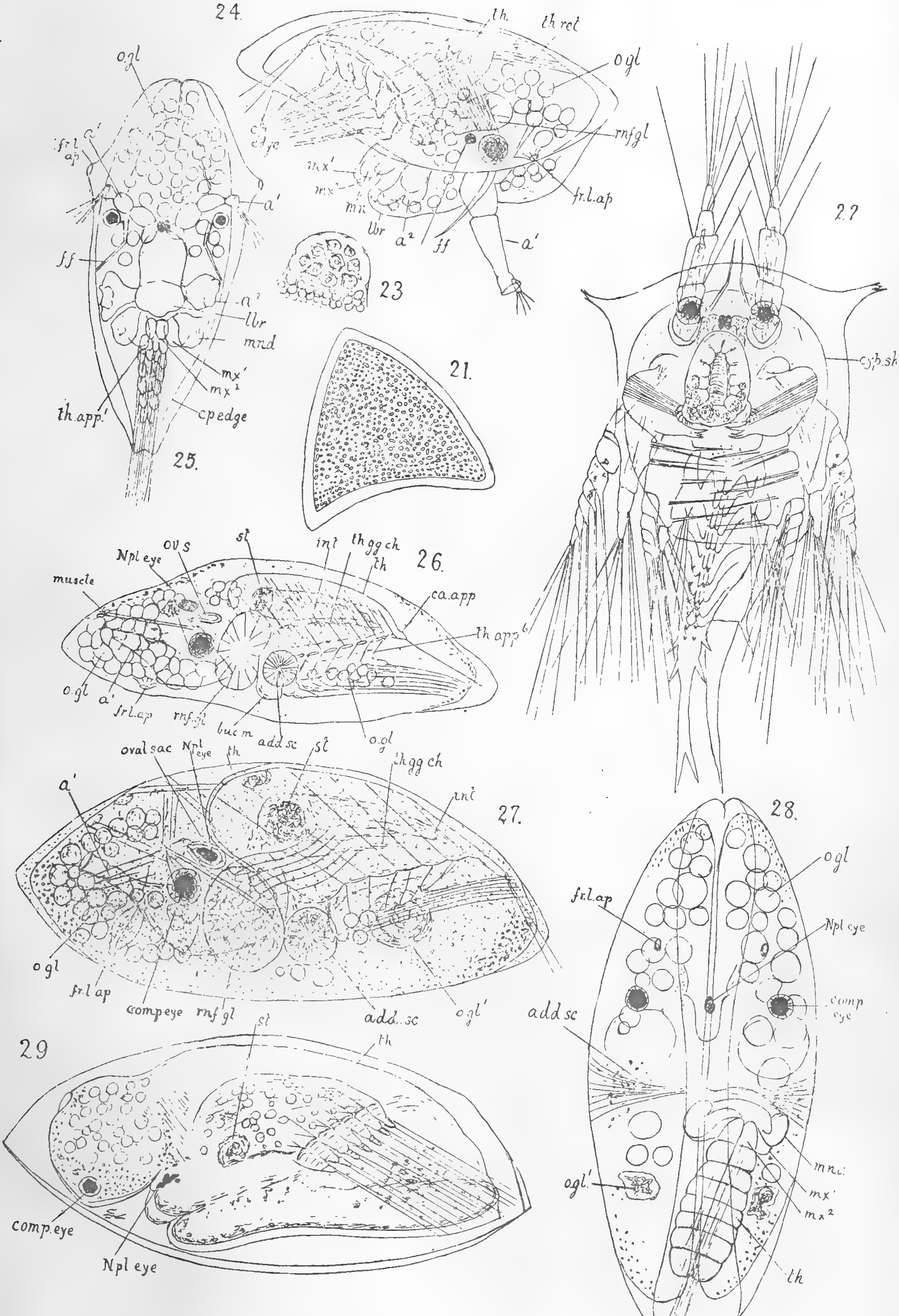
Fig. 26. Cypris-stage of an undetermined Cirripede, possibly that of *Chthamalus stellatus,* obtained from Plymouth.

Lettering :—*add. sc.* adductor muscle; a^1. prehensile antennule; *buc. m.* buccal mass; *ca. app.* caudal appendage; *fr. l. ap.* aperture of fronto-lateral gland; *int.* intestine; *Npl. eye,* Nauplius-eye; *o. gl.* oil globules (large and colourless); *o.* gl^1. masses of minute greenish yellow oil globules; *ov. s.* oval sac; *rnf. gl.* reniform gland; *st.* stomach; *th.* thorax; *th. gg. ch.* thoracic ganglionic chain.

Fig. 27. Side view of Cypris-stage of *Balanus balanoides.* Letters as in Fig. 26.

Fig. 28. Ventral view of same: the thorax lay obliquely in this specimen, an unusual condition. Letters as in Figs. 26 and 24.

Fig. 29. Cypris-stage of same species after fixation. The antennae, by means of which fixation occurred, have been torn away, having remained attached to the rock.



THEO. T. GROOM, DEL. AD NAT. J. HORNELL, SC.

THE DEVELOPMENT OF BALANUS.

ON THE IRREGULAR GROWTH OF THE SHELL OF THE COMMON LIMPET IN CONFINEMENT.

BY JOHN E. ROBSON, F.E.S.

Many years ago, when "The Aquarium" of the late Mr. Gosse gave such an impetus to the study of marine life, I became smitten with the prevailing fashion and determined to commence an Aquarium. Mr. Gosse did not say much about the difficulties in the way of success, and, in my ignorance, I imagined that marine animals would live in a small receptacle, just as they did in the little rock pools on the shore, not even taking into consideration the fact that these were over-washed twice a day by the tide. I was just ignorant enough to be unaware of my ignorance, and commenced with sufficient enthusiasm for a very much greater undertaking, had it only been tempered with a little knowledge or experience. I had a small gold-fish globe, holding perhaps a gallon of water, and this I deemed all sufficient for my purpose. I searched among the rock pools, and brought away one specimen of every different kind of small animal I could find, expecting them all to live and thrive in this little vessel. At least three species of fish, a small "dog-crab," a hermit crab, a shrimp, a periwinkle, a top shell, a limpet, the latter being on a piece of stone, partly covered with barnacles and small mussels. Some sand and fine gravel was put at the bottom, a few pieces of stone with seaweeds growing on them were piled up in the centre, and I expected I had done all that was necessary. Within twenty-four hours everything was dead, except the limpet. I could not understand it, but was quite ready to try again on the same lines. The dead animals were taken out, the barnacles and mussels scraped off the stone on which the limpet resided, more fish and other things were procured, only to share the fate of their predecessors. I am not sure that I even changed the water. Again it was re-stocked, but I removed the limpet from the stone, which now had a bad smell on the underside. The sides of the glass were beginning to be coated with green confervæ, and on this I placed the limpet. I had some difficulty in getting it to adhere to the double concave glass, which was very different from the level but rough surface of the stone on which it had resided. At last it fixed itself, and browsed contentedly away, mowing down the confervæ in regular curves as it slowly moved along. I do not wish to dwell on my continued failures, nor to record the slow process by which I eventually gained some little idea of the conditions necessary for success. While everything else perished, the limpet still survived, and at last I noticed it was adding to its shell. Ere long two things were apparent. First, the new shell was paler in colour than the old, and second, that the recently added portion was at a different angle to the original, so as to cover a larger surface, thus 

As the animal moved about, the shell was slightly raised from the surface, and owing to the double curve of the glass, it was evident it had to be raised more than was convenient or desirable. When the shell was widened it did not need to be raised so much.

This limpet lived a considerable time in this small vessel, and having now gained a little experience I ventured upon a further experiment. I procured a large propagating glass, had a stand made to fit the curved and knobbed end, and then had an Aquarium of considerable dimensions, holding several gallons of water. The glass formed only a single curve, the vessel being circular in shape, but the sides being straight. As soon as the sides had a coating of green I transferred the limpet to it. Here it lived for several months, during which time it again added considerably to its shell, and again the addition was at a different angle. 

Not so obtuse as the previous enlargement, nor yet so acute as the original shell. The change of angle was very distinct in each instance.

This I considered to be further evidence in support of the previous suggestion, that the shell was made wider so that the organs should not be unduly strained to raise it from the convex surface. The present glass, though not by any means so level as the rock on which it resided in a state of nature, had yet a curve of much greater radius than that of the former vessel, and the new curve was single, not double as before. Thus the changed angle enabled it to assume the required position with less inconvenience.

Was this the result of some volition on the part of the animal, or was it caused by the shell-secreting organs being forced from their normal position? In any case the change of angle appeared to be to the advantage of the animal, and I have no doubt were limpets reared from the commencement of their lives on curved surfaces like those of either of my vessels, the angle would be much greater, so as to produce a flatter shell than when they live on a level or nearly level rock.

A CONTRIBUTION TO THE ZONING OF THE SHORE.

BY JAMES HORNELL.

The zoning of the littoral of the south coast of Jersey, has of late attracted much of my attention. Here, owing to several physical causes, the conditions of life are most peculiar. The tide has a rise of fully 40 feet at certain times; the littoral is extremely broad and diversified—two miles of rugged reefs, rock-pools, gullies, and zostera banks, often intervening between high and low water marks; life competition is wonderfully keen, and the variety of this life is immense; finally, the mildness of the climate and the balmy warmth of the Gulf Stream waters that impinge on the coast, have stimulating effects upon the littoral life that can with difficulty be adequately appreciated by those not intimately acquainted with such influences.

Undoubtedly the most conspicuous instance of zoning is afforded by the olive-green (brown) seaweeds. On this coast they furnish well marked regions, and in descending order are :—

1. **Zone of Fucus canaliculatus,** some four to five feet broad—the upper edge not covered at high water of neap tides.
2. **Zone of Fucus vesiculosus** and **F. platycarpus,** extending from the lower edge of the preceding to half-tide mark.
3. **Zone of F. nodosus,** from half-tide down to five feet above low water.
4. **Zoue of F. serratus**—the five feet above low-water mark, where *F. serratus* grows *without intermingling* of other species. It is also found as far up as half-tide, *mingling with F. nodosus,* whose zone it thus overlaps.
5. **Zone of Laminaria,** extending downwards from low water, with an average breadth of 25 to 30 feet.

Another distinct set of zones on this coast is made thus :—

1. **Balanus zone.** The barren region covered with innumerable *B. balanoides,* lying between high water mark of spring and of neap tide.
2. **Limpet zone.** Somewhat overlapping the lower edge of the *Balanus* region, and ranging downwards to low water; the limpets grow very scarce as the Laminarian zone is approached.
3. **Haliotis zone.** Almost equivalent with "Laminarian zone." Characterized by the presence of the magnificent gastropod *Haliotis tuberculata.*

Sars and Loven and others intercalate a fourth zone, that of the pink seaweed *Corallina officinalis,* between 2 and 3, giving in descending order: 1, *Balanus;* 2, *Limpets;* 3, *Corallina;* 4, *Laminaria.*

Such cannot, in Jersey, be made out, for the *Corallina* region ranges considerably further than half way up the Limpet zone, and is indeed inextricably commingled with it, while Limpets are to be found almost at low water limit, though in small number.

As useful guides in fixing the vertical distribution of other animals, both these zonings are faulty; the first because of the frequent absence of fucoid growth in particular localities, and the second because we require a greater splitting up of the space to be mapped.

For this purpose it is indispensable to choose a group comprising numerous fairly common species, preferably sedentary.

The Sponges, I find, are too aggregated in the lower half of the littoral, to be serviceable. Thus the highest-living species, *Halichondria panicea,* is not met with at all above half-tide mark. It however forms a very well marked zone, extending in solid phalanx to within 5 to 4 feet from extreme low water, the intervening space being what I would term the **Pachychalina zone,** characterized by the presence of *Pachychalina montagui, Isodictya ingalli,* and a multitude of ascidians—*Ciona, Aplidium elegans, Morchellium,* and the *Botryllids.*

Below this, and corresponding with the Laminarian zone, comes a region for which, in the zoning of the Sponges, I would propose the term **Tetractinellid Zone,** signalised by the occurrence there of the massive sponges *Pachymatisma, Stelletta collingsi and Dercitus niger.* It may be noted, in passing, that one common Tetractinellid sponge, viz., *Tethya lyncurium,* is sometimes numerous in the Pachychalina zone.

The Ascidians are still more aggregated at low horizons than the Sponges, while the Hydrozoa and the Polyzoa are often so fastidious and erratic in their choice of habitat, that, to be used as general indices, they are ill suited. I do not, however, wish it to be understood that they are not to be found occupying well-defined zones. Far from this being the case, their dominions have very rigid bounds, capable of exact demarcation. I only mean that, for no apparent reason, they may be absent from their particular zone in one part of the shore, while common at the same height in another; a tantalising inconstance, if we desire to use them as shore-marks.

The group, which, after this process of elimination, I found to be the most generally useful in the demarcation of the shore, was that of the Anemones. Here is no massing of species within narrow limits; the range is well nigh up to high water mark, and progresses by well marked and fairly regular steps to deep water.

Highest is the zone of *Actinia equina, L. (A. mesembryanthemum)*, lurking in tiny pools and cool crevices quite up to high water of neap tides; very tolerant of, and indeed happy in, periodical exposure to the air. The vertical height of this region is probably about 12 feet, merging towards the lower margin into a narrower zone characterized by the presence, in crannies, of the lovely Gem Anemone, *Bunodes gemmaceus.* This zone is not always well marked, and at times, seems almost co-terminous with that of *Actinia;* where best shown, it forms a band beginning some 8 feet from high water of neap tides, and extending to some 4 to 5 feet further than the lower margin of the *Actinia* zone, *i.e.*, to some 16 to 17 feet from neap tide high water.

This region, at its lower boundary, passes rather abruptly into that of the extremely common and hardy *Anemonia sulcata* (Penn.)—the *Anthea cereus* of Gossé. Of the various species of Anemone, this is the most abundant here; common equally in rock-pool, among the fronds of zostera, and scattered over the stony surface of many of the bays. Not less than 10 feet vertically is taken up by this species, and so brings us to within 5 feet of the lowest margin of spring tides—an interval filled in by *Tealia felina (T. crassicornis)*, whose zone extends well down through the Laminarian region.

In the deeper parts of the Laminarian zone, the commensal anemone *Adamsia rondeletii* comes, while from the deeper water of the Coralline zone (20 to 30 fathoms), we obtain the other British species of the same genus, viz., *A. palliata.* Here too a large and pale-coloured variety of *Tealia* lives.

To tabulate these regions, we have, taken in descending order, the following:—

1. **Actinia equina zone;** Vertical range :—from high water to 12-ft. down.
2. **Bunodes gemmaceus zone**; do. :—8-ft., beginning at 8-ft. down.
3. **Anemonia sulcata zone**; do. :—10-ft., " " 16-ft. "
4. **Tealia felina zone**; do. :—the last 5-ft. of the littoral, beginning at 26-ft. down (also the higher part of the Laminarian zone).
5. **Adamsia rondeletii zone**; the lower part of the Laminarian and the upper margin of the Coralline zone; vertical range from 6 to 20 fathoms.
6. **Adamsia palliata zone**; the Coralline zone, from 18 to 30 fathoms.

All data from high water of neap tides.

MICROSCOPICAL STUDIES IN MARINE ZOOLOGY.

BY JAMES HORNELL.

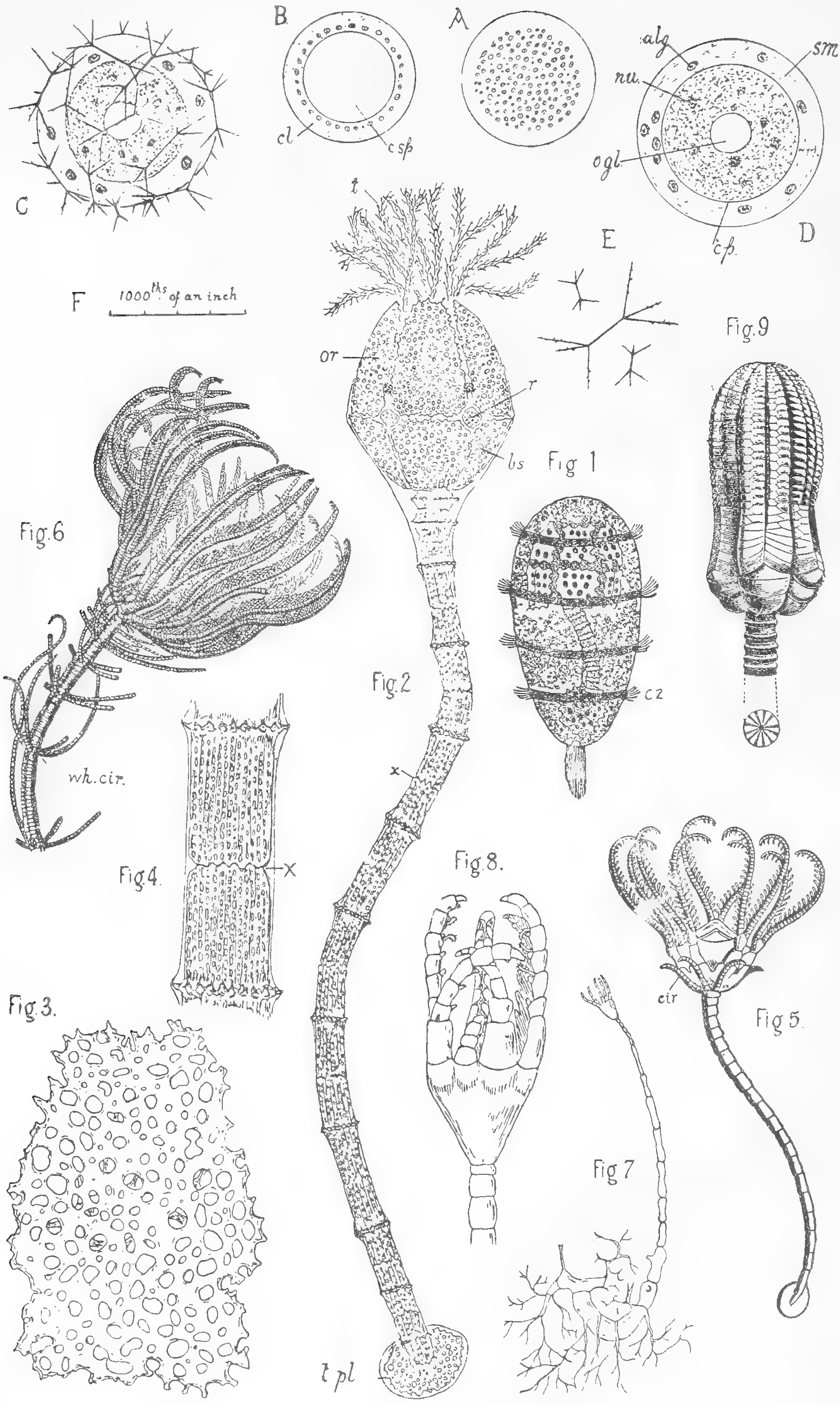
Study XIV.—Sphærozoum punctatum, a Colonial Radiolarian.

No group of animals possesses such intense interest to the Biologist as does that of the Protozoa. Located on the very outskirts of life, one searches among their lower forms and studies their every phase and attribute, in the hope of obtaining the faintest clue as to the origin of life itself. Their higher developments we scrutinize equally closely, for evidence as to the particular evolution of the sponges, simplest among the higher animals—those Metazoa whose bodies are made up of aggregations of cells, not one of which is, of itself, capable of prolonged separate existence, but requires the co-operative assistance of other units, other cells, to carry on "life."

The Protozoa are, we know, typically unicellular, but many of the most interesting forms seem very closely to counterfeit the metazoan plan; though ever with this distinction,—separate one of their cells, and straightway it can sustain long life and multiply its species as though nothing radical had occurred. With these latter, our attention now lies.

Most of us have seen, and admired with enthusiasm, that lovely emerald-jewelled rotating globe of colonial life, the tiny *Volvox* of our ponds. And though we cannot nowadays accept the firm belief entertained by mariners of ancient times, that the sea contains counterparts of everything moving on the land and in fresh water, yet as regards *Volvox*, we may claim in *Sphærozoum* and its allies, at least forms having many outward resemblances.

Sphærozoum is a colonial Radiolarian in which the skeleton consists of loose spicules surrounding each individual of the colony, but before going into details of anatomy, it will be well for us to cast a survey over the group wherein it is included. In the first place, Radiolaria belong to that group of the Protozoa known as the Rhizopoda, animals where locomotion and the capture of food is effected by extensions (**pseudopodia**—" false-feet ") of the outer layer of the body, **ectosarc.** The well-known *Amœba*—long ago known as the proteus animalcule on account of its constant change of shape, due to the thrusting out of these pseudopodia first from one spot and then from another—is one of the most primitive members. It is little else than an animated microscopic speck of granular jelly-like protoplasm, **endosarc,** surrounded by a slightly denser and clearer layer, the **ectosarc;** having a peculiarly-endowed dense speck, termed the **nucleus,** embedded in the endosarc, and wherein lies the potentiality for future multiplication.



Jas. Hornell, Del. ad Nat.
Figs. A to E, and 1, 2, 3 & 4.

SPHAEROZOUM AND LARVAL ANTEDON.

Explanation of Plate II, Vol. II.

Figs. A to F, Sphærozoum punctatum.

Fig. A. Natural appearance of a colony, showing the numerous individuals surrounded by the clear layer of the calymna. × 6.

Fig. B. Diagrammatic section through the same, showing it to consist of a hollow sphere; *cl.* calymna; *c. sp.* central space.

Fig. C. View of an isolated individual surrounded by a loose network of spicules.

Fig. D. The same, with spicules removed.
o. gl. great oil-globule of capsule; *nu.* one of the several nuclei; *cp.* capsular membrane; *sm.* sarcomatrix; *alg.* symbiotic algæ.

Fig. E. Three of the six-rayed spicules.

Fig. F. Scale of magnification of Figs. C, D, E, 3 & 4 (all original).

Figs. 1 to 9, Crinoids.

Fig. 1. Free-swimming larva of Antedon (Rosy Feather Star), with the calcareous plates of the stalked larva formed within. *c. z.* one of the four ciliary zones. (After Thompson).

Fig. 2. Young attached larva of same; *t. pl.* terminal or attachment plate; *x.* articulation of the joints of the stalk; *bs.* a basal plate of the calyx; *or.* an oral plate; *r.* a radial plate just beginning to form; *t.* circle of tentacles round mouth. (Original).

Fig. 3. An oral plate magnified to scale of fig. F. (Original).

Fig. 4. Halves of adjoining joints of stalk, to show their cribriform nature and mode of articulation at *x.* Same magnification. (Original).

Fig. 5. A later stage than fig. 2, and just prior to commencement of adult life. The dorsal cirri (*cir.*) and 5 pairs of arms have just appeared. (After Thompson).

Fig. 6. *Pentacrinus caput-medusæ* (after J. Müller), a form stalked throughout life. The stalk has whorls of cirri (*wh. cir.*) at intervals.

Fig. 7. *Rhizocrinus lofotensis,* a young individual (after Sars). This species remains stalked all through life, but instead of a basal plate of attachment, is anchored by ramifying root-like processes which twine round stones and other objects.

Fig. 8. Magnified view of the "head" of an older stage of same.

Fig. 9. *Encrinus liliiformis,* one of the most numerous of fossil crinoids.

Explanation of Plate III, Vol. II.

Creseis acicula.

Fig. 1. *Creseis acicula.* Several of the internal organs are drawn in optical section. *a.* anus; *al. gl.* receptaculum seminis; *c. f.* ciliated furrow for conveying spermatozoa from the sexual orifice to the penis; *ci. sh.* ciliated shield, respiratory in function; *f. n.* main branch of fin-nerve; *g.* subœsophageal portion of central nerve mass, showing the great fin-nerves being given off from the anterior corners, and the otoconia lying beneath; *h. d.* duct of receptaculum seminis; *h. gl.* ovo-testis, or hermaphrodite gland; *i.* intestine; *l.* liver; *m. l.* middle and rudimentary lobe of foot; *m. n.* mantle nerve; *np.* nephridium; *o.* mouth; *oe.* oesophagus; *ot.* one of the two otocysts, containing, not a single spherical body or otolith, but numerous small calcareous bodies, whose mass is termed an otoconia, (the function of these bodies is supposed to be auditory); *p. o.* penial aperture situated at the base of the rudimentary right tentacle; *p. g.* penial gland, or rather, the indrawn penis; *r. m.* retractor muscle; *sh.* shell; *st.* stomach; *sw. l.* swimming lobe or fin; *ut. di.* uterine dilatation; *ve.* ventricle of heart.

Fig. 2. View of an entire *Creseis* (Fig. 1. had to be drawn in two portions, as the length was too great for the size of the plate).

Fig. C shows the homologies of a typical Pteropod larva, (*Cymbulia*), with the larvæ of typical Gastropods, A and B; A being a younger and B an older stage. (After Gegenbaner). *v.* velum; *c.* shell; *f.* foot; *op.* operculum; *t.* tentacles.

Fig. D. Diagram of a simple bilaterally symmetric or Isopleurous Gastropod (*Chiton*).

Fig. E. Diagram of an asymmetric or Anisopleurous Gastropod.

Fig. F. Diagram of a naked Pteropod.

Fig. G. " " thecate or shell-bearing Pteropod.

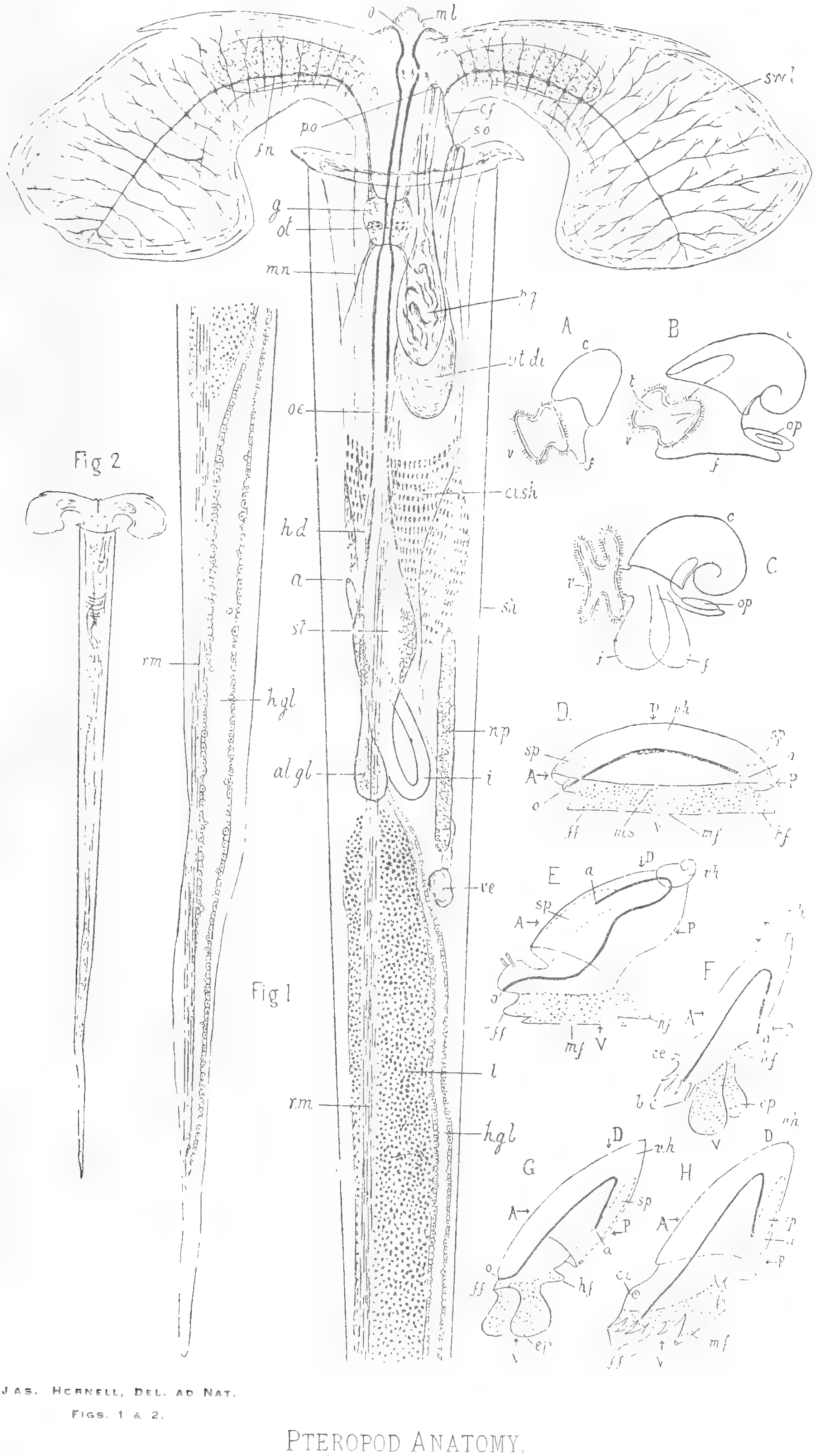
Fig. H. " " Cephalopod.

(All after Lankester, G being modified).

D, V, A, and P point respectively to the dorsal, ventral, anterior, and posterior aspects of the body.

The extent of the foot in each case is denoted by the dotted shading.

o. mouth; *a.* anus; *ff.* fore-foot; *m. f.* mid-foot; *h. f.* hind-foot; *ep.* epilobium; *c. e.* cephalic eyes; *s. p.* sub-pallial space; *m. s.* mantle skirt or flap; *vs.* visceral hump or dome.



JAS. HORNELL, DEL. AD NAT.
FIGS. 1 & 2.

PTEROPOD ANATOMY.

A higher division of the same Rhizopoda are the Foraminifera, animals of the amœba-type endowed with the faculty of building up a skeleton, usually of lime (calcium carbonate), from whose surface and from apertures in which, are given off numerous long whip-like threads of protoplasm, or pseudopodia, locking and inter-locking with one another (anastomosing); the same in kind, though differing markedly in degree, as the few coarse and short pseudopodia of *Amœba*. Then we cross at once to the class we have to deal with, the Radiolaria, where the power lies of building up a skeleton of flinty matter (silica) the same in chemical composition as the fine quartz crystals from which much optical glass is made. But this spicular coating is not essential to existence, for many species (*Collozoum*) possess none. Let me therefore consider such an individual, which may be taken as representing the fundamental or primitive type of Radiolarian, the skeleton being an after assumption in the class, though in *Collozoum* the absence is not due to primitive want of it, but rather to degeneration.

Comparing with Amœba, we would say that in the Radiolaria the body is nearly constant in shape to the globular form, and what answers to the endosarc of the other, is separated from the outer layers by a membrane (chitonous ?) which we term the capsular membrane. This is pierced usually by numerous minute openings and bedded in the protoplasm within the capsule (intra-capsular), lie several nuclei—a characteristic of the group, and a very large oil-globule.

The extra-capsular substance consists of two well defined layers, the inner **(sarcomatrix)** which invests closely the capsule, is protoplasmic and granular; while the outer layer, the **calymna,** is of a structureless, gelatinous nature. From this layer arises an often wonderfully beautiful flinty (siliceous) skeleton, built up sometimes as a lattice-work bell, or it may be into a lace-work globe with great projecting spines. The calymna is penetrated by delicate tubules through which pass fine threads of protoplasm originating from the sarcomatrix. Having passed through the calymna, these threads pass out on the surface of the globe into a network, the sarcoplegma, and from this are projected into the water around, long filamentous pseudopodia, closely akin to those of the Foraminifera. With these long tendrils, prey is entangled and is then passed inwards.

The vast majority of Radiolarians—and their name is legion—are such as we have described, but a small group live colonial lives, numerous individuals massed in tiny communities, and modified in certain points consequent upon the mutual duties devolving upon the several individuals.

Thus the individual skeleton is reduced and even lost. In *Sphærozoum*, each individual is surrounded by a lattice-work of loose spicules of the elegant six-spined form shown at fig. E, Pl. II. In other species, it is absent (*Collozoum*). Sometimes these colonies reach considerable size. *Collozoum* attains a full inch in length. *Sphærozoum* is smaller and usually globular, perhaps $\frac{1}{12}$-in. in length, but sausage-shaped colonies of $\frac{1}{4}$-in. long are fairly common. 200 to 300 individuals are frequently associated together, being arranged peripherally in a hollow gelatinous sphere, arising from the general coalescence of the gelatinous outer extra-capsular layer (calymna) of each member. This layer being common to all, it follows that the protoplasmic network of the surface, and the radiating pseudopodia are also common, ensuring the even distribution of nutriment. Thus in a Radiolarian colony such as *Sphærozoum*, we have each individual with its own separate central capsule, its own separate sarcomatrix and its own protecting lattice work of spicules; but calymna, sarcoplegma and pseudopodia are shared in common by the colony.

If we examine carefully the sarcomatrix of *Sphærozoum*, we see a varying number of deeply stained bodies lying irregularly spread in the sarcomatrix of each individual. Some have many, some have few, and it may happen that we may see some possessing none. In life, these bodies are yellowish, and it is inferred that they are parasitic, or, more probably, symbiotic algæ. It appears that these yellow cells can live equally well, and even multiply, when separated from their host. Each has been found to possess a distinct cell-wall of cellulose, a nucleus, two colouring matters, one of which is chlorophyll, and lastly, to complete the vegetal characters, the power of forming starch. They are present in nearly all species, though some individuals are occasionally free from them. In the present species, some individuals are crowded with them, while others have comparatively few. These cells multiply within the host by the division of their protoplasm into four parts which secrete separate cell-walls and then break through the parent membrane. If removed from the host, they eventually become biflagellate, *i.e.* provided with two whip-like threads of protoplasm, flagella, their locomotive organs. Some have referred them to a distinct genus of algæ, while others believe them to be the swarm spores of several species of olive-green seaweeds (*Fucus, &c.*) It is probable that they assist in the respiration and nutrition of their hosts, by contributing oxygen and starch.

The **reproduction** of the Radiolaria is most intricate, and betokens the high development to which the group has attained. If we take a fully adult colony of *Sphærozoum*, we find that the individual members, at a certain period, break up into innumerable tiny spores; these spores may be of two distinct series. Thus one colony may give rise to spores all of the same size, **isospores,** while another may give rise by another method to spores of two sizes **(anisospores).** The former are probably asexual; the latter sexual, giving a typical alternation of generation. Both forms are produced within the central capsule. In the formation of isospores, the nuclei of the parent multiply by fission and scatter throughout the capsular protoplasm; each nucleus appropriates a certain amount of protoplasm, and a minute crystal, and receives several tiny oil globules from the breaking up of the great oil globule. When ripe, each of these masses assumes a pear-shaped form, with the nucleus at the narrow end, whence proceed two flagella which propel the spore through the water, when liberated by the breaking down of the capsular membrane and when disintegration of the extra-capsular matter takes place.

Anisospores arise also from the multiplication of the mother-nuclei, but the mode is somewhat different. Within the same individual, two well-marked sizes occur; the larger are termed **macrospores,** the smaller **microspores,** and they escape in the same way as do the isospores. Analogy suggests that in these macro- and microspores we have a sexual stage, but the conjugation of these two bodies, which is required to prove this theory, has not been observed. The shape of both forms of anisospores is reniform (kidney-shaped); they are propelled either by one or by two flagella. Isospores and anisospores alike give rise to an ordinary Radiolarian having the typical structure. This by fission of the central capsule repeated frequently, and by gemmation also (?), produces the colonial mass we have before us. Then when the full of adult life is reached, the intra-capsular protoplasm breaks up into either iso- or anisospores. The Life-cycle of such a Radiolarian can be tabulated thus:—

1. Isospore (asexual spore).
2. Young Radiolarian individual.
3. Colony (produced by fission and gemmation).
4. Anisospores = macrospores, and microspores (Sexual spores) (?).
5. Conjugation of macro- with microspore (?).
6. Young Radiolarian individual.
7. Colony.
8. Isospore (asexual spore).

Stage 4 may not necessarily alternate with stage 8; indeed it is probable, by analogy, that under favourable life-conditions, the formation of anisospores seldom occurs—many repetitions of isospore generations taking place before one of the anisospore stages recurs. The latter probably occurs when new vigour requires to be infused into the organism, either through weakening occasioned by too frequent repetition of the isosporulation, or else from external life-conditions of an unfavourable nature.

It is worthy of note that the tendency among colonial forms is towards the suppression of a skeleton. *Collozoum* has none; *Sphærozoum* has loose spicules only. The reason probably is the hindrance to the formation of new individuals by the fission of the central capsule, which a hard resistent casing to the latter would entail. With loose spicules, if the central capsule divides, then each half simply takes its share of the spicules with it.

Distribution. All latitudes know the Radiolarians, but they abound most in the warm seas between the tropics. The majority are pelagic; *Sphærozoum* and *Collozoum* among the number. Many of the great depths of the sea are covered by ooze formed all but entirely of their decaying remains, *e.g.* 2—3000 fathom depths of the Pacific and Indian Oceans. To other deep ocean oozes, the Red-clay deposits, and the *Globigerina*-ooze, they contribute largely. The familiar Tripoli powder, used for polishing, consists largely of their remains; many fine whetstones are slaty rock formed in great part of their siliceous skeletons. In many lands they largely compose certain clays and marls, thus indicating, albeit in fragmentary manner, the localities of uprisings of some ancient sea-bottoms of great depths. Deposits in the Barbadoes and the Nicobar Islands, in Algeria and Greece, are the best known of these—and it is from such localities, especially from the first-named, that are obtained by careful washing and separation, those beautiful fossil forms so well known as microscopical preparations. These are all of Cainozoic age, but other fossil species date from early Palæozoic times, while in Jurassic rocks, they even form quartzite, so compactly are they knit together.

Study XV.—The Hydroid stage of Obelia geniculata.

Obelia constitutes a very typical form of Thecate Zoophyte, and a study of the slide now sent out, taken in conjunction with reference to Study XI, and Plate IX in last volume, will furnish materials for a ready comprehension of the essential details of the anatomy and of the life-history.

Study XVI.—The stalked larva of Antedon.

Few of us are unfamiliar, at least by name, with *Antedon*, the Rosy Feather Star. The extreme elegance of its long slender arms has long made it famous among the artistic triumphs of the world of life, rivalling in slender gracefulness even the rare beauty of the ferns. To those who have however seen it in life among its natural surroundings, the charm deepens, and *Antedon* is for ever linked with happy life-marks fondly remembered. Shall I ever forget that day out lobster-potting with an old fisherman, when the first pot we pulled up, was fairly encrusted with the rosy twining pinnated arms of this most lovely of starfishes! Surely if the fisherman's calling is rough and uninviting at times, such experiences as these go far to compensate. Rough fellows most are, but the sea has a silent eloquence that finds its way to their hearts, and to those who have served the apprenticeship, its fascination is magical; even I, who have other pleasures, and have never been fairly inoculated, have still at times to respond to the urgent calling of the sea.

Antedon is fairly common around the British Coast; in favorable localities occurring in great multitudes. In anatomy it differs extremely from the ordinary stout starfishes, such as the common cross-fish *Asterias rubens*, but as we are not concerned at the present with its anatomy, suffice it to note that its body consists of a disc some ½ inch across, from which proceed ten long slender arms bearing numerous pinnules on either side, these often reach 3½ inches in length so that the animal has a full span of 7 inches. The sexes are separate, and the genital organs are located not in the body disc, but in the tiny pinnules of the arms. The fertilized ova are set free as barrel-shaped embryos which acquire four encircling or zonal bands of cilia—the hoops of the barrel—propelling it through the water. Next appear a few minute calcareous plates within this embryo, forming as it were, a tiny cask set up on an even more tiny stalk. Free-swimming life being now all but ended, a disk containing a perforated plate appears at the lower extremity of the stalk, and by this, attachment is made to any object that happens in the way; it may be the stiff framework of a colony of Hydrozoa or of Polyzoa, or it may be a frond of the great oar-weed *(Laminaria)*. All this time the soft barrel-shaped mass of the swimming larva has been shrinking and adapting itself to the form of the enclosed calcareous skeleton, and now the creature is fairly launched upon the stalked and anchored period of its life.

In this stage the skeleton is made up of a basal plate (Pl. II, fig. 2, *t. pl.*) where the animal is rooted to its host; a considerable number of joints set end to end, forming the stalk, upon which is seated the cup-shaped framework of the body, consisting of two circles of large perforated plates, the members of each, superposed to one another. These are respectively the **basals** *(bs)* and the **orals** *(or)*, the former forming the base of the cup, supported on the summit of the stalk, while the orals are the upper ones, receiving their name from their encircling of the mouth. All these plates can be made out in the last stage of the swimming embryo (fig. 1) and characterize the stage of most of the fixed larvæ in the microscopic preparations accompanying this article. A few however show a further stage, where a third row of tiny plates is intercalated between the two original rows of basals and orals; these small plates are the **first radials** *(r)*, each is alternate with the larger plates of the skeletal basin. The several rows may be formulated thus :—

O O O O O
R R R R R
B B B B B

Each ring will be noticed to comprise five plates, the fundamental echinoderm index. The mouth, as before mentioned, is centrally in the calyx formed by these perforate or **cribriform** plates, and is surrounded by a row of tentacles armed with a limited number of delicate thread-like processes.

Growth after this is rapid, a second circle of radials appears superposed to the first and then a third upon the second. From the third proceed the arms double the index number, two being borne on each third radial, which has two fascets for this purpose on its upper surface. At the same time the topmost joint of the stalk has been enlarging and becomes a great plate-like structure, the **centro-dorsal** plate from which arise a number of claw-like jointed organs, the cirri.

Soon after this, the body with its now long arms, breaks off from its stalk at a point just below the centro-dorsal plate, and enters upon adult life, free at will either to creep amid the mud or rocks, or to swim with rythmic beats of its long feather-like arms through the water. It is however doubtful if it makes much use of its powers. It certainly does not travel far from certain favorite localities, where it is usually found gripping stones or weed with the circle of hooked cirri borne on the centro-dorsal plate. When disturbed, its mode of swimming is extremely graceful, the arms being alternately contracted and expanded as in the pulsations of a medusa.

For long, the stalked larva was considered a distinct animal from the adult, receiving the name *Pentacrinus europæus,* as it was believed to be a tiny relative of that large and lovely stalked crinoid, *Pentacrinus caput-medusæ,* from the Antilles, then known from rare specimens held precious by a few fortunate museums.

Special interest attaches to this beautiful creature from the great part played by its relations, if not its ancestors, that lived during former periods of the world's history, for the Encrinites whose remains have contributed so greatly to build up the huge masses of our mountain limestones, and many of our Jurassic beds, were but gigantic Pentacrinoids of structure practically identical with the stalked larvæ of *Antedon*, that seem so like tiny attenuated Pentacrinoids.

STUDY XVII.—CRESEIS, A TYPICAL PTEROPOD.

The struggle for mastery and bare existence gives many unexpected results: we see the huge monsters of ocean, not of true finny lineage, but interlopers from the land; we see the cousins of our starfishes and sea-urchins, taking on the outward form of burrowing worms; insects become, in appearance, indistinguishable from sticks and leaves; birds leave their kingdom of air, and pursue their livelihood amid the waters, seeking prey by diving and swimming; but perhaps stranger than all, the butterflies of ocean, whose winged and shimmering myriads are familiar to voyagers on the high seas, are nowise akin to the gaudy visitants to our flowers; neither have they relationship, as we might excusably guess, with the great group of the Crustaceans. The latter, diverse as the insects in habit, and ready as they, to change form, and to adapt themselves to any new life where there may be a prospect of easier existence, yet put in no claim to the title, and it is reserved to the humbler molluscs—to creatures allied to the slow creeping snail, and lethargic limpet—to furnish representatives charged with the duty of peopling the waves with gay flutterers. Yes, the Pteropods, as the Butterflies of the Sea are called, are undoubted molluscs, closely related on the one hand to such Gastropods as the snail, on the other to the Cephalopods—the Octopus and Cuttlefish. But before discussing their place in Nature, let us examine the anatomy of the typical form, *Creseis acicula* (Rang), which is the subject matter of this paper.

Creseis is the most slender, but not the shortest of Pteropods. The body is lodged in a delicate needle-shaped shell (whence the name *acicula*), not $\frac{3}{4}$-in. in length. This shell, transparent and colourless, and composed of carbonate of lime, is very gradually tapered and extremely narrow, even at the broader end. The pointed end is closed, while from the other protrude two tiny wing-like fins, the means of locomotion—hence the significance of the term Pteropod or "wing-footed." Coinciding with the form of the shell, the body is greatly elongated, especially that part lodging the central portion of the viscera—the visceral hump or dome, which is spoken of as the upper end of the animal (see last paragraph of this article). The shell is lined and produced by a fold of the body-wall, called the mantle, between which and the body, a large space, the mantle cavity, is formed, lying on the posterior aspect of the body, and opening to the exterior by a slit at the ventral end, *i.e.* at the mouth of the shell.(1)

There is no distinguishable head, and of head appendages only two tiny, easily overlooked, tentacles lying just behind the fins. These have evidently suffered degeneration, showing in their minute size, and in the tiny eye-speck at the tips, but little resemblance to the great organs so familiar upon the head of the snail.

Two slight eminences guard the entrance to the mouth. Within this a radula or teeth-bearing ribbon is found, whence a long œsophagus leads straight backwards or rather upwards, into a dilated stomach. The intestine is continued backwards for some distance, then abruptly turns and passes forwards (downwards) to open laterally into the mantle cavity at a point on the left side.

Lying close to the intestinal bend, is the anterior end of the enormous sausage-shaped secretive organ which for convenience we may term **liver** (*l*). It runs backwards parallel with the anterior half of the ovo-testis.

As regards muscular tissue, such is developed sparsely except in the fins, and in a great strand of fibres that originates from a point only a little below the apex of the shell, runs parallel with the ovo-testis and liver, thence forward and to the right, to the oral end of the body, and to the copulatory organs. Its name, the *retractor muscle*, denotes its function.

On the right side, in the region of the intestine, lies an elongated cylindrical organ, the **nephridium** or kidney. This has at one end an opening communicating with the exterior, while at the other —the end turned towards the apex of the visceral hump—a passage is found leading into the pericardium. Probably this is a means for introducing sea-water into the blood at stated intervals, thus giving an additional and interesting function to the nephridium.

The heart, lying dorsal, to the nephridium and like it on the right side of the body, consists of a globular ventricle and of a delicate auricle. From the former a large artery is given off, leading into several smaller branches. These however, instead of in turn leading into capillaries and thence into veins, open into an irregular chain or network of indefinitely shaped spaces **(lacunæ)** disposed in the tissues, and without definite walls. From these the impure blood is gathered into a large venous or pericardial sinus, whence it is passed into the auricle.

(1). To arrive at the right application of the terms dorsal, ventral, anterior, and posterior, to the body of a Pteropod, one must picture it as in fig. G, Pl. III, the mouth downwards and the apex of the shell directed upwards.

The respiratory region in this species lies on the inner side of the mantle, therefore on what is apparently the ventral aspect of the animal, but which strictly is the posterior. In some species the general surface of the mantle functions, but in this, the chief seat of respiration is a shield-shaped area in the region of the stomach, where the mantle is thrown into curved and transverse folds, bearing cells richly ciliated, whereby the water is kept continuously in motion.

The central mass of the nervous system is formed by the concentration of three pairs of ganglia around the anterior end of the œsophagus; that part lying above, representing the supra-œsophageal ganglia; that beneath, of two pairs, named respectively the visceral and the pedal ganglia. Nerves going to the mantle and to the alimentary organs can readily be traced proceeding from the hinder part of the nerve-mass, but in size, these are far surpassed by two enormous nerves (*f. n.*) given off, one on either side, by the pedal ganglia, for the nerve supply of the swimming fins. Each on entry, throws off a smaller branch, and then proceeds to give off with remarkable regularity, some 20 pairs of lateral nerves at short intervals. Each pair consists of a right and a left nerve originating from the same point. The same arrangement is repeated by the smaller branch.

For so small an animal, the reproductive organs are extremely complex and are complicated by the creature, like all Pteropods, being hermaphrodite. Ova and spermatozoa are produced in the same gland, the **ovo-testis** or hermaphrodite gland. This lies, as a compact elongated mass, in the hinder (dorsal) end of the body, parallel with the liver. It is connected by a fine efferent duct with the sexual orifice which opens on the right side just dorsal to the base of the right fin. Connected with the lower end is a side pouch—the uterine cæcum. Another pouch-like organ of equally great size, opens close by the genital aperture, and just at the base of the right rudimentary tentacle (*p. g.*) This is the invaginated (indrawn) penis or penial gland, the external male sexual organ, highly specialised as in the gastropod molluscs, and here as in other Pteropods, of very large size. The spermatozoa pass from the common sexual orifice to the penis by a short ciliated external gutter or furrow (*c. f.*) Self fertilization is obviated by the male and female elements maturing at different periods. When copulation with another individual takes place, the great penis is evaginated and inserted into the uterine cæcum, the spermatozoa pass in, and thence are conveyed to a small vesicle, the receptaculum seminis, there to await the arrival of mature ova from the hermaphrodite gland. When this occurs, the sperm escapes from its confinement and fertilizes the ova, which are then ejected in long gelatinous cords that float hither and thither at the mercy of the waves till hatching takes place.

Adult Pteropods all progress by jerky flappings of the wings. Agassiz says they can remain suspended in the water for hours, simply by spreading these wings, and then suddenly drop to the bottom by folding them. They are also said to creep about by means of these same appendages.

The group of Pteropoda is not large, and its members fall naturally into two well marked divisions—those like *Creseis*, with a well developed shell, form the order **Thecosomata**; those naked and without shell, the **Gymnosomata.** Few are ever seen near land, they prefer the high seas, and are spread under all latitudes, little more plentiful in the Tropics than in the Northern regions of Baffins Bay and Davis Strait and the Polar Sea generally—where indeed the multitudes of two species, *Clione borealis* and *Limacina arctica*, form a substantial item in the dietary of the whale.

In considering the place in nature of these animals, the possession of an odontophore (lingual ribbon or radula) at once discovers their close relationship to the Gastropods and to the Cephalopods, and with these and the little group of Scaphopods (*Dentalium*), form the compact branch, **Glossophora,** ("tongue-bearers"), of the phylum Mollusca. (*a*) In the arrangement of the genital system, the Pteropods are extremely like many forms of hermaphrodite Gastropods; the snail and the sea-slug (*Aplysia*) for example, agreeing closely in all the larger details, while in this, they differ markedly from the Cephalopoda, where the sexes are always separate. (*b*) Outwardly usually bilaterally symmetric like the Cephalopods, Pteropods are all fundamentally asymmetric, and here again approach to the most usual Gastropod likeness, for as in the latter, both the anus and the sexual organs are lateral and asymmetric, the one in *Creseis* being turned to the right, the others to the left. (*c*) A third link with the Gastropods is found in the possession by certain genera (*Spirialis*) of an operculum. (*d*) On the other hand, Pteropods of the shell-less group, have processes developed from the "head," of arm-like form; in some cases even bearing suckers—a wonderfully close approach in appearance to the familiar arms of the Octopus and the Cuttlefishes. So close, indeed, is this resemblance, that Prof. Ray Lankester has not hesitated to class both Pteropods and Cuttlefish in one all-embracing division, the Cephalopoda, forging a new term, Siphonopoda, for the diverse company of the Octopus, Nautilus and Cuttles. Such considerations as *a b* and *c* make against this view, and it is significant that the nerve supply to these head-arms has different origin in the two divisions, being supplied from the brain (cerebral ganglia) in the Pteropods, and from the pedal or foot ganglia in the Cuttles. Hence it seems much more likely that the resemblances between the Pteropods and Siphonopods are rather homoplastic than homologous, *i.e.,* have arisen independently rather than being possessed of common origin. Like circumstances not infrequently produce analogous shapes and organs in animals of distant relationship, and the case in point is probably of this nature. It is to be remembered too, that it is only the division of shell-less Pteropods that in any way simulates the appearance of the Siphonopods; the shell-bearing forms (Thecosomata), such as *Creseis,* are very closely approximated to the Gastropods in all details of organization. Thus we may conclude that the Pteropods are a branch from the Gastropod stock, modified by pelagic habit, and in some respects even degenerate (*i.e.* degenerate from the stand-point of the Gastropod) and having their most specialized members approximated in outward form to the Siphonopod type. As to this latter designation, it appears thus more fitting to displace it and to restore the term Cephalopoda to its older and more restricted meaning whereby it is applicable to the Octopus class alone.

The diagrams Pl. III, figs. D to H (modified from Lankester) show graphically the mutual relation and modification of the several parts of the body as seen among the principal types of Glossophorous Molluscs. Fig. D shows a simple type of Gastropod, such as *Chiton,* where the mouth and anus are at opposite ends of the body, the foot large and extending the whole length of the body on the ventral side, while the central part of the back is more or less humped—forming the visceral hump or dome, as in it most of the viscera are lodged. Fig. E indicates the modifications in the relative arrangement of parts due to the bending and coiling of the visceral hump, as seen in such Gastropods as the snail and the whelk. G and F represent respectively a shell-bearing and a naked Pteropod, and show how in these animals the visceral dome is much elongated and drawn out, causing thus a great bend in the alimentary canal. The foot in both is represented by little else than two wing-like fins, believed to arise from two lateral flaps—**epipodia**—of the middle division of the foot. In several Gastropods, such flaps are well developed; thus in the sea-slug *Aplysia,* they rise from either side of the foot and fold over the back. In F, the "head-arms" or "buccal cones," that are so curiously like the arms of Cephalopods, are represented, but are not here shaded similarly as having a like origin for the reason already given.

Fig. H is a diagram of a Cephalopod given for comparison. Here part of the epipodia (?) form arms beset with suckers in place of swimming fins, while the funnel is also formed from part of the ancestral foot. The figures also illustrate the true application of the terms dorsal, ventral, anterior and posterior to the body aspects in Pteropods and Cephalopods.

It may now be useful to show in tabular form, the place assigned to the Pteropods, in the phylum Mollusca, and to give a summary of orders and other divisions :—

Phylum :—**Mollusca.**

Branch A :—**Glossophora** (possessing a radula).	Branch B :—**Lipocephala** (without radula & without "head.")
Class I.—Gastropoda (types — Whelk and Limpet).	Class I.—Lamellibranchiata (types — Mussel, Oyster, Cockle).
" II.—Scaphopoda (type — *Dentalium*).	
" III.—Pteropoda (types — *Creseis* and *Clio*).	
" IV.—Cephalopoda (type — Octopus).	

Pteropoda.

Order I.—**Thecosomata**; body protected by a shell.

Family I :—Hyalæidæ, shell calcareous or horny, symmetric. Types—*Hyalaea* (horny); *Creseis* (calcareous); *Cleodora.*

Family II :—Cymbulinidæ, shell slipper or boat-shaped and with some short " arms. Types—*Cymbulia* and *Tiedemannia.*

Family III :—Limacinidæ. Type — *Spirialis,* with spirally coiled shell having sinistral flexure, i.e. coiling in the reverse direction to that usually seen in Gastropod Shells.

Order II.—**Gymnosomata**; body naked.

Family I :—Clionidæ, without gills, but with short arms devoid of suckers. Type—*Clione (Clio) borealis.*

Family II :—Pneumodermonidæ, with gills at apex of body, and with arms beset with suckers. Type—*Pneumodermon.*

Cleodora pyramidata is phosphorescent and probably others are also. In *Cymbulia,* the small chitonous shell is internal. *Spirialis* is the most closely related to the Gastropod form, its peculiarities extending to the possession of both a spiral shell and an operculum. The larvæ or veligers of *Cymbulia* and *Tiedemannia* also possess opercula.

Tiedemannia, like the Cephalopods, possessed well developed pigment-spots (Chromatophores) on the surface of the body, doubtless a protective device.

Delay in Issue.—The Editor extremely regrets the delay that has occurred in the issue of the present number. The causes have been several, the chief being that since the last issue, Mr. Sinel's assistance has been lost to the Station, through his acceptance of the management of an Oyster Culture Company now established in this island. This has naturally thrown much extra work upon the writer, but he believes that the new arrangements he has made, will obviate any similar delays in the future.

The Journal of Marine Zoology and Microscopy:

A PLAINLY WORDED BIOLOGICAL QUARTERLY.

VOL. II. No. 6. OCTOBER, 1895.

SPIRULA PERONII, Lam.

BY ERNEST H. L. SCHWARZ, A.R.C.S.

From the Geological Research Laboratory, Royal College of Science.

EVERY one who takes an interest in shells is familiar with the little "Post-horns," as the shells of *Spirula* have been named; they are found in vast quantities on most of the shores of the Southern Seas, some even, as Mr. Hornell tells me, finding their way to the shores of Jersey, while in France they are reported from La Rochelle and the bay of Gascony; but the animal is known from only a very few imperfect specimens. We have here the case of a deep-sea animal, living, we know not where, in countless thousands, casting its shells over the entire world, in most cases far from its natural habitat: and supposing these shores in the future ages to become covered with sediment, it might, with apparent justice, be inferred that the animal had a world-wide distribution, which is not the case: and we actually do find similarly constituted shells, the Ammonites and the Nautili, massed together in bands in various strata, and wherever we find beds of an equivalent age, no matter whether they are as distant as the poles, we find, species for species, the same fauna, and our little *Spirula* gives us a clue as to how this has come about(1).

So long ago as 1705, Rumphius(2) gave an account of the living *Spirula*, but the first clear description of the animal was by Lamarck(3) (who gave it the specific name of *Peronii*) and Péron(4); these two established the fact that the arms bore suckers, while de Blainville(5) pointed out that it belonged to the class Decapoda a deduction which was confirmed by Gray(6) and Lovell Reeve(7) from

(1). Wurtenburger, *Studien ueber Stammes Geschichte der Ammonit.*, Leipzig, 1880; also Lindström, *Konigl. Svenska Vetenskaps Akad. Handlin.*, No. 12, p. 4, 1888.

(2). *D'Amboinische Rariteit-Kamer*, p. 68; translation by Müller, Vienna, 1765.

(3). *Encyclopédie Methodique*, pl. 465, fig. 5; *Mem. Soc. d'Hist. Nat.*, 1799.

(4). *Atlas du Voyage aux Terres Australes*, tab. xxx, fig. 4.

(5). *Annal. Françaises et Etrangères d'Anat. et de Phys.*, vol. 1, p. 369, 1837.

(6). *Ann. and Mag. Nat. Hist.*, vol. xv, p. 257.

(7). *Elements of Conchology*, p. 16.

an examination of the entire animal of *Spirula australis* from New Zealand, taken by Mr. Earl, and now in the National Museum. In the *Buffon de Sonnini*, Péron's specimen was exactly described by Roissy, but afterwards this priceless treasure was lost. On the voyage of the *Samarang*, a mutilated specimen was obtained by Sir E. Belcher in the Indian Archepelago, and was handed to Sir R. Owen for dissection, forming the subject for a short memoir by the latter(8), wherein he establishes a third species, *S. reticulata*, from the peculiarity of its skin; this latter came from Tamor. Lastly, a good specimen was dissected by Professor Huxley, but we have yet to await the published description.

The body of the animal is cylindrical, compressed laterally, with the head about twice as long as broad: at the hinder end, enclosed in the mantle, is the small coiled shell which in all known specimens is visible on the dorsal and ventral portions, where it is covered only by a thin membrane. The head is not constricted externally from the body, and bears two eyes, eight short tentacles, and two long ones, probably expanded into two lobes like in *Sepia*. The infundibulum or funnel is entire, not, as in the Nautilus, divided down the middle, and bears a terminal valve; just behind it, lodged in the cartilaginous cranium, are the two capsules containing otoliths, said to function as hearing organs. The branchial chamber has no septum as in the Octopoda, and the gills, two in number, are elongated, narrow-triangular in form, each consisting of about 24 folds, and bearing at the base a branchial heart with an appendage attached. The liver consists of two lobes; through the interspace thus formed, the œsophagus, aorta, and visceral nerve pass; the relation of the inkbag and generative organs, in like manner, resemble those of *Sepia*. Whatever the soft parts may teach us, it is to the shell that we must look if we wish to understand the place of *Spirula* among other Cephalopoda, the vast majority of which are only known to us by their hard parts.

Of the shells there are many apparent species, but on examining a large number, these sink into merely varietal significance, and the authorities of the British Museum acknowledge only one species, *S. Peronii*, Lam. The differences as far as I can make them out are: 1, the thickness of the shell; 2, the figure of the transverse section, some being circular, others strongly depressed and oval; 3, the amount of evolution, in some the whorls touch, in others they are widely separated; 4, the presence or absence of a keel on the inner side of the first whorl; and 5, the size and shape of the first chamber being often spherical, egg-shaped, or drupe-shaped.

(8). *Zoology of the Voyage of H.M.S. Samarang*, Mollusca, p. 6, 1850.

The most instructive way of examining the shell is to cut a thin section passing through all the whorls in the plane of coiling, whereby the structure of the walls and septa, as well as their mutual relation is well exposed. As far as I know, such a section has not been figured or described; it is exceedingly difficult to accomplish, and requires the sacrifice of many specimens. The best way to do it, is to take the shell just as it is, lay it on its side on a keen, perfectly flat Water-of-Ayr stone, and rub it carefully till the middle is reached; mount it then direct on the glass slip with hardened balsam, and rub the other side down till the requisite thinness is obtained. In putting on the cover-glass, drop some hot balsam on to the slide, and do not warm it in the usual manner, as the whole thing will float away in pieces.

The walls of the shell are formed of two layers. The inner consists of a semi-transparent, porcellanous material with a steep imbrication, that is, it appears to be made up of layers which are inclined at a good angle with the surface. It has no trace of prismatic structure which would homologise it with the inner, mother-of-pearl layer of the Nautilus and the Ammonites, but resembles rather the outer granular layer of these though the granules seem arranged in fibres which are extended at right angles to the surface. Each layer readily splits away from its fellows and the shell consequently is very brittle but breaks regularly in rings corresponding with the laminæ.

The outer layer is clear and glassy, and is riddled through with little tubules running parallel to the surface on which they frequently open, thus giving the shell the roughness which has caused the term "shagreen" to be applied to this layer, and which Sandberger(9) homologises with the peculiar wrinkled layer found between the whorls of some Ammonites, and which is similar in position to the black layer of the recent Nautilus; at any rate, it has nothing to do with the shagreen on the shells of the Decapoda which consists of a deposit freely poured out and hardening in spherulitic knobs(10).

The septa are truly prismatic, and the shell-substance is identical with that forming the septa of Nautili and Ammonites; at the outer periphery they expand somewhat and the successive layers of which they are composed are separated, while a prolongation of the inner layer of the shell-wall covers the upper surface for a short distance. This latter fact, showing that the inner wall was formed after the completion of the septum, proves that the septa are not morphologically equivalent to those of the camerated shells (Ectocochlia). On the under surface there is a grey-looking deposit, constituting a half

(9). *Verstein. Rhein. Schicht. in Nassau*, 1858, p. 58.
(10). Moynier de Villepoix, *Journ. Phys.*, Paris, 1892, p. 618.

false septum, beneath this again is an axillary deposit. On the inner side of the shell the septum bends down to form the septal funnel which reaches the preceding septum, thus making a closed tube; at the end of the funnel there is a ring of denser shell material just as in the short funnels of the recent Nautilus[11].

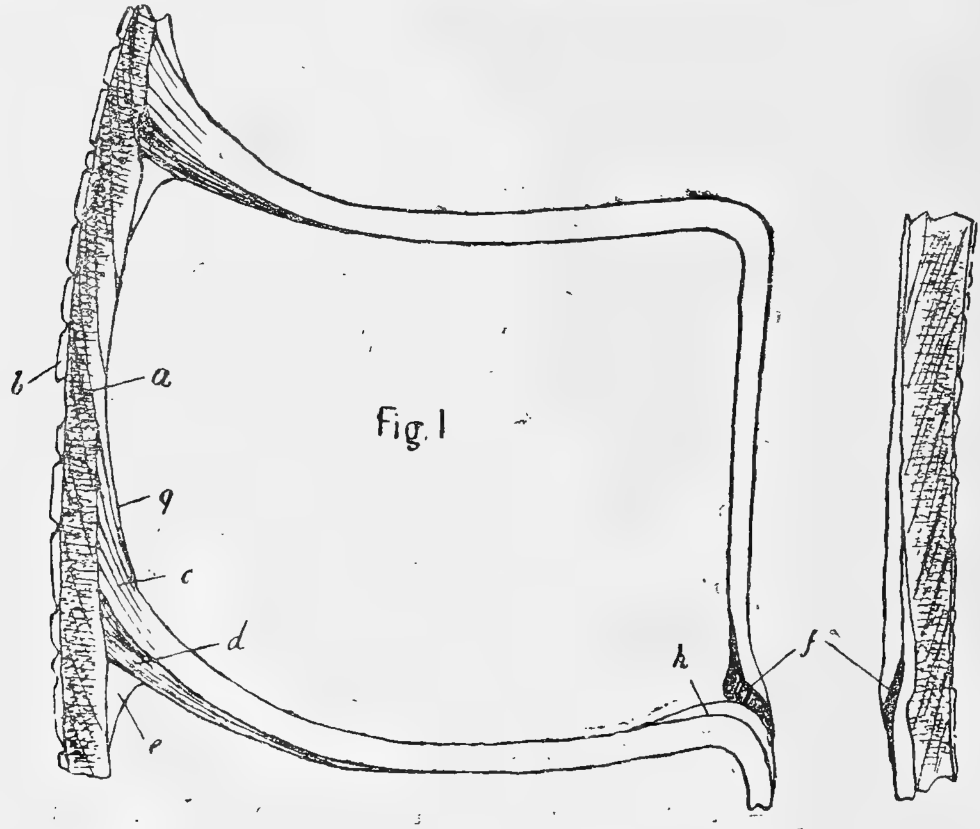


Fig 2

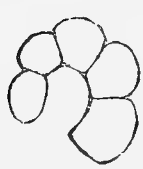


Fig 3

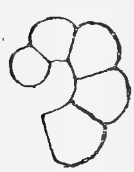


Fig 4

Fig 5.

Fig. 1. Section through the shell of *Spirula Peronii*, Lam.: *a*, Inner fibro-granular layer, covering the septum, *c*, by the prolongation, *g*; *b*, outer transparent layer; *d*, false septum; *e*, axillary deposit; *f*, ring of dense shell material at the end of the siphonal funnel; *h*, deposit of transparent material between the end of the siphonal funnel and septum; the letter *f*, is placed in the siphonal cavity, *a*, in the air-chamber.

Figs. 2 and 3. First half whorl of *Spirula*, showing in one case the oval ovicell like in *Bactrites* and *Goniatites compressus*; in the other the short spherical one as in other asellate *Goniatites* and *Orthoceras*.

Figs. 4 and 5. After Amos P. Brown. Fig. 4, protoconch of Ammonites as usually figured; Fig. 5, protoconch of *Baculites compressus*, Say, showing the extension of the shell in front of the first septum.

(11). Brooks, *Proc. Boston Soc. Nat. Hist.*, vol. xxiii, p. 380.

Let us now turn from the section to the first chamber. This, as I have said, consists of a small rounded body bounded on one side by the first septum, through which bulges the end of the siphuncle or fleshy tube, contained within the septal funnels. Munier-Chalmas[12] has described a little membraneous tube which stretches through the empty chamber and forms a prolongation of the siphuncle, which he calls the *prosiphon.* I have soaked the first chambers of several specimens in refractive media, so that they became transparent, and have also broken open some with needles, but I have failed to see this prosiphon which thus apparently can only be seen in exceptionally preserved specimens. It is also said to occur in the first chambers of the Ammonites.

I have purposely not called the first chamber the protoconch, by which it is usually known, because there are three distinct things united under the name. First, there are the primary chambers of the Ammonites, to which I propose to limit the name protoconch. These are little miniatures of the adult, *within which* the first septum is formed; the walls are continuous with those of the succeeding chambers[13].

Secondly, there are the forms exemplified by the first chambers of *Spirula, Belemnites, Goniatites* (*Mimoceras*) *compressus,* and the lately described form of *Othoceras*[14], for these I propose to revive the term "ovicell," because they stand in the same relation to the adult as the egg-shell does to the bird. In these the form is inflated and sharply constricted off from the succeeding chamber, with whose walls it is not continuous; the first septum is found at the apex, and not within the chamber. The embryo, in emerging, apparently gnawed a hole in the egg out of which it squeezed, and reared the adult shell with this as its basis. As the above mentioned *Othoceras* teaches us, the Nautili had eggs of this sort, but they usually discarded them; in some it seems to have been retained for a considerable time, and the place of attachment is marked by a scar, as in the recent Nautilus; but in others, often closely related to forms with the cicatrix, the apex is smooth[15], showing that in these the animal must have lived some time in a naked state, as the more highly organized Ammonites certainly did.

Thirdly, there is the type exhibited in *Nanno* (*Endoceras*) *belemnitiforme,* Hohn[16], which is of such a size that in cross section it is more than half the size of the adult. Now we know that among

(12). *Comptes Rendus,* vol. lxxvii, 1873, p. 1557.
(13). Brown, *Proc. Acad. Nat. Sci.,* Philadelphia, 1892, p. 139.
(14). Clarke, *American Geol.,* vol. xii, 1893, p. 112.
(15). De Koninck, Calcaire Carbonifère, *Ann. du Mus. roy. de Belgique,* 1850.
(16). Hohn, Dames and Kayser's *Pal. Abhandl.,* vol. iii, 1885; Clarke, *Amer. Geologist,* vol. xiv, 1894, p. 205; Bather, *Nat. Sci.,* 1894, p. 422.

birds, for instance, the Kiwi lays an egg almost as disproportionate, but considering the mode of parturition in the Cephalopods, it is improbable that this is the true size of the embryo. In this the animal must have emerged from the egg and swam about naked till it assumed nearly its adult size, so that the first chamber here represents one of the chambers in the middle of an *Orthoceras* shell; possibly, the earlier shell was once present, but was cast off, as is so commonly the case with these early Nautiloids. The inflated end of the siphonal tube has no claim whatever to be called a protoconch, since it is homologous with the little bulging portion at the end of the siphuncle in *Spirula,* and contained within the ovicell.

Spirula, then, is in its anatomy closely related to *Sepia:* its protoconch tells us nothing, since forms widely separated possess identically shaped ones; the structure of the shell proves it to be unique among shells yet described. If it occurred in ancient strata then we might have considered it closely related to Nautilus, as Linnæus and Cuvier did (by the former, it was named *Nautilus spirula*), and then, by the formation of a deposit on the under surface we should pass to *Spirulirostra,* then by the straightening of the chambered portion we should derive the Belemnites; but though in a recent authoritative article this descent was actually insisted upon, the Belemnites occur first in the earth's history, and the *Spirula* last, so that with the evidence at present available we must reverse the process, and derive *Spirula* from the Belemnites through *Spirulirostra.*

THE WORK OF THE JERSEY BIOLOGICAL STATION DURING 1895.

In most respects progress has been extremely gratifying this season, and the number of workers using the Laboratory has increased to an extent beyond anticipation. To meet the consequent need for greater accommodation, the room used as a type Museum, has been altered in such manner that while still available for the original purpose, the addition of a laboratory table, with shelving, gas and water supplies, sinks, &c., enables it to be used as a first-class and roomy Research Laboratory.

The list of workers, who, during the past summer, have testified by their presence to the value of the Station from the purely scientific standpoint, comprises the following, arranged according to the respective dates of laboratory occupancy :—

Mr. —. Bowden, St. Bartholomew's Hospital.—*General.*
Mr. —. Pearce, St. Bartholomew's Hospital.—*General.*
Mr. Hy. Scherren, London.—*Amphipods.*
Prof. Herdman, Liverpool.—*Oyster-cultivation and Tunicata.*
Mr. A. Edmunds, King's College, London.—*General.*
Mr. Hy. Hanna, Queen's College, Belfast.—*Methods of preservation of Marine Animals.*
Mr. R. Arnott Staig, New School of Medicine, Edinburgh.—*Laboratory methods.*
Mr. E. T. Mellor, Owen's College, Manchester.—*General.*
Mr. J. H. Ashworth, Owen's College, Manchester.—*General.*
Prof. Maisonnenue, Angers.—*General.*
Dr. W. B. Benham, Oxford.—*Nervous system of Polychæta.*
Mr. J. C. Stogdon, Budleigh Salterton.—*General.*
Mr. H. C. E. Zacharias, Berlin University.—*Rotifers and habits of Marine Animals.*
Dr. J. Justus Andeer, Paris.—*Extirpation of organs in Fishes.*
Mr. H. Fleure, Guernsey.—*General.*

Few of these have occupied tables for less than a month each, and while all have expressed themselves highly satisfied with the arrangements for work, one, Mr. H. C. E. Zacharias, has been so greatly impressed with the richness of the littoral and the facilities for research, that he has arranged to occupy a table permanently, with the view of continuing his investigations of the habits of marine animals. As Research Assistant, he will also devote a considerable portion of his time to morphological research upon some of the rarer representatives of our Fauna.

Many other Biologists, including a number of French and Swiss, have also paid flying visits to the Station during the summer, and it is gratifying that there has been great unanimity in their praise of the practical and useful arrangement of the Station. From the promises to return to work in the Laboratory at a future date, a busy summer is augured for the coming year.

As regards the supply department, the present year has been one of transition. The arrangements I made last spring did not fulfil my expectations, and in consequence, I have been compelled to resume the entire charge of all conservation work. With the extra time which I shall be able to devote to this in future, I can confidently promise that all material sent out from this date will be as nearly perfect as it is possible to attain. In this connection, I may mention that I have been experimenting largely for the last six months, with *Formalin* as a preservative medium, and I shall take an opportunity in the next issue of this Journal, to detail fully my methods and the chief results obtained, in the hope of thus helping workers at other Biological Stations.

I greatly regret one circumstance in the year's work, namely, the delay in the issue of the present number. I trust, however, that the friends of my work will bear with me patiently, and remember that in this enterprise I am engaged single-handed, and that the entire labour of the sketching out and final drawing of the plates, together with that of the articles connected therewith, falls upon my shoulders *solely*. In conjunction with the responsibility and time taken up in the busy summer in the active direction of the Station, such work has been almost too great for me and at times I have been tempted to regret the inception of the enterprise. However, I shall struggle on, in the hope of being able to recover lost ground, now that the long evenings of winter are coming to my aid. My friends must bear in mind that these literary labours are of themselves absolutely unremunerative, and that I can only afford to continue them by stealing the necessary time from hours which by right should be devoted to relaxation. Those whose sympathy is not wide enough to influence them to extend their patience towards me, must perforce cease subscribing. I esteem my subscribers my friends, and if they are not my friends, I would prefer that they should not be subscribers.

FISHERY WORK.—Under Mr. Sinel's fostering care, the Oyster-parks recently constructed at Green Island (S.E. coast of Jersey) are now in a flourishing condition. Phenomenal growth has taken place—"seed-oysters" of 1 to 1½ centimetres in diameter, laid down on June 1st, have now (Sept. 30) attained a diameter of 3½ to 4, and even 4½ centimetres. The increase in weight is proportionate, as 5-lbs. of "seed" has in the same time increased to 18-lbs.—fully demonstrating the forecaste made of the suitability of the Jersey littoral for the remunerative rearing of this mollusc. Further ground is being taken in to form other parks, and the success of this new undertaking is assured.

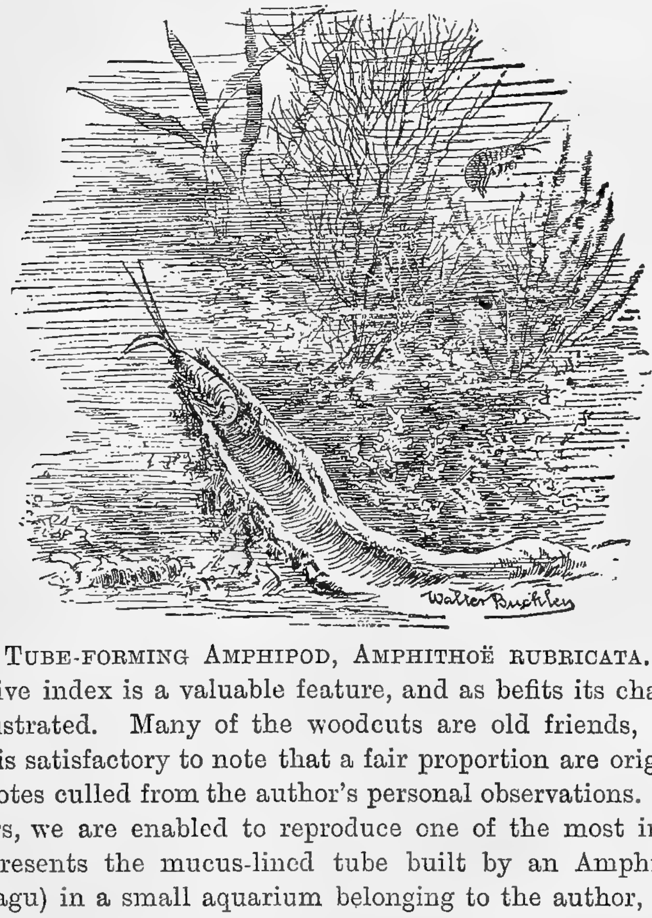
Besides this practical outcome, the Station's influence is being felt generally in the more living local interest that is springing up in general fishery matters, and I hope to have further direct progress to report shortly.

Among other lines of research, I have been, this year, pursuing investigations upon the difficult bait problem, and have had, within the last few days, an apparent partial success—a result somewhat unexpected. It will however be a considerable time ere I shall be in a position to publish results, as the Station being without subsidy of any kind, I can with difficulty spare the time and incur the expense needful for such experiments. J. HORNELL, *Director.*

BOOK NOTICE.

"*Popular History of Animals for Young People,*" by Henry Scherren, F.Z.S., 376 pp., 13 coloured plates and woodcuts in text. (London; Cassell & Co., Ld., 1895). Price 7s. 6d.

Unusual activity exists at the present day in the production of Popular Natural Histories, and though it may seem difficult to break comparatively new ground, yet Mr. Scherren undoubtedly does so in the direction made plain by the title as above. It is scientific Natural History written down to the comprehension of youngsters, and in every way the volume is satisfactory. The facts are well selected, well connected, and ably presented in simple telling language, and in the handsome dress in which Messrs. Cassell present it, it is just the book to awaken or strengthen a genuine love for animal history among our younger friends. It is refreshing to note that marine invertebrates are not neglected and thrown aside as beneath the notice of ordinary nature lovers but are accorded over 30 pages of first-class matter. This out of a total of 368 is something to be thankful for. Even a woodcut of *Balanoglossus* is given. The thin end of the marine Zoologist's wedge has evidently been inserted!



TUBE-FORMING AMPHIPOD, AMPHITHOË RUBRICATA.

An exhaustive index is a valuable feature, and as befits its character, the work is profusely illustrated. Many of the woodcuts are old friends, but they are all suitable, and it is satisfactory to note that a fair proportion are original and accompanied too, by notes culled from the author's personal observations. By the courtesy of the publishers, we are enabled to reproduce one of the most interesting of the former. It represents the mucus-lined tube built by an Amphipod (*Amphithoë rubricata,* Montagu) in a small aquarium belonging to the author, and the interest is the greater, as the animal sketched was one of several sent by the writer to Mr. Scherren some few months ago. J. H.

MICROSCOPICAL STUDIES IN MARINE ZOOLOGY.

BY JAMES HORNELL.

Study XVIII.—The Corynidæ.

The family Corynidæ, in its inclusion of the two distinctive genera *Coryne* and *Syncoryne,* furnishes a perfect object lesson in the gradations of development that prevail among Hydroid Zoophytes; ranging from that fullness of development characterized by definite and distinct Hydroid and Medusoid stages, down to the utter suppression of the latter stage and its replacement by what are mere sessile bags containing the reproductive elements—degeneration of the most marked description. Such gradations are always of great interest and value to the evolutionist, for though the series is one of degeneration rather than of progress upwards, still, it bears conclusive evidence of the readiness and ease with which organisms can undergo radical alteration in vital and conspicuous organs, and if a species can so easily retrogress, the inference that others may as readily advance by the elaboration of new organs, is logical and reasonable.

Intimate knowledge of a representative species in each of the two genera referred to, is readily obtained, for both *Coryne* and *Syncoryne* are present on many parts of the British Coast.

Syncoryne, which, of the two, has the more typical life-cycle, grows in littoral pools in low bushy colonies, comparatively little-branched, and with a creeping stolon connecting the various main stems. The latter, in *S. eximia,* are brown and horny, and annulated only towards the base; the twigs on the other hand are closely ringed, transparent and colourless.

The polypites are not seated in cups at the extremities of the branches as in *Obelia,* but are naked and without any protective envelope into which they can retract upon irritation. As a natural compensation, or rather adaptation, the polypites are much larger and stouter, and their tentacles better equipped with stinging cells. Some slight suggestion of a cup is, however, present, as the edge of the chitonous tube which forms the branchlet is expanded slightly as a very delicate tiny chalice at the very base of the polypite. It is however of absolutely no use as a protective sheath, both on account of its extreme thinness, being cuticular rather than horny or chitinous, and on account of small size, only $\frac{1}{5}$th of the length of the polyp.

Indeed in specimens mounted in balsam, it is so transparent as to be most difficult to see. The polypites, while possessed of as great retractile power as those of the Thecate Zoophytes, have not the same rapidity of movement, and answer to a stimulus or irritation much more slowly.

Among the Calyptoblastic Hydroids, the **hydranth** or polypite is usually cup-shaped, with the tentacles arranged in one or more rings around the mouth. In *Syncoryne,* the body is as a rule spindle-shaped, though by elongation it may at times appear almost cylindrical; while the tentacles are disposed irregularly over the whole surface, standing out stiffly, so many spikes on a war-club. The form of the tentacles, too, is peculiar, each being swollen at the extremity—**capitate**—a characteristic shared by *Syncoryne* and other members of the family. The reason for this capitate form is not far to seek: it owes origin to the peculiar grouping or massing of the nematocysts at the apex—a striking divergence from the prevalent arrangement among other families, where the collections or batteries of stinging cells are situated at intervals on the general surface of the tentacles. It is interesting to note that the tentacles of the medusa-stage of *Syncoryne* have the ordinary arrangement of stinging cells at intervals along the length, *i.e.* without any suggestion of the massing seen in the tentacles of the Hydroid stage.

Viewed with good illumination, the unburst stinging-cells can readily be observed in the terminal knobs as more or less lenticular bodies, and by judicious squeezing of a living polypite, some of these may be pressed out, and a number will be certain to project the long whip-like process which serves as the active agency in conveying the poisonous secretion of the cell into the organism against which it is launched.

The isolated undischarged nematocyst can be made out to be a cell of unusual size, somewhat ovoid in shape, and in which the most conspicuous content is a great clear cyst, highly refractive, and filled with a clear fluid, lying wherein is a spirally coiled filament. The cyst does not occupy the entire cavity of the parent cell, but leaves a space, most marked towards the base, filled with dense protoplasm, in which lies a well-defined nucleus. From the apex of the cell projects a pointed process of the cell wall, named the "**trigger**" and which functions as such on contact with a suitable body (prey). It appears to stimulate the cell to a contraction, resulting in the violent expulsion of the sting thread. The thread thus expelled is not solid but is hollow, and in reality a tenuous prolongation of the upper end of the cyst. It arose as an ingrowth or invagination of the summit of the cyst, and when projected went through an instantaneous process of **evagination,** *i.e.* was turned inside out as the finger of a glove can be turned, and if we remember that the content of the cyst is a watery fluid under considerable tension, one can easily understand that if this tension be greatly and suddenly intensified by pressure upon the walls from without, an instantaneous throwing out of the ingrown hollow thread must ensue.

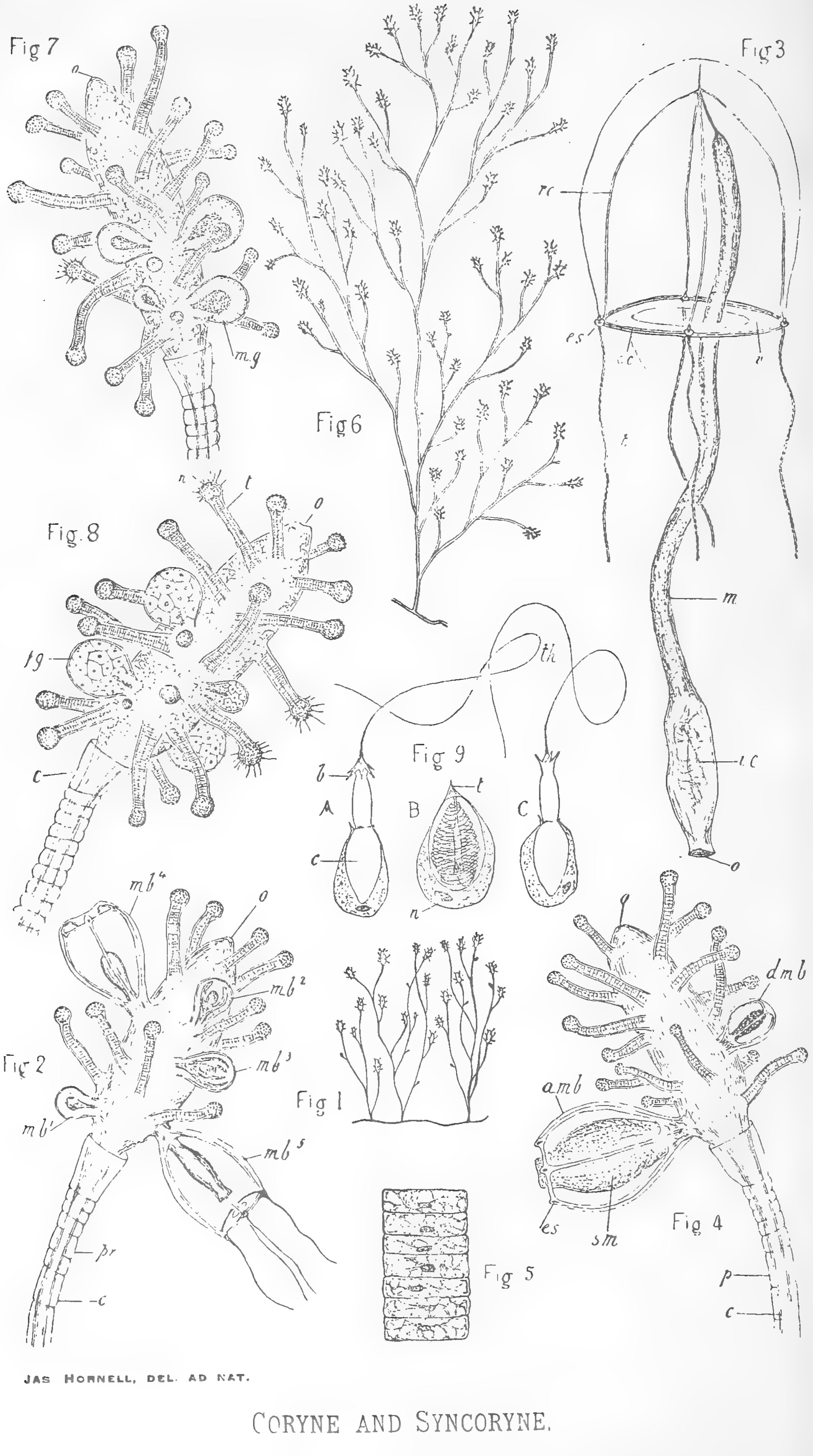
A working model of such a cyst can be made of india-rubber tissue, if fashioned in the form of a hollow bulb with the apex dwindling down into a finger-shaped hollow appendix. If this hollow model were partly filled with water and the filiform apex thrust inwards (invaginated), then by squeezing the bulbous part, the pressure of the contained water would force outwards the invaginated finger—the equivalent of the hollow filiform thread of the nematocyst. In the Corynidæ, the base of the thread is stout and furnished with barbs.

The stem of the tentacle is formed as in *Obelia* of a solid core of vacuolated stiff-walled cells of endodermal origin, that act as a supporting axis. The ectoderm is thin, but furnishes very delicate yet powerful muscle elements that control the elongation and retraction of the tentacles.

The mouth that is fed by these ministering and food-capturing tentacles is small and terminal and difficult to distinguish, appearing as a mere opening at the anterior end of the polypite. The large cavity of the polypite is where digestion takes place, the endoderm cells of this region secreting a fluid which rapidly dissolves the tissues of the prey. Thence this nutrient fluid is passed along the hollow cœnosarc to aid in the sustenance of the general body of the colony.

Reproduction.—Normally *Syncoryne* produces buds at various and indefinite points scattered over the body of the polypite and between the tentacles. These buds at first consist of a layer of ectoderm covering a hollow button-like outgrowth of endoderm. Next this endoderm projects four hollow radial processes which ultimately become the four radial canals of the Medusa, into which the bud eventually develops. At the same time a median outgrowth of hollow endoderm, the future manubrium, grows down between the four radial bands.

With growth the form becomes distinctly bell-shaped, the four marginal tentacles appear associated with the four radial canals, and a pigmented eyespot—**ocellus**—develops at the base of each tentacle. Thus, little by little, the bud changes into a well marked medusiform organism connected to the polypite by a narrow neck. At this stage the medusiform bud is usually nearly as large as the polypite itself. At length, it begins to pulsate, to long for separate and free existence, and its efforts quickly effect severance from the mother polypite.



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CORYNE AND SYNCORYNE.

Explanation of Plate IV.

The Corynidæ.

Fig. 1. *Syncoryne eximia,* natural size of colony.

Fig. 2. Normal hydranth of same showing developing medusiform persons, mb^1 to mb^5, in various stages, disposed irregularly between the capitate tentacles; mb^5 is the oldest and is all but ready to be set free; *pr.* perisarc. × 30.

Fig. 3. A free medusa (*Sarsia*) of *Syncoryne,* fully mature (probably two months after being set free); *m.* manubrium, within whose walls sperm has been developed, this individual being a male; *i.c.* a captured Copepod being digested within the cavity of the manubrium; *r.c.* radial canals; *c.c.* circular canal; *e.s.* eye-spot or ocellus; *o.* mouth; *v.* velum; *t.* tentacle. × 4½.

Fig. 4. Hydranth showing abnormal medusiform person, *a.m.b.,* wherein, while the bell is fully developed, the tentacles are aborted, and the manubrium functions solely as a reproductive organ (in this case, a spermarium). The bell remains permanently attached and the reproductive products are ripened in situ; *d.m.b.* developing medusa-bud; *e.s.* eye-spot; *p.* perisarc; *c.* cœnosarc; *o.* mouth.

Fig. 5. A row of axial endoderm cells from a tentacle of *Syncoryne.* × 180.

Fig. 6. Colony of *Coryne vaginata,* nat. size. (The annulations of the stem are not visible to the naked eye, in living specimens).

Fig. 7. Hydranth from a male colony of same species; *m.g.* male reproductive capsule, representing a degenerate medusa.

Fig. 8. Hydranth from a female colony; *f.g.* female capsules filled with ova; *t.* tentacles; *n.* stinging threads of nematocysts; *o.* mouth; *c.* tiny membraneous cup at the base of the hydranth. × 30.

Fig. 9. Nematocysts from tentacle of *Coryne vaginata,* × 600.

A & C, two burst nematocysts, showing barbs (*b.*) in different positions; *th.* the evaginated threads; B, an unburst nematocyst, showing the trigger (*t*), and the coiled thread lying within the cyst (*c*); *n.* nucleus.

Explanation of Plate V.

Figs 1 to 8, Cirripedia.

Fig. 1. *Sacculina carcini* (Thomps.) seen in plan, showing by means of the dotted outline of the crab upon which it is parasitic, the manner in which the root-tubules ramify through the host's body. Natural size.

b.s. body-sac of *Sacculina*; *cl.* cloacal opening; *b.m.* basilar membrane; *i.r.* the roots which ramify around the intestine and the associated organs; *h.r.* hepatic roots ramifying among the cæca of the liver; *br.c.* branchial cavity of the host.

Fig. 2. Lateral view of same.

Fig. 3. Life appearance of Rock Barnacle (*B. balanoides*), enlarged.

Fig. 4. The same seen from above. *a, b, c, d, e,* and *f,* the six plates making up the circular mantle "rampart."

Fig. 5. Dissection (partly diagrammatic) of *B. balanoides,* the right half of the mantle-wall removed; the "liver," cement gland, and branchiæ are omitted; the alimentary canal is depicted black; for clearness, the male organs are not lettered, but reference to Fig. 7 will indicate their parts.

Fig. 6. A Ship-Barnacle (*Lepas*) having the right side of the mantle removed. The penis should *not* be apparent, as it lies normally folded up between the cirri.

Fig. 7. Dissection of same, on the lines of Fig. 5.

Fig. 8. External appearance of *Lepas anatifera,* natural size.

Lettering the same for all the figures:—*a'* remains of the anterior antennæ; *an.* anus; *a.m.* adductor muscle; *c.* carina; *c.f.* caudal forks; *c.g.* cement gland; *cr.* cirriform feet; *c.s.* calcareous rampart-shell of mantle; *f.a.* filiform appendages of 1st pair of feet; *h.* liver; *l.* labrum; *m'* retractor muscle of scutum: *m''* retractor muscle of tergum; *m.c.* mantle cavity; *od.* oviduct; *or.c.* buccal eminence; *o.* mouth; *ov.* ovary; *p.* penis; *pd.* peduncle or stalk; *s.* scutum; *t.* tergum; *ts.* testis; *v.d.* vas deferens; *v.s.* seminal vesicle.

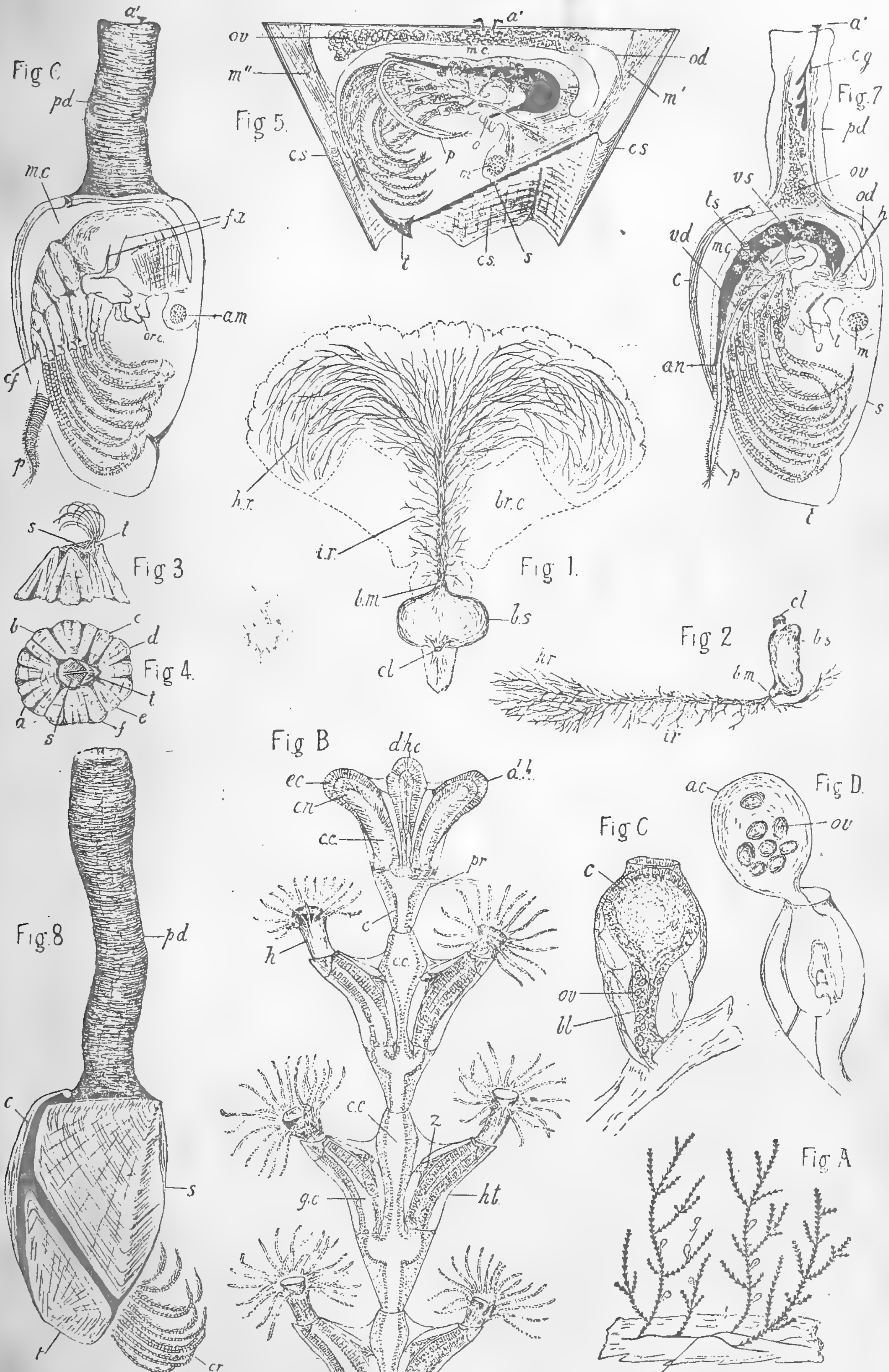
Figs A to D, Plumularia pumila.

Fig. A. Branches of *P. pumila,* slightly larger than life. *g.* gonangia; *s.* creeping stem or stolon connecting the various bundles.

Fig. B. Portion of branch, highly magnified, hydranths or polypites in various stages of extension; *h.* body of the hydranth; *ht.* hydrotheca lodging hydranth; *g.c.* gastric cavity of hydranth; *c.* cœnosarc; *c.c.* cavity of the cœnosarcal tube; *pr.* perisarc; *z.* tissue connecting hydranth with lateral and internal surface of hydrotheca; *ec.* ectoderm; *en.* endoderm; *d.hc.* developing hydrocaulus or stem; *d.h.* developing hydranth.

Fig. C. Female gonangium; *bl.* blastostyle; *c.* swollen hollow apex of blastostyle nearly ready to force its way through the mouth of the gonangium; *ov.* ova.

Fig. D. The same fully developed, showing the acrocyst containing ova. (After Lindström).



JAS. HORNELL, DEL. AD NAT.

SERTULARIA AND CIRRIPEDE MORPHOLOGY.

Once freed, it begins a long, free-swimming existence and rapidly increases in size till it reaches fully ¼-in. in length. The manubrium in this species attains enormous proportions—sometimes, when fully extended, quite thrice the length of the bell. In this and allied forms (*i.e.* among all the Gymnoblastic Hydroids), the genital organs appear in the walls of the manubrium of the medusa. The sexes are separate, and the embryos that are produced settle down and develop hydroid stocks or colonies.

I have said that the foregoing is the normal course of reproduction—but certain species, and among others that under present consideration, *S. eximia,* have an alternative mode. This however is practised only at the end of the breeding season (April) when the reproductive buds, in place of developing into free medusæ (*Sarsia,* as this form of medusa was called before it was recognised as one stage in the life-cycle of this Hydroid), remain permanently attached to the hydroid stock. In form they have the same bell shape as the true medusa-buds, but they seldom produce tentacles (stunted when produced), and the manubrium becomes enormously swollen with the reproductive products. The lack of tentacles is to be adduced to the fact that owing to the permanence of attachment to the parent, all nutritive matter is obtained from that source, and the manubrium has no call to act as a digestive organ, but simply as a reproductive gland.

The next and final stage of degeneration is found in such forms as constitute the genus *Coryne,* of which the lovely species *C. vaginata,* grows luxuriantly in Jersey rock-pools and gullies—where it forms elegant branched colonies that appear miniature shrubs, crowded with delicately tinted pink florets. Both the main stem and the branches are horny and closely annulated. In the details of the anatomy of the polypites there is practical identity with those of *Syncoryne.* In *Coryne,* however, the polypite is considerably larger, but it is solely the divergence of the reproductive plan that entitles this species and its congeners to the dignity of a separate genus.

The colonies are again unisexual, some bearing only male buds, while others bear female ones. These appear as numerous rounded bodies clustered on the polypites between the bases of the tentacles. The male ones consist solely of masses of cells—spermatoblasts—which produce spermatozoa; while each of the female buds becomes filled with 20 to 25 large ova. When the male capsules burst, it is probable that the spermatozoa find their way to the female organs, guided by some sense or attraction we know not what, and pierce the membranous envelope, thereby gaining admission to the ova. The latter, thus fertilized, by segmention form tiny embryos, which issue forth as four-armed hydriform larvæ, that crawl about like so many miniature Octopods. This free life is rapidly run and then they settle down and become attached to rock or weed. In this situation they rapidly reproduce, by continued budding, the typical hydroid stock. Here, then, there is no trace whatever of medusæ, whether fully developed as free-swimming organisms, or bereft of a free existence and tied for life to the mother polypite: nought is left of the medusa-stage save the reproductive organs, and as these are, among the Gymnoblastic Hydroids, situated in the walls of the manubrium, we may homologize the sexual buds of *Coryne*, with the manubria of such medusæ.

As *Obelia* may be taken as typical in every sense of the **Calyptoblastic Hydroidea,** where the polypites are lodged in cup-like expansions of the horny perisarc, the medusæ usually provided with otocysts (rarely with eye-spots), and the genital glands developed upon the radial canals, so *Coryne* and *Syncoryne* may be taken as the types of that other great division of the Hydroidea, known as the **Gymnoblastic**—characterised by the polypites being naked or athecate, the medusæ, when produced, provided with eye-spots **(ocelli)** and never with otocysts, and with the genital glands lodged in the walls of the manubrium, and not in the course of the radial canals.

To the student of the smaller forms of marine life, the stems of the Corynidæ offer endless material for research, so abundantly are they clothed, at times, with a fluffy growth that under the microscope is revealed to consist of multiform Diatoms, lovely in the delicacy of their glassy sculpturing and in the rich hues of the living matter within them; of more minute Infusorians, the cups, and bells and tassels of those that live their lives attached, and still smaller forms, cilia-rowed and free-swimming, that speed and rotate and take eccentric course among the miniature undergrowth upon the crowded stems; here and there too, can be spied a slow-crawling Foraminifer whose porcellain-white shell gleams brilliantly, while from innumerable pores stretch living threads along which hurry, this way and that, the tiny particles that are engaged in the life-building of the tiny creature; the stout bobbing heads of that curious Polyzoon, *Pedicellina,* are frequent, curtseying and bowing to one another, with old world homage; to the keen-eyed, interesting forms of Rotifers, so rare in the sea, may occasionally reveal themselves spinning erratic course through the water or climbing about with jerk and double among the rich growth of the tiny algæ that form nevertheless the giants of this tiny microscopic forest.

None of these can be accounted parasites; they occasion no harm to the host and simply live together—a crowd of commensals.

A true parasite, however, sometimes afflicts colonies of *Syncoryne*, as one of the curious Pycnogonidæ (sea-spiders) makes use of the developing buds as incubatory sacs, wherein their larvæ may develop. How the ova are deposited in the Zoophyte is unknown—but as the larvæ are only found in young buds, it is likely that these are selected as being without the hard perisarc which is present at other parts of the colony and which would render an incision difficult. Probably the Pycnogonid breaks a hole in the crown of the bud and introduces therein the ova. The effect is to arrest normal growth and to convert the bud into a "gall"—wherein the larvæ live, nourished by the nutrient fluid of the cœnosarcal tube, a branch of which penetrates the bud. In due season the larvæ burst from the gall and become free.

Study XIX.—On Sertularia pumila.

Just as *Obelia geniculata* forms miniature forests on the broad leaves of *Laminaria* (oar-weed) at a horizon seldom left bare except at very low tides, so another species of the Hydroidea, *Sertularia pumila,* in favourable situations, monopolizes the fronds of *Fucus* at a zone some feet higher. Ellis, the worthy pioneer in our knowledge of these forms, named it the "Sea-oak Coralline," an appropriate name, and one suggestive of the strong, stunted and rather coarsely denticulated appearance it assumes when removed from the water. It seldom attains luxuriant growth; most frequently it is barely $\frac{3}{4}$ of an inch in height and as it retains the same breadth from base to apex and is hardly branched at all, it has an incomplete and truncated appearance that does not make for gracefulness.

Occasionally, however, it grows to the height of an inch and a quarter and is then beautified with several branches arranged symmetrically in pairs.

In texture it is horny, owing to the perisarc being strongly chitinized. Examining a living branch in water under a low power of the microscope, we forget its apparently coarse nature in the loveliness of the expanded polypites. They are exquisite in their slenderness, and have a great power of protrusion. Equally long and graceful are the hyaline tentacles, a living rosette that surrounds in a single wreath the broad and button-shaped proboscis, whose summit breaks into a large and mobile mouth. The cups **(hydrothecæ)** that lodge these polyps are paired, one on either side of each segment or internode in the stem. Somewhat tubular in form, each cup is, at the lower end, pressed to the side of the stem internode, while the upper extremity is free and bends outwards, so that each pair, with their stem internode, form a V-shaped figure. The aperture of each hydrotheca is somewhat narrowed and sculptured into points —mucronate. The body of each polypite is nearly cylindrical (compare with the cup-shaped body in *Obelia*) and has a special bundle of retractile fibres inserted on the outer surface of the body, some little way beneath the tentacles on the side turned towards the axis of the stem. Thence they pass inwards and slightly downwards to become attached to the wall of the hydrotheca where fused with the stem perisarc. By contraction these fibres energetically assist in the retraction of the polypite.

The body wall of each polypite, as also the cœnosarcal tube, consists essentially of a simple ectoderm layer separated from a ciliated endoderm by a delicate supporting lamina.

The endoderm is usually separated by a space from the investing perisarc, except at the base of each hydranth and at the points where growth is taking place.

The perisarc is a secretion of the ectoderm and thus, where a polyp bud or a new branch is originating, the ectodermal cells are of enormous size. As the perisarc is completed the ectodermal cells dwindle and shrink away from it.

The special growth of the branch is as follows:—the perisarc between the two terminal hydrothecæ becomes absorbed and the blind termination of the cœnosarc pushes through; next, this throws out a hollow bud on either side. In these three buds, the ectoderm is very thick and active and rapidly forms a layer of perisarc, the lateral buds becoming hydranths, the median, an internode of the hydrocaulus or stem.

The branches bear in their number a direct ratio to the abundance of nutriment and other favourable life conditions; when present, they have always one definite point of origin, and that is, from the hydrocaulus just beneath the base of a hydrotheca. There the perisarc is absorbed and the cœnosarc pushes out a tiny bud which in further development repeats the process of apical growth already described.

The tentacles have the same structure as in *Obelia*.

Reproduction.—In the breeding season numerous large ovate sacs—the **gonothecæ** or **gonangia** appear here and there on the main stems and branches. Their origin is similar to that of the branches, by absorption of the perisarc and thrusting out of a hollow bud of cœnosarc. These sacs produce in due course the reproductive elements.

The sexes are separate and in separate colonies. Male gonangia can usually be distinguished from female by their shape — the former being regularly oval, the latter irregularly ovate.

The prolongation of the cœnosarc into the gonangium is termed the **blastostyle.** This fills but a small space and is little more than a narrow column in the centre. In its walls are developed sperm or ova as the case may be, and thus while it (the blastostyle) represents really the medusiform person, the medusa itself is entirely abortive, the reproductive organs alone being retained.

Fertilization takes place as in *Coryne,* and then a peculiar occurrence takes place. The apex of the blastostyle gradually expands into a hollow globe with gelatinous walls, which pushes its way through the aperture of the gonangium to hang from the mouth as a miniature bladder. Into this pouch, the **acrocyst** or **marsupium**—the fertilized ova are passed and therein undergo segmentation. They pass out as planulæ—which after a short free life settle down, and by the usual process of growth and budding complete the life-cycle by developing new colonial organisms.

Sertularia obviously belongs to the Calyptoblastic or Thecate Hydroids, the polypites being lodged in thecæ, and it is significant to note that it occupies the same relative position to *Obelia* in regard to mode of reproduction, as *Coryne* occupies to *Syncoryne* among Gymnoblastic Hydroids. In both *Sertularia* and *Coryne* there is suppression of a medusiform stage. In *Obelia* and *Syncoryne,* free sexual medusæ are produced—a striking parallel.

From the geological standpoint, *Sertularia* is of considerable interest, as it seems to offer the most probable relationship to the curious *Graptolites,* those most abundant fossils of Silurian rocks; the short sessile hydrothecæ of *Sertularia,* giving its stems a serrate appearance, offering great suggestive resemblance to the denticulated margins of the fossils in question.

Study XX.—The Cirripedia.

Than the Barnacles or Cirripedes ("cirrus-footed"), few marine animals are more familiar to dwellers by the sea; the sessile forms exist everywhere upon the littoral; the stalked are known world-wide as Ship-Barnacles, adhering to the bottoms of ships or to wave-tossed timbers.

The greatest diversity of form is found in this order, from the great stalked forms and the mollusc-like Rock-Barnacles, encased in shelly walls, that cover in multitudes all high-tide rocks; from parasitic species, more or less degraded, yet endowed with optional freedom, down to curious bag-shaped parasites whose lives are bound up absolutely with that of the host, and through whose vitals their ramifying roots bend and twist. All agree, however, in larval history, passing successively through those special phases known as the **Nauplius** and **Cypris stages.**

The most primitive type is that of the stalked or **pedunculate** forms, and of these, *Lepas* is the most typical genus. The young of this, emerge from the egg as very tiny Nauplii—minute larvæ furnished with but three pairs of appendages, all used at first as swimming organs (Fig. 19, Pl. viii, Vol. I). The two anterior pairs represent the two pairs of antennæ while the third pair ultimately become the mandibles in the adult. The first pair of these limbs are simple; the others are biramose (two-branched). One eye, unpaired and median—the Nauplius-eye—is developed, and the body is protected by a dorsal shield-shaped fold of integument, the broad anterior margin produced on either side into a fronto-lateral horn. Mouth, alimentary canal and anus are present, and the creature feeds eagerly. Frequent moults **(ecdyses)** take place, and with each such change, important additions are made to the number of the organs and appendages; a series of segments are produced posteriorly, destined to form the adult thorax; limbs sprout from these, and a compound eye appears on either side of the Nauplius-eye.

At last a moult occurs when a larva quite different to any of the preceding Nauplius gradations issues from the old skin. In this new phase the larva has the general form of an Ostracod—hence is called the **Cypris-stage**—being provided with a bivalve shell, composed of two oval convex valves, open along the ventral edge, within which the entire body and its limbs can be retracted. All three regions of the typical crustacean body, head, thorax and abdomen, can be traced (Fig. 24, Pl. I). The thorax has six strong limbs, while the abdomen, short and insignificant, possesses but a single pair. Of the appendages of the head, the second pair representing the posterior antennæ—have disappeared, while the third pair are reduced from their former important biramose character to small mouth organs—the mandibles. Tiny swellings, that ultimately become the first and second maxillæ, are also to be seen. The first antennæ on the other hand, increase in size and become provided with a bell-like sucker on the penultimate joint, and on this sucker opens a cement-producing gland. The larva now ceases feeding, much food reserve appearing as oil-globules, especially at the anterior end of the body.

The time has now arrived for the assumption of adult life, and this is set about by the larva attaching itself—preferably to some floating body—by means of the suckers on the first antennæ. Next the cement glands pour out their secretion at the same spot, and embed the anterior end of the body firmly. The head region elongates, becomes a mere stalk, the bivalve cypris-shells fall away, a chitinous fold of the integument grows around the trunk, and in the substance of this **mantle** or **pallial fold,** five protective calcareous plates are formed, one unpaired and the others paired. Early adult form is now attained.

When fully grown and sexually mature, *Lepas* has the external appearance shown in Fig. 8, Pl. 5. The anterior end of the head has become a great wrinkled **peduncle** or stalk, terminated posteriorly in a shelly pouch, the mantle, enveloping the main mass of the body and open only along a slit on the ventral border. Of the calcareous plates strengthening this mantle, the larger of the two pairs, situated towards the insertion of the peduncle, are termed the **scuta** (*s*); the other pair placed at the far end of the mantle sac, are the **terga** (*t*), while the unpaired plate, the **carina** (*c*), is a long and narrow keel and separates, on the dorsal aspect, the opposite plates of the terga and the scuta.

Removing one side of the mantle, with its scutum and its tergum, the actual body of the Barnacle is exposed—an obscurely segmented fleshy mass, bearing conspicuous tendril-like limbs. What corresponds with the typical Crustacean head lies before these latter, and is divided into 3 regions; the anterior lies without the mantle and is the peduncle; the median is short and narrow and being attached to the mantle and connected along the inner surface with the peduncle, forms an "isthmus"; the posterior, the most important, is large and fleshy, and bears the mouth and its organs.

Succeeding the posterior division of the head lies the partly segmented limb-bearing thorax, and behind this again is found a very small and rudimentary truncated abdomen terminating in two tiny pointed processes. Tiny though it be, the abdomen is of importance, for upon the dorsal surface is the anus, and it as well gives origin to an organ many times larger than itself; an organ long, stout, cylindrical, annulated and setose, that functions as the male copulatory organ, and may be termed the penis. In life this organ is bent down between the thoracic limbs, as shown in Fig. 5 (*p*), and not as in Figs. 6 and 7, where it is straightened for the purpose of clearness in the drawing.

Of the appendages of the head, the anterior antennæ persist in a very minute and attenuated condition, at the anterior end of the peduncle, where they lie embedded in the attaching cement; posterior antennæ are absent, and the mouth parts are much reduced, forming a small eminence surrounding the mouth. The parts comprise an upper lip or labrum with labial palps, two mandibles and four maxillæ, of which the hinder pair form a lower lip.

The thoracic appendages or feet, six pairs in number, are all tendril-like, long, slender, many-jointed, and closely set with a double row of stiff hairs. Each is **biramose,** *i.e.* composed of two branches, which arise from a single stout basal joint, the **protopodite.**

Alimentary Canal.—The mouth opens into a short straight œsophagus, leading into a capacious stomach, beset at the anterior end with glandular diverticula (liver). Posteriorly the stomach narrows gradually to merge into a long intestine, with anus opening on the dorsal face of the truncated abdomen. Food is obtained by the sweeping motion of the thoracic appendages, which by alternate protrusion and retraction sweep inwards towards the mouth such microscopical food as suffices.

The **nervous system** is limited to a paired cerebral ganglion and a short ventral chain of 5 paired ganglia. Except a double pigment-spot representing the eyes, no definite sense organs are known.

In the isthmus attaching the main body mass to the mantle, is a strong transverse adductor muscle connecting the scuta of opposite sides. By means of this, are controlled the opening and the closing of the mantle cleft through which are protruded the cirriform feet. Numerous other muscles are also found in the posterior head region, chiefly concerned in controlling those movements of the body which alternately elevate and depress the limbs and allow their sweeping motion to perform at fullest advantage. In the walls of the peduncle we also find strong muscles, having a longitudinal arrangement.

Reproduction.—*Lepas* is hermaphrodite, possessing both testes and ovaries. The former consist of ramified arborescent whitish tubules lying along either side of the digestive canal and penetrating even into the basal joints of the limbs. The product of these glands is gathered into canals tributary to larger, which finally pour it into two conspicuous milk-white seminal vesicles, whose vasa differentia run separate almost to the base of the penis. At this point the two unite and form a common ejaculatory duct passing through the penis. The ramified ovaries, purplish in colour, lie within the posterior portion of the peduncle, and the two oviducts (*ov.* Fig. 7) after passing through the isthmus, open, one on either side of the head, at the base of the first pair of thoracic feet—a forward position wholly exceptional among Crustaceans where the usual position for the female orifices is upon the first abdominal segment among the lower forms (Copepods, &c.), while in the higher (*Malacostraca*), it is constant to the antepenultimate thoracic segment.

The ova when extruded become cemented together into two large purplish plate-shaped masses enfolding the main body region. These plates are nearly always present, and on removing the mantle are most conspicuous objects. Two small simple folds of the mantle integument—the **ovigerous frena**—arising close to the isthmus, furnish attachment to these ova masses, and prevent them being washed away. It is interesting to note that among the sessile Cirripedes, the Balanidæ, &c., these mantle folds are greatly developed, and in some cases have their surface area increased by further folding. Very probably their function under such conditions is branchial, and we may be warranted in describing them as branchiæ.

As in all other Cirripedes, no distinct blood system can be traced in *Lepas*.

The second common Cirripede type in our seas, is the little Acorn-shell, or Rock-barnacle (*Balanus*). In larval history it is identical with *Lepas*, but in external adult form, it presents a wonderful contrast. Fleshy stalk has entirely disappeared and the pallial sac, which lodges the body proper, is therefore sessile. Much modification of the shelly plates of the mantle has taken place, the parts being so arranged as to form a shelly palisade, wherein six distinct pieces are to be traced, roofed in by two pairs of plates, one pair representing the terga of *Lepas*, the other and larger pair, the scuta. When the tide flows over these tiny creatures, a slit-like opening between these opercular plates is revealed, through which sweep in and out, with elegant motion, tiny feather cirri, the thoracic feet (Fig. 3). With the receding tide, life-functions are partly suspended, the cirri are retracted, and the scuta and terga are shut down tightly, so as to retain some moisture till the tide returns. Quite an appreciable noise is made in the tightening of the valves when in this quiescent condition, and the low crackling murmur heard when walking over rocks thickly coated with Barnacles, is very familiar to me. Apparently the vibration of a heavy footstep is perceptible to them, and lest it betoken danger, they take the precaution of tightening their opercular valves, and in so doing form some tiny water-bubbles, which in breaking give out sufficient sound to be very noticeable when joined in by thousands of individuals.

In the anatomy of the body, apart from the mantle, there is practical similarity to that of *Lepas*; the main differences are that the cement gland is greatly increased, the ovigerous frena developed into two large folds functioning probably as branchiæ, while two special and strong muscles are developed at either end of the rampart-like shell to control the closing of the scuta and terga (m^1 and m^2, Fig. 5). Yet another and more important difference is seen in the ventral nerve ganglia being concentrated into a single large ganglionic mass.

The third type of Cirripede which I select, is as utterly unlike either of the preceding as it is possible to conceive, appearing simply as an oval bag without calcareous plates or even sculpturing, attached to the under surface of the abdomen of crabs. From this external sac penetrate into the interior of the host long branching tubuli, twining around the viscera and insinuated among the cæca of the liver. Nutrient matter is there obtained and is thence conveyed to the sac-like body. The latter contains neither alimentary canal, limbs, or other appendages. Shortly stated, its structure is that of a double walled sac, the inner of which contains large lobate ovaries, closely united, 2 testes, 2 cement glands, and a single nerve ganglion. The ovaries and the cement glands open by small apertures into a large space, the **brood cavity,** occupying the space between the outer and the inner sacs. Here the ova undergo their early development, and as *Nauplii* pass forth through a well-marked opening, the **cloaca** (*cl.*, Figs. 1 and 2, Pl. 5) possessed of a strong closing or sphincter muscle. Externally the cloacal aperture is obvious as a prominent papilla.

The young issue forth as fairly typical Nauplii, but differ from those of *Lepas* and *Balanus* in being destitute of paired eyes, mouth, and alimentary canal; a central cellular mass, the rudiment of the ovaries, is conspicuous. The Cypris-stage, into which the larva enters after its fourth moult, also resembles a normal Cirripede Cypris-larva, but deviates also in the absence of alimentary canal and paired eyes. To this point the larval history is that of an ordinary Cirripede, and by this fact alone are we enabled to class *Sacculina* definitely as a Cirripede Crustacean. Without such knowledge it would be practically impossible to properly access its position in nature's scale.

After a short free life, the Cypris-larva attaches itself by the anterior antennæ to the base of a seta or bristle upon the abdomen of a young crab. In Jersey, I find *Cancer pagurus* (the edible-crab) to be the most frequently attacked; *Pilumnus hirtellus* is also commonly infested. On the other hand, I scarcely ever see *Carcinus mœnas* attacked, and this is strange, as elsewhere this species is credited with being the favourite haunt of the parasite.

Following upon attachment, the thoracic region and its limbs, together with the abdomen, are severed and thrown away; the head appendages wither and the cellular mass which alone remains of the contents of the Cypris-valves, secretes a containing bag-shaped cuticle, marking the formation of the **Kentrogon larval stage**; the Cypris-valves fall away; a second cuticle forms within the first cuticle of the kentrogon sac; the anterior end is produced into a hollow arrow-like process, which, passing forwards through the cavity of the anchoring antenna, forces its way into the body of the crab-host. Through this channel the contents of the sac pass, and then become surrounded by a fresh cuticle. From this sac are thrown out branched roots ramifying in the course of time among the whole of the organs of the crab.

By these complicated phases *Sacculina* becomes primarily an *internal* parasite, but as the size of the sac gradually enlarges, it exercises so great pressure upon the integument of the abdomen of the host as to cause such thinning as permits the sac to burst its way through, and to appear as an *external* parasite. It is probable that the internal stage is assumed to obviate the danger of being thrown off and thereby destroyed, on the occasions of its host's moulting during the early period of the attachment and before its roots have had time to ramify extensively. It is significant of the paralizing effect exercised upon the growth of the crab, that once the sac has become external, *i.e.* when it has reached adult life, with its roots ramifying extrusively through the viscera, that moulting ceases, the crab remaining stationary in size.

Occasionally I have found two *Sacculinæ* parasitic upon the same crab. An interesting feature in *Sacculina*, is that, although hermaphrodite, complimental males exist, located usually around the cloacal aperture of the sac. They have a Cypris-like appearance.

The three species of Cirripedes above described are thus all connected by similarity in larval history (ontogeny). The diverse adult forms are also linked together by a gradation of intermediate types of great interest, that throw much light on the evolution of the more changed. Thus the change from the stalked *Lepas* to the sessile *Balanus*, can be understood by reference to *Scalpellum*, a stalked genus where the peduncle is reduced and the number of the calcareous plates of the mantle so augmented, some being intercalated between the terga and scuta and the border of the peduncle, that if the latter be lost and the carina and certain of the additional plates join laterally and arrange themselves as a circular wall pushing away the terga and scuta, we obtain the modification seen in *Balanus*—a ring of plates with the opening closed, lid-like, by the four plates of the terga and scuta. To the sac-like and limbless form of *Sacculina*, the gap is largely bridged by our knowledge of such genera as *Alcippe* and *Cryptophialus*, degenerate forms enveloped in bag-shaped mantles, and provided with but three pairs of cirriform feet, and which live parasitically in holes bored in shells. More degenerate still is *Proteolepas*, a remarkable grub-like form living in the mantle cavity of other Cirripedes; limbs are entirely absent and the digestive tube is rudimentary.

Classification :—

Class.—**CRUSTACEA.** Sub-Class.—**Entomostraca.**

Order.—CIRRIPEDIA.

Sub-Order I.—**Thoracica**; thorax always present, usually provided with cirriform feet; mouth and alimentary canal present.

Tribe I.—PEDUNCULATA; stalked, six pairs thoracic limbs.

Families.—*Lepadidæ* (stalks without calcareous plates or hairs); and *Pollicepedidæ* (stalks with hairs or plates).

Tribe II.—OPERCULATA; sessile, limbs same as in *Pedunculata.*

Families.—*Balanidæ* and *Chthamalidæ* (closely related, both with a symmetric calcareous ring, each branchia a single fold); *Coronulidæ* (symmetric ring of plates, each branchia doubly folded); *Verrucidæ* (calcareous ring asymmetric).

Tribe III.—ABDOMINALIA; thorax reduced, bearing three pairs of cirriform limbs.

Family I.—*Alcippidæ,* four pairs thoracic limbs, three pairs being cirriform.

Family II.—*Cryptophialidæ,* three pairs only of thoracic appendages—all cirriform.

Tribe IV.—APODA; no thoracic limbs, grub-like.

Family.—*Proteolepadidæ.*

Sub-Order II.—**Rhizocephala**; parasitic—body sac-like—without mouth or alimentary canal; possessing root-like processes that ramify in the viscera of the host.

One family only.—*Kentrogonidæ.* The chief genera are *Peltogaster,* parasitic on Hermit Crabs, and *Sacculina,* parasitic on *Cancer, Carcinus,* &c.

BOOK NOTICE.

"*Elementary Physiology,*" by Prof. J. R. Ainsworth Davis, 223 pp., 3 coloured plates and 104 figures in text. (London; Blackie & Son, Ld., 1895). Price 2/-.

Practical zeal and discrimination are impressed so characteristically upon all work undertaken by Prof. Ainsworth Davis, that one is inclined to accord this little work a hearty welcome on the strength of the author's credit alone. Detailed examination confirms this view, and as an introductory text-book, we believe it to be quite the best of its class. One cannot be too thankful to the author for the stress with which he emphasizes the fact that Human Physiology is but a small portion of Animal Physiology—too many students have, in the past, unconsciously grown into the belief that the two are interchangeable terms. Prof. Davis takes a very practical way of clinching his warning, by introducing an ably written chapter upon the digestion of the ox, and the secretion of milk. This is as it ought to be. In the chapter on practical work, the innovation is carried further still, for the frog, rabbit, rat, sheep, and bullock are all pressed into service, and so induce the requisite comprehension that all the vertebrates, including man, are upon essentially the same plan.

The work is well and judiciously illustrated, and while invaluable to those entering upon the study of this particular science, it ought also to be in the hands of every intelligent person interested in the way his own body is built up. It will also be invaluable to agricultural students, and specially to those engaged in dairying.

A good index, and two sets of examination questions are appended.

The Journal of Marine Zoology and Microscopy:
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REPORT ON THE SCHIZOPODA, CUMACEA, ISOPODA, AND AMPHIPODA OF THE CHANNEL ISLANDS.

BY ALFRED O. WALKER, F.L.S. AND JAMES HORNELL.

INTRODUCTION.

THE Crustacea in the following list (excepting those printed in heavy type) were collected by Monsieur E. Chevreux, the well known French Carcinologist, who was so obliging as to send me the list he had intended to publish in this Journal, by Dr. C. H. Hurst, Mr. Hornell, and myself, as indicated below. Some of the names also are taken from a collection of Jersey Crustacea in the Free Public Museum at Bootle, Lancashire,[1] sent to me for identification by Mr. Chadwick.

To make the list as complete as possible, Mr. J. Hornell, the Director of the Jersey Biological Station, has added a number of additional species and localities, which have either been recorded in previous publications, or have been collected and identified by him or by Mr. J. Sinel, and of which latter, the present is the first publication. All these additional forms are distinguished by being printed in heavy black type.

The following are the localities indicated by the letters and figures attached to the names :—

Jersey (J).

1. Two miles off St. Helier's Harbour, 9-10 fath. March 26, 1892 ; A.O.W. & C.H.H.
2. Near the Red Buoy at the harbour entrance, 4 faths. gravel, clinkers with *Sabella* tubes, &c. ; same date and collectors.
3. Shore near St. Helier's ; A.O.W. & C.H.H. March 27 and 28.
4. Shore Portelet Bay. March 30. A.O.W. & C.H.H.
5. Shore, Grande Azette, low spring tide ; March 31, A.O.W. and J. Hornell.

[1] These were collected by Mr. J. Sinel in former years.—ED.

6. 4 miles S.E. of harbour, 10-12 fath., stony and rocky ground, April 1 ; A.O.W. & C.H.H.
7. Shore below Grand Hotel, half tide ; April 2, A.O.W.
8. Collections from Jas. Hornell, July, 1892, &c.
9. Half-tide ponds among the reefs in St. Clement's Bay.
10. Between tide-marks, S. coast Jersey—chiefly from low-tide zone.
11. Tow-netted off S. coast Jersey.

Ch.—Collected and named by Monsieur E. Chevreux from low tide on Grêve d'Azette, 1895.

Bo. Mus.—Collection from Bootle Museum, 1895.

Guernsey (G).

1. Off St. Peter's Port ; 7 fath., gravel, clinkers and shells. April 4, 1892, A.O.W.
2. Between the Castle and St. Martin's, 10-15 faths. ; April 5, A.O.W.
3. Off St. Martin's, 25 fath., April 5, A.O.W.
4. Between tide-marks, chiefly low-tide.

S.B.—Indicates records from the Channel Islands in Spence Bate & Westwood's "*History of the Br. Sessile-eyed Crustacea,*" London 1863 to 1868.

R.K.—Species and localities recorded by Prof. R. Kœhler in "*Recherches sur la Faune Marine des Iles Anglo-Normandes,*" Nancy, 1885, which are not overlapped by other records.

* A prefixed asterisk indicates such species of Isopods and Amphipods as are named in the last cited work.

S. & H.—Collected or identified by J. Sinel and Jas. Hornell.

A.O.W.

SCHIZOPODA.

Macromysis flexuosus (Müller). J 11, common (S. & H.).
" *neglectus* (Sars). J 11 (S. & H.).
" *inermis* (Rathke). J 1, also from Guernsey by Canon A. M. Norman ("*Ann. & Mag. Nat. Hist.,*" Series 5, No. xix.)
Macropsis Slabberi, van Beneden. Bo. Mus.
Schistomysis Helleri (Sars). J 11 (S. & H.).
Gastrosaccus spinifer (Goës). Bo. Mus.
Anchialus agilis, G. O. Sars. G 1, G 2.
Cynthilia (Siriella) crassipes (G. O. Sars). G 2, also recorded by Norman, from Jersey *loc. cit.*
Cynthilia armata (M. Edw). Jersey (Norman, *loc. cit.*)

CUMACEA.

Iphinoë trispinosa (Goodsir). J 1, J 2.
Nannastacus unguiculatus, Bate. G 2.
Pseudocuma longicornis (Bate). J 1, J 2.
Diastylis spinosa, Norman. G 1.

ISOPODA.

**Tanais vittatus* (Rathke). J 10, G 4 (S. & H.).

***Leptochelia Savignyi** (Kröyer),=*L. Edwardsi* (Kröyer). G 4 (S.B.); J 10 (S. & H.); Sark (R.K.)

**Paratanais Batei*, Sars,=*P. forcipatus* (Lillj.). Bo. Mus.; Guernsey (S.B.); J 10 (S. & H.): Sark (R.K.)

Apseudes Latreillei (M. Edw.). J 2, G 1.

***Apseudes talpa** (Mont.). off Guernsey (S.B.); J 10 (S. & H.).

Anthura gracilis (Mont.). With *Corophium* and *Obisium* in rock crevices, Jersey (S. & H.).

***Paranthura nigropunctata** (Lucas)=*P. costana*, Bate & West. J 9 (S. & H.); off Jersey (S.B.); J 12 & G 4 (R.K.).

**Gnathia maxillaris* (Montagu). Bo. Mus.; common in all the islands, often commensal with sponges, &c., and also free, in the tow-net (S. & H.).

***Anilocra asilus** (Linn),=*A. mediterranea*, Leach. Herm (S.B.); common as parasites, male and female together, upon the head of Wrasse (Labridæ) (S. & H.).

Aega rosacea (Risso),=*A. bicarinata*, Leach. Two specimens on a *Squatina angelus*, Jersey (S. & H.).

***Cirolana Cranchii**, Leach. Off coast of Jersey (R.K.).

Eurydice spinigera, Hansen. Probably identical with *E. truncata*, Norman. Bo. Mus.

Eurydice achatus (Slabber),=*E. pulchra*, Leach. Common Jersey and Guernsey (S. & H.).

**Conilera cylindracea* (Mont.). Bo. Mus.; Guernsey (S.B.); Jersey (S. & H.).

**Sphaeroma serratum* (Fabr.). J 7; common under stones, Jersey (S. & H.) & (R.K.).

**Sphaeroma curtum*, Leach. The *S. Prideauxianum*, Leach, of Kœhler's list, is probably this species, as the two names are now considered synonyms. J 8; common (S. & H.).

Sphaeroma Hookeri, Leach. Guernsey (S.B.).

Campecopea hirsuta (Mont.). Common in the dry Fuci at high-water mark in all the islands (S. & H.).

**Dynamene rubra* (Mont.),=*D. viridis*, Leach. J 3, J 8; common (S. & H.).

***Dynamene Montagui**, Leach. In empty *Balani* shells (R.K.).

***Cymodoce truncata** (Mont.). Bo. Mus.; J 10 (S. & H.).

***Nœsa bidentata** (Adams). Vazon Bay, Guernsey (S.B.); in empty *Balani* shells, Jersey (R.K. and S. & H.).

**Idotea marina* (Linn.), *I. tricuspidata*, Desm. and *I. pelagica*, Leach. J 4; all islands, among algæ, and also in tow-net at night (S. & H.).

**Idotea linearis* (Pennant). Guernsey (S.B.); J 10 & 11 (S. & H.).

***Idotea emarginata** (Fabr.). Tow-net only, Jersey (R.K.).

Zenobiana prismatica, Risso. Bo. Mus.

***Stenosoma acuminata** (Leach). A single specimen, St. Aubin's (R.K).

***Stenosoma lancifer** (Leach),=*S. appendiculata* (Risso).

Munna Kroyeri, Goodsir. J 9 (S. & H.).

**Janira maculosa*, Leach. J 4; Common under stones, Jersey (R.K.) and (S. & H.).

Jæra albifrons, Leach. J 7; Common (S. & H.).

***Jæra nordmanni** (Rathke). J 10 (S. & H.); Sark (R.K.).

***Jæropsis brevicornis**, Kœhler. Gouliot Caves, Sark (R.K.).

Asellus aquaticus (Linn.). Common in ponds and ditches (S. & H.).

***Limnoria lignorum** (Rathke). Common in piles and wooden staging in the sea (S. & H.).

Ione thoracica (Mont.) A male and a female on a *Callianassa*, Jersey (S. & H.)

Gyge hippolytes (Kröyer.) Parasitic on *Hippolyte* (S. & H.).

Gyge galatheæ, Sp. Bate & West. Parasitic on *Galathea squamifera* chiefly, Jersey and Guernsey (S. & H.) ; Herm (S.B.)

*****Bopyrus squillarum,** Latr. Parasitic upon *Palæmon serratus* very commonly at all the islands (S. & H.) ; S.B. records it upon *P. Leachii* from same localities.

Liriopsis pygmæa (Rathke). In dredge off Guernsey (S.B.).

**Ligia oceanica* (Linn.) Bo. Mus. ; Common among rocks near high water mark, even invading houses at times (S. & H.).

Oniscus asellus (Linn.). Very common under decaying wood and similar habitats (S. & H.).

Porcellio scaber (Latr.). Common, Jersey (S. & H.).

Armadillo vulgaris (Latr.). Common amid decaying wood, &c. (S. & H.).

AMPHIPODA.

**Orchestia mediterranea*, Costa. J 3 ; Ch. ; male specimens were 20 mm. long ; common, J 9 (S. & H.).

**Talitrus locusta* (Pallas). Bo. Mus. ; Ch. ; Very common towards high-water, even invading houses at high spring tides (S. & H.).

Hyale Nilssoni (Rathke). J 3, 7, Ch.

Lysianax longicornis (Lucas). J 5, 8, G 2 ; J II (S. & H.).

Lysianax Costæ (M.Edw.). G 2.

Perrierella Audouiniana (Bate). Ch.

Orchomene Batei, Sars. J 5. 6 ; Ch. ; rather rare, Jersey (S. & H.).

Nannonyx Goësii (Boeck). J 5.

Tryphosa Sarsii (Bonnier). J 5.

Lepidepecreum carinatum, Bate. G 1. ; Jersey (S. & H.).

Bathyporeia norvegica, Sars. Ch.

Bathyporeia pilosa, Lindström. Under this species I include *B. pelagica*, Bate, and *B. Robertsonii*, Bate. G 1 ; common in certain spots on the Jersey coast, burrowing in sand (S. & H.).

Urothoë marinus, Bate. Bo. Mus. ; Ch.

Urothoë brevicornis, Bate. G 1, 2, 3 ; J 11 (S. & H.).

Urothoë pulchella (Costa). Ch.

Phoxocephalus Fultoni (Scott). J 6 ; G 3.

Phoxocephalus pectinatus, Walker. (Ann. & Mag. of Nat. Hist., Ser. 6. Vol. xvii. p. 343).=*P. simplex*, Calman, in Trans. Royal Irish Academy, Ap., 1896, nec Sp. Bate ; see also Ann. & Mag. of Nat. Hist., xviii. p. 156. The type specimens from which the specific diagnosis was made were dredged off St. Peter's Port, Guernsey, in 7 faths., Apr. 4, 1892.

Ampelisca typica (Bate). Ch. ; dredged off Noirmont Point, Jersey (S. & H.).

Ampelisca brevicornis (Costa),=*A. lævigata*, Lillj. Bo. Mus. ; Ch. ; taken in company with the preceding species in dredge (S. & H.).

Ampelisca tenuicornis, Lilljeborg. G 1, 2 ; Ch.

Ampelisca gibba, Sars. G 1.

Amphilochus manudens, Bate. Bo. Mus. ; J 9 (S. & H.).

Amphilochus melanops, Walker. (Rev. of Amphipoda of L. M. B. C. District, Trans. L'pool Biol. Soc., IX., 1895, p. 298, Pl. 18, 19).

Stenothoë monoculoides (Mont.). J 3 ; G 1 ; Ch. ; J 9 (S. & H.).
Metopa borealis, Sars. G 3.
Leucothoë spinicarpa (Abildgaard). J 5, 8 ; G 2 ; J 9 (S. & H.).
Leucothoë Lilljeborgii, Boeck. G 3 ; Ch.
Monoculodes carinatus, Bate. J 1, 2 ; Ch.
Perioculodes longimanus (Bate). J 1, 2 ; G 1, 2 ; Ch.
Synchelidium haplocheles (Grube). J 1, 2 ; G 1, 2, 3 ; Ch.
Pontocrates norvegicus, Boeck. Ch.
Iphimedia obesa, Rathke. G 2.
Eusirus longipes, Boeck. G 3.
Apherusa Jurinii (M. Edw.),=*Pherusa fucicola*, Leach. J 3, 8.
Apherusa cirrus (Bate),=*Pherusa bicuspis*, Bate. J 5 ; Ch.
Apherusa bispinosa (Bate). J 1, 2, 6, 8 ; G 1, 2, 3 ; Ch.
Calliopius leviusculus (Kröyer). J 4.
Paratylus Swammerdamii (M. Edw.). J 2, 4, 6 ; Ch.
Paratylus vedlomensis (Bate). J 1 ; G 2, 3.
Dexamine spinosa (Mont.). J 2, 5, 8 ; Ch. ; Common (S. & H.).
Dexamine thea, Boeck. J 8 ; Ch.
Tritæta gibbosa (Bate). J 3.
Amathilla homari (Fabr.),=*A. sabini* (Leach). Bo. Mus. ; Jersey (S. & H.).
Gammarus marinus, Leach. J 5, 6 ; G 2 ; Ch. ; Common (S. & H.).
Gammarus campylops, Leach. Ch. ; Jersey (S. & H.).
Gammarus locusta (Linn.). G 2 ; Ch. ; Jersey (S. & H.).
Gammarus Berilloni, Catta. Valley des Vaux and a ditch near St. Brelade's Bay, Jersey (Ch.). Hitherto this species has been met with only in the Western Pyrenees, and hence its presence in Jersey is an interesting and difficult problem. For a valuable account of this species, together with figures of its distinctive characters, see M. Ed. Chevreux's paper "*Sur le Gammarus Berilloni, Catta*," in *Bulletin de la Soc. Zool. de France*, tome XXI. p. 29.
Gammarus pulex (de Geer). Common in ditches and fresh water streams in Jersey and Sark (Ch.) ; Jersey and Guernsey (S. & H.).
Melita palmata (Mont.). J 4, 5 ; Ch.
Melita obtusata (Mont.) J 2 ; Ch. ; Jersey (S. & H.).
Melita gladiosa, Bate. G 2 ; low-tide pool, Bordeaux Harbour, Guernsey (S. & H.).
Mœra grossimana (Mont.). J 5 ; G 1 ; Ch. ; J 10, very common (S. & H.).
Mœra Othonis (M. Edw.). G 1, 2, 3.
Mœra semiserrata (Bate). G 2, 3.

The last two species I consider to be identical, the latter being the immature form.

Mœra Batei, Norman. G 1, 2.
Megaluropus agilis, Norman. G 1.
Cheirocratus Sundevalli (Rathke). G 1, 2 ; Ch.
Cheirocratus assimilis (Lilljeborg). G 2, 3.
Gammarella brevicaudata (M. Edw.). Probably the *G. longicornis* of Kœhler ; see Stebbing on "Challenger" Amphipoda, p. 566. J 2, 5, 7.
Microdeutopus damnoniensis (Bate). J 3 ; G 1 ; Ch.
Microdeutopus gryllotalpa, Costa. Ch.
Microdeutopus (Stimpsonella) chelifera (Bate). Ch. ; J 9 (S. & H.).
Microdeutopus versiculatus, Bate. Ch.

Aora gracilis, Bate. G 2, 5, 8.

Leptocheirus pilosus, Zaddach,=*L. pectinatus* (Norman). G 1 ; Ch. Monsieur Chevreux expresses doubt as to the identity of the above species mainly on the ground that while Norman describes the dactylus of the 1st gnathopods as "much longer than the truncated extremity of the propodos," Zaddach, as translated by Spence Bate, says it is "as long as the palm." But it seems to me that Zaddach considered the palm to be defined by the spine which is situated a little below the ill-defined angle formed by the truncated extremity and the posterior margin, in which case both his definition and Norman's would be correct.

Gammaropsis maculata (Johnston),=*G. erythrophthalmus*, Lillj. J 3, 6 ; J 9 (S. & H.).

Megamphopus cornutus, Norman. J 6 ; G 3.

Microprotopus maculatus, Norman. J 2 ; Ch.

Photis longicaudatus (Bate). G 1, a large male ; dredged off La Rocque, Jersey (S. & H.).

Amphithoë rubricata (Mont.) ; J 5, 7 ; G 1 ; Ch.

Pleonexes gammaroides, Bate. J 5 ; Ch. ; J 9 (S. & H.).

Sunamphithoë conformata, Bate. Bo. Mus. ; Ch.

Podocerus falcatus (Mont.). J 1, 4 (S. & H.).

Podocerus ocius, Bate. A male, J 8.

Erichthonius abditus (Templeton). J 6 ; G 1.

Siphonœcetes Colletti, Boeck. G 1 ; Ch. ; J 11 (S. & H.).

Corophium crassicorne, Bruzelius. G 3 ; Ch.

Corophium grossipes (Linn.). Bo. Mus. ; Jersey (S. & H.).

Colomastix pusilla, Grube,=*Exunguia stillipes*, Nordm. of Kœhler's list. Ch. Sark (R.K.)

Chelura terebrans, Philippi. J 2 ; Common (S. & H.).

Dulichia porrecta, Bate. J 6 ; G 2.

Phtisica marina, Slabber. J 4, 5 ; Ch. ; on trawl rope, Jersey (S. & H.).

Pariambus typicus (Kröyer). J 2.

Caprella acanthifera, Leach. The *C. hystrix* of Kœhler's list. Ch. ; Common, Jersey (S. & H.).

Caprella acutifrons, Latreille. J 6.

The following additional species of Amphipods are communicated by Mr. Jas. Hornell as collected and identified by him and Mr. Sinel :—

Hoplonyx cicada (Fabr.),=*Anonyx Holboli*, Kröyer. Jersey.

Menigrates obtusifrons Boeck,=*Anonyx plautus*, Kröyer. Guernsey.

Pontocrates arenarius (Bate). Jersey.

Laphystius sturionis, Kröyer,=*Darwinia compressa*, Bate. Fairly common. J 9.

Urothoë elegans (Bate). J 9, 11 ; not common.

Isœa Montagui, M. Edw. J 9.

Iphimedia eblanœ, Bate = ? *I. minuta*, Sars. A single specimen dredged off Grève d'Azette. Oct., 1887.

Niphargus fontanus, Bate. Several specimens have been procured from two wells on the outskirts of St. Helier, Jersey.

Lœtmatophilus tuberculatus, Bruzelius,=*Cyrtophium Darwinii*, Bate. J 9, common.

Hyperia galba (Mont.). Frequent in the genital pouches of *Rhizostoma.*
Caprella linearis. Not uncommon. J 10.

As completing the list of the known Amphipod Fauna of the Channel Islands, Mr. Hornell adds the following six species which have so far been recorded by Prof. Kœhler alone *(loc. cit.)* :—

Orchestia littorea, Leach. Jersey, among algæ.
Nicea Lubbockiana, Sp. Bate. Sark ; Jersey, in company with *Styelopsis.*
Stenothoë marina, Sp. Bate. Sark ; Jersey, in same habitats as *Nicea.*
Podocerus capillatus, Rathke. Sark ; among *Styelopsis,* Jersey.
Lembos Websteri, Sp. Bate. Sark.
Protella phasma, Sp. Bate. Jersey.

THE USE OF FORMALIN AS A PRESERVATIVE FLUID.

BY JAMES HORNELL.

For considerably more than a year I have had the action of Formalin as a preservative fluid under constant observatiou, and, as the results may prove useful to many readers, I will now summarise them as much as possible.

The fluid as commercially sold is a 40 % aqueous solution of formaldehyde, but in use, for ease in reckoning percentages, this must be considered as representing 100 %. Thus a 5 % solution of formalin is made up of 5 parts of the fluid as commercially sold, diluted with 95 parts of water.

The chief biological value of formalin is essentially in the preparation and preservation of specimens intended for dissection and Museum purposes ; in microscopical technique—for reasons to be mentioned later—its use is entirely secondary and limited.

Reviewing its application among the various phyla of animals we find that :—

SPONGES are most beautifully preserved by simple immersion, without previous fixation. No contraction of even the most delicate membrane is observable, and where there is natural transparency or semi-opalescence, this is perfectly retained—*Halisarca* is a good instance in point: spirit specimens become opaque and leathery-looking ; formalin ones retain the characteristic jelly-like appearance, with, however, a sensible stiffening that is just sufficient to become valuable as diminishing the danger of injury to the specimen in handling, &c.

HYDROZOA. Hydroid stocks of the smaller sizes, being usually required for microscopical examination, mounted in balsam, are best preserved in the ordinary way by fixing and subsequent grading into spirit ; this, because I find that the staining of formalin-preserved specimens is inferior to that of well fixed spirit ones, as differention is comparatively poor in the former case. For Medusæ, great and small, and for many Siphonophores, formalin finds one of its most valuable applications. For instance, the large Medusæ, *Aurelia, Chrysaora*, and *Rhizostoma* are preserved perfectly by simple immersion in a 5% solution. No special care whatever is needed, except that the animals should be perfectly healthy and active when put in. They may remain in the original fluid indefinitely, though in the casé of animals containing a maximum of water in the tissues, as do the large medusæ, it is advantageous to change to a fresh solution in the course of several days. The advisability for this depends very greatly upon the relative volume of the fluid contained in the receptacle as compared with the bulk of the animals immersed therein. The small medusæ, *Sarsia*, &c., are also a great success when treated in the same way. Here, where the objects are of great delicacy, I wish to emphasize the importance of making up the Formalin solution with *sea-water*. The observance of this precaution in some cases is absolutely necessary. With large and stout animals, as fish, molluscs and the like, a fresh water solution is, however, perfectly admissible.

ACTINOZOA preserve well also, but though the new treatment has its advantages in transparency, I hesitate to say that it is better for museum purposes than well prepared spirit specimens, as alcohol imparts a very useful stiffness to the tentacles that is somewhat lacking in the formalin ones. Much depends upon the dangers of transit ; thus where specimens can be prepared on the spot and deposited on the museum shelves without a railway journey, then I would recommend the formalin preparation made with a 6 °/ₒ or 7 °/ₒ solution, but if this cannot be done on the spot, then spirit specimens will probably stand a railway journey better. For dissection purposes, formalin is, however, fully equal, and in some cases decidedly superior.

ECHINODERMS. Here I incline to prefer spirit to formalin though both are good.

VERMES. The same remark applies here as in the preceding case. There is really little to choose between the two methods.

CRUSTACEA. For the smaller, such as Copepods, Amphipods, &c., formalin is very useful when the objects are not required to be mounted to show internal anatomy. Especially good is it for those doing tow-netting, &c., at a distance from a laboratory base, where all facilities are at hand. In such cases all that is requisite is to kill the organisms either by the application of an ordinary fixative or by pouring in a little strong formalin to cause the animals to settle to the bottom of the vessel, so allowing the superfluous water to be poured off ; this done, all that remains is to bottle the remainder in a strong solution—I prefer an 8 °/ₒ strength—label and put away.

For the larger specimens it also does well if *used strong ;* if used at all weak, there is a tendency for the carapace to rise, leaving an unnatural space between the hinder edge, and the anterior edge of the succeeding segment. I notice, too, that limbs tend to become more brittle than in the case of spirit specimens, while the fluid frequently becomes milky, due, I believe, to chemical action on the lime set up by some acid product of the formalin solution. Hence it is inadvisable to use this fluid for museum preparations when much caleareous matter is present.

MOLLUSCA gives most excellent results by formalin, and are superior in appearance, and in dissection qualities, to spirit ones. I cannot award too high praise to formalin for use upon these animals.

TUNICATA. The same praise applies equally here, especially in regard to the compound forms, such as *Botryllus*, *Aplidium*, and the like, where spirit results are notably so unsatisfactory. Comparative retention of transparency with little or no shrinkage takes place among even the most delicate, especially if a sea-water solution be used.

PISCES. Formalin is here again unmistakeably superior to spirit, but as the former is somewhat inferior in penetrative power, when its internal organs, viscera, brain, &c., are required for dissection, it is essential that these should be carefully exposed and frequently moved during the first few days to ensure the fluid having free access to the inner parts. When once stiffened, they keep perfectly in a 4°/₀ or 5°/₀ solution, though even lower strengths will ensure preservation. Such lower strengths are however not advisable, for as the price of even a strong formalin solution is much less than spirit, it would be folly to risk spoiling good specimens for the sake of a few pence.

Sponges, medusæ, molluscs, tunicates and fishes are the groups where the value of formalin reaches a maximum.

COLOUR. Some writers have stated that formalin preserves most colours unimpaired, but such an assertion can arise only from an insufficient experience of its action. Lengthy familiarity has convinced me that its extractive action in this respect is very similar to that of spirit, and that the only difference is one of degree and not of kind. Given a prolonged soaking in formalin, a red sea-weed or an orange sponge will as surely fade as if they were in spirit, though if kept out of strong light, the change may be so gradual as not to be very noticeable for some time; a weak solution, of course, takes much longer to impair colour than a strong, and indeed if perfect internal preservation be not an essential, the employment of a 2°/₀ solution will not appreciably impair the colour for a fairly considerable time.

Where not stated otherwise in the preceding notes, a 5°/₀ solution is to be inferred as the requisite strength.

As indicating the comparative price of formalin as opposed to spirit, I may mention that at present average prices, a 5°/₀ solution should cost considerably less than half the price of spirit, and in this connection it must further be borne in mind that in order to perfectly preserve in spirit several changes are necessary—whereas in formalin, except in rare cases, not even one change is needful—hence the cost of a formalin solution ranges, in reality, from one quarter to one third of that of spirit.

ON SURFACE TENSION AS AN AID TO LOCOMOTION AMONG MARINE ANIMALS.

BY JAMES HORNELL.

It has long been known that certain species of nudibranch molluscs can crawl in an inverted position on the surface of water, taking advantage of that peculiarity residing in the surface film known as surface-tension, but as I doubt if the extended range of this habit is generally known, I venture to enumerate several instances that have come under my personal observation; some of these have probably not been previously recorded.

The opisthobranch molluscs utilize surface tension the most commonly. No species that I have watched fails to practise the habit. *Eolis papillosa*, *Doris tuberculata*, *D. pilosa*, *Elysia viridis*, *Pleurobranchus membranaceus*, and *P. plumula*, continually do it, and small individuals of *Aplysia punctata* at times adopt it. Size appears to have little controlling effect, as large *Doris*, 5 inches long and 3 inches broad, progress thus as easily and as rapidly as the tiny *Elysia*. *Pleurobranchus plumula* is, however, the most persistent in the habit, sometimes passing hours together moving or at rest in the inverted position at the surface. *Eolis* comes next in point of frequency in similar habits.

The little Cowry, *Cypræa europæa*, is another and even more interesting instance. In confinement, in a tank, it frequently crawls inverted along the surface of the water, and occasionally may be seen to form a little disc of mucus from which it lowers itself gently by a mucous thread till it hangs in mid-water, dangling in the fashion of a spider at the end of its silken cord. The cowry's disc of mucus thus functions as a float, supported not by any inherent lightness as is cork or wood, but by the aid given by the tension of the surface film being sufficiently great to prevent the mucous mass from breaking through.

This habit of the cowry is to be correlated to that more familiar and natural one so readily verified by any observer who visits the low-tide caves and gullies where, among sponges and ascidians, this animal loves so to live. Here, when the tide recedes, cowries more or less enveloped in their bright coloured mantle lobes, are often seen passively hanging suspended from the gully's roof, or from points and jutting ledges by a stout mucous thread.

It is noteworthy that *Eolis* occasionally suspends itself from the surface of water in a similar manner to the cowry, that is by a mucous thread pendant from a float of the same nature. Several times I have noticed this to occur when *Eolis* has been crawling inverted along the surface. The length of the mucous cord was often as much as four and five inches.

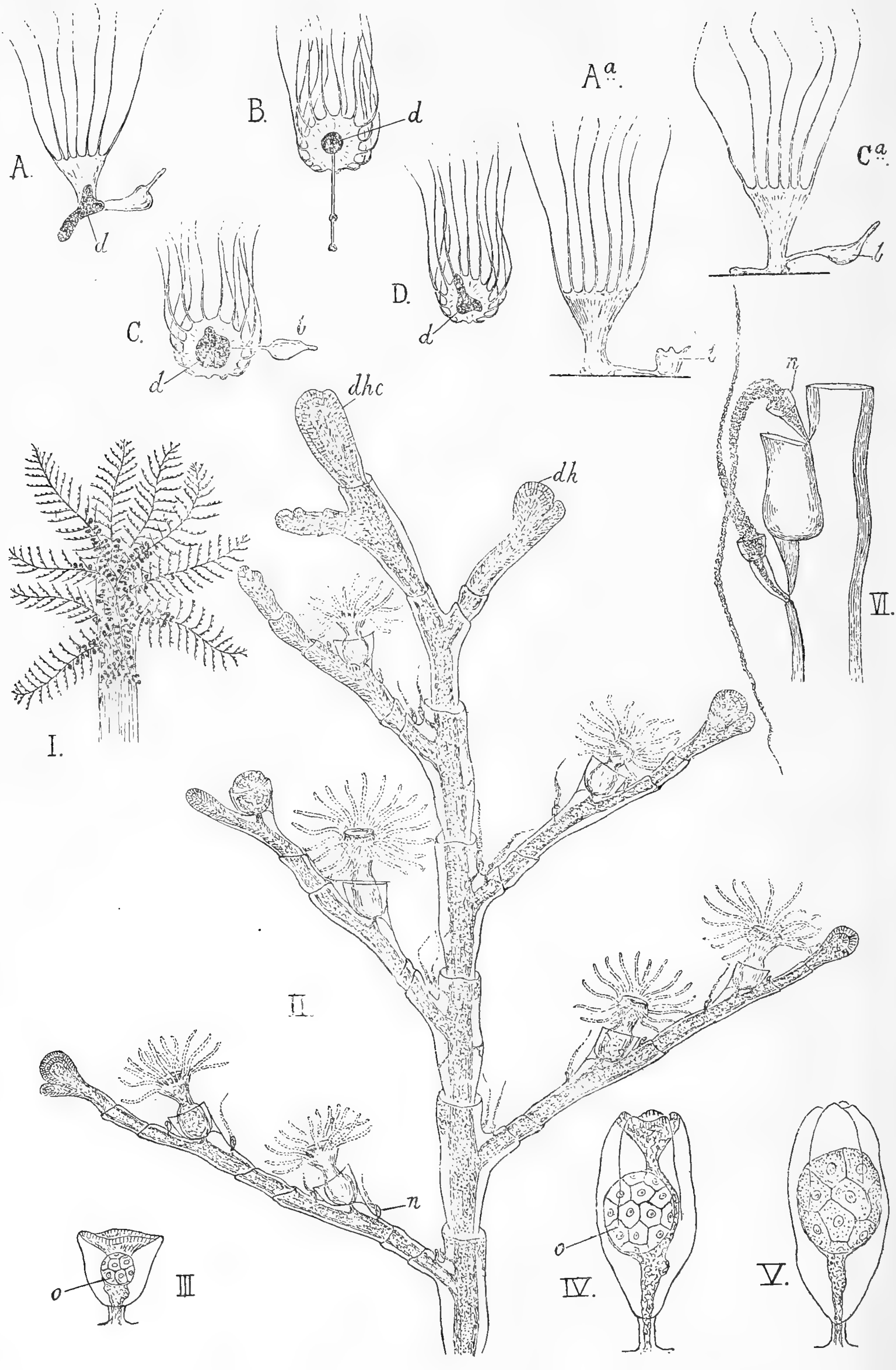
Passing to another group, we find that many of the smaller crustaceans profit largely under natural conditions from the flotation support afforded by the surface film. *Nebalia* especially utilizes it, and indeed seems to require to exert a special effort in order to break through the film when wishful to descend. The Amphipod *Mœra* (various species) is another similar instance out of several other genera of Amphipods. Indeed there are quite a number of small crustaceans which may be occasionally seen floating on the surface by this means. Conspicuous among these others are the Cypris or pupal larvæ of the Barnacle *(Balanus)* and the fine Ostracod, *Asterope mariæ.* To the former this habit is a very valuable one, as it enables them to be lodged by the receding tide on the higher rocks of the shore, just the situation suitable to their requirements; the presence of numerous oil-globules in these larvæ, is of much interest in this connection, and must be of the utmost use to the animals in bringing and keeping them within the influence of surface tension. The nauplii of this creature, though much smaller, are scarcely ever seen on the surface film, as they keep at a lower level; it is obvious that were they to rise into the surface film they would experience great danger of being cast ashore, a fatal accident for them but just the contingency required by the Cypris-larvæ.

While in *Nebalia*, *Mœra*, the Cypris-larvæ of *Balanus* and some others, the habit is adopted, I believe, with a definite object, there are many instances where it is practically certain that the flotation is not voluntary and is accidental, the animal having either jumped or been splashed on to the surface, where it is retained by tension of the water-film, till, by a vigorous effort it breaks through and is able to descend beneath the surface.

In confinement, I have several times noticed anemones, chiefly *Actinoloba dianthus*, floating on the surface, foot upwards, suspended by the action of surface tension. This obviously is a ready mode of transport but how far it is accidental and induced by the unusual nature of its environment is difficult to determine, though as *Actinoloba* often frequents quiet land-locked localities, *e.g.* Southampton Water, where perfectly smooth water is of common occurrence, it may be that it is a natural habit. Actual observation in such localities is therefore required to determine the question.

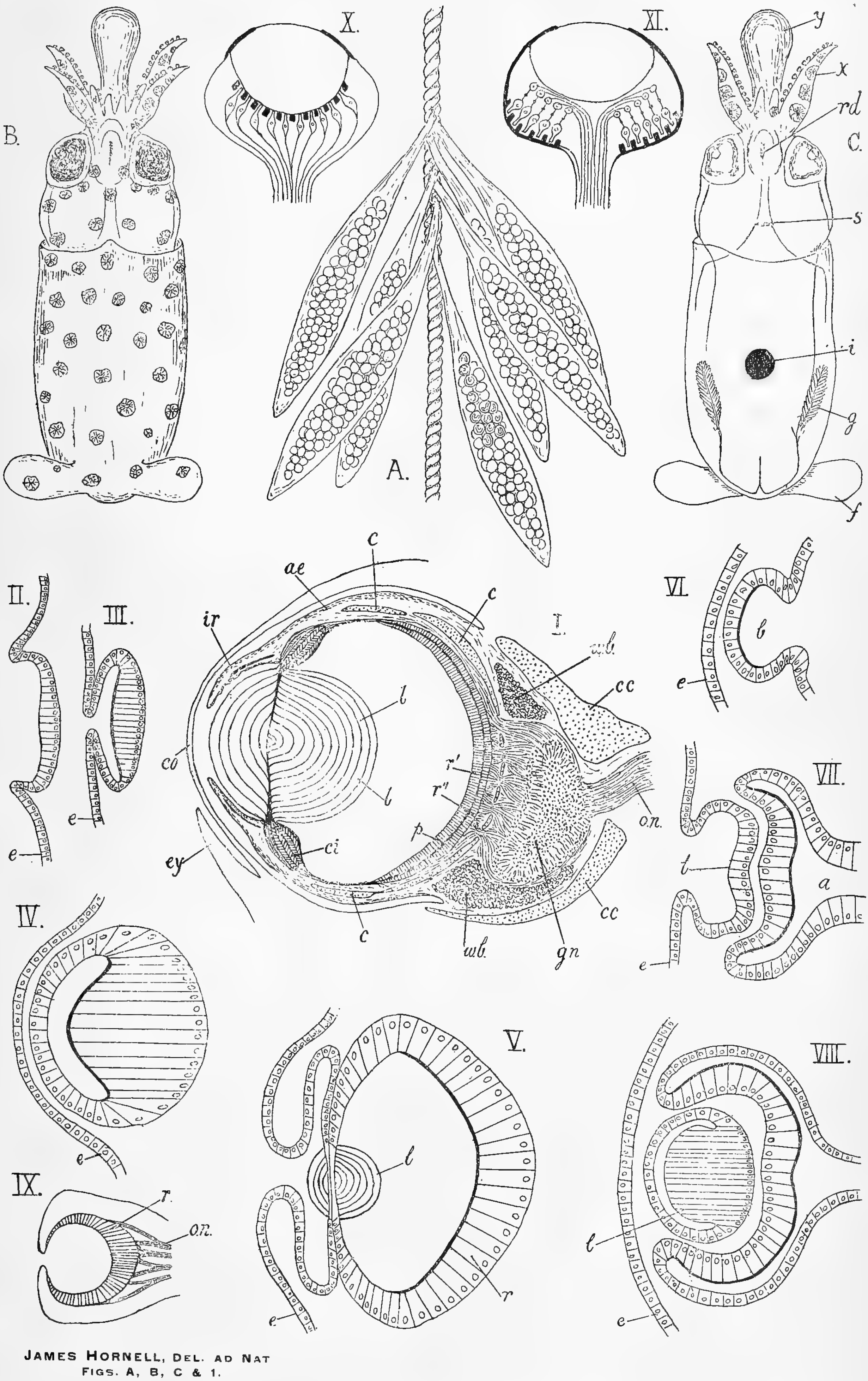
As to the Molluscs, the smaller ones, such as *Elysia*, which commonly frequent tidal pools where the water is normally quiet, certainly do make use of this mode of progression, but it is more than doubtful if the large *Doris* do under purely natural conditions.

It is, however, among the Crustaceans that real service is obtained by animals from the phenomenon of surface tension. To the other groups it is at most but of very occasional use; to *Nebalia*, Cirripede pupal larvæ, &c., it is of constant value, and of the highest importance in the routine of their life history, indeed as regards the Cypris larvæ, very much emphasis must be laid upon the correlation of this peculiar flotation with the special habitat of the *adult* animals.



JAMES HORNELL, DEL. AD NAT.
(FIG. VI EXCEPTED)

AURELIA AND PLUMULARIA.



JAMES HORNELL, DEL. AD NAT
FIGS. A, B, C & 1.

CEPHALOPODA.

THE PERMANENCE OF THE SCYPHISTOMA STAGE OF AURELIA.

BY JAMES HORNELL.

Three years ago, in 1893, large numbers of the Scyphistoma or Hydra-tuba stage of the Medusa *Aurelia aurita* appeared on boulders in several of the tanks of the Jersey Biological Station. Since then, colonies produced from these individuals have been permanent on the same stones. The continuity has been absolute, individuals having practically been under daily observation since their first appearance.

Under favourable conditions of food supply and temperature the increase in their numbers by budding was very rapid. The buds grew out from any part of the body; lengthened each into a stolon that crept along the rock till some quarter inch away from the parent, then made adhesion by a part that would finally become the basal disc, quickly budded forth a ring of tiny tentacles, opened a mouth aperture and finally constricted and then cut through the bond with the parent, the two parts of the stolon being absorbed by the respective individuals. Sometimes a Scyphistoma would give off two or even three stolons at the same time, and as the growth of the young individuals from these outgrowths is sometimes very rapid, the vast increase of the colonies is comprehensible. No wonder that *Aureliæ* some seasons swarm in countless millions in our seas!

While this process of multiplication goes on very rapidly during the greater part of the year, towards the end of January and the beginning of February a second mode of reproduction, **strobilation,** takes place. This, as is so well known, is the constriction of the polyp-like body of the scyphistoma into short-armed plate-like divisions or discs, arranged in a manner similar to a rouleau of coins. One by one the discs broken off from the stock, float away as **ephyræ** —little pulsating plates that by gradual change and growth, pass imperceptibly into the adult sexual medusa, the female producing ciliated embryos that, after a short free-swimming existence, settle down, form tentacles and mouth and assume the alternate sexless or Scyphistoma-stage.

Every year since 1893, my captive colonies have thrown off their ephyræ, but the individuals never assume the polydisc or typical form, usually—I believe—most common in strobilating individuals in the open sea. Mine have all been monodisc strobilæ, producing not a rouleau of ephyræ discs, but each a single ephyra. This I am inclined to attribute to a lower vitality than is posessed by those in the sea, induced by the smaller food supply available in the tank water, which is to a large extent filtered prior to admission to the tanks.

Apparently a colony can exist indefinitely; the specimens I now have are exactly of the same appearance as those that appeared three years ago, save that they have spread and multiplied exceedingly. Excepting accidents they are likely to exist as long as they receive the moderate attention they have had so far. I do not, however, mean to assert that the same individuals are now alive as in the beginning, though it is probable they may live two or more seasons. The chapter of accidents is long and those living to-day are in most cases, at least, the budded off and replace successors of the original ones.

On Pl. VI., figs. A. to D., are drawn a group of four as seen when in active budding on Christmas Day, 1894. They were attached to the side of a bell jar in a most favourable position for observation. Fig. A[a] shows side view of one of these to show how in some cases the stolon has been given off from the polyp body at a point considerably above the attachment disc; thus the stolon bends down to root at a distance from the parent, after the fashion of the branches of the banyan and the mangrove. In others it emerges low down as at fig. C[a].

Explanation of Pl. VI. Figs. A to C.

Fig. A, B, C & D. A group of Scyphistomata of *Aurelia aurita*, drawn on Christmas day, 1894, when attached to the side of a bell jar. *d* is the adhesion disc, *b* a proliferated bud; B shows in the best manner, the development of a stolon. A[a] and C[a] are profile views of A and C respectively.

MICROSCOPICAL STUDIES IN MARINE ZOOLOGY.

BY JAMES HORNELL.

STUDY XXI.—THE PLUMULARIDÆ.

None of our Zoophytes are more graceful than are the Plumularidæ—their form justly entitles them to the name they bear, so exquisitely beautiful are their feathery plumes, borne sometimes on the green blades of the sea-grass *(Zostera)*, or on the stout brown edges of *Fucus*, or even on the bare rocky sides of some sheltered pool.

Very nearly related in general form to the Sertularidæ, this family differs in two important points: in the former, the polyps are arranged along both sides of the branches, in the latter, a row is found on one side only; again, among the Plumularidæ, minute and degraded individuals are found, known under the name of **nematophores**—organs entirely wanting among the Sertularidæ. In the species here figured, one occurs just beyond, and another below each hydrotheca, whilst two are located in the axils of the stem and branches. Considerable mystery attaches to these structures, their function being still problematical. In form they are tiny chitinous cups wherefrom project extremely extensile sarcodal threads. The term **sarcotheca** is applied to the cups; **sarcostyle** to the thread. The latter, though extremely slender and tenuous, and not unlike the gigantic pseudopodia of some monstre Foraminiferon, are truly cellular, composed of an outer ectodermal layer sheathing an endodermal core. A remarkable feature is the projection of pseudopodia-like processes from the surface of the sarcostyle. The cell-walls are all extremely tenuous and thus capable of great elongation. The extensile power of these threads is indeed marvellous. Fig. VI., Pl. VI., gives but a faint idea of this. When active, they may be seen winding and coiling with snake-like litheness around the hydrothecæ and the branches. Especially active are they in the neighbourhood of dead polyps, and here perhaps is their sphere of usefulness, in the removal of decaying matter—a theory strengthened by the presence of foreign particles in certain amœboid cells of the surface.

The great reproductive capsules or gonangia are especially well-developed in this species, crowding the lower end of the main stem (hydrocaulus), the lower branches, and especially the creeping stem or stolon that connects the various plumes of the commonwealth. In these the reproductive cells mature and undergo segmentation, but, thanks to Weismann's researches (*Die Enstetnung der Sexualzellen bei den Hydromedusen*) we now know that in this family, the Plumularidæ, they do not originate within the gonangia, but arise in the endoderm of the stem, whence they migrate to the gonangia as into incubatory pouches. Figs. 3, 4 and 5, Pl. VI., illustrate these protective sacs in various stages, and show how the sexual cells congregate in a sphærical mass—a false ovary.

The family Plumularidæ is represented by three genera in British waters, *Plumularia*, *Aglaophenia*, and *Antennularia*. The last named is distinguished by the whorled arrangement of its characteristically short or bristle-like branches. The two former are plumously branched ; in *Plumularia*, the gonangia are scattered along the branches and the stems ; in *Aglaophenia*, they are collected into great basket-like structures, called **corbulæ**, formed by the modification of an entire branch or pinna. The arrangement of the nematophores is also distinct in the two genera.

Explanation of Pl. VI; Figs. I. to V.

Fig. I. Natural appearance of fronds of a species of *Plumularia* growing upon the extremity of a blade of *Zostera*. The black buds are gonangia, attached to the creeping and connecting stolon or hydroriza and to the lower parts of the fronds.

Fig. II. A young frond, greatly enlarged, showing polyps in various positions, and also the position of the nematophores (*n*) both below and above the hydrothecæ, and in the axils of the branches ; *dh.* developing hydranth ; *dhc.* developing extremity of the stem or hydrocaulus.

Fig. III., IV. and V. Various stages in the history of a gonangium ; *o.* ova.

Fig. VI. Shows two nematophores of another species. *n.* the chitinous sarcotheca, emitting the highly extensile whip of sarcostyle (after Hincks).

Study XXII.—The Eggs and Young of Cephalopods.

In the Cephalopods, we see the highest development of the Mollusca, a superiority at once obvious when we consider their powers for rapid locomotion, their powers of offence, their keen vision, and the large size of their central nervous mass, the brain. In their development, this vast gap that separates them from their fellows in the common phylum, is emphasized strongly. Lamellibranchs, marine Gastropods, &c., have all one characteristic larval form, the **veliger**—a tiny, free-swimming larva propelled by powerful cilia, and housed in a transparent shell. Among Cephalopods no trace of this is seen.

Of the species found upon our coasts, the large *Loligo Forbesii* deposits her eggs in masses of candle-shaped cocoons, attached at one end to seaweed or other objects. This spring, on one occasion, we found a considerable number of cocoons attached to the buoy rope of a lobster pot (Plate VII., Fig. A), from which they hung in bunches, recalling the primitive "dip" candles of auld lang syne. These cocoons are transparent, gelatinous, and tough, and composed of several layers, enclosing a large number of eggs—each egg in turn encased in a transparent spherical membrane.

The course of development of the embryos is abbreviated, for when they free themselves from the egg-membranes, they possess the general structure of the adult. Indeed, as soon as born, they swim and dart about with all the confidence of full-grown individuals. Even the ink bag is developed at the time of hatching, and is to be seen as a tiny black spot, and upon irritation, the little creatures can cause the contents to be ejected in a tiny black cloud. There are also present **chromatophores**—very conspicuous vesicles of pigment, governed by sets of muscles that produce by alternate expansion and contraction the pretty blushings and pallor so marked a feature among the adult Cephalopods. I noticed, however, that the chromatophores are normally kept in a state of contraction so long as the animal is unhatched, the whole mass being glassy transparent till then. For a long time before freedom is gained, the embryos can move freely in their capsules. In these young forms, a tiny remnant of the yolk sac, attached in the centre of the arms, is sometimes unabsorbed at the moment of birth. Two flap-like fins are present at the extremity of the abdomen—and of very different shape to the adult fins.

The young of *Sepia* have a similar history, but here the eggs are laid in separate egg capsules and not in cocoons. Black and of the form of grapes, these eggs produce each a single embryo.

In the mounted specimens of the embryo, notice the pair of gills at the hinder part of the mantle cavity, a number characteristic of all living Cephalopods excepting the pearly *Nautilus* which possesses four gills. On this account we class all Cephalopods as either DIBRANCHS or TETRABRANCHS. The present day representatives of the class are grouped as follows :—

Class :—CEPHALOPODA.

ORDER I :—TETRABRANCHIATA. One living genus only ;—*Nautilus*.

ORDER II :—DIBRANCHIATA.

SUB-ORDER I :—**Octopoda** (possessing eight arms), whereof the best known genera are *Argonauta*, *Octopus*, and *Eledone*.

SUB-ORDER II :—**Decapoda** (possessing ten arms), containing a very large number of genera ; among others being *Sepia*, *Sepiola*, *Loligo*, *Rossia*, *Ommatostrephes*, *Loligopsis*, and *Spirula*.

EXPLANATION OF PL. VII. Figs. A. B. & C.

Fig. A. A cluster of egg capsules of *Loliga Forbesii*, attached to a rope. x ½.

Fig. B. Young of *L. Forbesii* just after it has broken through the egg membrane ; chromatophores shown relaxed.

Fig. C. The same viewed as a transparent object. *f.* fins ; *g.* gills ; *i.* ink sac ; *rd.* radula ; *s.* siphon ; *x,* chromatophores ; *y.* remnant of yolk sac, as yet unabsorbed ; the eyes are shown in optical section.

STUDY XXIII.—THE VISUAL ORGANS OF THE MOLLUSCA.

The organs of sight in their frequently perfect adaptation to the sensory function they perform, claim our admiration in a degree greatly superior to that which we accord to any other organ of the body. Nor is our interest lessened when we see the manifold modifications of structure presented by them ; how, even in the same phylum, one family may be endowed with such organs formed in the most complex manner, whilst closely related forms may possess but the simplest of structures, crudely functioning towards a similar end ; how here, the optic mechanism is prominently and closely associated with the brain ; how, among others, organs arise independently from the most diverse regions to assume a physiological equality with the cephalic eyes of other types.

Nowhere do we find greater variability in the origin and structure of the visual organs than among the Mollusca. Thus, while the Gastropoda and the Cephalopoda possess paired cephalic eyes, the Lamellibranchs possess none, their place being taken by numerous peripheral eyes arranged along the edge of the mantle.

In structure, apart from the mere pigment spots that are borne upon the extremities of the siphons in *Solen*, *Venus*, &c., there exist five principal types of eye among the Mollusca.

The simplest form, found in the eyes of the Limpet *(Patella)*, is a mere bowl-shaped depression of the epidermis, the lining of which has become modified into a visual layer, or retina, into which the optic nerve penetrates by numerous fibre-branches. A slightly higher modification is seen in the eyes of *Nautilus*, where the ocular pit is excavated out of a broad conical stalk, and with the aperture constricted to a mere pin-hole, the whole recalling forcibly both the outline and the section of a young Fig-fruit. In this eye, as in that of the Limpet, the retina is bathed directly by the sea-water. (Figs. II. and IX, Pl. VII.).

The second type of Molluscan eye shows considerable advance upon the first. It has the form of a closed capsule and is directly derivable from the simple cup-form, by the ingrowth and fusion of the lips of the cup. This optic capsule usually separates from the epidermis from whose ingrowth it arose, the superficial epidermal layer closes over, becomes transparent, and then may be termed a cornea, as it becomes a transparent protective window for the capsule beneath. Another advance is made by the formation of a gelatinous substance in the cavity of the capsule. This is a vitreous humour and is a prelude to the appearance of a lens. The eyes of the Roman Snail *(Helix pomatia)* and of *Tritonium* are typical examples.

The third type, found solely among the Cephalopoda, is formed in direct sequence with the form last mentioned, but before treating of its origin, we will detail the chief points in its structure, taking for our text the eye of the Cuttlefish *(Sepia officinalis)*. In this species, as is usual among the Cephalopods generally, the eyes are placed prominently upon either side of the head. Each consists of a hollow bulb sunk in a deep orbit in large measure hollowed out of the cephalic cartilages. This orbit becomes a closed chamber, the **optic capsule,** by the extension across it, and in front of the optic bulb, of a transparent fold of skin, which functions as a cornea.

If we now bisect the optic bulb we find it contains but a single chamber filled with gelatinous vitreous humour, bounded in front by a very large bipartite crystalline lens, and elsewhere by thin walls that are stiffened, and thus prevented from collapse, by the presence of delicate plates of cartilage in their middle subtance. External to these cartilages, and obvious to the naked eye as a brilliant bronze-hued coating, are two layers of pigmented membrane, the *argentea externa* and *interna.*

Internal to the cartilaginous and fibrous layers of the bulb is the retina, lining the hinder part of the ocular cavity, the front being occupied in large measure by the lens. The latter is almost globular in shape, the longest diameter coinciding with the visual axis. It is made up of the junction along a transverse plane of two unequal plano-convex lenses. The anterior is the smaller. As a consequence, the posterior has much greater convexity, and projects boldly into the ocular chamber. After hardening in spirit or otherwise, each portion of the lens can readily be split into a large number of concentric layers, whose curvature coincides with the external convexity of that half of the lens to which they respectively belong. A fine membrane stretches across the lens at the junction of the two halves, and passes at the edge into a fibrous and muscular sphincter-like organ, known as the ciliary body. This, in turn, merges with the fibrous wall of the ocular bull. The use of this ciliary body is the regulation of the convexity of the lens, to permit of its adaptation to near or to distant vision.

A fold of the external coat of the bulb is carried part way over the outer aspect of the lens, and is the **iris** entrusted with the important duty of regulating the quantity of light passing through the lens. It is strengthened internally with thin plates of cartilage. In *Sepia*, it has an upper and a lower fold that have much superficial resemblance to eyelids and give the eye a slit-like pupil. In passing, it may be mentioned that *Sepia* possesses a true eyelid, consisting of a horizontal external fold of skin extending along the lower side of the eye. In *Octopus* the eyelid is sphincter-shaped.

The retina, bounded internally by a thin transparent or hyaline membrane, consists of two distinct portions, the outer and the inner, separated by a sharply defined layer of black pigment. The inner layer is made up of rods, the outer of nerve cells and nerve ramifications. The optic nerve in Cephalopods is very short and stout. On entering the optic capsule it forms an immense ganglion whence arise very numerous nerve fibres. These gain access to the interior of the optic bulb through sieve-like openings in the cartilaginous layer of the wall of the bulb. Thence they pass to the *external* surface of the retina. In front, and partly at the sides, of the ganglion lies a peculiar soft whitish organ, the white body *(w.b.)*.

Examined superficially, the general structure of such an eye seems partially identical with that of a Vertebrate eye, except in the absence of an anterior chamber. In reality, there are some very radical divergences ; thus in the Cephalopoda the retina has its layer of rods turned *inwards, i.e.*, pointing towards the interior of the eye ; in Vertebrates, this layer of rods is external, directed outwards ; in Cephalopods the pigment layer divides the retina into two regions ; in the Vertebrates it lies external to the rods and cones. Most important difference of all, the optic fibres proceeding from the large optic ganglion pass into the retina from the exterior in Cephalopod eyes, whereas in Vertebrates the optic nerve forms no ganglionic mass, but passes through the wall of the optic bulb by a single opening and then breaks through the retina in the same way, spreading a network of fibres over the *internal* surface of the retina. Hence light entering the eye of Cephalopods, impinges first upon the retina and passes directly downwards to the nervous layer beyond. In the Vertebrate eye, the impressions of sight fall first upon the nervous layer, are transmitted thence through the various layers till the rods and cones are reached and thence returned by them through the same layers to the nerve fibres upon which they first impinged. This fundamental divergence is clearly diagrammatised in figs. X. and XI., Plate VII.

A less important difference is that of the cornea being part of the optic bulb in the Vertebrates, separate and part of the optic capsule in the Cephalopods.

In the latter the bulb represents the Vertebrate eyeball, minus the cornea and sclerotic, the equivalents of these being here possessed by the optic capsule, which here functions as an orbit.

The development of the Cephalopod eye is very instructive, both as throwing light on its origin and relationship with the other forms of molluscan eyes, and also in regard to the origin of its divergences from the Vertebrate type of eye. Figs.I. to V., Plate VII. graphically describe the stages.

The earliest stage (Fig. II.) is the equivalent of the optical stage attained in the eye of the Limpet ; the epidermis at one spot, having sunk down to form a shallow depression wherein the cells forming the floor of the cavity constitute a primitive retina.

In Fig. III., the edges of the optical pit have grown horizontally inwards so as to reduce the mouth of the pit to a small round opening. This pit raised up on a stalk marks the permanent condition of the eye in *Nautilus* (Fig. IX.). In the embryo *Sepia*, the aperture is early obliterated by the approximation of the free edge of the epidermal fold. This accomplished, we have a hollow globe formed overlaid by a continuous epidermal layer (*e*, Fig. IV.) A condition of eye exactly corresponding to this stage, is the adult form of eye of *Helix* as described above.

By a second downgrowth of the surface epidermis, another pit-like cavity is formed, the floor of which impinges upon and fuses with the anterior wall of the previously formed hollow ocular sphere. Fig. V. illustrates this stage. At the centre of the area where the two layers fuse, a transparent nearly spherical body, the future lens, begins to form. According to Carrière the external of the two fused layers forms the external part, whereas the anterior wall of the optic sphere forms the larger internal half. Hence the plane of division that cuts the mature lens into two parts represents two fused epidermal layers, and the fibrous strands of which it is composed merge equatorially into the surrounding ciliary body. The lens itself is composed of structureless layers, that are however only revealed after treatment with chemical reagents. Naturally, it is transparent, tough, semi-gelatinous, and apparently homogeneous. The folds in front of lens (*e*) represent the origin of the ultimate iris ; the cornea is likewise formed by another fold of the epidermis turning inwards and fusing in the same manner as the layer *e* in figs. III. and IV.

The mature form of the eye is now reached, the posterior wall of the ocular sphere becoming modified into the retinal layer by differentiation of the cells. Comparing the development of the vertebrate eye, we find the retina is there formed, not directly from an epidermal invagination, but as an outgrowth from one of the primitive vesicles of the brain (Fig. VII.), which eventually assume the form of a double walled stalked cup, through the external wall of the outgrowth becoming pushed in upon itself, while the hollow stalk comes finally to represent the optic nerve. Synchronizing with these changes, an epidermal invagination has been taking place, which by ingrowth of the lips is at first a closed sac connected at one spot with the overlying epidermis, but which is quickly severed and sinking inwards, is subsequently converted into a transparent lens, filling the mouth of the retinal cup. The cornea here, as in the eye of *Sepia*, is formed by the epidermal layer that overlies the lens losing its cellular nature and becoming transparent and colourless.

It will be seen from the foregoing that in *Sepia*, except for the nerve fibres that surround and penetrate the retina, and for the supporting tissues (cartilages, muscle fibres, &c.) of the wall of the bulb, all parts of the eye have direct epidermal origin, whereas in the Vertebrate eye the cornea and lens alone have direct epidermal origin, as the retina is entirely derived from an outgrowth from the embryonic brain. The heavy black lines in Figs. III. to VII. indicate the external margin of the layer of retinal rods. They show how in in the Cephalopod eye this layer is turned towards the light, while in the Vertebrate eye it is turned in the opposite direction. Thus while the higher Cephalopod eye reaches what is practically the same perfection and same plan of optical mechanism as the Vertebrate eye, it does so by a different avenue of development.

As already noticed, the majority of Molluscan eyes belong to one or other of the three types so far described, and which may be exemplified respectively by the the eyes of the Limpet, the Snail and the Cuttlefish, ranked in order of development. These in structure and development are in direct sequence. Their homologies are definite and fixed. All are cephalic eyes, and in close relationship to the central nervous mass.

Hence, when among the Pectens and allied Lamellibranchs we find visual organs that from their position are obviously not homologous in origin, it is specially interesting to see what differences in structure prevail. In such forms cephalic eyes are wanting, their place being taken by small organs placed upon short, deeply pigmented papillæ, arranged at intervals along the edge of the mantle or pallium, whence they derive their name of pallial eyes. Stated briefly the structure is as follows. The ocular papilla is clothed with an epithelial layer, deeply pigmened except at the summit, where the cells are colourless and flattened. Beneath this layer lies the tiny ocular sphere divided into two halves by a partition, the anterior containing a transparent cellular lens, the posterior, a several-layered retina of ordinary structure. The arrangement, however, of the rods and cones is the reverse of that found in the cephalic eyes of Molluscs, as they are here turned away from the light and are underlaid by a pigmented layer. Again fibres from the optic nerve form a layer anterior to the other retinal layer, so that light must traverse this nervous layer before it can reach that of the rods and cones. The plan of structure is therefore practically identical with that found in the Vertebrate eye save that the optic nerve does not pass through the retina, but attains its connection with the rods and cones by passing around one side of this layer and thence spreading out over the distal surface.

Very curiously nearly similar eyes are found upon dorsal processes in a peculiar Gastropod, *Onchidium*, and here even closer approximation is made to the plan of the Vertebrate eye. Instead of the optic nerve turning the flank of the rods and cones, it passes through at one point, thereby producing a blind spot exactly analogous to that found in the Vertebrate eye. This eye of *Onchidium* constitutes the fifth and perhaps the most interesting of the types of Molluscan eye—for, standing as it does alone, it furnishes us with one of the most remarkable instances of independent evolution that we are at present aware of.

And in this connection it is important to notice that no other organ has had so many independent evolutions as has the eye. Nothing could so strongly emphasize the supreme importance of sight to the majority of creatures. Here, within the types referred to above, four distinct evolutions of ocular organs undoubtedly took place. No one can for a moment deny that the cephalic eyes of Cephalopods and of Vertebrates have had independent and consequently dissimilar origin. Embryology at once marks out this divergence; while the peripheral position of the eyes of Lamellibranchs is sufficient to separate them from each of the former. Again one cannot gainsay divergence of origin to the dorsal eyes of an aberrant Gastropod and the pallial eyes of the Lamellibranchs. If only our knowledge of the homologies of the more obscure organs were on a par with that of the eye—though much remains to be done even here—our attempts at constructing phylogenetic tables or trees of descent, would be infinitely simplified. Indeed, it may be considered a biological axiom that no reliable phylogenetic tree can be constructed till the homologies of individual organs have been exhaustively made known.

Explanation of Pl. VII. Figs. I. to XI.

The Cephalopod Eye.

Fig. I. Section through eye of *Sepia officinalis*. *ae.* argentea externa; *ey.* eyelid; *c.* cartilages of optic bulb; *cc.* cephalic cartilages; *ci.* ciliary body; *co.* cornea; *gn.* optic ganglion; *ir.* iris, showing a thin plate of strengthening cartilage; *l.* lens; *on.* optic nerve; *p.* retinal layer of pigment; *r'* internal layer of retina; *r''* external layer of retina; *wb.* white body.

Figs. II. to V. Diagrams of the chief phases in the development of the Cephalopod eye. III. represents that stage which in *Nautilus* is the permanent condition; IV. is practically a diagram of the eye in *Helix*; *e.* unmodified epidermis; *l.* lens; *r.* retinal layer; a thick black layer denotes the position of the distal margin of the layer of rods and cones.

Figs. VI. to VIII. Diagrams illustrative of the development of the Vertebrate eye. *b.* represents a hollow outgrowth from the brain which eventually form the retina and the optic nerve. In Fig. VII. the epidermis is sinking downwards to meet this hollow outgrowth, while in VIII. it has become pinched off and forms now the basis of the future crystalline lens. *e.* epidermis.

(Figs. II. to VIII. are after Carrière, "Die Sehorgane der Thiere," München and Leipsig, 1885).

Fig. IX. Diagram of the structure of the eye in *Nautilus; on.* branches of the optic nerve ; *r.* retina.

Fig. X. Diagrammatic representation of the eye structure in Cephalopods, to show the arrangement of the retinal elements in relation to the optic nerves. (After Graber).

Fig. XI. A similar representation of the retinal arrangement, &c., of the Vertebrate eye. (After Graber).

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The Possibilities of Fishery Improvement in Jersey;

With Notes on the Present State of Marine Pisciculture and Fishery Regulation.*

BY JAMES HORNELL

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1. The continuous decay of inshore fisheries, here and abroad; the chief causes locally.
2. Remedial measures pursued elsewhere.
3. Scope and Programme of the investigations and experiments requisite locally.
4. Summary of the Fishery Laws having force in Jersey; their inadequacy to meet present requirements.
5. Forecast of the probable outcome of an adequate local fishery investigation.

PART 1.—*The continuous decay of inshore fisheries and the chief local causes.*

DURING recent years, in well-nigh every fishing hamlet in Great Britain the plaint of lessened catches in the places where fish formerly abounded has been practically unanimous. The total catches landed on the quays have, however, not decreased; on the contrary, by the employment of powerful steam trawlers able to fish far from home, by the longer journeys made by sail-trawlers and by the larger liners, and by the invention of improved methods and appliances, the fish supply of Great Britain has materially increased, but an increase entirely obtained from extra-territorial waters. The inshore fishermen, such as we have in Jersey, the men who fish in small undecked boats, have no share in this prosperity; these men find their own particular grounds rapidly becoming depopulated, and, unable to seek the more distant fishing-grounds, are compelled either to seek new occupations or to languish on earnings that are miserably insufficient. Along the French coast a similar evil state of matters exists; thus, my esteemed friend Dr. Canu, Director of the Station Aquicole at Boulogne, and the foremost authority on pisciculture in France, writes:—" In the Eastern portion of the English Channel, the majority of the banks formerly frequented on account of the number

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and the quality of their fish, have long since witnessed the loss of their reputation; they are even partially abandoned." And again: "The diminution of fish catches on the banks which line our Channel coast can no longer be disputed." . . . "The decrease of our small Northern fishing ports is more eloquent than any statistics upon this point." So well authenticated and so well recognised by the fishers themselves is this decadence in Jersey, that it requires little or no demonstration from me. Indeed, in view of the absence of local statistics as to catches, it is impossible of verification in figures. However, I have the authority of our best informed fishermen for stating definitely that a diminution of 30 per cent. to 40 per cent. has been observable in their catches of many of the most important of our local fishes during recent years, such as sand-eels, *gras-dos* (smelts), gurnard, conger, whiting, *sarde* (red bream), flat-fishes, &c., to say nothing of the dead oyster and ormer fisheries, or of black breams and lobsters, about which we have statistics, definite and incontrovertible. The decrease which is caused by actual scarcity of the fish themselves is most marked in the catches of the flat-fishes generally (plaice, soles, turbots, &c.), the bream, sand-eels, *gras-dos*, and lobsters; in the case of the larger round fishes such as the whiting and the conger, the cause is probably due to the marked decrease in the supply of bait available in Jersey, especially so in the case of the squids (*Sepia* and *Loligo*), and of the "red-cat" bait worms (*Nereis*). Seven or eight years ago plaice of large size were common in the large bays, measuring some fourteen inches long on the average; to-day such fine fish are extremely rare, and our market depends for its supply upon imports from Plymouth, Lowestoft and Grimsby. It is significant to notice that this decline in plaice coincides with the sudden increase in the use of set-nets and draw-nets in our bays that occurred some few years ago. Again, ten years ago over forty boats hailing from the south coast, from La Rocque, Pontac, St. Clement, St. Helier, and St. Aubin, earned large profits from the breaming industry. This year the number was reduced to some half-dozen boats taking largely reduced quantities. As to lobsters, I have been fortunate in being kindly permitted access to certain private statistics going back over thirty years; and while I am not permitted to quote figures, I may say that the decrease has progressed with ever-increasing and most alarming rapidity, while the present year is practically the worst on record.

It is pertinent at this point to ask what are the probable causes of such decrease. The chief may be listed as follows:—

a. The use of nets of destructive form or with meshes of insufficient size, whereby there is a pernicious destruction of immature fish.

b. The want of adequate protection accorded to fish during the breeding or spawning period and also while immature. The latter are of trivial value as human food, but by reason of having survived through the fry stage, that period of their lives most fraught with danger, they would possess a great potential value if left in the sea to mature. As regards plaice and lobsters, we have a law affording protection until they reach the size of nine inches; but though the law is good, it has become valueless as we do not seem to possess police machinery to enforce it. As a consequence certain people have been known to feed their pigs with multitudes of tiny plaice taken in set nets in St. Aubin's Bay, while at every Spring tide, hordes of men and boys invade the littoral armed with basket and hook, bent on an indiscriminate collection of crabs and lobsters of any size procurable. I have known as many as 200 immature Guernsey crabs (*Cancer pagurus*) in one man's basket, not one of which was of the proper size of 4¼ inches across the back, while time after time I have seen men bringing back six to twelve or more lobsters averaging from five to seven inches long. What wonder, then, that after such improvident and senseless procedure, there should ensue a period of dearth?

c. Insufficient supplies of bait, especially of squid, "red-cat" worm, and sand-eels. As regards the "red-cat" worm (*Nereis cultrifera*) once so abundant, and now extremely scarce, the harm has arisen through lack of protection afforded during the breeding season, and from the free and unrestricted digging permitted.

d. Trawling within the three-mile limit is considered by liners as highly prejudicial on account of the wholesale destruction it effects. In Scotland trawling is now prohibited, both within the three-mile limit and also in certain of the great bays or Firths, and many authorities are extremely anxious to have the range of prohibition extended further, so that the territorial waters shall form a zone of, say, seven or even thirteen miles in width, wherein trawling shall be rigorously suppressed.

e. Competition at a disadvantage with larger and better equipped French craft, which constantly infringe upon the territorial waters round our island—the special heritage of our own men. From their larger size and better supply of bait, these boats are enabled to keep the sea longer than our boats, and as a consequence they can remain longer upon the fishing grounds. A great source of annoyance to our men lies in the fact that these boats after poaching all night in Jersey waters, sail into the harbour here and dispose of their fish—congers chiefly—without paying duties or impôt, whereas our men are debarred by the high protective tariff from selling their catches in French ports, and hence have to restrict their runs to the vicinity of Jersey.

PART 2.—*Remedial measures pursued elsewhere.*

The premises granted, if we wish to be in a position to apply remedies, it is essential that we should know what practical measures are being pursued successfully elsewhere towards this end. Such measures are divisible into two classes—those that aim at the protection and efficient regulation of fisheries now existing, and those strictly scientific remedies where artificial means are taken for the re-stocking of extinct or moribund fisheries by means of hatchery and planting.

Protective laws are no creation of to-day; to go no further back than the time of the Second Charles, we find Parliament and local authorities passing measures for the regulation and protection of fisheries. Thus we have among other measures, "an Act for the regulation of the sardine fishery in the counties of Devon and Cornwall," while, in 1663, we find that the long-headed folk of Edinburgh, alarmed for the welfare of their oyster-beds, drew up detailed regulations to prevent abuses, and to ensure if possible a continuance of prosperity.

The difficulties in the way of rapid transit from the coast to the great inland centres of population barred the way to any extensive expansion of fishing industries until the advent of the railway system. From that period onward the trade has grown by leaps and bounds, and, as was to be expected, Fishery Commissions, Regulations and Laws, appeared with ever-increasing frequency. A host of regulations as to the form of nets, the size of meshes, the minimum size of immature fish, close times and the like have thus been promulgated, amended, abrogated, renewed and so on from time to time; but until twelve years ago, when the Board of British White Herring Fishery was reconstituted with increased powers as the "Fishery Board for Scotland," there was little or no attempt at any comprehensive and continuous series of scientifically carried out investigations and experiments to serve as secure bases for the enactment of remedial measures. With the advent of this Scottish Board we had for the first time in Great Britain the provision of adequate and sustained means for the enforcement of such regulations as are desirable, while from the constitution and powers of the Board, sufficient elasticity is present to permit of local needs receiving due attention.

Immediately following this epoch-making event, another very great and real impetus was given to the organization of our fisheries on true scientific lines through the wonderful interest aroused in the welfare of this industry by the great International Fisheries Exhibition held in London in 1883, the way for which had been opened by the pioneer Exhibitions of Norwich and Edinburgh that had worthily preceded it. Largely from the attention thus focussed upon fisheries, a healthy public interest was aroused, and the natural results followed, when, as one item in local government, powers were granted some eight years ago to county councils in England and Wales to form local fishery committees for the protection and improvement of the fisheries along their littoral, and to formulate by-laws calculated to this end. Such powers were gradually availed of, and with varying energy the fight has been begun all along the English coast line. Controlled by special local needs, and necessarily tentative as much of the work has been, great good has undoubtedly accrued. With the increase of knowledge given by continued experiment and greater experience, the authorities concerned are well satisfied that future progress is assured. Intense hopefulness is essentially the characteristic of those actively engaged in these remedial measures, so solid has been the progress made, considering what obscurity enveloped so many of the problems when they were grappled with.

Of the various English Sea Fisheries' Committees, that of Lancashire holds the premier position, alike in priority of origin, in the able and practical administration and scientific conduct of the work, and in the amount of practical good already resulting and abundantly apparent from its efforts. Hence a brief sketch of its work will be useful to detail, especially as I have personal knowledge of the district in question.

The Lancashire Committee, as soon as the proposed amalgamation with the Western Sea Fisheries District is completed, will exercise control of a coast line of 345 nautical miles and over an area of territorial waters of some 1,300 square miles. The administrative staff consists of a superintendent, seven fishery officers or water bailiffs, and a steamer crew of six, also empowered to act as bailiffs. For the use of this department a powerful screw steamer, the "*John Fell*," is provided, together with three sailing cutters of about ten tons each. The scientific work is carried on by the Hon. Director of the Fisheries' Laboratory, Prof. Herdman, F.R.S., with the assistance of two trained investigators. This scientific staff possess two laboratories for investigation, one at University College, Liverpool, and the other at Roa Island, Barrow-in-Furness—the latter a large building fitted with gas-engine, tanks, and other appliances for the hatching and rearing of fishes.

Work accomplished :—After numerous long-continued experiments a code of bye-laws was framed, of which the following is a summary as furnished by Mr. Dawson, the Superintendent: "Only nets can be used which will allow fish of small size to escape through the meshes; a certain area off Blackpool where young fish are found in great abundance, is closed entirely to all net fishing, except drift-net fishing, sea fish taken in shrimp nets along with the shrimps have to be picked out and thrown overboard as soon as possible, crabs, lobsters, mussels, cockles, and oysters may not be taken under certain sizes, and no berried lobsters or edible berried crab may be taken; forms and sizes of nets and other instruments are regulated, also the methods of using them, and the places where they may be used; a close time for mussels and sparling is enforced, and steam trawling within the territorial waters is abolished."

One of the bye-laws enforced is the increase of the size of mesh in trawl-nets from 4½ inches to 7 inches, *i.e.*, the mesh measured around the four sides; as demonstrating the need for regulation, it is interesting to quote again from Mr. Dawson the results of two hauls made with trawls of only 25 feet between the trawl heads. In these trials a net of 7 inch mesh was used, which had a net of 4½ inch mesh laced round the cod end in such a manner that no fish could get into the net of 4½ inch mesh without first passing through the net of 7 inch mesh.

Haul made June 29th, 1894, net down one hour :—

In the net of 7 inch mesh.	397 plaice,	average length,	9 inches.	
	100 dabs,	" "	8 "	
	16 flounders,	" "	9 "	
	1 skate,	" "	7½ broad.	
Total..514				

In the net of 4½ inch mesh.	4,710 plaice,	average length	6½ inches.
	2,515 dabs,	" "	5½ "
	35 young ray, very small		
Total..7,260			

The above shows that under ordinary circumstances 7,260 small fish in the one short drag would have escaped through the 7-inch mesh, and remained to grow larger. As will be seen by the sizes, the fish taken in the 7 inch mesh net were mostly over ¼-lb., whilst those which passed through were all under that weight.

"In a second haul, made on July 19th, 1894, the result was as follows (net down 1½ hours):

"In net of 7-inch mesh.	23 soles,	length in inches	9½ to 14½
	131 plaice,	" "	8 " 11
	19 dabs,	" "	9 " 10
	1 skate,	" "	10 broad.
Total..174			

"In net of 4½-inch mesh.	6 soles,	" "	5 to 8
	610 plaice,	" "	4 " 8
	323 dabs,	" "	4 " 7
	4 gurnet	" "	6
	1 whiting,	" "	6
	87 young ray, very small.		
Total..1,031			

The result of the second drag shows that under ordinary circumstances out of a total of 1,205 fish, 1,031 which were under 4 oz. in weight would have passed through the net of 7 inch mesh, and so escaped, and further, that the 7 inch mesh will take soles much under the size represented at some of the inquiries made in the district. Although the proportions as regards number retained in the net of 7 inch mesh was much smaller than that retained in the net of 4½ mesh, it represented a larger monetary value, owing to the fish being larger and in better condition."

Comment on such figures is superflous; they demonstrate conclusively the need for a thorough local investigation here, with, of course, careful regard to special local needs and circumstances, as our coast line is governed by exceedingly complex conditions. One of the special duties of the officers of a Fishery Committee is obviously to make a careful survey of their whole area to determine the spawning grounds and nurseries, *i.e.*, grounds frequented by immature fish, and, when determined, to take measures to protect such efficiently. Such a ground was discovered on the Lancashire coast opposite Blackpool, and the utility of such a regulation is demonstrated by quotation of the results of three typical hauls of a shrimp trawl on this ground, also given by Mr. Dawson.

November 7th, 1893:—

5½	quarts of shrimps	The trawl was fishing 30 minutes.
6,117	flat fish	
81	round fish	
6,198		

December 28th, 1893:—

22½	quarts of shrimps	The trawl was fishing 40 minutes.
20,772	flat fish	
117	round fish	
20,889		

January 2nd, 1894:—

6	quarts of shrimps	The trawl was fishing 45 minutes.
8,356	flat fish	
156	round fish	
8,512		

"The flat fish taken in these hauls comprised soles, plaice, and dabs; the round fish, whiting, codling and herrings; these were all immature and undersized, ranging from about 1 to 3 inches in length and of no use whatever for market. When it is considered that from 70 to 90 boats used to be employed shrimping on that particular ground, each boat making from four to five hauls per tide, it will not be wondered at that the Committee closed it, nor can it be denied that such must be of immense benefit in the protection of under-sized sea-fish."

The Scientific Department's work is of necessity less showy in immediately practical results, though it must be borne in mind that the labours of this Department are indispensable in arriving at a knowledge of the factors that have to be understood before the framing of administrative bye-laws. The general scope of this Department's work may be summarised as the investigation of the food and feeding habits of fish, their spawning habits and early history; the controlling conditions and localities of their migrations; experiments with a view to the introduction of oyster and mussel culture or of improved methods; investigation into the connection between oysters and the transmission of disease, the artificial hatching, &c., of sea-fish and lobsters, the giving of free fishery lectures and demonstrations, the preparation of a fishery exhibition illustrative of the methods of fishing and fish food, fish enemies, &c., locally and abroad.

The cost of all this work is about £2,700 per annum, and the increase in the value of catches within the Lancashire sea fisheries district in 1895 was £78,761 over the value of the catches of 1891, the year in which the Committee commenced its labours. From the nature of the case, it is, of course, impossible to say what part of this increase is due to the efforts of the Committee; but it can fairly claim, I believe, that such have had a really considerable effect in the production of this favourable result.

I have gone into the foregoing details at considerable length as the scheme of work in the district is definite, has been successful, and the local factors are somewhat analogous to our own.

At the same time, the work of our English Fishery Committees is at present much behind that of Scotland and of several foreign nations, in one respect, viz., the establishment of sea-hatcheries for fish, lobsters, &c. Scotland, the U.S.A., Newfoundland, Canada, and Norway have all important establishments from which millions of young are annually turned into the sea, whereas in England the Lancashire Committee is the only one making definite preparations for the inception of such work.

To the U.S.A. we owe the inception of marine fish hatchery, as it was at the Fishing Station at Gloucester (Mass.) in 1878 that the eggs of the cod, the whiting, and the herring, were successfully hatched. Norway very quickly hastened to take the matter up, and from the great hatchery at Flödevigen turns out annually many millions of young cod. Captain G. M. Dannevig, the greatest expert in this work, asserts that it is only the effects of this hatchery that prevent the extinction of a fishery valued at several hundred thousand pounds a year. That the Norwegians themselves are convinced of the practical benefit is best proved by the fact that the yearly grant to the hatchery has always been made with the greatest willingness, notwithstanding the meagre financial resources of the nation; when last year an adverse motion was introduced in their Parliament it was negatived by 114 votes to 11, a conclusive vote of confidence.

The Dunbar hatchery instituted by the Fishery Board for Scotland, is engaged chiefly in the hatching of plaice. In this work, therefore, we have naturally greater direct interest than in that of the Norway establishment, which is concerned most largely with the culture of codfish. In structure and arrangement the Scottish Fishery Board has followed strictly the model of the Norwegian hatchery, and consists essentially of:—

1st. A pond subject to the rise and fall of the tides, wherein are stored a selected stock of adult fish sufficient to provide the quantity of fertilised eggs required for the purposes of the hatchery.

2nd. A boiler and pumping room.

3rd. The spawning pond in which the spawners (males and females) are placed when extrusion of the spawn and milt is about to begin.

4th. The collector, or system of filters necessary for separating and gathering the floating eggs.

5th. A main Hatchery-room fitted with the Dannevig floating-egg incubators, capable of dealing efficiently with 56,000,000 eggs of plaice or with 80,000,000 eggs of the cod, at one time.

The Dannevig apparatus, which is intended for buoyant eggs alone, consists essentially of a wooden box, 8 feet long, 2 ft. 3 in. broad and 1 foot deep, and divided into two longitudinal compartments by a partition. Each compartment is again transversely divided into seven others, and in each of these (excepting the end ones) a wooden lid-less box is hinged by one edge to the top of the wooden transverse partition; the other edge is free, and when water is admitted, rises above the level of the water; the bottom of each floating box consists of hair-cloth and acts as a sieve. To obviate the permanent eddies and currents caused by the constant course of the inflowing water, Capt. Dannevig invented a beautifully simple arrangement whereby the rythmic depression of a long lever bearing transverse bars catching the sides of the floating boxes, causes the latter to rise and fall several times per minute; this breaks up the eddies, and ensures an equal distribution of the eggs through the water. Each box can accommodate half a million eggs of the cod, or 300,000 eggs of the plaice; each apparatus contains 10 of these boxes. A Dannevig incubator can thus deal with five millions of cod eggs simultaneously.

The output of fry from this hatchery in 1895 was: — Plaice, 38,615,000; cod, 2,760,000; turbot, 3,800,000; miscellaneous, 1,050,000; a grand total of 46,225,000.

It is worthy of note that the authorities consider the services rendered by the Fishery Board for Scotland fully justify the indefinite continuance of the grant of £23,000 per annum.

In Newfoundland, the great work of hatchery effected at Dildo Island in Trinity Bay, and at various outlying points along the coast, has also special interest for us in Jersey, for while the hatching of cod fry is the chief item in the official programme (221,500,000 being set free in 1894), it is here we have to turn as to the fountain head for information upon the artificial hatching of lobsters. Whereas the cod fry are all hatched out at Dildo, the vast majority of the lobsters are hatched out in numerous small floating wooden incubators stationed up and down the coast. In these boxes the eggs are placed after being stripped from the berried females. This obviates the certain destruction of the eggs as they would otherwise pass to the cannery along with the parent. During five years, dating from 1890, the almost incredible number of 2,340,657,000 lobster fry have been liberated from these floating incubators alone; about 645 millions of cod, and about 33 millions of lobsters were in addition set free from the main hatchery. The total annual expense of the Newfoundland establishment is from £1,000 to £1,200 annually, out of which the Superintendent draws a salary of £600.

Canada does similar work, dating from 1891, at Bay View, Picton County, Nova Scotia, and is likewise largely concerned with the hatching of lobsters.

In the U.S.A. two chief marine hatching stations are in operation, viz, Gloucester (Mass.) and Wood's Holl; from the latter alone were hatched during 1895 seventy millions of cod and whiting fry, two millions of plaice fry and seventy-five millions of lobster larvæ, while at several sub-stations vast quantities of shad fry *(Clupea sapidissima)* were hatched and set free.

Turning to other forms of practical fishery work, we find that the Congested Districts Board of Ireland are planting the coasts of Galway and Donegal with large and efficient fishing boats, built and furnished with gear after the most approved Scottish pattern, to replace the flimsy canvas and wicker coracles and curraghs still in use by the impoverished fishers of the districts. Picked fishermen from the Fraserburgh district are provided by the Board to introduce and teach the fishing methods as practised successfully on the Aberdeenshire coast, and the Irish fishers are found very apt to learn and quite alive to the advantages of this training. Nor is this all; the Board lends money on the recommendations of the Fishery Inspectors for the purchase of improved boats and gear; up to the 31st March, 1896, £9,515 had been so issued.

The Fishery Commissioners for Ireland have pursued the same plan since 1891, for districts outside the jurisdiction of the Congested Districts Board, and up to 31st Dec., 1896, had issued £14,843 in loans to fishermen, whereof £6,782 has already been repaid in capital and interest. Considering the largeness of the figures, and the character of the people lent to, it is extremely satisfactory to learn that the entire arrears for capital amount to the comparatively trifling sum of £160.

Another striking and very practical instance of the energy developed by governing bodies at the present day in favour of improvement in fisheries is the step taken this year by the Cape Government in obtaining a first-class steam trawler to place at the disposal of their scientific staff. The dimensions of this vessel, the "*Pieter Faure*," are 110ft. by 21ft., and she is fitted with triple expansion engines of the highest class. Her first and primary duty is to explore for fishing grounds off the coast of Cape

Colony, and to demonstrate practically to the capitalists and fishermen of the Colony what undeveloped resources are ready to their hand if they will but equip proper vessels—the steam trawler being unknown there at present, as a consequence of want of knowledge of any suitably extensive fishing banks. According to recent advices, the results attained have surpassed the most sanguine anticipations, as immense catches of fine marketable fish have been made in many of the trial hauls.

Acclimatisation while of the greatest success with regard to fresh water fish, has only been tried with sea-fish upon anything approaching a commercial scale by the United States. The experiment was begun 26 years ago, when 12,000 shad fry *(Clupea sapidissima)* brought from the Atlantic Seaboard, were liberated at the mouth of Sacramento River, on the Pacific Coast. During the ensuing 15 years 1,519,000 Atlantic fry were set free at various points on the same coast. The result has been truly marvellous and one about the success of which there can be no question; thus in 1892, the fishery upon the West coast was estimated at 700,000lbs., and this, too, without special effort being made to capture ; most was taken unintentionally in salmon nets and otherwise. So abundant indeed were the fish, that the price there was lower than upon the Atlantic coast. Besides the shad, the United States Fishery Commission has introduced the Atlantic striped bass *(Roccus lineatus)* into the Pacific. In 1879 about 150 individuals were freed at the mouth of the Sacramento River, and three years later another batch of 300 were liberated at the same spot. The result of these two small introductions is that a new and growing industry has developed ; so early as 1892 it produced 43,000lbs. of fish.

As a concluding item in this all too brief and imperfect survey, we have to note that two years ago the States of Guernsey appropriated £100 for experiments in Lobster hatching and another £140 this year, with a view to increase the supply of this crustacean. Last year was tentative and an extremely small number were set free. This year at the beginning of July, five of the Nielson floating-incubators were in operation at Grand Havre, two at Perelle Bay and one at St. Sampson's.

PART 3.—*Scope and programme of the Investigation and Experiments requisite locally.*

Such work falls naturally into three divisions :—

1. Investigation.
2. Experiment.
3. Education and the supply of information.

1.—*Investigation.*

a. It is important that an exhaustive investigation of the methods of fishing now pursued upon the Jersey coast, should first be undertaken, with a view to acquire data whereby we may learn what methods are detrimental, together with the probable remedies required. Especially should this investigation be directed to the merits and demerits of *chervin* fishing, set-nets, draw-nets, and raking for sand-eels—questions to which Deputy E. B. Renouf has already drawn the attention of our Legislature, thereby earning the sincere gratitude of our fishermen.

b. If alteration be needed in the size of mesh in any form of net at present in use.

c. To what extent and upon what lines should low-water shore-fishing be restricted. This is very probably an important item, as the wide stretch of shore from high to low-water marks forms an important resort for immature crabs, lobsters, etc., to say nothing of the scope it offers for the future culture of shell-fish.

d. Over what animals (fishes and baits) should the protection of close-time be conferred, and what the duration of the same.

e. The dates at which spawning occurs locally in all our food fishes and baits. This obviously must be determined with exactitude prior to the institution of close-times.

f. To define the best size below which the capture and sale of certain fishes should be interdicted.

g. To ascertain the exact nature of the food of our common local fishes, the object being to take measures, if possible, to increase the quantity of such supply.

h. To discover and define the extent of local spawning grounds.

i. Should certain areas of the inshore waters be set apart as closed grounds where fishing should be prohibited; these to serve as nurseries or shelter grounds for immature fish.

j. To ascertain if the amount of destruction of young fish by sea gulls is sufficiently serious as to call for the amendment of existing laws protecting such birds.

k. As to the extent of French "poaching" within the three mile limit, and the steps to be taken to prevent this.

l A survey of the whole coast to ascertain what localities are suitable for the culture of such useful shell-fish as cockles, clams, and mussels.

m. To re-investigate in the light of modern knowledge the causes of the decay of the oyster beds off Gorey, and to devise means for their restoration.

n. What restrictions, if any, should be placed upon the sale of "berried" lobsters.

2.—*Experiments.*

The chief experiments that suggest themselves as likely to have practical and useful outcome may be enumerated as follows:—

a. To ascertain to what extent the free-swimming larvæ of lobsters are strictly surface swimmers.

b. To ascertain by means of "drifters" the mean or usual drift of our surface currents under definite conditions of wind. This with a view to learn the probable drift of pelagic fry were they to be hatched in, and liberated from, an incubating station on the coast.

c. To ascertain the course of the migrations of our local food fishes and the determining causes. Although this is difficult work, the experience of Dr. Wemyss Fulton, upon the coast of Scotland, is that in regard to certain fish, such as plaice, this knowledge can be gained by the marking of the fish by means of metal discs each impressed with a consecutive number and securely fastened to the fish, the fish being subsequently liberated. Rewards are then offered for the capture of such marked individuals. In this way Dr. Fulton has found that there is a general northward movement of plaice upon the east coast of Scotland. More than 10 per cent. of the marked plaice—over 1,000—have been recovered, a very satisfactory percentage.

d. To adopt or to discover a cheap means for the preservation of bait for lengthy periods and to elaborate a scheme for its storage in sufficient quantities.

e The introduction and culture of a better class "red-cat" bait worm, such as the giant "creeper" (*Nereis virens*) of the Irish Sea fishermen.

f. The introduction of the culture of the cockle, a highly lucrative industry wherever pursued. In England and in France it gives employment to thousands of fishermen.

g. The introduction of mussel culture. If this were successful it would tend to lessen the disability under which our local fishermen so frequently labour on account of scarcity of bait. On the Scottish coast the mussel is the most important of the baits used by the liners.

h. The re-introduction of the ormer (*Haliotis*) on an extensive scale.

3.—*Education and Information Bureau.*

Such practical work as is detailed above should, however, be supplemented by means of :—

a. Free lectures to fishermen upon fishery problems, to enable them to follow closely the development of fishery methods elsewhere. Demonstrations upon methods of fishing and of shell-fish cultivation in other lands should also be included, together with some instruction in the elementary facts in the life-histories and habits of our common fishes.

b. Prizes to fishermen for the encouragement of suitable objects.

c. The establishment of a Fisheries Collection, to illustrate by actual specimens and by models, drawings and the like, the varied methods of fishing pursued abroad and at home, preserved specimens of the animals injurious to fishes; a series to illustrate the nature and variety of the food of each of our food fishes; samples of the "bottoms" around Jersey, &c., &c.

Such an exhibition, open free to fishermen, would be of very great educational value to them in their calling, especially as showing them what is being done elsewhere by methods different from their own.

3. The establishment of an Information Bureau, which, among other uses, could, by means of a simple system of corresponding agents in a few of the home and continental fish centres, advise fishermen as to the supplies of bait obtainable elsewhere in times of bait scarcity here, and, if desired, to take measures to put the fishers here in communication with bait sellers abroad. Other useful work would consist in the collection and tabulation of local fishery statistics.

Part 4.—*Summary of the Fishery Laws relating to Jersey waters; their inadequacy to meet present requirements.*

Having thus taken note of the chief lines upon which investigation and experiment should proceed, it behoves us to inquire into the provisions of the Fishery Laws already existing in the statute book.

During the present century, three Fishery Laws have been enacted by the States of Jersey, while four Acts of the Imperial Parliament have been registered here, and have accordingly full effect in this Island. They may be summarised as follows:—

1. The regulations with regard to the oyster fishery off Gorey, made during the preceding century, having failed in their object of safeguarding the beds, the States, in 1841, passed a fresh law re-regulating the details of the fishery with great precision; and the Harbour Master of Mont Orgueil was appointed Inspector of the fishery to ensure the due observance of the various provisions. This law, however, proved equally inadequate to prevent the practical extinction of the industry, as it contained no provision for preserving a reserve sufficient to keep up the supply of spat. Between September 1st and May 31st, fishing on the outer beds was permitted to all comers of British nationality and as many oysters might be removed as they were able to dredge. The height of this transitory prosperity was between 1840 and 1850, when 250 boats were not uncommonly employed simultaneously. The average catch was enormous; about 40 tubs each, and when we learn that a tub contained from 300 to 400 oysters, giving a catch of 12,000 to 16,000 oysters per boat per day we cannot wonder at the rapid exhaustion of the beds. Even these catches were frequently exceeded; thus Mr. J. Perchard, of Gorey, one of the oldest dredgermen living in Jersey, has informed me that his boat on one occasion took 120 tubs, the equivalent of 36,000 oysters at a low estimate. Again, I have record of another

boat having taken, about 1845, 327 tubs in three consecutive trips. The natural consequence of this course of wholesale and disgracefully improvident exploitation of the beds is seen in the fact that this great industry has dwindled to such an extent as to be represented in the present year (1897) by a single small dredging boat taking on an average not more than 200 to 300 oysters per day.

2. In 1843 an Act of the Imperial Parliament was registered in Jersey minutely regulating fishing methods, even to specifying the size of the mesh in the chief forms of nets then in general use. Thus the centre net of trammels had to have a mesh measuring 2in. along each side, and many other items of a like character. This law, most useful in many of its provisions, was repealed by the Act of 1868.

3. In 1862, the States passed a local law—subsequently modified in 1869 and 1886—the main provisions now in force being:—

a. That all nets, excepting seines or draw-nets for the capture of smelts *(gras-dos)*, and sand-eels, shall have a mesh measuring at least 1½ in. along each side, being the equivalent to what the fishermen now call a 3-in. mesh.

b. That the use is forbidden of draw-nets or other nets employed to draw fish to shore, in the bays of St. Aubin, St. Brelade, Grouville, and St. Clement.

c. That a minimum size of 9 inches in length is prescribed for lobsters and plaice; the capture and sale of smaller-sized fish being prohibited under penalty.

This law so far as it goes, is most excellent, but has been treated as non-existent by many people, as no adequate machinery exists to enforce its respect.

4. In 1869, "The Sea Fisheries Act, 1868," was registered in Jersey whereby numerous prior restrictions and regulations of sea-fishing contained in the Act of 1843 were annulled—and no provision was made for their replacement by others.

This Act marks the climax of a period of reactionary thought in fishery matters, now all but universally condemned. This repeal of former restrictions was due to the misconception, entertained at that date by even the highest authorities, that the resources of the sea are inexhaustible; the enormous numbers and fecundity of the edible fishes and the vast extent of the waters round our coasts, appealed so vividly to the minds of the Commissioners appointed by Government to investigate, that they agreed that fishermen might fish when, where and how they liked, quite without restriction. The fishermen themselves thought differently, but arrayed against them were Professor Huxley and a band of highly talented and earnest men of authority, such for example as Lyon Playfair, Shaw Lefevre, Frank Buckland, and Spencer Walpole. The weight of authority prevailed, and fishermen were, in effect, told to go and catch as much fish where and how they liked, and to take no heed for the morrow.

Since 1868, statistics of fishery results have been kept with considerable exactitude, and the conclusion derived from a careful examination of the yearly differences in yield is that over the whole extent of the British sea-fishery area, the old fishing grounds are steadily becoming depopulated, and that to keep up the supply our fishers have to go further afield and the endeavour is constant to discover new grounds to replace the exhausted ones lying nearer home.

Hence, from the steady accumulation of such observations, the irresistible conclusion has been driven home to those watching the development of affairs, that the Act of 1868 has proved harmful. As a consequence of this feeling, Parliament, a few years ago, gave permission to the Maritime County Councils to form Fisheries Committees, part of whose duties it should be to pass bye-laws (under sanction of the Board of Trade) reguiating and restricting, where necessary, their local in-shore fisheries.

Deep-sea fishing still awaits legislative control, international agreement being difficult to effect.

5. The next Act concerning our fisheries in Jersey, is "The Fisheries (Oyster, Crab and Lobster) Act, 1877." The provisions which concern us are that by it are forbidden the capture, exposure, sale or purchase of soft crabs, *i.e.*, those that have recently cast their shells; of any edible crab less than $4\frac{1}{4}$ in. across the broadest part of the back; lastly of "berried" crabs. This law has in no wise been enforced in Jersey, and indeed the provision it makes as to the minimum size for crabs is absurd, for this takes no account of our local custom to consider several crabs edible which are not so considered in England. For example the common shore crab (*Carcinus mænas*) and the "Lady-crab" (*Portunus puber*) are both eaten here, and even when adult these species *rarely* reach the size limit given in the English Act.

6. Following this is a most excellent and well-considered measure, passed by the States in 1882 to facilitate the establishment of oyster parks along the littoral of our Island. It is under the ægis of this law that the one bright spot in our Island fishery-work has arisen, in the form of the formation of the Jersey Oyster Culture Co., Ltd., whose parks at Green Island are models of what such establishments should be.

7. The last measure of all, is one registered here in 1884, but as this relates largely to the provisions of the International Convention concerning the Fisheries in the North Sea and has no importance locally, we need not detail its enactments.

Summarizing the effects of the fore-going facts, we find that the Oyster Act of 1841 was insufficient to protect the industry in question, the result being the destruction of the beds; the useful Act of 1843 has been annulled; the Act of 1869 is worse than useless; that of 1877 is not applicable to our local needs, and is in some respects anomalous; the law of 1882 upon the establishment of oyster parks concerns the capitalist rather than the fishermen; that of 1884 has little or no local bearing.

We are thus left with the local Act of 1862, which so far as it goes, contains sound and useful provisions. Unfortunately we have no efficient means in existence to ensure due respect for its enactments; its scope, also, is much too limited when viewed in the light of recent research and knowledge.

The conclusion to be drawn is that our laws are quite inadequate to meet present requirements, while if satisfactory new ones be framed it is absolutely essential that there be made, *concurrently*, efficient provision for enforcement, otherwise, as at present and in times past, such laws will fail to compass their object and for all practical purposes will be treated by those desirous of doing so, as non-existent.

Let us rely no longer upon the sordid greed of the informer as the chief instrument for the detection of the law-breaker; let us rather delegate police duty to specially appointed men, who, working amicably with the better class of our fishermen, will honestly and impartially carry out their duty.

PART 5.—*Forecast of the probable outcome of an adequate local fishery investigation.*

The rôle of the prophet is notoriously a difficult one. Still, from the extent of my personal knowledge of local factors, I feel perfectly confident that the majority of the lines of reform indicated in the following sentences will be the correct ones to follow in case the authorities see their way to delegate a committee with power to make extensive investigations and experiments.

1. Restrictions upon the use of set-nets and draw-nets would hinder much unnecessary destruction of immature fish. The mesh of these nets, in case entire suppression be not enforced, should measure not less than 2 ins. along each side. With this increase in the mesh it might be possible still to permit the use of these nets during say the last three, and first two months of the year, and even during this period the use of draw-nets by night would probably have to be interdicted. Such restrictions would be welcomed by fishermen themselves, for *they* seldom abuse these modes of fishing. The real offenders are chiefly men who work these nets merely to gratify their instinct for sport and amusement, or from the wish to make a little extra pocket-money. Indeed, I have heard very definite whispers that members of the Honorary Police, men pledged to enforce the law, are to be found in the ranks of these illegal fishers.

I have it on good authority that over 30 draw nets were in use in St. Aubin's Bay one dark night recently, and I have myself seen net after net along the bay in active operation, hauling to shore quantities of small whiting, bass, and plaice, too small for useful food.

2. *Chervin* fishing calls for some regulation. So far as I know, it entails practically no destruction of fish fry, the contents of the net being a pure gathering of *Mysidæ*, a family of tiny shrimp-like creatures of no known use as human food, fished for solely to furnish a ground-bait in rod-fishing for mullet. They however constitute an important food supply to many species of our local fishes. Thus whiting, mullet, gurnard, young rays and other fishes are attracted inshore by the abundance of these *Mysidæ*, and their numbers around our coast depend to a certain extent upon the abundance of this food supply. A few days ago I counted nine men netting for *chervin* in St. Aubin's Bay, and as many as 30 have been known to be fishing during the same night, while eighteen is an ordinary number. The majority of these men are farmers and their servants to whom the discontinuance of this fishing would be no special loss. To a few, probably about eight in number, such would, however, be a distinct hardship—men who have worked at it as their chief source of livelihood for years. These men may therefore be said to have a certain prescriptive interest, and while *chervin*-fishery should eventually be prohibited, these men might be granted non-transferable licences, to expire with their discontinuance of the fishing. In this way the fishery would be extinguished without inflicting hardships upon any one. The export of *chervin* should also be prohibited.

3. *Close times.* Breaming has been continuously going from bad to worse of late years. When these fish *(Cantharus griseus)* come off our coasts, their spawning period is nigh—and it is probable that the continuous decrease in their numbers is due to too large a proportion of the spawners being captured. Hence a close time of, say a fortnight, at some period of the breaming season would be likely to effect an improvement in succeeding years by permitting the escape of spawners sufficiently numerous to maintain the race in undiminished numbers.

A close time for the " red-cat " worm *(Nereis)* during its breeding season would be certain of adoption, while in view of the introduction of the cultivation of the cockle and the mussel, close times for such should be instituted.

4. The interdiction of low-water or littoral hunting for crabs, lobsters and the like, over certain areas at least, would be productive of great good. Thousands upon thousands of undersized crustaceans are taken there, and this tends largely towards a poverty of adults in the deeper water. To remedy this, the littoral should be carefully protected as a nursery and feeding ground for these crustaceans.

5. Restrictions upon the capture and sale of berried lobsters should

be enacted, but if lobster incubation be feasible upon this coast, as I think now it is, the sale of such individuals would be permissible if the "coral" or eggs were given by the fishermen to the official in charge of the incubators.

6. The re-establishment of a profitable oyster industry is, in my opinion, by no means an illusory dream. A certain number of oysters are still present upon the beds, and if quantities of fresh, well-cleaned "culch," *i.e.* empty shells whereto the swimming spat may adhere, were to be thrown lavishly over the beds, at the beginning of the spawning period, I believe a good fall of spat would be secured under ordinary favourable conditions. Of course it would be necessary to interdict all dredging and trawling over such grounds for some years, with resumption only under very strict regulations. The beds are too greatly exhausted to recover if left to themselves, and a partial cultivation on the lines I indicate furnishes the only alternative.

In the event of the success of this treatment, with a little energy the fishermen themselves, by the exercise of a certain amount of co-operation, should be fully capable of caring for the beds, or at least of a portion of them.

Under such circumstances, those fishermen assuming such duties should have ample guarantee against any infringement of their rights. Either in addition to or in substitution of such oyster-farming, our fishers might be granted small areas of sea-bottom in shallow inshore waters, where spat might be laid down to fatten. The expense is a bagatelle; the only trouble would arise from poaching, and this is capable of solution.

7. By the judicious "planting" of a moderate quantity of imported cockles, in a properly protected area of one of our sandy bays, a cockle industry of considerable value is surely capable of development.

8. In regard to another of the minor fishing industries, to wit, the culture of mussels, our island offers considerable scope. Here again it would be necessary to import a quantity of mussels, probably both seed mussels and adults, to be judiciously "planted" in selected and protected localities. In France much of the mussel cultivation is upon the *Buchöt* system, which consists of long lines of piles closely interlaced with osiers, and is there extremely lucrative. The foreshore of one small village near La Rochelle is said to yield a sum of £50,000 to £70,000 per annum from mussel cultivation alone. After a careful estimate of the cost of such piles and the necessary osier, I find, however, that it is, in Jersey, so much higher than in France, that such a system of cultivation would not be profitable here. "Bed-culture" would be preferable in Jersey, being the form of culture practised in Scotland, a land where the mussel forms the staple bait of the fishermen.

9. The question of profitable fish-hatching depends, locally, almost

entirely upon the general set of the currents, and no inference of any real value can be deduced until a long and severe series of experiments with "drifters" be instituted, on the same lines as those adopted by the *Deutsche Seewarte* and the U.S. Hydrographical Survey in working out the Atlantic currents, by Prince Albert of Monaco in following the course of the Gulf Stream, and nearer home by the Fishery Board for Scotland. The drifters in use by the latter body are small thick glass bottles of 1oz. capacity, each containing a card with a request in English, German and Norwegian that the finder post particulars of the recovery of the bottle to the office of the Board in Edinburgh. These bottles are tested in a tub of water before being set free, and by means of a piece of lead wire twisted round the neck, they float mouth downwards, showing no surface above the water to catch the wind, attention to the latter point being very important. Wooden slips bearing the instructions tacked on and weighted at one end, so as to float upright, have also been used, but are found to be less satisfactory than the bottles, as the coating of paraffin wax necessary to prevent the soaking of the card and of the wood, is very liable to abrasion.

Various indications which have come to my knowledge incline me to entertain strong hope that the set of our currents, under the prevailing condition of S.W. winds, is such that any floating objects set free at definite times of the tide are carried backwards and forwards and even round and round our island, thus rendering economically feasible the liberation of fry from a hatchery on our coast. The indications I refer to are (*a*) the general belief held by fishermen that objects floating at the mercy of the tide during prevalence of certain winds perform the entire circuit of the island, reappearing at the place where they were first seen; and (*b*) the fact that in September, 1895, out of fourteen cases containing brood oysters which broke loose from the oyster beds at Green Island during a gale from the S.W., thirteen were recovered on this coast; all began by travelling to the eastward, nine were recovered at La Rocque, one or two were sighted off the north-east coast, and one off l'Etacq, the latter travelling southward; two were picked up at the Corbière, while the last two were found at the Sambue, not far from the starting point, having either travelled to and fro, or having made the complete circuit of the island. The longest afloat of the thirteen recovered was so for twenty-one days.

As regards improved bait supplies, I believe that great help could be accorded by a local Fishery Committee to the fishermen at little or no expense, in several ways. My own favourite idea is the initiation of a dry-air refrigerator, in which supplies of bait acquired here, or imported from abroad, would be stored—until such time as needed—when the fishermen would be allowed to purchase it at a price just sufficient to cover actual expenses. No greater boon could be granted to our fishermen, and it is one, too, that would be virtually self-supporting. For example, squid is often common in France when none is to be had here—and even if a French supply were to fail, the U.S.A. can furnish unlimited quantities, which could be shipped to Southampton or Bristol in one of the refrigerating chambers of a liner bound for one or other of these ports.

Such a programme as I have outlined above would necessarily take several years to work through. However, I see no reason to doubt that one year's work would be sufficient to accumulate the information necessary to settle the majority of the points listed under the head of "Investigations." Such information would then be available for the framing of well-considered bye-laws, regulating the existing fisheries. Some of the simpler experiments might also be worked upon during such initial year, together with the formation of a Fisheries' collection, the delivery of lectures, and other educational matters.

The second year should be occupied with the due enforcement of the new bye-laws; with the carrying out of further investigations; with the prosecution of the more important experiments; and with lobster hatching in floating incubators on a large scale, should investigation have shown that such may be done here with advantage. The inception of a small Bait-store might also be feasible during the second year.

The hatching of plaice fry—if considered desirable—together with an attempt at restocking the Gorey oyster beds by inducing a fresh and large fall of spat, might form the chief new items in the third year's work. Thereafter the steady development of these various undertakings and the consistent enforcement of the provisions of the law are chiefly what would be requisite, though new lines of investigation would undoubtedly be suggested from time to time. The circumstances of the hour would, of course, largely affect the order of this programme, as it is impossible to guage accurately the respective durations of the various investigations and experiments.

The cost of this work is difficult to assess—so much depends upon how many items are attempted in each year, but bearing in mind favourable local circumstances, I believe a grant of £150 would be sufficient, by the exercise of strict economy, to meet the expenses of the initial year's working, inclusive of salaries, boat hire, and minor items. The expenses of succeeding years would depend still more upon the character of the work attempted; probably £30 extra would be amply sufficient during the second year.

These figures are, I know, likely to be criticised by outside authorities as absurdly low and quite inadequate to the great range of work sketched out.

In explanation of this, I wish to state that such critics must remember that we already have in Jersey a Biological Station, which although it has never received a single penny of subsidy from any source, is now in full working order and provided with laboratories, pumping machinery, tanks and other appliances suitable for carrying out fishery experiments, and that if the States of Jersey think fit to take up the question of Fishery Reform in a broad spirit, I shall be willing to place the whole resources of my Biological Station at their disposal, free of charge, for experimental work, during the first year at least, upon no other condition except of recoupment of the bare extra expenses thereby entailed. Without such facilities, local fishery investigation would be seriously handicapped and its value largely reduced, while if specially provided as has been requisite elsewhere, an initial expenditure of several hundreds of pounds would have to be incurred. Such expense can be avoided in Jersey.

Again, if such fishery reform be decided upon, I would gladly devote the Museum Room of the Station to the purposes of a Fisheries Collection, getting together and preparing at my own sole espense the necessary exhibits, which moreover I would willingly throw open to fishermen free of charge.

This statement will therefore explain the obvious lowness of my estimate, which of course is contingent upon the continuance of my residence in Jersey, as otherwise the Biological Station would be devoted to other uses. In the latter case, if the programme of fishery work which I have sketched, were carried out, the estimate of cost would require to be very considerably augmented.

In closing this imperfect sketch of local fishery problems, I wish to express my very grateful thanks to Dr. F. Wemyss Fulton, Scientific Superintendent to the Fishery Board for Scotland; to Mr. Harald Dannevig, Superintendent of the Dunbar Hatchery; to Dr. Canu, Director of the Station Agricole at Boulogne; and to Mr. Robert A. Dawson, Superintendent to the Lancashire Sea Fisheries Committee, for the more than ordinary kindness with which they have rendered me invaluable assistance in the preparation of this paper.

REPORT ON THE
PLANKTON COPEPODA OF THE CHANNEL ISLANDS.

BY ISAAC C. THOMPSON, F.L.S.

A collection of thirty-nine bottles containing plankton, taken by tow-net at various dates between 1887 and 1897 about Jersey and Guernsey was lately placed in my hands for examination, by Mr. Hornell, the Director of the Jersey Biological Station. With the exception of one bottle marked December 7th (1892) all the material was taken between the months of February and September. By far the largest proportion of the material is Copepoda, with a profusion of Nauplii in those bottles collected during early Spring. Amphipoda, Cumaceæ, Appendiculariæ, Mysidæ, Sagittæ, &c., occur plentifully. It is with the Copepoda alone, however, that this report has to do. Thirty-one species are represented in the collection, as follows:—

Family:—Calanidæ.

1. *Calanus finmarchicus*, Gunn.

   This species, so commonly distributed throughout our seas, was present in about 25 per cent. of the bottles, but in none very abundantly, with the exception of that collected in December. As the chief food of the Greenland whale it is found profusely distributed in the Arctic seas. A parasite of the Calanus, *Microniscus calani*, G. O. Sars, was found attached to one of the specimens.

2. *Calanus propinquus*, Brady.

   One specimen of this rarer species was taken in St. Aubin's Bay, Jersey, in April.

3. *Pseudocalanus elongatus*, Baird.

   Probably the commonest of British Copepoda. It occurs in all the gatherings plentifully.

4. *Acartia clausii*, Giesbrecht.

   Almost as plentiful as the last species.

5. *Acartia discaudata*, Giesbrecht.

   A few specimens were taken in July, in St. Aubin's Bay, Jersey. It is easily distinguished from the previous species (*A. clausii*) by its short, rounded caudal stylets.

6. *Temora longicornis*, Müll.

   A very common British species, plentiful in nearly all the bottles, but rarely found except in British seas.

7. *Isias clavipes*, Boeck.

   This easily recognizable species occurs sparingly in several of the gatherings. Though generally distributed throughout British seas it is rarely found in quantity.

8. *Centropages hamatus*, Lillj.

Commonly distributed throughout the district.

9. *Centropages typicus*, Kr.

A few specimens were found in two of the gatherings taken in St. Aubin's Bay in July and August. It is easily distinguished from *C. hamatus* by the presence of three toothed spines on the anterior antennæ, and by the much finer character of the serrations on the terminal spines of the swimming feet.

10. *Metridia armata*, Boeck.

An open sea species, distinguishable by the leaf-like terminations to the swimming feet. It was found very sparingly in three gatherings from St. Aubin's Bay.

Family : – Candacidæ.

11. *Candace pectinata*, Brady.

One specimen only of this very striking and easily recognizable species was found in a gathering marked Jersey, April 4th, 1894, no precise locality being given. It was first found by Drs. Brady and Robertson at a depth of 40 fathoms, off the Scilly Islands, and I have on several occasions taken it very sparingly on the West coast of Scotland, and have more recently received it from Valentia, Ireland. Some years ago I took it very plentifully about the Canary Islands, and it seems probable that it comes to our westerly and southern shores through the influence of the warm North Atlantic drift. The deep brown colour of the terminations of the swimming feet and of its spines and antennæ render it very conspicuous.

Family :—Pontellidæ.

12. *Labidocera wollastoni*, Lubbock.

This species, which was originally reported by Lubbock, from Weymouth, in 1857, occurs sparingly in six gatherings taken in St. Aubin's Bay, Jersey. Though apparently nowhere common, I have on several occasions taken it in Liverpool Bay, and it has been reported from Heligoland by Claus, and by Canu from Wimereux.

13. *Anomalocera patersoni*, Temp.

This species, one of the largest and the most beautifully coloured of British Copepoda, occurs sparingly on three occasions, taken off Grêve d'Azette and in St. Aubin's Bay. It sometimes occurs in enormous shoals round our coasts, but appears to be nowhere generally common.

14. *Parapontella brevicornis*, Lubbock.

Generally present throughout the collection, often in great abundance.

Family:—CYCLOPIDÆ.

15. *Cyclopina littoralis*, Brady.

This species, generally distributed round British coasts, usually taken near to shore or amongst Algæ, occurred sparingly in one of the gatherings only, taken off Grêve d'Azette.

Family:—HARPACTICIDÆ.

16. *Delavalia reflexa*, Brady and Robertson.
17. *Dactylopus tisboides*, Claus.
18. *Thalestris clausii*, Norman.
19. *Thalestris longimana*, Claus.
20. *Harpacticus chelifer*, Müll.
21. *Harpacticus flexus*, Brady and Robertson.
22. *Zaus spinatus*, Goodsir.
23. *Alteutha depressa*, Baird.
24. *Alteutha interrupta*, Goodsir.
25. *Idya furcata*, Baird.
26. *Scutellidium tisboides*, Claus.

The above eleven species of the large family Harpacticidæ, although free swimmers at times and usually found near to shore, often in rock pools, are usually classed as semi-parasitic. In all of them the anterior antennæ are of small size, the mandibles and foot jaws being generally large and strong. Their presence in the tow-net is but small indication of their distribution, many of them doubtless being exceedingly common among the rock pools and in the littoral zone. Only isolated specimens occured throughout the collection.

Family:—MONSTRILLIDÆ.

Great interest attaches to this family through the recent important discovery of Prof. Giard, of Paris, and confirmed by M. Malaquin, that the early stages of one or more species of this group are spent parasitically in the body cavity of certain worms. (See *Comptes rendus*, 16 Novembre, 1896, and 21 Décembre, 1896, and 11 Janvier, 1897.)

Two species of each of the two genera Thaumaleus and Monstrilla comprised in the family Monstrillidæ appear to be not uncommon about the Channel Islands, viz.:

27. *Thaumaleus claparedi*, Giesbrecht.
28. *Thaumaleus thompsoni*, Giesbrecht.
29. *Monstrilla grandis*, Giesbrecht.

30. *Monstrilla anglica*, Lubbock.

All appear to be about equally common, or rather uncommon, for with the exception of a remarkable gathering taken in St. Aubin's Bay, at 9 p.m., on July 19th, 1897, when several dozen specimens of *T. thompsoni* occur, a few specimens only of it and the other species were present on only two or three occasions, and during the summer months.

An interesting article upon *Monstrilla anglica*, by Mr. J. Hornell, appeared in Vol. I., part 2, page 42, of the present Journal.

Family :—SAPPHIRINIDÆ.

31. *Lichomolgus fucicolus*, Brady.

One specimen only of this semi-parasitic species was found in an evening gathering from St. Aubin's Bay.

In conclusion, while a few species are absent which might have been expected to be present in an English Channel collection, it is probable that the above enumerated list is a fair representation of the free swimming Copepoda of the district. Doubtless any specialist devoting himself to their systematic collection consecutively, might considerably add to the number, and deduce valuable information as to their habits, and bearing on our supply of food fishes, and the causes which lead to the appearance of particular species at varying or definite periods.

The large number of sedentary species of Copepoda living at all depths on the sea bottom, and readily collected by careful washing from dredged material are not here alluded to, as also are not included the many highly organized forms as well as curiously degenerate species of parasitic Copepoda, which are found attached to the gills, scales or other parts of most fishes.

Each of these interesting classes might at a future time furnish material for special reports as distinctly different branches of the subject, and both capable of being well studied at the Channel Islands.

ON A CANCER PAGURUS WITH SUPERNUMERARY CHELÆ.

BY L. A. BORRADAILE, M.A.

(Lecturer in Natural Sciences at Selwyn College, Cambridge).

By the courtesy of Mr. J. Hornell, Director of the Jersey Marine Biological Station, I am permitted to describe a remarkable specimen in the possession of that institution. This is a female of the edible crab, taken in the Spring of 1897, at low water on the shore in Jersey. The carapace measures about 8 cm. by 12·5 cm. The peculiarity consists in the fact that the great *chela* on the right side is wanting, and is replaced by three small limbs resembling the normal *chela*, save in the minor points to be presently described. The other limbs are normal, though the second walking leg on the right side, and the moveable "finger" of the left *chela* are broken off. Of the three abnormal appendages two are directed forwards and the third outwards. Again, of the two forwardly-directed, one may be distinguished as the outer and the other as the inner. I shall refer to these by the letters FO and FI, while the outward limb will be called O. FO faces outwards, FI faces inwards, O faces forwards. Thus the three have the positions described by Bateson[1] as found in such cases of supernumerary limbs, or parts of limbs, in secondary symmetry—which is that each of two adjacent limbs bears to the other the relation of an object to its image in a mirror. FO and FI are each complete save for the basal joint or "coxopod." O wants also the basipod, the true second joint, fused, in this limb, to the next or "ischiopod," the true third joint. When a limb is cast off under the influence of fear, the break always takes place in the middle of the seeming second joint, really at the line of fusion of the basipod and ischiopod. We shall see that this fact has an important bearing on the case before us.

FO and FI lie close together back to back, but are quite free from one another, save in the basipods. This joint is distinct in each limb, but is connected with the similar joint in the fellow limb by a bridge of calcified material, similar to that composing the joint, at its far end. Centrally of this bridge the two basipods are connected by membranous skin. The basipods are not exactly similar in their ridges, etc., nor does either exactly resemble that of the normal *chela* on the opposite side. Of the other joints of the three limbs, the fourth joint (meropod) of FI has a somewhat shrunken and distorted appearance, while the moveable finger is bent dorsally. The sixth joint or hand of FO and O is somewhat rougher and has its ridges more prominent than that of either FI

1. W. Bateson, "*Materials for the Study of Variation,*" p. 479. London, 1894.

or the normal limb on the other side. Otherwise all three seem fairly normal in shape.

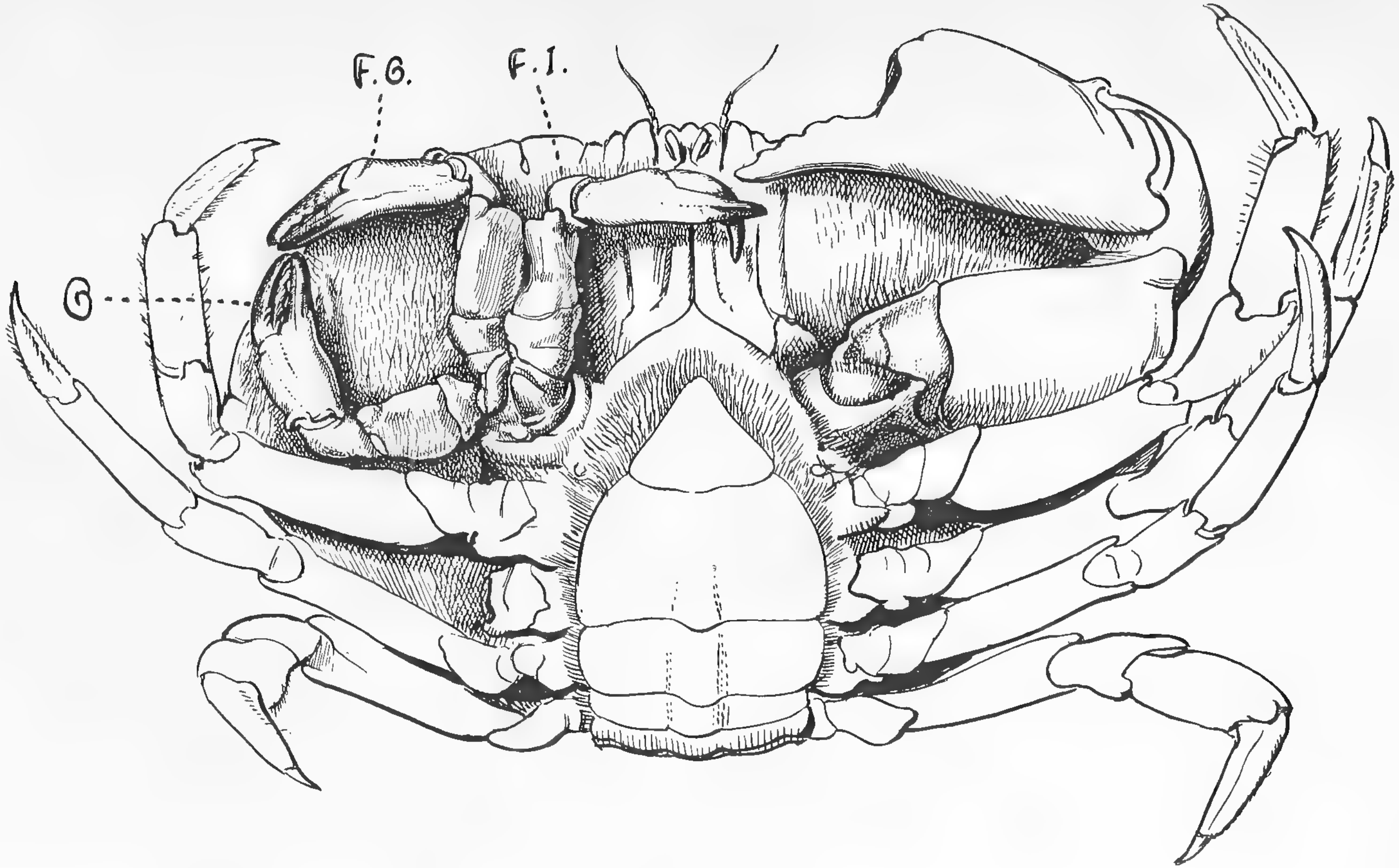
I have mentioned that the basal joint is wanting in each of the three abnormal limbs. They are all inserted by means of membrane within one large ring-like coxopod resembling that of the *chela* of the other side in size, but without the large extension on the outer side that bears the hinge for the rest of the limb.

An assumption which there is a natural tendency to make regarding this specimen is that the right *chela* may have been broken off and replaced abnormally by three. The small size of the abnormal limbs somewhat supports this. On the other hand, were the above the case, one would expect to find that the three limbs had not only the coxopod, but also the basipod in common, and there is, further, no reason why the coxopod should not resemble that of the opposite side, for there is no trace of its having been injured. Probably then, we have to deal with a true variation. Bateson[1] has shown that in such cases as this, of repetition of limbs or parts of limbs in secondary symmetry, one of the limbs represents the normal, while the other two are a pair—a right and a left—and further, that the additional pair bear a definite space-relation to one another and to the normal. In this instance it is impossible to determine with certainty which of the three is the normal limb. Still, certain guesses can be made.

In the first place, FO cannot be the true right *chela*, since it is a left limb. It lies, then, between FI and O, and of these two O seems the more likely to be the normal, since, as we have seen, FI is closely joined to O, which is known not to be the normal. For, to quote Bateson, "nearly always the extra legs are more or less compounded together at their point of origin." If, then, O be the normal, it has been displaced from its true position by a pair of extra limbs in position VVA[2]. If, on the other hand, FI be the normal, the extra pair are in the position DDA.

A number of cases of paired extra limbs or parts of limbs in secondary symmetry are quoted by Bateson among insects and crustacea. There is, however, only one case recorded of complete limbs being reproduced in a crustacean, namely, that of the left penultimate walking leg of a *Palinurus vulgaris*[3]. Here the limbs are in a different position from those of our crab; moreover, the three have a common basipod (with three articular surfaces), while in the crab one is remarkable in having no basipod, and the other two have this joint perfectly distinct in each. Lastly, the distinguishing peculiarity of the present specimen is the small size of the abnormal limbs.

1. Bateson, *loc. cit.*
2. See Bateson, *loc. cit.*, p. 481.
3. Bateson, *loc. cit.*, p. 527. Léger, Ann. Sci. Nat. Zool., vii. 1. p. 111. pl. 6 (1886).



E. Wilson, Del. ad Nat. Dec. 1897.

A Cancer Pagurus with Supernumerary Chelæ,

in the Collection belonging to the Jersey Biological Station.

NOTE ON THE PROTECTIVE DEVICES OF THE GENUS HIPPOLYTE.

BY JAMES HORNELL.

a. The colour adaptability of the adult *H. varians* to the hue of its environment.

b. The significance of the plumose hairs of *H. fascigera* is mimetic and not primarily sensory.

DURING the past summer (1897) I took advantage of an unusual abundance in the Jersey rock-pools of the little Æsop's Prawns, *Hippolyte* (*Virbius*) *varians*, Leach, and *H. fascigera*, Gosse, to carry out some experiments I had long contemplated relative to the protective colouration of these crustaceans.

That the former species is very variable in colour and that the colours are plainly of protective value are well-known facts; thus Professor Herdman in 1893 described in the "Sixth Annual Report of the Liverpool Marine Biology Committee," four variations of *H. varians*, each agreeing in hue with the colour of its special habitat. He put forward four alternative possibilities to account for such variability, thus :—

1. The colours noted may represent four distinct varieties which do not interbreed, keep to their own special habitat, and produce young of their own colours.

2. Or, there may be no permanent varieties, but the young may have great adaptability and assume the hue of the habitat they find themselves in and keep to this for the rest of their lives.

3. Or, this adaptability may be retained throughout the rest of their lives and the adults may change hue upon change of environment.

4. Or, the young may be very variable in tint and then by the action of natural selection, such as do not agree in hue with the surroundings will be eliminated.

He added that he was inclined to regard the last as the most probable explanation.

Starting my experiments with these possibilities in view, I collected a quantity of both our common local species and isolated the individuals in separate glass vessels, each containing sea-weed of a different hue to that of the prawn.

The experiments were conclusive and proved Professor Herdman's third alternative suggestion to be the correct one, namely, that the *adults* retain the power of changing their colour in accordance with that of their surroundings. Thus a pale olive brown *H. varians* taken from amid similarly coloured sea-weed became of a vivid green within an hour when placed with *Enteromorpha*, and the same specimen changed to a pinkish red within three hours when placed amid *Delesseria*.

Again, red coloured specimens of the same species from amongst tufts of red weed changed to green during a single night when placed with *Enteromorpha* or with *Cladophora*, and back again to red within four hours when placed once more amid red weed.

These two instances are representative of a large number of similar experiments, all having parallel results and demonstrating that the adult *Hippolyte varians* has great and rapid colour adaptability.

It is a remarkable fact that this change of hue takes place as rapidly in the dark as in the light; thus specimens placed in a dark cupboard in company with weed of a different colour, will be found to have assumed the colour of the weed in the course of a few hours. In the same way individuals left over night exhibit their appropriate colour change when examined before daybreak on the following morning.

As to *Hippolyte fascigera*, I find that this species possesses by no means equal colour adaptability; this power is much less developed. Thus it takes considerably longer time to adapt its hue to new colour surroundings, and the colour is but an imperfect approximation to the true one. For example, the majority of this species, which are found living among the mottled pink coarse *Corallina* of our pools, and have absolutely similar colouring, take fully twelve to fifteen hours to approximate partially to the white tint of sun-bleached tufts of weed.

Again, a lengthened sojourn of upwards of a week amid tufts of *Enteromorpha* does not effect any well marked assumption of green, though the pink is decidedly paler and a tinge of green can be made out without difficulty.

Such marked divergence in this power of colour adaptability between two species so closely akin* is extremely remarkable, and I had to make a very careful examination of the natural habitats and habits of the species in question ere I was able to solve the problem.

I find that *H. varians* is infinitely more numerous and more widely spread than is *H. fascigera*, being found in almost every pool, and

* Indeed, so closely akin that a cursory examination is apt to lead to the belief that *H. fascigera* is a mere variety of *H. varians*. Many points of permanent divergence are, however, present; the most marked is that in *H. fascigera* the only spines on the upper edge of the rostrum are three placed at the posterior end and really upon the carapace, while a single sharp tooth is set close to the tip on the straight under edge. In *H. varians*, the rostrum above has one tooth set near the base and another towards the tip, while below there is a well-marked two-toothed keel.

haunting tufts of weeds of every hue. In the *Zostera* meadows it is also abundant. No special preference is shown for any particular colour or species of weed, and it is essentially "cosmopolitan." On the other hand, *H. fascigera* is seldom found in any number except among tufts of coarse *Corallina*, with which it agrees *absolutely* in colour, and where it is often extremely abundant.

Thus we see that the species possessing the greater colour adaptability (*H. varians*) is much the more numerous, and the more extended in its range; *we may safely infer that the two latter characteristics are the direct outcome of the former.* *H. fascigera*, being less "plastic" in colouring, is on the contrary restricted in habitat to those weeds to which its colour has become perfectly approximated.

We may note further that the weeds affected by the smooth-skinned *H. varians*, in the great majority of cases, are smooth in surface and not over-grown with foreign matter.

In marked contrast, the body of *H. fascigera* is ornamented with tufts of brush-like hairs, especially upon the sides of the carapace, even invading the surface of the eye-stalks; now if we examine a spray of the coarse *Corallina* where this species makes its home, we will find the stems covered with a multitude of abodes of tiny "messmates"—porcelain-like coils of the little tube-worm *Spirorbis*, dull looking cylinders tenanted by that lovely minature Sabellid, *Othonia gracilis*, and crusting colonies of *Bryozoa* protruding ever and anon circlets of hair-like tentacles—that impart, when their owners put forth their feathery crowns, a minutely tufted appearance to the joints of the stem. Hence when the hairy *H. fascigera* is at rest on such a weed the mimetic adaptation is greatly accentuated. The smooth *H. varians* in a similar environment is much more easily detected.

As there is no doubt in my mind that the plumose hairs on *H. fascigera* are directly useful as aids in protective resemblance to environment, I believe, as a consequence, that we require no longer to accord to these hairs any *special* sensory function. Some authorities have considered the hairs of this species to be auditory, and while they presumably must possess a certain amount of tactile appreciation, their *direct* utility is, I feel assured, as conducing largely to the protective resemblance of the prawn to the appearance of its normal habitat.

In a future number I hope to recur to this subject and to give further details regarding the habits of these interesting Crustaceans.

MICROSCOPICAL STUDIES IN MARINE ZOOLOGY.

BY JAMES HORNELL.

STUDY XXIV.—Familiar British Bryozoa.

The Bryozoa—better known in this country under the name of Polyzoa—often constitute a source of delight at meetings of our Microscopical Societies; seldom, indeed, is a microscopical conversazione complete without at least one such exhibit set out proudly in all the glory of parabolic or spot-lens illumination. The beauty of the pellucid zooids in the full expansion of their glorious crowns of elegantly tapered tentacles, sentient and responsive to the slightest alarm, and the ceaseless lashing of the cilia clothing these tentacles and creating vortices big with fate for many a tiny organism swimming hard by, make up a picture wherein loveliness and interest chain the attention alike of the greybeard in microscopy and of the tyro in the science.

As a rule, the fresh-water Bryozoa are the forms thus exhibited, being the easier to procure in inland towns. The marine forms, however, are fully as beautiful, and in some respects are much more interesting as diversity of form is infinitely greater. If anything, the marine forms are even hardier than the fresh-water ones, and in these days of rapid postal communication and of Marine Biological Stations, inland microscopists have no difficulty in studying living marine species, and of thus comparing them with those they obtain from adjacent pond or sluggish canal.

The Bryozoa are colonial in habit of life, except one minute form, *Loxosoma*, found parasitic in multitudes of separate individuals upon the hinder end of the great Spoon-worm (*Phascolosoma*). The colonies, or **zoaria**, may be slender and branched (*Bowerbankia*), broadly foliaceous (*Flustra*), massive and calcareous (*Lepralia*), coiled in elegant spirals (*Bugula*), gelatinous as *Lophopus* and *Alcyonidium*, horny, hispid, smooth, or crusting. Almost all live attached, usually to stones or seaweeds, and often enough we find them growing in profusion upon the carapace and limbs of crabs. One form, *Cristatella*, crawls freely, with slug-like motion, over and amongst the weeds of its pond home, while others, the *Selenaridæ*, swim by the oar-like paddling of giant bristles—the vibracula. Can diversity be greater? Well might the earlier naturalists consider the slender forms to be zoophytes, and the massive ones to be coral growth.

Later, their affinities were recognised as apart from the zoophytes by the possession of a well-developed alimentary canal. Now they are accorded a place among that heterogenous assemblage, the "Worms," and their closest relationship is undoubtedly with *Phoronis*, the Sipunculid worms, and the Brachiopods. These agree in having tentacles round the mouth; an alimentary canal more or less U-shaped —the anus placed far to the front and often approximated to the mouth; nephridia (kidneys) reduced in number and rarely more than a single pair; the body unsegmented and often secreting a horny or calcareous covering; the nervous system greatly reduced; parapodia and setæ absent.

Two popular names are in use, "Corallines" and "Moss-polyps," the latter being the translation of the term Bryozoa.

Simplest of all the Bryozoa are the *Pedicellinidæ;* the typical species, *P. cernua* (Pallas) grows luxuriantly in Jersey rock-pools, clothing the stems of such algæ as small Fucoids, the pink *Corallina,* and the green *Cladophora.* The individuals or zooids are stalked, rising at short intervals along the creeping stem or stolon; in form they have a superficial resemblance to the Bell-animalcule (*Vorticella*), both having the shape of a wine-glass. *Pedicellina* is coy of full expansion, and the ordinary illustrations of text-books never do it justice; fig. 10, pl. ix., drawn from a zooid just taken from a rock-pool, gives a better though still inadequate idea of the graceful outward curve of the tentacles under natural conditions. The stalk is contractile and flexible and as we watch a group scarcely a moment passes without we see one or another bob the body almost down to the base of the stalk or maybe give a sweeping curtsey from side to side. At another time the whole cluster may bow in unison—a most comical sight, and one that caused me instinctively to christen it the Bobbing Coralline when first I made its acquaintance.

The stalk is usually spinous, but all gradations to a perfectly smooth condition are to be met with.

The tentacles are solid and are arranged in a circlet around the rim of the cup-shaped body. Such rim is the **lophophore** or tentacle-carrier. The lophophore is not retractile as in those forms yet to be named, but at will the tentacles can be folded inwards to form a rafter-like roof to the vestibule or depression found in the centre of lophophore.

A diaphragm separates the body from the stalk, and when, as sometimes happens, the former breaks off, it is not unfrequently replaced by budding from the summit of the stalk. This tendency of the body to break off is often very troublesome when one is endeavouring to stupefy a colony preparatory to fixing.

Within the depression (vestibule) enclosed by the ring of tentacles are two openings, the mouth and the anus. Between the two rises a small lobe, the **epistome**. Food is directed to the mouth by means of the currents set up by the cilia that clothe the inner or adoral surface of the tentacles. The alimentary canal is of the typical U shape, and is of the most primitive description.

A very curious point is the absence of any body-cavity (coelome). Its place is taken by gelatinous tissue lying between the alimentary canal and the body-wall. Muscular fibres are present in the stalk, and others control the movements of the tentacles.

The nervous system is little developed, consisting of a single ganglion lying beneath the œsophagus, and from which nerves proceed to the tentacles. Sensory cells are found on the outer surface of the tentacles.

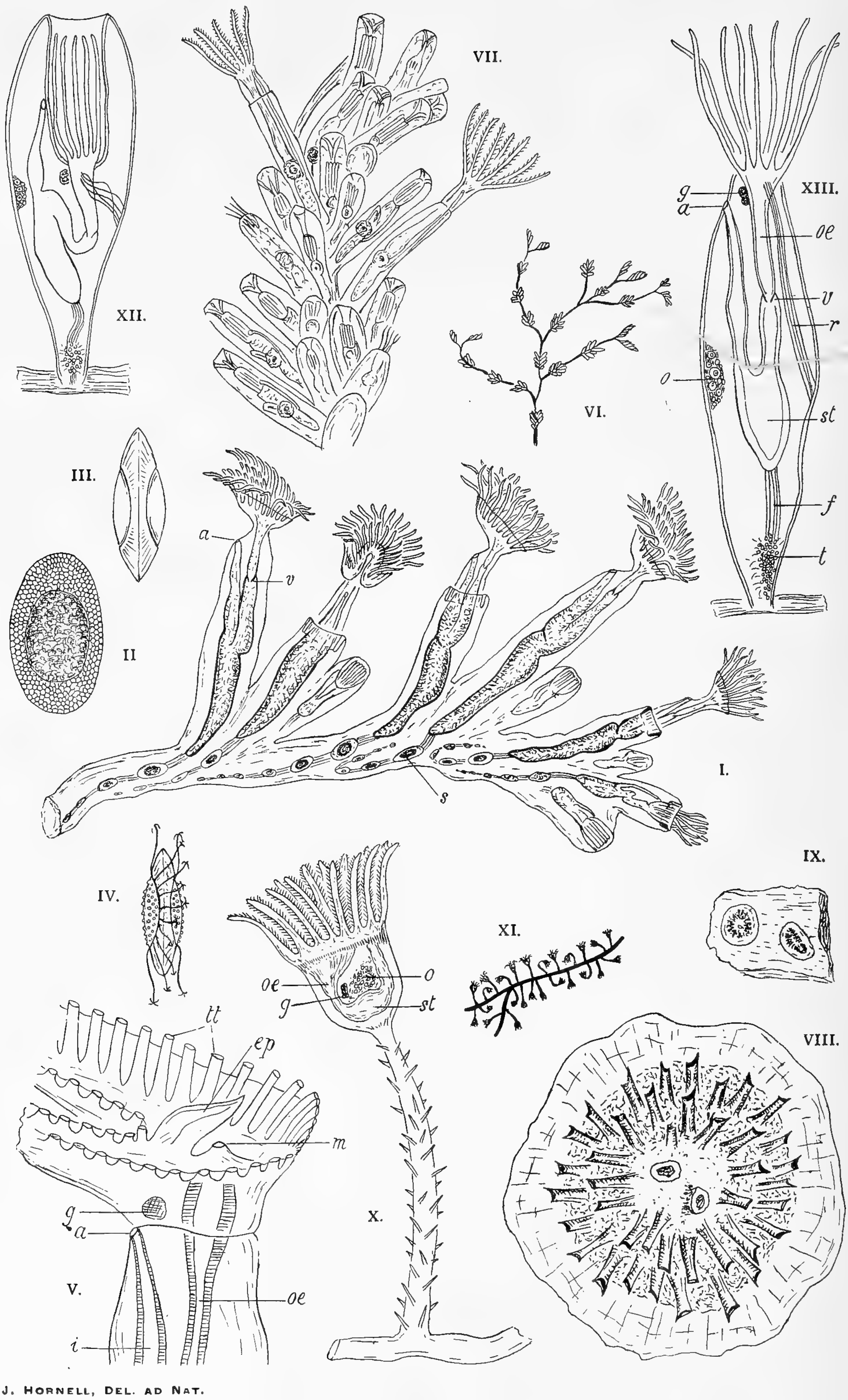
The excretory organs consist of two ciliated tubes opening close to the central ganglion.

The zooids are hermaphrodite, but it is probable that the reproductive products ripen at different periods. The larvæ are Trochospheres —tiny swimming spheres characterised by a circlet of cilia around the body anterior to the mouth (preoral)—as in the Polychætes, and the adults themselves retain a majority of the essential features distinctive of this larval form in the persistence of the simple alimentary canal of the latter, of a ciliated ring surrounding the mouth and anus (the tentacles are simply elongated processes of an encircling band), of the two ciliated canals of the larva as nephridia; the epistome is present in the trochosphere as a tufted eminence, and other minor common characteristics can also be traced.

The larvæ pass a considerable period of their development within the vestibule, which, with the tentacles protectingly overarched, forms an efficient incubatory pouch.

The higher Bryozoa fall naturally into two divisions according as the habitat is marine or fresh-water. The former are distinguished by the lophophore being circular and are termed **Gymnolæmata**; the latter, the **Phylactolæmata**, by the lophophore being horse-shoe shaped. In all, the anus lies outside of the lophophore, and this is the great distinguishing characteristic.

Of the fresh-water forms, *Lophopus* and *Plumatella* are typical, and resemble one another closely in all essential features. *Plumatella*, often found attached to water-weeds in canals and pools, has a creeping chitinoid stolon from which the zooids rise at short intervals. In *Lophopus*, the zooids are crowded into dense tufts and enclosed in a gelatinous matrix. In both, the zooids are capable of being wholly retracted within the zoöecia or cell-like cuticular envelope, chiefly by means of a powerful strand of muscular fibres (retractor muscle, *r*.) attached at one end to the anterior portion of the œsophagus and at the other to the lower inner surface of the resistent stolon-tube. Besides this, the zooid can be partially retracted by a set of small



J. Hornell, Del. ad Nat.
(Figs. IV., V., & VII. excepted).

TYPES OF BRITISH BRYOZOA.

Explanation of Plate IX.

Fig. I.—Portion of a colony of *Plumatella repens*, sketched from life, showing zooids in various states of expansion. (Original.)

Figs. II. and III.—Statoblasts of *Plumatella*, surface and edge view. (Original.)

Fig. IV.—Edge view of a statoblast of *Cristatella mucedo*, showing the projection of numerous barbed spines. (After Allman.)

Fig. V.—Anterior part of the body of *Lophopus*, seen from the right side. The free ends of the lophophore and of the tentacles are cut off. (After Allman.)

Fig. VI.—Life appearance of a colony of *Bowerbankia imbricata*, nat. size. (Original).

Fig. VII.—A cluster of zooids of the same, fully expanded. (After Hincks.)

Fig. VIII.—A calcareous colony of *Lichenopora hispida*, showing two ooecia in the centre. Drawn from Nature. (Original.)

Fig. IX.—Two colonies of the same, nat. size.

Fig. X.—*Pedicellina cernua*, showing the full expansion of the tentacles. From life. (Original.)

Fig. XI.—A cluster of *Pedicellina cernua* on a filament of seaweed, nat. size. (Original.)

Fig. XII.—Diagram of the structure of a Bryozoon zooid in a retracted condition. (Original.)

Fig. XIII.—The same in a state of expansion. (Original.)

Lettering :—*a.* anus ; *ep.* epistome ; *f.* funiculus ; *g.* nerve ganglion ; *i.* intestine ; *m.* mouth ; *o.* ovary ; *œ.* œsophagus ; *r.* retractor muscle ; *s.* statoblasts ; *st.* stomach ; *t.* testis ; *v.* œsophageal valve.

Classification :—

Class.—BRYOZOA (=POLYZOA).

Sub-Class I.—ENTOPROCTA ; Anus opening *within* the lophophore ; no body cavity ; tentacles non-retractile.

Family *a.*—Pedicellinidæ—colonial.

Family *b.*—Loxosomidæ—solitary.

Sub-Class II.—ECTOPROCTA ; anus opening *outside* the lophophore area ; well-developed body-cavity (coelom) ; tentacles retractile.

Order 1.—*Phylactolaemata.* Lophophore horseshoe-shaped ; with epistome ; membrane supporting bases of tentacles ; all fresh-water in habitat.

Order 2.—*Gymnolaemata.* Circular lophophore ; no epistome ; no membrane round bases of tentacles ; all marine except *Paludicella.*

Explanation of Plate X.

Fig. I.—*Sapphirina Edwardsii*, Haeckel, viewed from the ventral surface, and showing the course of the alimentary canal, the disposition of the dermal glands, fat spheres, eyes, and ramifications of the nervous system. (Note: The muscles, genital organs and swimming feet, etc., are omitted.)

Fig. II.—Anterior portion of cephalic region of same species, showing in greater detail the arrangement of the eyes, fat-body, dermal glands and nerve connections.

Fig. III.—Posterior "maxilliped" (really a branch of the second maxilla); same species.

Fig. IV.—Caudal plate; same species.

Fig. V.—Combination of a single-celled dermal gland and a terminal ganglion cell with its sensory bristle; same species.

Fig. VI.—*Sapphirina Gegenbauri*, Haeckel, ventral view to show the eyes, alimentary canal, liver lobes and reproductive system. (Nerves, muscles and most appendages are omitted.)

Fig. VII.—Posterior "maxilliped" (branch of the second maxilla); same species.

Fig. VIII.—Caudal plate; same species.

Fig. IX.—Caudal plate of *S. Clausi*, Haeckel.

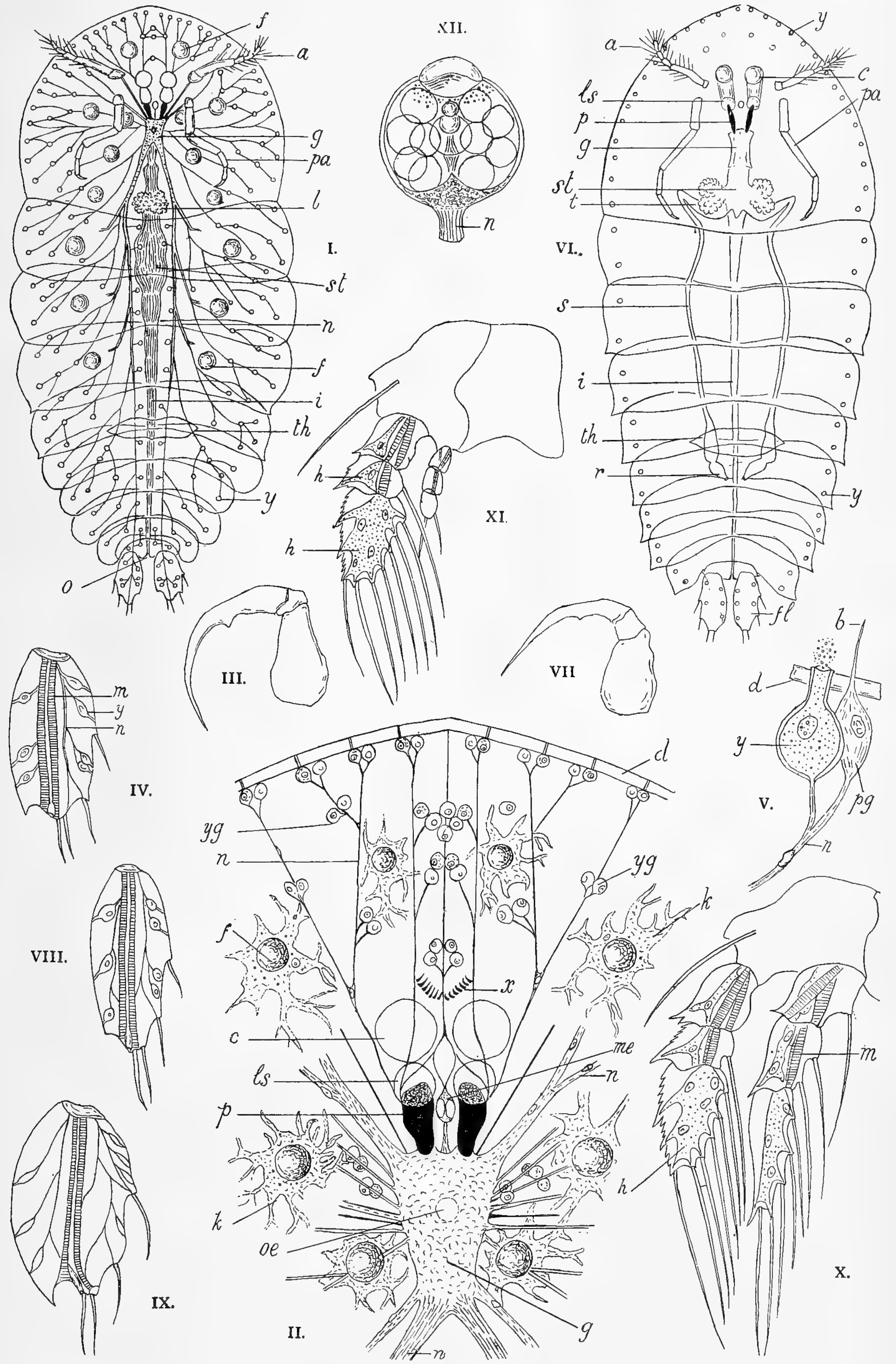
Fig. X.—A swimming foot of *S. Clausi* from the fourth segment, showing the two nearly equal branches.

Fig. XI.—A similar foot from *S. Darwinii*, Haeckel, showing how the inner branch is here almost suppressed.

Fig. XII.—The medium eye-spot in *S. Darwinii*, greatly magnified.

Lettering.—*a.* anterior antenna; *c.* corneal lens; *d.* chitinous cuticle; *f.* fat sphere, secreted by the "Fat-body"; *g.* central ganglionic mass penetrated by the œsophagus (*œ*); *h.* branch of that peculiar form of connective tissue know as the "Fat-body"; *i.* intestine; *k.* stellate branches of the "Fat-body"; *l.* liver lobes lying around the stomach; *ls.* crystalline cone; *m.* muscles; *me.* median unpaired eye; *n.* nerve; *o.* anus; *œ.* œsophagus; *p.* pigment body of the paired eyes; *pa.* posterior antenna; *pg.* peripheral ganglion cell with its sensory bristle; *r.* spermatophore pouch; *s.* vas deferens; *st.* stomach; *t.* testis; *y.* dermal gland; *yg.* double-cell consisting of a dermal gland and a ganglion cell; *x.* problematical organ (sensory?).

(All figures after Haeckel.)



J. Hornell, Del. (after Haeckel).

STRUCTURE OF SAPPHIRINA.

muscles causing a folding in that forward part of the body-wall called the tentacle sheath, as seen in the 2nd, 3rd, and 5th zooids counting from the left in Fig. I., Pl. IX.

A thin membrane protects the bases of the tentacles, which are ciliated on both surfaces. A well-marked ciliated lobe, the epistome, overhangs the mouth (*ep.*).

The alimentary canal hangs as a Y-shaped bag, suspended freely in the body cavity, and in all the fresh-water forms except *Paludicella*, the body cavity (coelome) is common to all the zooids—no partitions are found anywhere—and cilia cover the whole coelomic surface. The œsophagus is straight. Notice, as it enters the stomach, how it is furnished with a valvular arrangement (*v.*) projecting downwards and designed to prevent any backflow from the stomach. The latter has a great pendant bag-like region, the glandular cæcum, forming the straight part of the Y-shape. A strong cord, the funiculus, attaches the cæcum to the outer wall or ectocyst. The intestine is short and straight and lies parallel with the œsophagus ; the anus (*a.*) opens close to the base of the lophophore.

The food consists of microscopical organisms, chiefly infusoria, spores and the like, swept into the mouth by the currents produced by the waving of the tentacular cilia.

The nervous system is again confined to a small double ganglion lying between the œsophagus and the anus and giving off branches to the lophophore. A delicate commissure surrounds the œsophagus. No special sense organs are known.

No heart is present; the coelomic fluid, wherein corpuscles float, courses freely through all parts of the colony, kept continously in motion by the cilia of the internal surface. Aeration is secured in the thin-walled tentacles which are hollow, branches of the coelom being continued into them.

Reproduction.—The fresh-water bryozoa are hermaphrodite. Usually the testis is situated on the funiculus (*f.*), while the ovary is placed towards the forward end of the body (*o.*), and derived from the endocyst or lining of the ectocyst or cuticle.

In addition to this, the fresh-water Bryozoa are remarkable for an asexual reproduction by means of winterbuds or **statoblasts**. Upon the approach of winter, the era of dissolution for the adult colony, buds are formed on the funiculus ; the cells at one end of the bud grow round the remainder and form two convex horny plates attached by their margins to one another, and with air cells arranged in a marginal ring. In *Plumatella*, which we are now describing, the statoblast is plain, but in *Cristatella* it is an exceedingly beautiful object, studded with minute knobs and provided with barbed spines designed to aid in the dispersal of these resting buds. The marginal air-cushion found both in this genus and also in *Plumatella* and other fresh-water Bryozoa, has obviously a similar duty. In Fig. 1, Pl. IX., a string of statoblasts in various stages of development is seen upon the funiculus of each zooid; while Figs. 2 and 3 give side and face views of a single statoblast. The marginal air-cushion in mature buds shows under the microscope as a broad black border. The statoblasts becomes free upon the death and decay of the parent, rising to the surface and floating at the mercy of the currents. In some genera, as *Pectinella* and *Cristatella*, the whole parent stock breaks free and floats freely hither and thither—an additional help in the dispersal of the statoblasts. The latter remain without change during winter. In spring, under favourable conditions, the valves open, and a tiny minature of the parent zooid emerges. It floats passive for a while, then makes fast to some object, generally a water-weed, and soon by active budding becomes a colonial parent.

The asexual reproduction of the fresh-water Sponge by similar resting buds should be remembered—evidently a method towards the perpetuation of the species induced by similarly exceptional requirements.

The Gymnolæmata, which are all marine, save *Paludicella*, are infinitely more numerous and in form more diverse. Fig. 13 gives a fair diagrammatic idea of their structure, while Fig. 12 shows the same in a state of retraction. They differ from the fresh-water forms in the lophophore being circular and not crescentic, in frequently having the sexes separate, and in having no asexual reproduction by statoblasts.

Bowerbankia imbricata is a typical species, often cast up on our coast attached to the brown-podded sea-weed *Halidrys*. Fig. 6 shows a branch, natural size, while Fig. 7 shows a cluster of individuals. The cuticle is chitinous, and the zooids are very similar to the diagram given, save that they have a well-marked gizzard at the fore part of the stomach.

Figs. 8 and 9 show the calcareous framework of a pretty little Bryozoon called *Lichenopora hispida* (Fleming), often found in caves at extreme low-water mark within the Laminarian zone. It may also be procured in dredging over coralline bottom, attached to the great massive *Lepralia*, another calcareous Bryozoon.

Lichenopora, the Cup-Coralline, as it may be appropriately named, is about $\frac{1}{8}$ in. to $\frac{1}{6}$ in. in diameter; a snowy-white fragile porcelain cup, from whose hollow arise tubular columns, each the home of a delicate zooid. The calcareous wall of this tube is equivalent to the horny or gelatinous ectocyst or cuticle of *Plumatella* or *Lophopus*. In the centre of cup are usually one or two elevated trumpet-shaped openings, the **ooecia** or receptacles for the ova.

In both *Bowerbankia* and *Lichenopora* the zooids of each colony are very similar one to the other; in other genera, however, especially in *Bugula*, a distinct **polymorphism** seems to take place. *Bugula* lives in the Laminarian and Coralline Zones and except at very low spring tides can only be taken in the dredge. It is fairly abundant in British waters, and grows in loose spiral coils of great elegance. Examining a spray, we find the zoöecia or cells are arranged in tabular manner, edge to edge, the apertures all on the inner surface. The normal zooids approach closely to the form of those of *Bowerbankia*, but what arrests the attention at once is the presence of peculiar beak-like bodies scattered over the surface. Each is a small rounded object provided with a curved upper beak, to which is hinged a movable jaw-like mandible, constantly snapping viciously. The whole so closely resembles a bird's head and beak that it has received the name of **avicularium.** The only internal organs are two powerful muscles used to set the mandible in motion. According to many authorities, these avicularia are believed to be zooids modified for a highly specialised function, but this point is not assured. What the exact function is, is also doubtful. The more likely theory is that they are protective, scaring minute predatory creatures away by the constant gnashing of the jaws; some, however, have argued that they assist in procuring food. Thus they may sometimes be seen holding some minute worm or crustacean in their grip and while such object is useless, from its size, as food, yet if held till decay begins, the disintegrated particles may be swept into the mouth by the waving of the tentacular cilia. Among my microscopical preparations I have now one wherein an avicularium is holding the limb of a small Amphipod.

Whip-like organs, called **Vibracula**, are also seen in *Scrupocellaria* and other Bryozoa, and again are thought by many to be modified individuals bereft of alimentary, reproductive and other organs excepting muscles. The vibracula most probably also subserve a protective function, their constant lashing keeping unwelcome visitors at a respectful distance and also freeing the surface of the colony from decaying or otherwise undesirable matter. It may also be that the lashing serves to keep the water around in healthful motion and so to bring new food particles within reach of the ciliary vortices.

DIVISIONS OF THE GYMNOLÆMATA:—

Sub-Order *a.*—*Cyclostomata.* Zooecial orifices round, without avicularia or vibracula or opercular apparatus, *e.g.*, *Crisia*, *Lichenopora*.

Sub-Order *b.*—*Ctenostomata.* Zooecial orifices closed upon retraction by folds of the tentacular sheath or by a circlet of spines, *e.g.*, *Alcyonidium*, and *Bowerbankia* (marine) and *Paludicella* (fresh-water).

Sub-Order *c.*—*Cheilostomata.* Zooecial orifices furnished with a movable thickened lip or operculum, or with a sphincter muscle; vibracula and for avicularia usually present, *e.g.*, *Aetea*, *Bugula*, *Flustra*, *Scrupocellaria*, *Lepralia*.*

STUDY XXV.—THE SAPPHIRINIDÆ.

The Sapphirinidæ are Copepoda of large size found in warm seas. The males are free-swimming and pelagic, captured usually in the tow-net, whereas the females are seldom taken free, as they pass their life as commensals or messmates in the branchial cavities of such pelagic Ascidians as *Salpa*.

The females differ considerably from the males in form, as is usual with species where the sexes have divergent habits. In this article we shall confine attention to the males.

Male individuals of this family are all of comparatively large size, the body is dorso-ventrally compressed, and these characteristics in conjunction with the perfect transparency of the chitinous covering makes the *Sapphirinidæ* a splendid type-group wherein to study with ease the structure of all the internal organs.

The prevailing body-form of the Copepoda is pear-shaped, and the common *Cyclops*, abundant in fresh-water ponds, is a good representative. In the *Sapphirinidæ*, as already mentioned, the body is flattened; in contour it is oval, showing a large cephalic shield, five thoracic segments, and an equal number of abdominal segments terminating in two leaf-like caudal lamellæ. Only four of the thoracic segments are readily distinguishable, the fifth being rudimentary (Pl. X., Fig. 1, *th.*). The first abdominal is marked by the external openings of the sexual organs being here placed.

The appendages are of the normal Copepod type, save in the form of the posterior antennæ (*p.a.*) and of the appendages around the mouth (maxillæ), which terminate in hook-like claws well adapted both for clinging to the host should the Copepod be sojourning with one, and for grasping the female during accouplement. A swimming foot of *Sapphirina Clausi* of typical Copepod form is shown at Fig. X., consisting of an inner and an outer branch (endo- and exo-podite) of

* The marine Bryozoa live well in confinement and several kinds (*Pedicellina*, *Alcyonidium*, *Flustrella*, *Amathia*, &c.) can be supplied *living* from the Jersey Biological Station. It is advisable to give, if possible, a couple of days' notice. Full particulars supplied on application to the Director.

about equal size, and armed with strong oar-like bristles of great service in swimming, Sométimes, however, as in *S. Darwinii* (Haeckel), the inner branch is atrophied, indicating weaker swimming powers.

No gills are present; the cuticle is so thin and delicate that the whole surface of the body functions in breathing.

When seen swimming the Sapphirinids present a magnificent play of metallic colours—the acme of iridescence—as they drive rapidly through the water, mere sapphirine glints of darting light; the reason for the generic name is obvious. If we examine the cuticle, the cause of the ever-changing sheen is found to be due to excessively fine parallel and cross rulings upon the surface that produce the optical effect of lightning-swift colour change with every alteration in the incidence of the light.

The cuticle is underlaid and produced by an excessively thin layer, the *hypodermis*, in which lie numbers of most peculiar **dermal glands**. Their proportion varies greatly in different species, attaining greatest development in *S. Edwardsii* (Fig. I.), where they are thickly scattered over the whole body. Each opens to the exterior by a fine duct passing through the cuticle. Usually they are unicellular as in the species named; more rarely they are multicellular, as in *S. Darwinii*, composed of from three to seven or even more cells. Usually each gland is accompanied by a nerve ganglion giving off a sensory bristle or seta that projects from the surface of the cuticle. A common nerve serves each pair, breaking into two branches ere reaching them. The function of the glands is excretory; its activity is apparently controlled from its companion nerve cell, which in turn receives impressions from the surrounding medium through its projecting seta (see Figs. II. and V., *y.*, *pg.* and *yg.*).

A former article in Vol. I., p. 42, described the muscular arrangement of *Monstrilla*, an allied Copepod. That of *Sapphirina* is on the same plan.

The œsophagus passes through the centre of the ganglionic mass, and leads directly into a dilated stomach provided with glandular diverticula or pouches that may be considered as acting the parts of liver and pancreas (*l.*). The form of this "liver" varies with the species; note how in *S. Edwardsii* it forms a collar-like mass around the anterior end of the stomach, while in *S. Gegenbauri* it forms four pouch-like branches. The intestine is straight, ending between the caudal plates.

The **Nervous System** exhibits great centralization. There is no distinction into brain and ventral ganglionic chain such as is seen in the free-swimming Copepods. All are fused into one great ganglionic mass pierced by the œsophagus. But as a compensation, or indeed as a consequence, the radiating nerves are wonderfully numerous and strong. Anteriorly they branch off to the eyes and head appendages, while posteriorly two great trunks are given off to supply the swimming feet and the remainder of the thorax and abdomen. The way these nerves divide into a network of twigs serving the dermal glands has already been noticed.

Of **Sensory Organs**, the chief are the eyes, of which there are three—two complex lateral eyes lying on either side of a small and simple median eye. The structure of a lateral eye consists essentially of a very large globular corneal lens (*cl.*) lying in front of the true crystalline lens or "cone," behind which again is a large pigment body resting upon the ganglionic mass. The corneal lens is derived from the cuticle; in some species, as in *S. Edwardsii*, it rests directly on the crystalline lens; in others, as in *S. Gegenbauri*, and especially in *S. Clausi* and *S. Darwinii*, quite a considerable distance separates the two (Fig. VI.).

The sensory setæ of the peripheral nerve cells have already been referred to; the only other sensory organ is the frontal sensory organ of unknown use, seen between the corneal lenses (*x*). It is noteworthy that the Nauplius larvæ of the higher Crustacea also show similar organs, from which we may infer that this is an organ present in the ancestral Crustacean stem.

No heart or blood-vascular system is present. The blood or coelomic fluid moves freely in the whole of the coelome or body cavity.

Lining every part of the body wall is a peculiar stellately-branched and very delicate form of tissue, called the **Fat-body**, wherein are formed oil spheres of wonderfully large size. In some species they are specially numerous, as, for example, in *S. Clausi* and *S. Edwardsii*, and are symmetrically disposed. The fat-body as a whole serves as a reserve of nourishment, and is especially useful when the animal moults and when the reproductive function makes special drain upon the vitality of the individual.

Reproduction.—In the males here figured, note the two-lobed testis (Fig. VI., *t.*), stretching across the body close to the stomach. On either side is given off a long tubular vas deferens, glandular at its further end and then expanding into a wider region, the spermatophore pouch, wherein numerous spermatozoa lie encased in an envelope or **spermatophore** until such time as copulation shall take place, when the spermatophore being fixed by the male *upon* the genital segment of the female, the spermatozoa break through their envelope and pass individually into the oviducal openings.

The young pass through well-marked Nauplius stages.