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THE

BRITISH FRESHWATER RHIZOPODA AND HELIOZOA

BY

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AND

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ASSISTED BY

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Secretary of the Ray Society

VOLUME V

HELIOZOA

BY

G. H. WAILES

LONDON

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PREFACE.

The unfinished MS. and notes on the Heliozoa left by Cash have been kindly placed at my disposal and are utilised so far as possible, but his records are not numerous, and only one or two drawings were available; I am also indebted to the late Prof. G. S. West and to Mr. J. M. Brown for original drawings and records.

Unfortunately, during my examinations of British gatherings for Rhizopoda, the occurrences of Heliozoa were not specially noted, as it was anticipated that the authorship of the present volume would have been entrusted to more able hands.

Since that time, absence abroad until the outbreak of war, and then war-work together with travel restrictions in England, have prevented the collection of more than a few new records; this is the more to be regretted as there is in the Heliozoa a wide and almost unworked field open to investigation so far as their occurrence and distribution is concerned, and the life-histories of the majority of the species are still unknown.

The descriptions of the species not yet recorded as occurring in the British Isles are not properly within the scope of the present volume; but on account of their number and the likelihood that they may be recorded as British in the near future, their chief

characteristics have been added, and it is hoped that this will enable readers to identify any such species of Heliozoa which they may meet with. For further information Penard's work may most conveniently be consulted.

The sudden death of Mr. John Hopkinson in July, 1919, deprived me of his valuable assistance and has necessitated the omission of the complete bibliography of the Heliozoa which he had in preparation. The more important references, however, are given in the synonymy of each of the species. Mr. Hopkinson had revised the manuscript and arranged the plates and text-figures. He also re-drew several figures from the publications of previous authors.

Dr. Calman kindly undertook to see the volume through the press and to read the proofs. He has also verified all the bibliographical references and compiled the index. My thanks are due to him for his kind co-operation.

G. H. WAILES.

Cortes Island, B.C.,
Canada;
October, 1920.

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ERRATA AND CORRIGENDA.

Vol. III.

Page 7, *Euglypha scutigera*, Penard, *add* reference to Pl. XXXV, fig. 1.

Vol. IV.

Pl. LXI.—The following corrections to be made in the numbering of the figures:

for	8	*read*	11
,,	9	,,	8
,,	10	,,	9
,,	11	,,	10

Page 23, line 7 from bottom, and *passim*, *for* Whittle *read* Whipple.

Vol. V.

Page 4, lines 19 and 21, for *Rhaphidiophrys* read *Raphidiophrys*.

All measurements are expressed in micromillimetres (μ). 1 μ = 0·001 mm. or 0·00003937 in. ($\frac{1}{25400}$).

BRITISH FRESHWATER RHIZOPODA AND HELIOZOA, VOL. V.

Additional Errata.

Page 34, *Raphidiophrys viridis, for* Pl. LXIX, fig. 2, *read* Pl. LXIX, fig. 1.

Page 41, *Pompholyxophrys punicea, add* reference to Pl. LXIV, figs. 5 and 6.

Page 56, *Acanthocystis brevicirrhis, for* Pl. LXIX, fig. 1, *read* Pl. LXIX, fig. 2.

BRITISH FRESHWATER HELIOZOA.

INTRODUCTION.

Notices of the Heliozoa first occur during the second half of the eighteenth century. They are vague and concern only the commonest forms, but about 1840 superior microscopes enabled Ehrenberg to obtain better results, and since that date many eminent naturalists have made a study of them and their life-histories; in this country Carter, Archer, and Wallich are the most prominent.

In 1848 Brightwell issued a privately-printed volume containing records and drawings of infusoria found by him in the county of Norfolk*; among them are some Rhizopoda and Heliozoa which constitute the first British records of these organisms (Text-fig. 177).

The first British naturalist to devote much attention to the freshwater Heliozoa was Archer, whose careful biological observations and records, mostly of rare or obscure forms, were contributed to the Dublin Microscopical Club, and published in the 'Quarterly Journal of Microscopical Science,' together with summaries and discussions of papers written by contemporary foreign naturalists.

Since then British observers of this group have been few, and descriptions of newly-recorded species and biological investigations must be sought for

* Brightwell, T., 'Sketch of a Fauna Infusoria for East Norfolk,' Norwich, 1848.

principally among the various French and German scientific publications.

Leidy's systematic work on the Rhizopoda of the United States (1879) includes numerous records and figures of Heliozoa, but many of them cannot be absolutely identified owing to the absence of any indication of the necessary specific characteristics.

During the last decade of the nineteenth century interest in this group much revived when Brauer, Hertwig and Schaudinn amongst others devoted their attention to their life-histories. In 1904 Penard published his systematic monograph of the freshwater

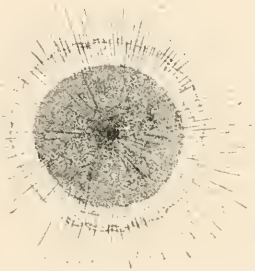

Fig. 177.—Copy of a figure in Brightwell's 'Infusoria of E. Norfolk,' representing *Actinosphærium eichhornii*.

forms ('Les Héliozoaires d'eau douce,' Genève), adding much to our biological knowledge of them and describing many new species.

Structure.

The stiff axes usually present in the radiating pseudopodia distinguish the Heliozoa from the Rhizopoda and the Foraminifera, and the absence of a central capsule from the Radiolaria.

Nearly all the Heliozoa possess some kind of silicious or chitinous spherical investment, and their classification is based on its nature.

The Chalarothoraca, or typical Heliozoa, are characterised by possessing skeletons which can usually be identified more or less readily by the forms of the

spicules of silica or other material of which they are composed, especially if these are isolated, a process which is a little troublesome, but is necessary in some cases. The DESMOTHORACA or genera with continuous and perforated tests are easily identified. There are various other organisms which may present a Heliozoan appearance, for instance the genus *Archerina*, Lankester, was at first described as belonging to the Heliozoa but is now classed with the Algæ; the genera *Nuclearia* and *Vampyrella*, described in the first volume of this work, have been treated by some authors as Heliozoa; also species of *Monobia* and *Ciliophrys* may present an Actinophrys-like appearance, and the same remark applies to other organisms, but the absence of stiff axes in the pseudopodia or cilia will always (when ascertained) show that such forms are not included in the Heliozoa as defined above. The spores of a few Fungi and some zoospores of Algæ may also present a superficial resemblance to the Heliozoa.

PLASMA.

This usually consists of a well-defined endoplasm nearly clear and containing only the nucleus or nuclei and the "central granule" or centrosome; this is surrounded by a zone of ectoplasm containing the contractile vesicle, vacuoles, and various inclusions such as food-particles, granules, crystals, and symbiotic zoochlorellæ.

The occurrence of included crystalline bodies is rare, but food-particles or green zoochlorellæ are often present and may be so numerous that the structure of the plasma and the nucleus are entirely concealed. Pulsating vesicles are normally present, but in those individuals and species containing green cells living symbiotically they seem to be as a rule wanting, and if we assume that their function is of a respiratory nature this absence would be accounted for by the

absorption of CO_2 and the liberation of oxygen from the included and living chlorophyll cells rendering the vesicles unnecessary; in some species, *e. g. Heterophrys fockei* and *Actinophrys sol*, the vesicles are particularly noticeable either for their size, number, or rapid pulsation.

Only one pulsating vesicle is normally present and its period of dilatation and contraction is usually between 40 and 100 seconds. The non-contractile vacuoles are as a rule numerous and disseminated throughout the ectoplasm.

The food of the Heliozoa consists of living animalcula or algæ, the smaller organisms being ingested by the ectoplasm whilst the larger are captured by means of the pseudopodia. Digestion takes place in vacuoles containing a clear secretion having digestive functions.

Some species of Heliozoa are normally infested by parasites; these may be species of bacteria as found in *Acanthocystis chætophora*, *A. spinifera*, *Rhaphidiophrys viridis*, and *Heterophrys myriopoda*; and even Ciliates or Rotifers in the case of *Rhaphidiophrys viridis* and *Acanthocystis chætophora*.

The more typical Heliozoa, that is those belonging to the order Chalarothoraca, have the nucleus and endoplasm placed eccentrically in the body whilst the centre of the spherical envelope is occupied by the "central granule" which appears to act as a true centrosome with the addition of certain kinetic functions; in those species in which the nucleus occupies the central position the centrosome is contained within it.

Nucleus.

The nucleus is present and single in all freshwater Heliozoa, except in the genus *Actinosphærium* which is multi-nuclear. Two or more nuclei may sometimes be found but this is due either to a process of division or to a merging together of two or more individuals.

It is hardly possible to identify the various species by their nuclei, but there are four distinct types of nucleus distinguished by Penard. The nuclei are always bounded by a definite membrane which in some cases appears as a double line, and they usually contain one or more nucleoli. When an individual assumes the resting-state all the chromatin may be collected into a large nucleolus instead of being disseminated in the form of a net-work.

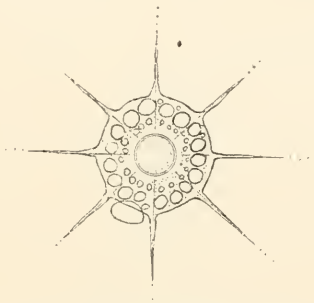

Fig. 178.—Diagram of a Heliozoon with central nucleus (*Actinophrys*-type). (After Penard.)

The nucleus is placed *centrally* (Text-fig. 178) in the following species:—

Actinophrys sol.
,, *vesiculata.*
Astrodisculus zonatus.
,, *araneiformis.*
Clathrulina elegans.
,, *cienkowskii.*
,, *stuhlmanni.*

The nucleus is eccentric (Text-fig. 179), and a centrosome or central granule is present in all other freshwater species except in the genus *Actinosphærium* which is multi-nuclear as are also some marine genera.

In those species of Heliozoa which have the nucleus placed eccentrically in respect to the envelope the centre of the organism is occupied by the central granule which is surrounded by a zone of clear plasma, the whole apparently functioning as a centre of kinetic activity; the axes of the pseudopodia arise

from the periphery of the clear zone, and appear to be connected with the centriole by faint radiating lines of minute granules the terminal ones of which adjoining the axes of the pseudopodia may be analogous to the blepharoplasts of Flagellates.

During fission or budding accompanied by simple division of the nucleus the central granule remains unaffected, but during the process of karyokinesis it divides and acts as a true centrosome.

When buds are formed they at first contain a nucleus only, which subsequently extrudes a centriole to form the central granule.

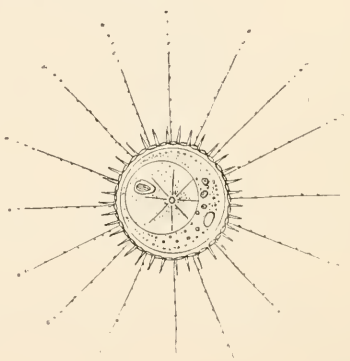

Fig. 179.—Diagram of a Heliozoon with eccentric nucleus (*Acanthocystis*-type). (After Penard.)

Except very rarely or in individuals of species which possess unusually clear plasma, the central granule is indistinguishable, being hidden by the various inclusions, food-particles, etc., and a gentle pressure on the animal is necessary to render it visible: this is the best applied by allowing the water under the cover glass to evaporate slowly.

Although the central granule performs the functions of a true centrosome it appears also to control the emission and withdrawal of the pseudopodia; it should therefore be considered as analogous to, rather than as homologous with, the centrosome of the metazoan

cell; for this reason Dobell* has lately proposed for it the name "centroplast."

Pseudopodia.

In the Heliozoa the pseudopodia are very attenuated, and scattered along them minute globules can generally be discerned; in drawings it is not practicable to depict them truthfully; a thin line of "gum-water" would perhaps be the nearest approach to giving an idea of their appearance.

Their length varies from less than the diameter of the animal's body to three or four times the diameter; their number is also very variable, in some species being a thousand or more, but usually the number is sufficiently few to be counted; this variation is found not only in different species but to some extent in individuals of the same species, and this applies not only to those of various sizes but also to those of the same size.

Every pseudopod usually has a firm central axis, but it is generally too filamentous and transparent to be readily detected, except in the genera *Actinophrys* and *Actinosphærium* in which it is plainly visible. This axis has some remarkable properties; in those species which possess a "central granule" and usually also in the case of those in which the nucleus is central, the axes of the pseudopodia are prolonged within the margin of the ectoplasm and continued through the plasma until the border of the nucleus or the central granule is reached; this axis endows each pseudopod with considerable rigidity and elasticity and reminds the observer of a colourless "spun" glass filament of great tenuity, but in spite of this rigidity the animal is able to retract or extend its pseudopodia with remarkable rapidity, their disappearance being apparently due to some modifying action of the endoplasm on the axis, which can be

* 'Quart. J. Micr. Sci.' lxii, 1917, p. 522.

exerted at will. The instantaneous appearance and disappearance of cils on the flowing plasma of *Amœba pilosa* Cash and *Mastigina setosa* Frenzel seems to be a similar phenomenon. In two species, *Acanthocystis rubella* Penard and *Raphidocystis stellata* Penard, the pseudopodial axes are formed by the silicious spines which invest their envelopes and are consequently permanent, only the plasma with which they are coated being retractile.

The Heliozoa use their pseudopodia as instruments of progression, their extremities attaching themselves to whatever support they happen to be on and then drawing the animal forward with a rolling motion, the various pseudopodia coming into action in succession; in furtherance of this action those about to come into use may be slightly elongated and bent forward; by these means a fairly rapid rolling progression may be attained. There is also evidence that they may be used for free-swimming movements. They are brought into action for the capture of food in which operation they may curve inwards and their extremities sometimes coalesce. With the above exceptions they do not ordinarily anastomose except in the species *Raphidiophrys viridis*, *Actinosphærium arachnoideum* and the genus *Clathrulina*. Amœboid pseudopodia are sometimes displayed by mutilated or detached portions of some species, and they may also appear just previous to encystment as in *Actinosphærium*, but with the above exceptions other than rigid pseudopodia are quite abnormal in mature forms; during the development of swarm-spores amœboid forms occur.

The pseudopodia of the Heliozoa are not analogous to those of the Rhizopoda, and under the description of *Dimorpha mutans* will be found reasons for thinking that they may possibly be derived from modified flagella.

Reproduction.

Solitary individuals in the Heliozoa may multiply by binary fission or budding, during which processes the nucleus may divide either directly or by karyokinesis; multiple budding or gemmation may take place similarly, and in some species this gives rise to temporary or permanent colonies.

The buds may grow directly into mature individuals or may form small flagellate or amœboid zoospores which are known as "swarm-spores." Syngamy or the conjugation of two individuals has been accurately observed in very few instances; the process in the case of *Actinophrys* is described below (p. 10).

Karyokinesis in the Heliozoa is of a normal type, the nuclear membrane being ruptured and either persisting or being absorbed.

Centrosomes may or may not be formed during division, depending on the species concerned and on the nature of the process which varies very considerably even in different members of the same order.

As previously stated there are three groups into which the Heliozoa may be divided according to their nuclear characteristics, viz.:

(1) Multi-nuclear.
(2) Nucleus placed centrally.
(3) Nucleus placed eccentrically.

Each of these groups presents certain differences in the processes of nuclear division which may be briefly summarised.

The first group is represented only by the genus *Actinosphærium* among the freshwater species. In *A. eichhornii*, which may possess some hundreds of nuclei, karyogamy has been observed and may be described as follows:—A single individual withdraws its pseudopodia, exhibits amœboid movements, ejects food-particles, and forms a membranous "mother" cyst, the peripheral vacuoles disappear and the nuclei are much reduced in number either by absorption or

fusion (it is uncertain which), the body then divides into portions, each of which contains a single nucleus, and these form "primary" cysts with silicious spicular investments; these each again divide into two, the nucleus dividing by a process of mitosis; the chromosomes are numerous, being estimated at from 130 to 150 in number; these secondary cysts behave like gametocytes and undergo two nuclear divisions, in each of which centrosomes are formed and one of the two polar bodies is extruded, with a resting-stage occurring between the processes; the two gametes thus formed from a primary cyst fuse into a zygote containing a single fertilised nucleus; a multiplication of nuclei then takes place within the cyst; and finally an amœboid multi-nuclear individual emerges. If division or budding takes place without encystment, no centrosomes are formed during the division of the nuclei, the process being amitotic.* The animal may also divide into various-sized multi-nuclear portions without any internal structural changes, the object being apparently merely to reduce its size.

The second group contains species which have the nucleus placed centrally, and the processes of reproduction which have been observed in *Actinophrys sol* are probably typical of those in the remaining species of the group.

Fission is most frequent (see Text-fig. 180), but copulation or syngamy also occurs; the latter process is preceded by the formation of a gelatinous cell-wall around two individuals; the two nuclei then divide by karyokinesis, one portion of each being extruded as a polar body or reduction nucleus, the remaining portions unite into a synkaryon and a complete fusion of the cytoplasms takes place; the result is a zygote which subsequently, with karyokinesis of the synkaryon, divides and forms two resting-spores from each of which a young individual eventually emerges.

* Brauer, A., 'Zeitschr. wiss. Zool.' lviii (1894), p. 184. Schaudinn, F., 'Verh. deutsch. zool. Ges. Bonn,' vi (1896), p. 113.

Encystment without conjugation and followed by division may also occur, but in this case no centrosomes are formed.

The third group consists of species having a single eccentrically placed nucleus and a "central granule." The processes of reproduction which take place in

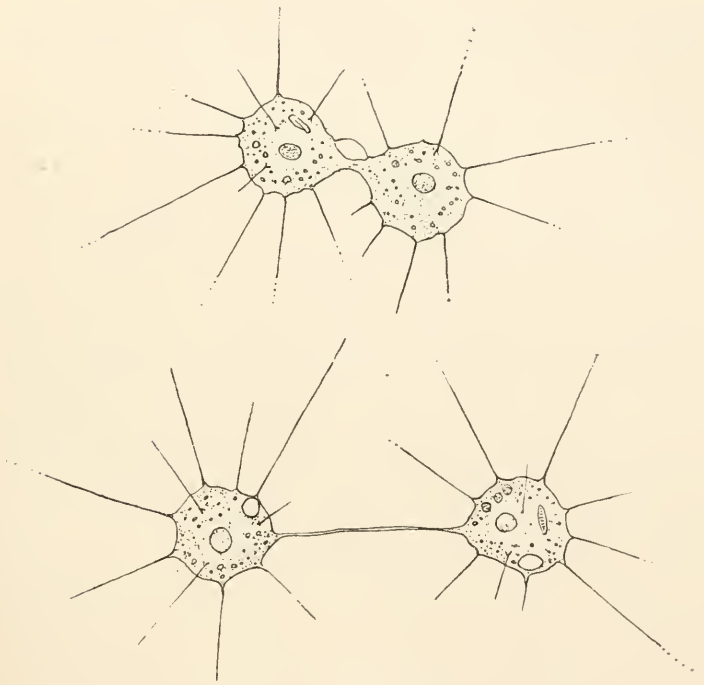

Fig. 180.—Successive stages of fission in *Actinophrys sol.*

Acanthocystis aculeata are probably typical for the group as a whole; the nucleus may divide by a process of mitosis or amitotic nuclear division may take place.

When mitotic division is about to occur in *Acanthocystis aculeata*, the first sign is the division of the "central granule" into two parts which separate and place themselves at two poles of the endoplasm, the nucleus becomes centrally placed and forms an equatorial band of chromosomes on the spindle which joins

the two centrosomes, the process is then completed in the normal way, and when the plasma finally divides two uni-nuclear individuals are the result.

Simple division in the same species without mitosis of the nucleus takes the form either of binary fission or of simple or multiple gemmation without any division of the centrosome; during the process the pseudopodia are not withdrawn and the nucleus divides directly one or more times, one of the resultant nuclei remains in the parent, the others travel to the periphery and each emerges with a bud which is covered with spicules derived from the parent and is uni-nuclear. After the buds are separated they may enter into a resting-stage prior to becoming mature individuals, or they may divide one or more times before developing pseudopodia; again, a bud may become amœboid and leave its investment of spicules, or it may by simple division give rise to several amœboid individuals, or again it may develop two flagella and become what is termed a "flagellula," retaining this form for a day or two before it becomes amœboid; these amœboid forms eventually all become spheroidal and secrete a spicular investment; the nucleus then gives rise to the centrosome, after which the radial axes of the pseudopodia are formed.

The formation of swarm-spores has been observed in the genera *Clathrulina*, *Acanthocystis*, and *Actinophrys*.* These spores are isogametes.

Collection and Examination.

Heliozoa are not uncommon in freshwater lakes, ponds, pools, and ditches; they can usually be found creeping on the bottom if the water is not muddy, or attached to algæ and aquatic plants; plankton gatherings taken in a finely-meshed net are also likely to yield them.

To collect Heliozoa from the bottom, if the water

* Cienkowski; Schaudinn; Penard.

is shallow enough, a large test-tube is very convenient, the mouth being stopped by the thumb until the bottom is reached, or a bottle will answer the same purpose; to collect from water-plants or algæ these should be gently squeezed into a wide-mouthed bottle, and after allowing a short interval for settlement, the upper portion may be poured away and the bottle replenished, the process being repeated several times. For preservation for future examination the sediment thus collected can be put into small tubes or bottled ($\frac{1}{2}$-oz. or 1-oz. size) and about 5 per cent. of carbolic acid or formaline added—or alcohol (spirits-of-wine) may be substituted for the water. If methylated spirit is used it must be of the kind that does not become cloudy on the addition of water. To collect plankton material a net of fine silk or calico can be towed from a boat, care being taken that the net is deep enough to prevent the contents from escaping; a galvanised iron ring about 10 inches in diameter is a convenient size on which to make the net. The gatherings may be kept in glass jars or in bowls out of the direct sunlight.

It is best to locate a specimen on the slide under the microscope previous to putting on a cover-glass, isolate it in a drop of clean water, and then place a cover-glass over it; the plasma, pseudopodia, etc., should be examined as far as it is possible to do so in the living state, and a careful drawing made, after which, if the endoplasm is hidden by the various inclusions, the water under the cover-glass may be allowed to evaporate until the envelope is ruptured and the contents are forced out.

To examine the component parts of the envelope the specimen should be immersed in dilute sulphuric acid by which means the chitinous and silicious elements are isolated; strong sulphuric acid will dissolve chitin and leave only the silicious parts.

HELIOZOA.

Sarcodina of spherical form with radiate non-anastomosing pseudopodia of granular protoplasm; each pseudopod usually having a stiff axial rod passing into the body-plasma; no central capsule or clear ectoplasm present; skeleton when present non-continuous or perforated, composed of silicious, chitinous, or foreign elements, often bearing radial spines of various shapes; nucleus in the freshwater genera (except *Actinosphærium*) single, placed centrally or eccentrically; contractile vacuoles one or more, usually superficial; reproduction by fission or budding in the active condition or by brood-formation in a cyst giving rise to resting-spores; conjugation isogamous (so far as known); habitat mostly in fresh water, on the bottom of lakes or pools, floating, or attached to weeds.

BRITISH FRESHWATER HELIOZOA.

The arrangement of the sub-orders and genera is as follows:—

Sub-order I. APHROTHORACA.

Genera: (1) *Actinosphærium*, (2) *Actinophrys*.

Sub-order II. CHLAMYDOPHORA.

Genus: (3) *Astrodisculus*.

Sub-order III. CHALAROTHORACA.

Genera: (4) *Heterophrys*, (5) *Raphidiophrys*, (6) *Pompholyxophrys*, (7) *Lithocolla*, (8) *Elæorhanis*, (9) *Acanthocystis*.

Sub-order IV. DESMOTHORACA.

Genera: (10) *Clathrulina*, (11) *Hedriocystis*.

Sub-order I. APHROTHORACA R. Hertwig.

Heliozoa without envelope or investment to the body except during encystment.

Synopsis of the British Genera.

Multi-nuclear	(1) *Actinosphærium*.
Nucleus single and placed centrally	(2) *Actinophrys*.

Genus 1. **ACTINOSPHÆRIUM** Stein.

Actinosphærium Stein Abh. Böhmisch. Ges. (ser. 5) X, Berichte, 1857, p. 41.

Ectoplasm consisting almost entirely of large vacuoles in one or more layers; endoplasm containing numerous small vacuoles; nuclei more or less numerous.

Only two species are included in this genus.

Synopsis of British Species.

Nuclei numerous; pseudopodia straight and radiating.
(1) *A. eichhornii.*
Nuclei few; some of the pseudopodia anastomosing.
(2) *A. arachnoideum.*

1. **Actinosphærium eichhornii** (Ehrenb.).

(Plate LXV, figs. 1 and 2.)

? *Trichoda sol* (part.)
Müller Verm. terr. fluv. I. 1773. p. 76.
"Der Stern" Eichhorn Zugabe Beytr. Wasserthiere. 1783. p. 15. ff. 1–7.
Actinophrys Eichhornii
Ehrenberg Ber. Akad.-Berlin, 1840, p. 198.
Actinosphærium Eichhornii
Stein Abh. Böhmisch. Ges. (ser. 5) X. Berichte, 1857. p. 41.
Leidy Rep. U. S. Geol. Surv. XII. 1879. p. 259, pl. xli.
Penard Héliozoaires, 1904. p. 120, ff. 1 and 2.

Body normally spherical, transparent and nearly colourless; outer portion or ectoplasm formed of one or two layers of large vacuoles closely pressed together, their walls more or less thinly lined with plasma; endoplasm containing numerous small vacuoles and separated from the ectoplasm by a narrow zone of denser plasma; nuclei numerous, disseminated in the endoplasm near its periphery, each nucleus containing several nucleoli; contractile vesicles two or more in number, spherical, large, pulsating slowly; pseudopodia of moderate length, numerous, not very close together, tapering, containing a firm axis arising from the narrow zone of denser plasma.

Diameter of mature individuals usually 80 μ to 300 μ or 400 μ but may attain 1000 μ or more; young individuals and detached portions are met with of all sizes from 30 μ or less upwards; the pseudopodia do not exceed the diameter of the body in length; nuclei usually from 12 μ to 20 μ in diameter.

Habitat.—Ponds and lakes. Amongst aquatic vegetation.

Distribution.—General in the British Isles; not uncommon but often local in occurrence.

The large vacuoles forming the ectoplasm of this species are very characteristic; they are so thickly crowded together that they have a cellular appearance and become polygonal in shape; they increase in size with the individual, the outer ones are apparently empty except for a thin layer of plasma coating their sides and bases, the next layers have increasingly larger quantities of plasma attached to their interior walls. The plasma has few inclusions and these consist of food substances and undigested particles but it is remarkably free from parasites and symbiotic organisms; the food consists of algæ, diatoms, etc., and small infusoria such as ciliates, crustaceans and rotifers; these active creatures fall victims to the *Actinosphærium* by becoming entangled among its viscid pseudopodia, where they soon die and are absorbed into the endoplasm (Text-fig. 181). Vogt and Jung have described the formation of an amœboid pseudopodium during the process of ingestion.

The processes of reproduction in this species have been described above (p. 9), but in addition to these, increase of numbers may result from what may be termed mechanical division; this usually takes place if an individual becomes very large in bulk when it simply separates into two or more portions; small portions artificially separated also possess the power to coalesce again.

This tendency to divide may be due to the inability of large individuals to retain their normal spherical form; naturally detached portions are often 40 μ or less in diameter; in these small individuals the large vacuoles are frequently absent, the plasma presenting a fairly uniform finely granular appearance.

There are records of this species attaining to a size of 1000 μ (Schaudinn) and 1360 μ (Calvin) in diameter, but it is very doubtful if the normal spherical shape is retained at over half these dimensions.

Wallich (1863) records an individual found at Hampstead, London, 500 μ in diameter, spherical in shape and resting attached by the extremities of its pseudopodia to the sides of a glass vessel.

The nuclei have a tendency to increase in size as the individual grows; in a specimen from Hampshire measuring 550 μ in diameter many of the nuclei were 25 μ in diameter, but as it was observed under a cover-

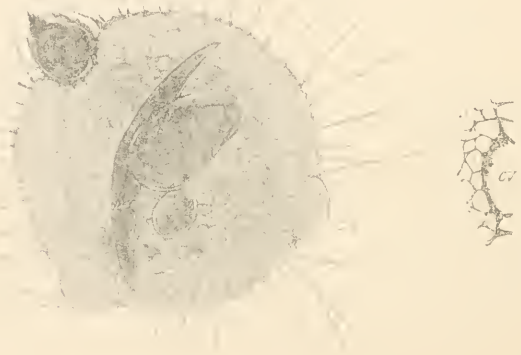

Fig. 181.—*Actinosphærium eichhornii*. A small animal captured by the pseudopodia is seen at *m.* in process of ingestion. Other organisms are enclosed in food-vacuoles in the endoplasm. *c.v.* Contractile vesicles. The figure on the right shows the depression left on the collapse of a contractile vesicle. (After Wallich.)

glass its normal spherical diameter might have been less than this.

The number of nuclei varies greatly, but increases with the size of the individual; the numbers visible in a living specimen, however, are many fewer than those that may be recognised if it be stained and compressed under a cover-glass, by which means from one to three hundred nuclei may be found, according to the size of the specimen.

2. **Actinosphærium arachnoideum** Penard.

(Plate LXVI, fig. 1.)

Actinosphærium arachnoideum
PENARD Héliozoaires, 1904, p. 137, fig.

Body spherical, of a grey colour; ectoplasm formed of large vacuoles merging gradually into the endoplasm; endoplasm granular, containing minute vacuoles and refringent particles; nuclei placed in central region, not exceeding twelve in number, usually fewer than six, large, granular, containing numerous nucleoli; contractile vesicles large, one to three in number; pseudopodia of two kinds, one long, straight, with a firm central axis, the other filiform, amœboid and anastomosing.

Diameter of body 50 μ to 90 μ; nuclei 12 μ in diameter or less; pseudopodia may attain four times diameter of the body in length.

Habitat.—Marshy pools.

Distribution.—ENGLAND.—Delamere, Cheshire (*Cash*).

Cash describes the plasma of the individual shown on Plate LXVI, fig. 1, as greenish owing to the contained chlorophyll particles mixed with some of a golden yellow; the contractile vesicle had a period of about one minute.

Unless the anastomosing pseudopodia were expanded an individual of this species would probably be taken for *Actinosphærium eichhornii*.

Genus 2. **ACTINOPHRYS** Ehrenb.

Actinophrys EHRENBERG Abh. Akad. Berl. 1830, p. 42.

Body spherical, contained in a smooth membranous envelope; plasma containing numerous vacuoles, the largest situated in the zone of the ectoplasm; zoochlorellæ often present living symbiotically; nucleus single, placed centrally; contractile vesicle large,

usually single; pseudopodia radial, numerous, straight, each containing a stiff axis originating from near the nucleus.

Since microscopes of any considerable power first came into use references to this genus are very numerous.

Heliozoa were at first known as "Sun animalcules," and this popular term is still in use. The name *Trichoda sol* O. F. Müller (1773) was probably applied indiscriminately to various spherical forms with radiating pseudopodia; one of these, and perhaps the one most frequently met with, was distinguished by Ehrenberg (1830) under the name of *Actinophrys sol*. This species, which is decidedly variable in appearance, has since then received a bewildering number of names, and forms have been identified with it which may belong to other species of *Actinophrys* or even to species in other genera, but in the absence of sufficient details of specific value in the descriptions given by their authors we can only assume that they refer to the Heliozoan most commonly found.

Three species are comprised in this genus:

A. vesiculata Pen. is similar to *A. sol*, but usually smaller, being about 30 μ in diameter; the contractile vesicles emerge from the periphery and become pendulous before collapsing.

A. paradoxa Carter is probably a species of *Cochliopodium*.

Synopsis of British Species.

Plasma containing numerous large vacuoles; diameter 40 μ to 50 μ. (1) *A. sol*.

Plasma without vacuoles; diameter 40 μ to 60 μ. (2) *A. subalpina*.

1. **Actinophrys sol** Ehrenb.

(Plates LXIV, figs. 1–3, LXVII, figs. 1–6, LXXII, figs. 1.)

? *Trichoda sol* (part)
Muller Verm. terr. fluv. I, 1773, p. 76.

Peritricha sol
BORY DE ST. VINCENT Encycl. méth., Zoophytes, 1824, p. 614.
Actinophrys sol
EHRENBERG Abh. Akad. Berl. 1830, p. 42, pl. ii, f. 4.
LEIDY Rep. U.S. Geol. Surv. XII, 1879, p. 235, pl. xl.
PENARD Héliozoaires, 1904, p. 98, ff. 1 and 2.
A. difformis
EHRENBERG Abh. Akad. Berl. 1831 (1832), p. 102.
A. marina
DUJARDIN Hist. Nat. Zooph. Infus. 1841, p. 264, pl. i, f. 18.
A. stella
PERTY Z. Kennt. Kleinster Lebensformen, 1852, p. 160, pl. viii, f. 5.
A. oculata
STEIN Die Infusionsthiere auf Entw. unters. 1854, p. 157, pl. v, f. 25.
A. Eichhornii
CLAPARÈDE Arch. Anat. Phys. 1854, p. 398, pl. xv. ff. 1–6.
A. tenuipes
CLAPARÈDE ET LACHMANN Études s. l. Infusoires. Mém. Inst. Nation. Genevois, VI, 1859, p. 451, pl. xxii, f. 4.
A. fissipes
LACHMANN Verh. nat. Ver. preuss. Rheinlande, XVI, 1859, Sitz Ber. p. 61.
A longipes
LACHMANN T.c. p. 61.
A. tunicata
LACHMANN T.c. p. 93.
A. limbata
LACHMANN T.c. p. 93.
A. paradoxa
CARTER Ann. Mag. Nat. Hist. (3), XIII, 1864, p. 34, pl. ii, f. 20.
A. picta
LEIDY Rep. U.S. Geol. Surv. XII, 1879, p. 241, pl. xlvi, f. 4.
A. alveolata
SCHEWIAKOFF Mém. Acad. St. Petersb. (7), XLI, No. 8, 1893, p. 8, pl. i, f. 4
? Monobia solitaria
SCHEWIAKOFF T.c. p. 7, pl. i, f. 3.

Body spherical with a fine membranous investment; ectoplasm containing numerous large vacuoles; endoplasm granular, colourless, containing numerous small vacuoles; nucleus large, placed centrally in the body; contractile vesicle large, usually single; pseudopodia radial, numerous, long, attenuate, each containing a rigid axis arising from near the nucleus; reproduction usually by division with or without previous encystment or by syngamy of two individuals within a cyst; habit usually solitary but may be colonial especially when young.

Diameter of body when mature about 40 μ to 50 μ;

diameter of nucleus about one quarter the diameter of the body: length of pseudopodia variable, usually one and a-half times the diameter of the body.

Habitat.—In still waters amongst aquatic vegetation.

Distribution.—General in Great Britain and Ireland.

The nucleus in this species is of large size with a clear central portion and the periphery with a granular appearance. The enclosing membrane is of appreciable thickness. Surrounding the nucleus is a zone of clear cytoplasm, through which may be traced the pseudopodial axes which have their origin close to the nuclear membrane.

The processes of reproduction have been described on p. 10; when encystment takes place an outer test is formed of minute silicious scales cemented together, inside which is a smaller membranous sac into which the animal contracts; the outer test has a mucilaginous coating for purposes of attachment. When the period of encystment expires the two envelopes are ruptured and the animal emerges in an amœboid form which soon protrudes flagella-like pseudopodia and exhibits a general likeness to a *Ciliophrys*; at this stage multiple division may take place giving rise to colonies of small individuals; these colonies may quickly break up or may be more or less persistent.

Actinophrys as a rule is carnivorous but algæ also serve it for food (Text-fig. 182); its usual prey consists of ciliates and small rotifers which it entangles in its pseudopodia and appears to numb or kill by the emission of some poisonous secretion; during this process the pseudopodia are often bent over and draw the captured animal to the periphery of its body where it is ingested and enclosed in a digestive vacuole, which in this species is usually voluminous, especially when as sometimes happens two or three individuals form a group with a single vacuole in common.

Green algæ or zoochlorellæ are seldom found living symbiotically in *A. sol* although Leidy records several

instances in which the plasma was crowded with living green algal cells; these individuals he referred to a separate species, *A. picta*, but we follow Penard in considering this a synonym.

The contractile vesicle is unusually large and prominent, discharging at intervals of about one to two minutes; occasionally two or rarely three of these may be present.

The movements of the animal are normally very slow, in fact it usually remains motionless, but on occasion it can progress by a rolling motion set up

FIG. 182.—*Actinophrys sol.* Individual which had ingested a large diatom. (After Wallich.)

by the pseudopodia elongating and bending towards a supporting surface to which the foremost ones adhere and pull the organism forwards.

The appearance of *A. sol* varies greatly, for although the plasma itself is transparent and colourless, containing normally numerous vacuoles, it may be so loaded with food particles and other matter that it becomes quite opaque; the large vacuoles are also often absent, their place being sometimes taken by one or more "food vacuoles" containing ingested food immersed in a pale greyish-coloured liquid.

Sometimes a gathering is found to contain numerous small individuals measuring only 15 μ to 25 μ in diameter; these usually contain many small particles

of green food, giving them a pale green colour and hiding the nucleus from observation; in these young forms noticeable vacuoles are usually absent.

Groups containing several individuals are not uncommon.

These variations in appearance and size are no doubt accountable for the number of synonyms given to this species.

2. **Actinophrys subalpina** West.

(Plate LXVI, fig. 2.)

Actinophrys subalpina
West J. Linn. Soc. Zool. XXVIII, 1901, p. 335, pl. xxx, f. 36.
? *A. sol* var. *fusca*
Penard Héliozoaires, 1904, p. 113, figs.

Body spherical or sub-spherical; plasma finely granular, colourless, free from vacuoles; nucleus placed centrally, large, granular, usually clearly distinguishable; contractile vesicle single, prominent; pseudopodia long, straight, rigid, tapering and granuliferous.

Diameter of body 42 μ to 61 μ; length of pseudopodia up to two or three times the diameter of the body.

Habitat.—Wet moss on dripping rocks.

Distribution.—N. Wales, Snowdon (*G. S. West*).

The locality in which this species was found is a peculiar one for Heliozoa, and the altitude, namely 3000 ft., considerable.

The plasma was of a yellowish colour and the pseudopodia had smooth edges; with the exception of these characteristics the resemblance to *A. sol* var. *fusca* Penard is very close, both forms being of large size, the plasma free from vacuoles, nucleus large and prominent and having a large protruding contractile vesicle.

Penard's species, however, flourishes in quiet pools and lakes; its diameter is 60 μ to 80 μ.

Further records and observations of *A. subalpina* in this country are to be desired.

Sub-order II. CHLAMYDOPHORA Archer.

Body invested with a mucilaginous envelope containing no silicious or other scales.

Only one freshwater genus is included in this sub-order.

Genus 3. **ASTRODISCULUS** Greeff.

Astrodisculus Greeff Arch. mikr. Anat. V, 1869, p. 496.

Envelope mucilaginous, transparent, free from inclusions, occasionally absent.

Body spherical; ectoplasm merging gradually into the endoplasm; pseudopodia tenuous and not usually granuliferous.

A. radians is the only species of this genus that has been recorded from the British Isles up to the present.

Three other species are described by Penard namely:

A. araneiformis Schewiakoff. The mucilaginous envelope may or may not be present; the pseudopodia are long (30 μ to 40 μ) with bead-like expansions along their length; the nucleus is placed centrally; the contractile vesicle prominent. Diameter 15 μ.

A. laciniatus Pen. The envelope thick with the outer surface fimbriated; nucleus placed eccentrically; pseudopodia very numerous, tenuous and finely granuliferous. Diameter over the envelope 42 μ.

A. zonatus Pen. Envelope double, the outer portion the thicker; nucleus placed centrally; pseudopodia tenuous, without granulations. Diameter 40 μ to 45 μ including the envelope.

1. **Astrodisculus radians** Greeff.

(Text-fig. 183.)

Astrodisculus radians
Greeff Arch. mikr. Anat. V, 1869, p. 500, pl. xxvii, ff. 36, 36a.
Penard Héliozoaires, 1904. p. 140, fig.
A. ruber
Greeff T.c. p. 497, pl. xxvii. f. 31.
A. flavescens
Greeff T.c. p. 499, pl. xxvii, ff. 32, 32a.
A. flavo-capsulatus
Greeff T.c. p. 499, pl. xxvii, ff. 33, 33a.
Heliosphærium aster
Frenzel Bibl. Zool. IV, 1892, p. 76, pl. vi, ff. 10, 11, pl. x, f. 4.
H. polyedricum
Frenzel T.c. p. 79, pl. vi, ff. 6, 9, 17, pl. x, f. 5.
Heliophrys varians
West J. Linn. Soc. Zool. XXVIII, 1901, p. 336.

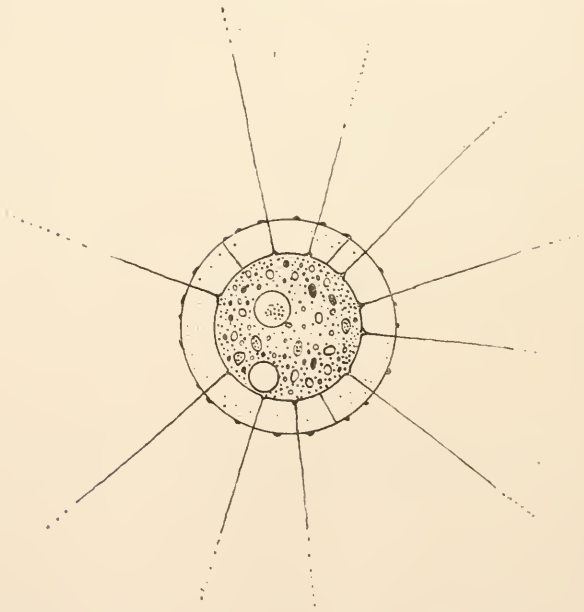

Fig. 183.—*Astrodisculus radians*. × 900. (After Penard.)

Body spherical, with a thick, colourless, mucilaginous investment without any inclusions, but its outer surface often defined by extraneous particles and bacteria

adhering to it; ectoplasm merging gradually into the endoplasm and more or less loaded with granules of a green, yellow or brown colour; pseudopodia attenuate, straight, not granuliferous, of moderate length; nucleus not large, placed eccentrically; a single contractile vesicle usually present.

Diameter of body 13 μ to 17 μ (Penard); 25 μ (*West*). Diameter of mucilaginous investment about twice that of the body.

Habitat.—Pools and ditches.

Distribution. — England. — Brigg, Lincolnshire (*West*).

Scotland.—Inverary (*Brown*).

Some of the pseudopodial axes frequently do not project beyond the mucilaginous zone, and it is probably to these that Greeff refers when he speaks of spicules being imbedded in the outer envelope.

Heliophrys varians (Schulze) as described by West (1901) is undoubtedly an *Astrodisculus*, and differs from *A. radians* only in its slightly larger size and the branching of some of the pseudopodia.

Heterophrys varians Schulze and *Heliophrys variabilis* Greeff appear to be *Nuclearia* and not identical with *A. radians*.

Sub-order III. CHALAROTHORACA Hertwig & Lesser.

Heliozoa having an external envelope composed of solid elements with or without a matrix of plasma.

Synopsis of the Freshwater Genera.

(*a*) Envelope consisting of a thick layer of plasma containing—

Chitinous spicules.	(4) *Heterophrys*.
Silicious spicules.	(5) *Raphidiophrys*.
Spicules of special forms.	*Raphidocystis*.

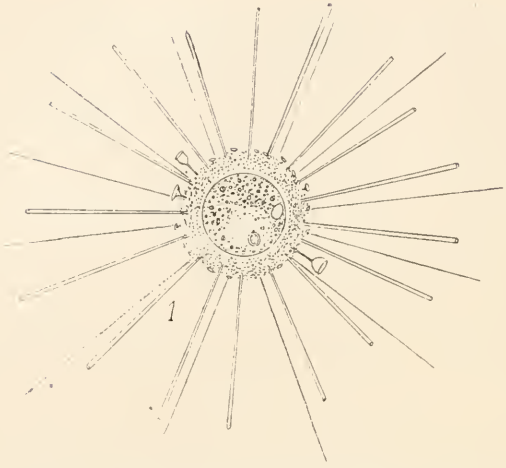

Fig. 184.—*Raphidocystis lemani* Penard. The average diameter is 25–35 μ. (After Penard.)

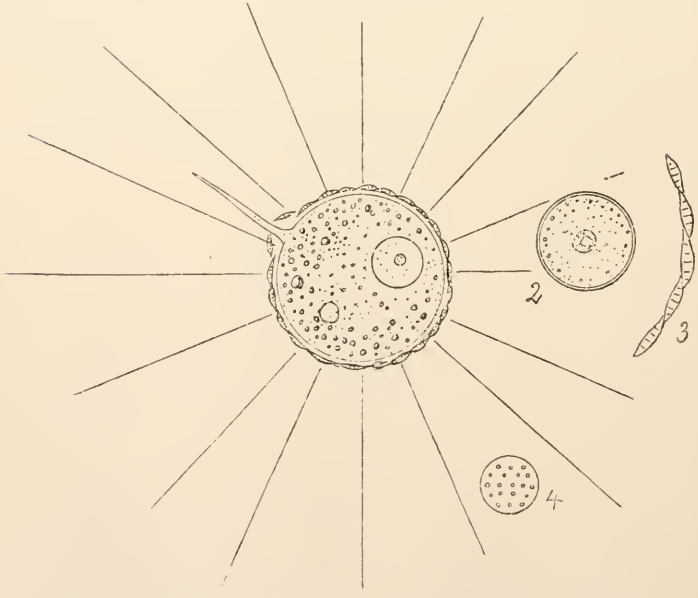

Fig. 185.—*Pinaciophora fluviatilis* Greef. 2. Nucleus. 3. Portion of test in optical section. 4. One of the perforated plates composing the test. The average diameter is 45–50 μ. (After Penard.)

(*b*) Envelope of silicious elements and little or no plasma consisting of—

Imbricated discs.	*Pinaciophora*.
Silicious globules.	(6) *Pompholyxophrys*.
Extraneous silicious materials closely investing the body.	(7) *Lithocolla*.
Extraneous silicious materials separated from the body by a zone of liquid.	(8) *Elæorhanis*.
Tangential scales and radial spicules.	(9) *Acanthocystis*.

The genera numbered 4 to 9 are those of which species have been recorded from the British Isles. For comparison with the British forms figures of *Raphidocystis* and *Pinaciophora* are here reproduced (Figs. 184 and 185).

Genus 4. **HETEROPHRYS** Archer.

Heterophrys Archer Qrt. Jrn. Micr. Sci. (n.s.) IX, 1869, p. 267.

Envelope thick, formed of mucilaginous plasma, finely granular, having imbedded in it numerous radial, chitinous spicules which project beyond its periphery; body spherical; nucleus and endoplasm placed eccentrically; pseudopodia straight, radiating, their axes arising from a "central granule."

Archer in his diagnosis of this genus describes the radial spicules projecting beyond the boundary of the envelope as "marginal processes"; these he recognised as linear and hyaline in the case of *H. myriopoda*, but evidently had not been able to resolve them in *H. fockei*, in which species he called them "indefinite and variously figured." In 1876, however, he describes the outer envelope in this genus as "being superficially drawn out into these superficial, linear, capillary and acute pointed processes (spines, Hertwig & Lesser)."

H. varians F. E. Schulze is a synonym for *Nuclearia delicatula* (*vide* Vol. I, p. 110).

Synopsis of the British Species.

Usually of a green colour; no contractile vesicle normally present; diameter about 70 μ. (1) *H. myriopoda.*

Green corpuscles usually absent; several contractile vesicles usually present; diameter of body about 22 μ. (2) *H. fockei.*

No contractile vesicles usually present; outer envelope finely fimbriated; diameter of body about 21 μ. (3) *H. radiata.*

The fourth species belonging to this genus has not been recorded from the British Isles; its description is as follows: *H. glabrescens* Pen. Of small size; outer mucilaginous envelope rudimentary or invisible; numerous long radial spines present which are invisible in the living animal but apparent in a dry state; pseudopodia long, granuliferous, retractile. Diameter 11 μ to 15 μ.

1. **Heterophrys myriopoda** Archer.

(Plate LXVIII, figs. 1 and 2.)

Heterophrys myriopoda
Archer Qrt. Jrn. Micr. Sci. (N.S.) IX, 1869, p. 267, pl. xvii, f. 4.
Penard Héliozoaires, 1904, p. 149, figs.
H. marina
Hertwig & Lesser Arch. mikr. Anat. X, 1874, Suppl., p. 213, pl. iv, f. 4.
? *Acanthocystis tenuispina*
Zacharias Forschungsber. Plön III, 1895, p. 73, pl. i, f. 4.

Body spherical; outer envelope thick, mucilaginous, closely beset with numerous fine, chitinous spicules partially embedded in it; endoplasm differentiated from the ectoplasm and placed eccentrically; ectoplasm usually crowded with spherical green algæ living in symbiosis; nucleus single, placed eccentrically; central granule present; pseudopodia numerous, long, tapering, finely granuliferous, their axes arising from the central granule; pulsating vesicle usually absent.

Diameter of body 50 μ to 64 μ (Penard); 65 μ to 80 μ (Archer). Outer zone 10 μ to 15 μ thick.

Habitat.—Moorland pools and marshes.

Distribution. — N. Wales. — Llyn - y - cwm - ffynon (*West*).

Ireland.—Wicklow (*Archer*).

The body is nearly always crowded with symbiotic green algal cells (*Chlorella vulgaris* Beyerink), which hide all view of the endoplasm and nucleus in the living animal; mixed with these Penard found starch grains and pale blue spherules, which are readily coloured by carmine and might be mistaken for nuclei.

The nucleus is normally spherical but may be deformed by the pseudopodial axes radiating from the central granule.

The aspect of the outer envelope when examined in a dry state is much altered and shows in addition to the fringe of spicules, which are all that are visible in water, that the whole of this zone is densely crowded with innumerable needle-like spines, 12 μ to 14 μ in length, some attached together by their bases in pairs, others radially in threes, the whole forming an almost felt-like layer around the body of the animal.

The pseudopodia are exceptionally numerous and long; from a comparatively thick base they taper gradually to a fine point, the axes being coated with finely granuliferous plasma which occasionally forms slight swellings.

The species is exceptionally active for a heliozoan; Penard states they can travel at the rate of 125 μ in 30 seconds with a rolling motion.

2. **Heterophrys fockei** Archer.

(Plate LXVIII, fig. 3; Pl. LXIX, fig. 3.)

Heterophrys Fockii
Archer Qrt. Jrn. Micr. Sci. (n. s.) IX, 1869, p. 267, pl. xvi, f. 3; *H. Fockei* Penard Héliozoaires, 1904, p. 157, fig.

Sphærastrum conglobatum
Archer Qrt. Jrn. Micr. Sci. (n. s.) XVI, 1876, p. 356 (*non S. conglobatum* Greeff Arch. mikr. Anat. XI, 1875, p. 29, pl. ii, ff. 24–26).

Sphærastrum Fockei
West J. Linn. Soc. Zool. XXVIII, 1901, p. 338.
Heterophrys spinifera
Hertwig and Lesser Arch. mikr. Anat. X, 1874, Suppl., p. 215, pl. v, f. 3.
Heterophrys tenella
Penard Jahrb. Nassau. Ver. Naturk. XLIII, 1890, p. 18, pl. i, ff. 13, 14.

Body spherical but deformable; outer envelope thick, mucilaginous, with numerous, fine, radial spicules partially embedded in it; ectoplasm granular, with various inclusions but seldom any green algæ; endoplasm bluish-grey, eccentric; nucleus single, placed eccentrically; a central granule present from which the pseudopodial axes originate; contractile vesicles large, numerous; pseudopodia numerous, long, granuliferous. Habit solitary or in small groups; somewhat active.

Diameter of body about 25 μ.

Habitat.—Moorland pools, ponds, etc.

Distribution.—England.—Bricket Wood Common, Herts (*J. Hopkinson*).

N. Wales.—Llyn Teyrn (*West*).

Ireland.—Wicklow, Cork, Kerry, Westmeath (*Archer*).

In the living animal the nucleus is rarely visible and the application of some staining fluid is usually necessary before it can be identified.

3. **Heterophrys radiata** West.

(Plate LXVIII, fig. 4.)

Heterophrys radiata
West J. Linn. Soc. Zool. XXVIII, 1901, p. 337, pl. xxx, f. 34.
Penard Héliozoaires, 1904, p. 160, fig.

Body small, spherical; outer gelatinous envelope colourless, thick, with a finely fimbriated outer surface; plasma dark grey in colour, filled with numerous granules of various sizes; no differentiated endoplasm

observed; nucleus single, placed eccentrically; no central granule observed; pseudopodia numerous, long, delicate, granuliferous; no pulsating vesicle observed.

Diameter of body 21 μ; diameter of outer envelope 53 μ; length of pseudopodia 43 μ.

Habitat.—On vegetation (*Myriophyllum*) in ponds.

Distribution.—England.—Epping Forest, Essex (*West*).

None of the observed individuals contained any green algal cells.

The pseudopodia had numerous relatively large granules scattered at intervals along their length.

Genus 5. **RAPHIDIOPHRYS** Archer.

Raphidiophrys Archer Qrt. Jrn. Micr. Sci. (n.s.) VII, 1867, p. 179.

Body enclosed in a mucilaginous envelope containing spicules, spindle-, awl-, or disc-shaped, which normally extend outwards along the pseudopodia; nucleus and endoplasm placed eccentrically.

The identification of the species in this genus largely depends on the shapes of the investing spicules; this may necessitate the isolation of the individual and its examination either in a dry state or after treatment with sulphuric acid; in either case a high magnification is desirable.

The following is a short description of the species belonging to this genus which have not up till now been recorded from the British Isles:

R. socialis Leidy.—Usually in large colonies in which the individuals, sometimes as many as one hundred, are loosely associated; spicules numerous, straight, extremely tenuous; several contractile vesicles may be present; the nucleus stated to be placed centrally, but as Leidy gave no drawing and no subsequent record has been published this statement requires corroboration. Individuals 24 μ to 36 μ diameter of body.

R. intermedia Penard.—Spicules short, elliptical in broad view with curved ends in narrow view, not numerous and all arranged tangentially; pseudopodia tenuous, granuliferous. Diameter 35 μ to 40 μ.

R. brunii Penard.—Body small; spicules numerous, small, acicular, extending for a considerable distance along each of the pseudopodia; the pseudopodia are long, tenuous and granuliferous. Diameter 12 μ to 13 μ.

R. cærulea Penard.—Body small; spicules not numerous, small, acicular, arranged tangentially around the body; nucleus large; contractile vesicles large, several in number; plasma bluish in colour; pseudopodia long, tenuous, granuliferous. Diameter 13 μ to 16 μ.

R. ambigua Penard.—Spicules comprising three kinds of thin discs, in broad view respectively oval, elongate oval and fusiform, the latter extending for a considerable distance along the pseudopodia; one or more contractile vesicles. Diameter of body 30 μ to 40 μ; size of spicules about 5 μ by 3 μ, 12 μ by 3 μ and 20 μ by 2 μ respectively.

R. symmetrica Penard.—Spicules comprising two kinds of thin discs, in broad view elliptical, one kind being about 10 μ in length, the other 8 μ, both about 2·5 μ in width and slightly curved in narrow side view, the larger of these forming tubular-shaped investments around the pseudopodia for the major portion of their length. Contractile vesicles one or more; pseudopodia tenuous, granuliferous. Diameter of body 20 μ to 25 μ or sometimes more; diameter over spicular investment up to 64 μ.

Synopsis of British Species.

Spicules spindle-shaped with flattened points; usually in colonies; diameter of body about 80 μ. (1) *R. viridis.*

Spicules disc-shaped; usually in colonies; diameter of body about 30 μ. (2) *R. elegans.*

Spicules spindle-shaped, with acicular points; usually solitary; diameter of body about 55 μ. (3) *R. pallida.*

1. **Raphidiophrys viridis** Archer.

(Plate LXIX, fig 2; Pl. LXX, fig. 2.)

Raphidiophrys viridis
Archer Qrt. Jrn. Micr. Sci. (n.s.) VII, 1867, p. 179; *op. cit.* IX, 1869, p. 255, pl. xvi, f. 2.

Leidy Rep. U.S. Geol. Survey. XII. 1879, p. 248, pl. xlvi, ff. 1, 2.
Penard Héliozoaires, 1904, p. 165, figs.
Raphidiophrys glomerata
Penard Rev. Suisse Zool. IX, 1901, p. 297, pl. xvi, ff. 9–11.

Body spherical, usually in closely-packed colonies surrounded by a common outer gelatinous investment crowded with comparatively long, awl-like spicules with cone-shaped accumulations around many of the pseudopodia; plasma usually filled with green zoochlorella cells living symbiotically; endoplasm placed eccentrically; nucleus single, placed eccentrically, spherical, containing a central spherical nucleolus; contractile vesicles normally absent; central granule present from which the pseudopodial axes radiate; pseudopodia long, straight, their axes thinly covered with plasma.

Diameter of individual bodies 60 μ to 90 μ; diameter of colony up to 190 μ or over; length of pseudopodia may equal twice the diameter of the colony; length of spicules up to 32 μ.

Habitat.—Amongst aquatic vegetation in moorland pools, etc.

Distribution.—Ireland.—Carrig Mountain and Tinnehely, Wicklow; Multyfarnham, Westmeath; Glengariff, Co. Cork (*Archer*).

Solitary individuals are occasionally found but spherical colonies containing five to twelve are the rule; these probably result from incomplete binary fission; the common investment which surrounds these colonies is crowded with spicules throughout except a narrow zone on its inner periphery.

The spicules are silicious and of peculiar form which is characteristic of the species; they are either hyaline or yellowish in colour. For their examination and exact determination it is necessary to isolate them as they are so refringent (especially in Canada balsam) that their outlines in the mass are quite indistinct.

As Archer pointed out the spicules are clustered

round some only of the pseudopodia these being spaced at fairly equal distances apart; the substance of the envelope appears to carry the spicules along the pseudopodia, and this action causes those furthest out to lie more or less parallel to the pseudopodial axis.

The pseudopodia which radiate from the colonies were found by Penard to originate from the central granules of the individuals; they are characterised by their great length and are usually perfectly straight and thinly and evenly covered with plasma, although occasionally this is disposed in a series of elongated drops.

When disturbed an individual or a colony is apt to divest itself of most or all of its spicules, during which process as the animal moves forward the pseudopodia in the rear are bent backwards, two often lying together, side by side in an investment of plasma, the rejected spicules being left in the track of the animal.

Without special preparation little can be seen of the plasma or its contents, everything being hidden by the crowd of spherical green alga cells normally living in symbiotic relationship within the body; as is usual in these circumstances contractile vesicles are absent, but they appear to be developed when, as occasionally happens, the algal cells are wanting.

The nucleus is spherical and contains a large central spherical nucleolus.

The central grain is sub-spherical and has a central granule which becomes visible after staining by carmine.

Microbes normally infest the outer envelope. They are small, round, or ovoid, and are stated by Penard to divide transversely; the same author considers that the ciliates which often invade the body itself, living there parasitically, are related to the genus *Blepharisma*.

Archer considered this to be one of the handsomest

of the freshwater Heliozoa, the largest colonies being just visible to the naked eye. It is a species that appears to be very local in its occurrence as he found it in only about six localities and the pools which it inhabited did not number more than a dozen out of the large numbers that existed there.

It is curious that there has been no other record of it in Great Britain since it was first described by Archer.

It has been recorded from the continent of Europe and North America.

2. **Raphidiophrys elegans** Hertwig & Lesser.

(Plate LXX, fig. 1.)

Raphidiophrys elegans
Hertwig & Lesser Arch. mikr. Anat. X, 1874, Suppl. p. 218, pl. iv, f. 1.
Leidy Rep. U.S. Geol. Surv. XII, 1879, p. 250, pl. xlii, ff. 1–6.
Penard Héliozoaires, 1904, p. 170, fig.
Sphærastrum conglobatum
Greeff Arch. mikr. Anat. XI, 1875, p. 29, pl. ii, ff. 24–26.

Body small, more or less spherical, usually in colonies, the individuals a little distance apart, but connected by bands of plasma; the outer gelatinous envelope crowded with sub-circular, disc-shaped spicules having thickened edges and forming elongated cone-shaped accumulations around many of the pseudopodia; ectoplasm containing numerous granules, with or without green particles and seldom living green algal cells; endoplasm slightly eccentric, transparent; nucleus single, placed eccentrically, containing a large nucleolus; one contractile vesicle normally present; pseudopodia numerous, long, straight, smooth or granuliferous, their axes arising from a central granule.

Diameter of body 30 μ to 40 μ; length of pseudopodia up to three or more times the diameter of the body; spicules 7 μ to 8 μ in length and about 6 μ in breadth.

Habitat.—Aquatic vegetation in still waters.

Distribution.—England.—Birmingham (*Bolton*).
Ireland.—? Wicklow (*Archer*).

The colonies in this species are seldom so compact as is the case with *R. viridis*; they usually number six to twelve individuals, although Leidy records thirty-eight in one group, which however shortly broke up into three portions. The individuals are placed a little distance apart, being connected together by strands or bands of plasma which lengthen out when a colony is moving; these strands are disposed in a fairly regular manner and appear to have a pseudopodial origin, that is the plasma forming them collects around a pseudopod.

The spicules are characteristic of this species and distinguish it from others of the same genus; Hertwig and Lesser first described them as half rings, but Penard found them to be elliptical plates with thickened edges, which in the mass have a lunate or semicircular appearance.

The granules enclosed in the ectoplasm have the appearance of starch grains; the green cells which may be entirely absent or present more or less numerously are sometimes no doubt living symbiotically in their host, in which case contractile vesicles may be absent as recorded by several observers.

The endoplasm is usually distinguishable merely as a nearly central light coloured circle. It contains the nucleus placed eccentrically with respect to the periphery of the animal and a central grain from which the pseudopodial axes originate.

The nucleus is pale in colour, spherical or slightly pyriform and almost entirely occupied by the nucleolus.

The pseudopodia are numerous, very long and straight and may be either smooth or granuliferous.

Leidy (*op. cit.*, Pl. XLII, fig. 5) illustrates the method of ingesting an algal zoospore by a solitary individual.

3. **Raphidiophrys pallida** F. E. Schulze.

(Plate LXX, fig. 3, Text-fig. 186.)

Raphidiophrys pallida
F. E. Schulze Arch. mikr. Anat. X, 1874, p. 377, pl. xxvi, f. 1.
Archer Qrt. Jrn. Micr. Sci. (n.s.) XVI, 1876, p. 370.
West Jrn. Linn. Soc. Zool. XXVIII, 1901, p. 339, pl. xxx, f. 35.
Penard Héliozoaires, 1904, p. 176, fig.
Brown Ann. Scot. Nat. Hist. 1911, p. 231.
? *R. ambigua*
Schewiakoff Mem. Acad. St. Petersb. ser. 7, XLI, 1893, No. 8.
Raphidiophrys
Leidy Rep. U.S. Geol. Surv. XII, 1879, pl. xlvi, f. 3.

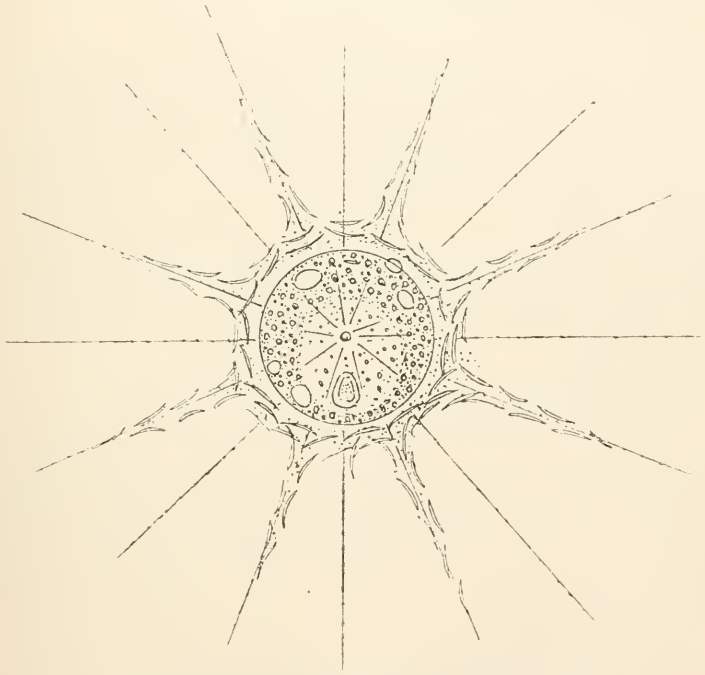

Fig. 186.—*Raphidiophrys pallida*. (After Penard.)

Body large, spherical; outer gelatinous envelope crowded with curved lenticular spicules forming cone-shaped accumulations around many of the pseudopodia; ectoplasm containing numerous granules and usually food particles; endoplasm placed eccentrically, colour-

less; nucleus placed eccentrically, more or less pyriform, containing a single large nucleolus; several contractile vesicles; pseudopodia numerous, long, granuliferous, their axes arising from a central granule; habit solitary.

Diameter of body 50 μ to 60 μ; diameter of nucleus 12 μ to 15 μ in greatest width; spicules 20 μ in length.

Habitat.—Aquatic vegetation in lakes and pools, etc.

Distribution.—England.—Kinderscout, Derbyshire; Sheffield district, W. Yorkshire (*Brown*).

Wales.—Llyn Idwal, N. Wales (*West*).

Scotland.—Cairnwell; Aberfoyle (*Brown*).

Ireland.—? Wicklow (*Archer*).

This species has not been recorded as found in colonies. The plasma contains only food particles and numerous granules without living green algal cells.

The nucleus is pyriform in shape as in the genus *Acanthocystis* and placed with the smaller end pointing inwards.

The spicules are straight or irregularly curved with pointed ends and lenticular or linear in broad view; they are characteristic of the species, and extend as a thin covering for a considerable distance along the pseudopodia.

West's identification of the forms found by him is somewhat uncertain as they only measured 42 μ in diameter and contained numerous "chlorophyll bodies (zoochlorellids ?)"; he does not give the form of the spicules. Penard thinks his record may refer to *R. ambigua* Penard, which measures 30 μ to 40 μ in diameter.

R. pallida is a somewhat rare species.

Genus 6. **POMPHOLYXOPHRYS** Archer.

Pompholyxophrys Archer Qrt. Jrn. Micr. Sci. (n.s.) IX, 1869, p. 386.

Hyalolampe Greeff Arch. mikr. Anat. V, 1869, p. 501.

Body spherical; outer envelope of small, colourless

spherules arranged more or less regularly in concentric layers, immersed in a small quantity of mucilaginous matter; contractile vesicles absent; nucleus single, placed eccentrically; pseudopodia elongate, non-coalescing, acicular.

All the species in this genus are of small size, the body measuring from about 20 μ to 30 μ in diameter.

The outer investment of spherules is continuous in appearance but its components are not attached to one another, being easily separated either for the protrusion of the pseudopodia or for the passage of food to the interior.

Synopsis of British Species.

Outer envelope formed of three zones or layers of spherules each 2 μ to 4 μ in diameter. (1) *P. punicea.*

Outer envelope formed of ovoid globules each 2 μ to 3 μ in length. (2) *P. ovuligera.*

P. exigua Hertwig & Lesser has the outer envelope formed of 5 or 6 layers of very small spherules measuring about ·6 μ in diameter and has not up to the present been recorded from the British Isles. Diameter of body 20 μ to 30 μ.

1. **Pompholyxophrys punicea** Archer.

(Plate LXIX, figs. 4, 5.)

Pompholyxophrys punicea
Archer Qrt. Jrn. Micr. Sci. (N.S.) IX, 1869, p. 386, pl. xvi. ff. 4, 5.
West Jrn. Linn. Soc. Zool. XXVIII. 1901, p. 339.
Penard Héliozoaires, 1904, p. 208, fig.
Hyalolampe fenestrata
Greeff Arch. mikr. Anat. V, 1869, p. 501, pl. xxvii. f. 37.
Leidy Rep. U.S. Geol. Surv. XII, 1879, p. 271, pl. xlv, f. 9.

Body small, approximately spherical; outer envelope composed usually of three layers or zones of spherical globules in a sparse mucilaginous investment; ectoplasm clear, colourless or reddish, containing numerous coloured granules of various sizes and green, yellow or brown vegetable food particles; endoplasm not distinctly differentiated; nucleus large, placed eccentri-

cally, containing one or sometimes two nucleoli; contractile vesicles absent; pseudopodia acicular, tenuous, very finely granuliferous; habit solitary, active.

Diameter of body usually 25 μ to 30 μ but may attain 36 μ.

Diameter of outer envelope 5 μ to 10 μ larger than that of the body.

Spherules in outer investment 2 μ to 4 μ in diameter.

Habitat.—Moorland pools.

Distribution.—England.—Isle of Wight (*Brown*). Epping Forest, Essex (*Cash*).

Scotland.—Isle of May (*Brown*).

Ireland.—Wicklow; Co. Cork; Kerry; Westmeath (*Archer*, "Scanty but not unfrequently encountered.")

The spherules which surround the body are apparently of a silicious nature and secreted by the ectoplasm; they are hollow and unaffected by boiling sulphuric acid, which, however, caused bubbles of gas to form in their interior, showing that they are porous although no apertures could be detected (Penard).

Archer (whose description of this species was published two weeks previous to that by Greeff) thought the spherules consisted of a protoplasmic material but pointed out that they were easily detachable; Greeff, under the name of *Hyalolampe fenestra*, described this species as having spherules formed of silica but asserted they were cemented together, interstices being left for the protrusion of the pseudopodia.

A considerable amount of controversy has taken place due to the nearly simultaneous publication of, and discrepancies in, the descriptions of the two authors.

P. punicea is one of the most active of the Heliozoa, its comparatively rapid progression being effected by means of its pseudopodia by which it achieves a rolling motion; as in all members of this genus, they are of extreme tenuity and require careful illumination for their examination.

The ectoplasm is usually of a red tint, due to numerous granules of various shades of colour, and in addition to these, food particles of vegetable origin varying in colour from green through yellow to brown are generally present.

Large spherical bodies are sometimes found in the plasma which may attain a diameter equal to half that of the animal itself; they appear to be cysts and are enclosed in a rigid membrane with a granulated surface.

The large nucleus is usually hidden from view by the numerous inclusions in the plasma and perhaps for the same reason no central granule has been detected.

Division by binary fission was observed by Cash, the process occupying about 30 minutes.

2. **Pompholyxophrys ovuligera** Penard.

(Text-fig. 187.)

Pompholyxophrys ovuligera
Penard Héliozoaires, 1904, p. 214, fig.
Brown Ann. Scot. Nat. Hist. 1912, p. 113.

Body small, spherical; outer envelope composed of three or four layers of ovoid globules in a sparse mucilaginous investment; ectoplasm usually reddish in colour, containing numerous coloured granules, also food particles; endoplasm not distinctly differentiated; nucleus large, placed eccentrically, containing a single small nucleolus; contractile vesicles usually absent; pseudopodia tenuous, finely granuliferous.

Diameter of body about 25 μ to 30 μ; diameter of outer envelope 6 μ to 10 μ larger; spherules in outer investment 2 μ to 3 μ in larger diameter.

Habitat.—Moorland pools.

Distribution.—England.—Isle of Wight (*Brown*).
Scotland.—Isle of May (*Brown*).

This species resembles *P. punicea* in its active and

solitary habits, also in the appearance of the plasma with its numerous coloured inclusions, but the outer investment formed of ovoid instead of spherical globules and its more exactly circular outline differentiate it clearly.

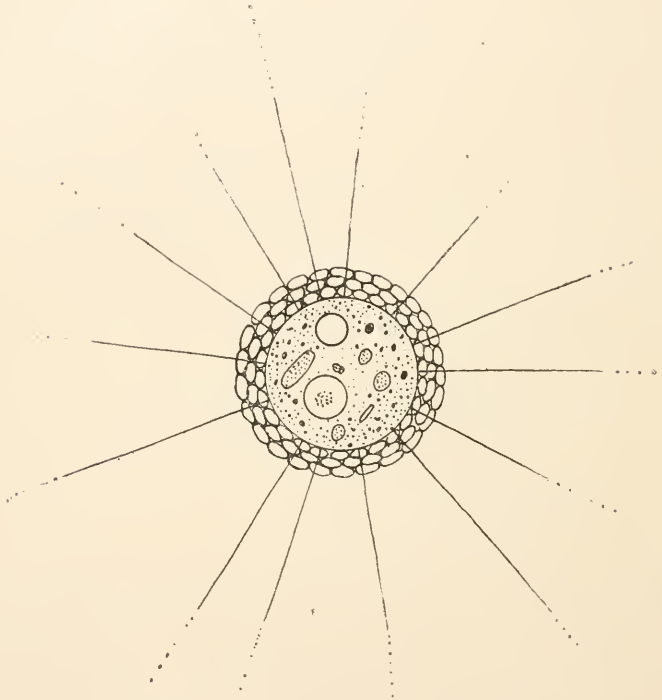

Fig. 187.—*Pompholyxophrys ovuligera.* × 900. (After Penard.)

P. exigua Hertwig & Lesser is distinguished from both this and the preceding species by the very minute size of the globules forming its outer covering.

Genus 7. **LITHOCOLLA** F. E. Schulze.

Lithocolla F. E. Schulze Arch. mikr. Anat. X, 1874, p. 389.

Plasma enclosed in a spherical outer envelope composed of heterogeneous silicious elements, usually

consisting of grains of sand and diatom frustules; nucleus single, placed eccentrically.

Two species are included in this genus, *L. globosa* F. E. Schulze and *L. flavescens* Penard; *Elæorhanis arenosa* Frenzel (*Lithosphærella arenosa* Schaudinn) is probably a synonym for the former, whilst the marine species *Raphidiophrys arenosa* Gruber* has much resemblance to the latter.

Some authorities consider that the differences between the genera *Lithocolla* and *Elæorhanis* are insufficient to warrant their being separated; their exact position among the Heliozoa or Pseudo-heliozoa is also still open to question.

Only *L. globosa* has been recorded from the British Isles; *L. flavescens* (Penard) is much smaller, measuring about 18 μ in diameter over the outer envelope, which consists of very minute silicious grains.

Lithocolla globosa F. E. Schulze.

(Text-fig. 188.)

Lithocolla globosa
F. E. Schulze Arch. mikr. Anat. X, 1874, p. 389, pl. xxvi, ff. 6–10.
Archer Qrt. Jrn. Micr. Sci. (N.S.) XVI. 1876, pl. xxi, f. 9.
Penard Jahrb. Nassau. Ver. Naturk. XLIII, 1890, p. 17, pl. i, f. 12.
West Jrn. Linn. Soc. Zool. XXVIII, 1901, p. 338.
Penard Héliozoaires, 1904, p. 216, fig.
Zykoff Zool. Anz. XXV, 1902, p. 178.

Body spherical; outer envelope composed mostly of sand grains and diatom frustules cemented together; ectoplasm of a more or less pronounced reddish colour, of a liquid consistency, containing numerous small coloured granules, also frequently food particles and diatoms; endoplasm not differentiated; nucleus large, containing a single central nucleolus, placed eccentrically; no contractile vesicle but often a large vacuole present; pseudopodia tenuous, not long, finely granuliferous; central granule not observed.

* 'Nova Acta Acad. Leop. Carol.,' XLVI, 1884, p. 507, pl. ix, fig. 34 *a*, *b*.

Diameter of outer envelope 35 μ to 50 μ, usually between 40 μ and 45 μ; length of pseudopodia equal to about the diameter of the body.

Habitat.—Lakes, ponds and rivers; also marine. Rare.

Distribution. — N. Wales. — Capel Curig (*G. S. West*).

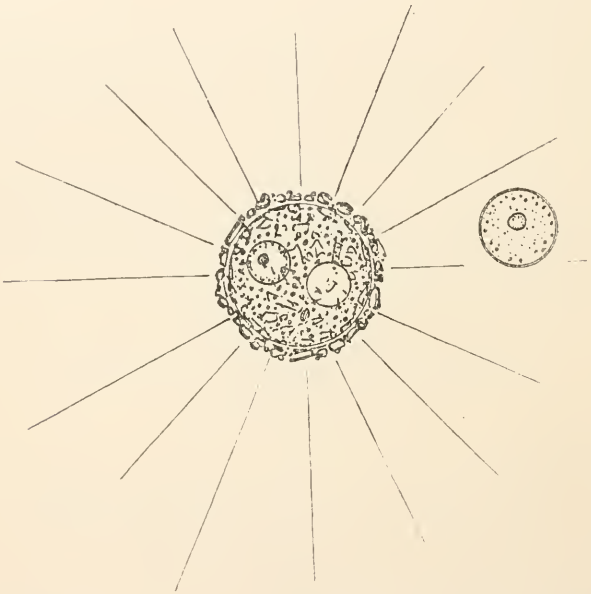

Fig. 188.—*Lithocolla globosa*. On the right, the nucleus, further enlarged. (After Penard.)

West gives 23 μ as the diameter of the individual observed by him and states that the sand grains composing the envelope were small and compact, a description that might possibly indicate *L. flavescens* as having been the species under observation; the length of the pseudopodia, 31 μ, also gives support to this supposition.

Schulze in his original illustration of *L. globosa* shows the outer envelope composed entirely of coarse angular sand grains.

Genus 8. **ELÆORHANIS** Greeff.

Elæorhanis Greeff Sitzber. Ges. Marburg, 1873, p. 57.

Body spherical; outer envelope composed of silicious grains and diatom frustules; plasma containing a large oil globule but no food particles; nucleus single, placed eccentrically; a contractile vesicle usually present; pseudopodia tenuous, non-granuliferous.

E. oculea is the only species of this genus; the identity of *E. arenosa* with *Lithocolla globosa* has been noticed above, as has also the affinity of this to the preceding genus *Lithocolla*.

1. **Elæorhanis oculea** (Archer).

(Text-fig. 189.)

Cystophrys oculea
Archer Qrt. Jrn. Micr. Sci. (n.s.) IX, 1869, p. 265, pl. xvii, f. 3; *op. cit.* X, 1870, p. 112.
Elæorhanis cincta
Greeff Sitzber. Ges. Marburg, 1873, p. 57; Arch. mikr. Anat. XI, 1875, p. 23, pl. i, f. 10.
Penard Héliozoaires, 1904, p. 222, figs.

Body enclosed in a spherical membrane surrounded by liquid; outer investment spherical or ellipsoidal composed of diatom frustules and sand grains cemented together by a grey coloured mucilage; plasma bluish in colour containing a large yellow oil globule without any food particles; nucleus single, placed eccentrically, containing a single nucleolus; one or more contractile vesicles usually present; no central granule observed; pseudopodia of moderate length, rigid, without central axes, occasionally forked, non-granuliferous; habit colonial when young and solitary when mature.

Diameter of outer envelope in adult individuals 50 μ to 60 μ; diameter of body about half that of the envelope; young individuals with outer membranes from 7 μ in diameter and upwards; embryos in colonies about 4 μ in diameter.

Habitat.—Lakes and moorland pools; rare.

Distribution.—England.—Windermere, Cumberland (*Brown*).

Ireland.—Callery and Carrig; Wicklow (*Archer*).

The most striking feature in the appearance of this species is the large golden yellow oil-like globule enclosed in the plasma, which may attain a diameter

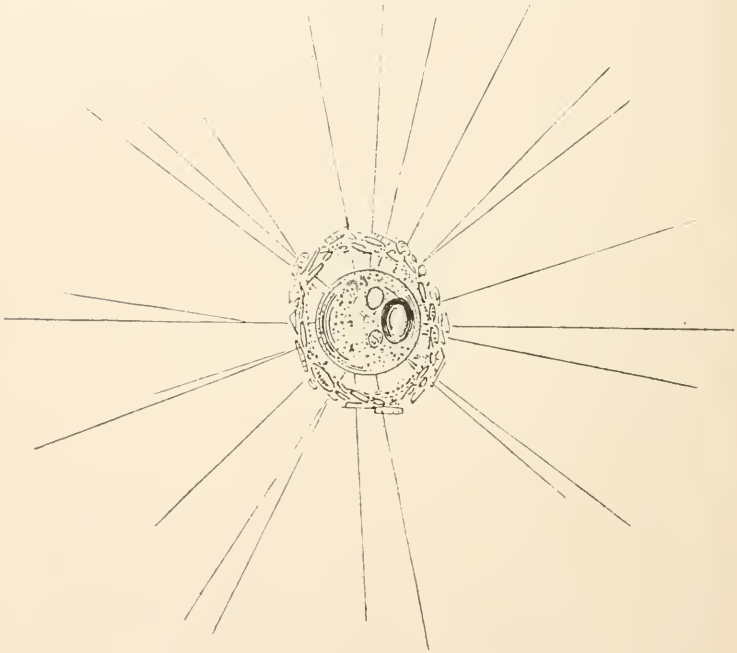

Fig. 189.—*Elæorhanis oculea.* (After Penard.)

equal to about three-quarters that of the body; occasionally it is replaced by two or three smaller ones, but in one form or the other it is always present and doubtless plays a necessary part in the vital economy of the animal.

No food particles have been recorded as present in the plasma so that nutrition is apparently saprophytic.

The body of the animal floats freely in the interior of the outer envelope, its position being controlled

only by the force of gravity and the pseudopodia which pass from it.

The nucleus is difficult to distinguish; it is of a very pale colour and has a small central nucleolus.

The pseudopodia are about one and a half times the diameter of the outer covering in length and have a tendency to originate in groups; they are not unfrequently forked; the orifices in the outer covering through which they pass are not distinguishable.

Binary fission has been observed and colonies of embryos have frequently been recorded, although for a long time their origin was unknown. These colonies are of fairly large size, have amœboid movements and radiating pseudopodia; the very numerous individuals composing them are each about 4 μ in diameter and contain a minute golden-yellow or red-coloured globule. Young solitary individuals are met with numerously at times and they range from 7 μ to 10 μ and upwards in diameter.

Archer (1869) described these colonies of embryos under the name of *Cystophrys oculea*, grouping them with similar colonies, *Cystophrys hæckeliana* (Archer), which were subsequently found to be the young of *Diplophrys archeri* (Baker), described in Vol. III of this work (p. 147). Leidy (1879) illustrates a colony of this species, but attributes it to *Diplophrys archeri*, which has analogous methods of reproduction and alimentation, but whose embryos contain grey or yellowish coloured spots.

The colonies of embryos appear to result from multiple division or gemmation as swarm spores have not been recorded.

Genus 9. **ACANTHOCYSTIS** Carter.

Acanthocystis Carter Ann. Mag. Nat. Hist. (3) XII, 1863, p. 263.

Outer envelope formed of a spherical investment of

silicious scales arranged tangentially and the bases of radial silicious spines of various forms; no mucilaginous investment present; nucleus and endoplasm placed eccentrically.

There are eight species belonging to this genus that have not been recorded from the British Isles; the absence of any record of *A. aculeata* from our fauna is certainly remarkable as it is one of the commonest species on the continent of Europe. A brief description of these eight species is here given.

A. aculeata H. & L. (*A. flava* Greeff). Envelope of firm consistency, formed of several layers composed of the bases of the radial spines and tangentially arranged scales; the radial spines stout, tapering, sharply pointed, straight or slightly curved, the bases enlarged and nail-headed in form; the tangential scales of various irregular forms; plasma grey in colour; contractile vesicle single; pseudopodia tenuous, long, granuliferous. Diameter of envelope 35 μ to 40 μ; radial spines about one-third of the diameter of the envelope in length.

A. mimetica Penard. Body small; the envelope composed of tangentially arranged scales and the bases of the radial spines; the radial spines are truncate with bases pin-head in form and are invisible in the living animal; zoochlorellæ often present in the plasma; pseudopodia very long, tenuous, retractile and granuliferous. Diameter of envelope 12 μ to 20 μ; length of radial spines 7 μ to 12 μ.

A. spinifera Greeff, Penard emendat. This is apparently an autonomous species and quite distinct from the true *A. spinifera* Greeff. The envelope is formed in the usual way; the radial spines are not tapering, are truncate and of two different kinds, one longer than the other. Diameter of envelope 40 μ to 50 μ; the length of the longer spines equal to about three-quarters of the diameter of the envelope and that of the shorter spines equal to about one-third the diameter.

A. rubella Penard. The envelope formed in the usual way; the radial spines are long, tenuous, pointed and invisible in the living animal; they normally form the axes for the pseudopodia; the plasma reddish in colour; no contractile vesicle observed. Diameter 23 μ to 27 μ.

A. longiseta Penard. Envelope rather thick, of the usual structure; the radial spines tapering but not sharply pointed, about two-thirds of the diameter of the envelope in length; contractile vesicle usually absent. Diameter of envelope about 40 μ.

A. pantopoda Penard. Body small; envelope formed of

pellucid oval spicules arranged tangentially and of the bases of long radial spines which are cylindrical and truncate; plasma bluish in colour. Diameter of body 13 μ to 16 μ; radial spines 20 μ to 30 μ in length.

A. pectinata Penard. Body small; envelope normal; the radial spines short, tenuous and all of equal length; plasma bluish in colour; pseudopodia very long, tenuous. Diameter of envelope 15 μ to 18 μ; spines about 3 μ in length.

A. lüdibunda Penard. Envelope formed of a single layer of silicious spherules; the radial spines acicular with enlarged bases similar to pin-heads; plasma filled with red coloured granules. Diameter of envelope 28 μ to 35 μ; length of spines 7 μ to 10 μ; diameter of spherules about 2 μ.

Synopsis of British Freshwater Species.

(*a*) Spines of two kinds, long and short.
Spines forked. (1) *A. chætophora.*
(*b*) Spines all of one kind.
Spines short and curved. (2) *A. erinaceus.*
„ straight and slender. (3) *A. spinifera.*
„ straight or slightly curved, short. (4) *A. brevicirrhis.*
„ long, tapering, very numerous. (5) *A. myriospina.*

1. **Acanthocystis chætophora** (Schrank).

(Plate LXXI, fig. 1; Pl. LXXII, fig. 2.)

Trichoda chætophora
Schrank, Fauna Boica, Ingolstadt, 1803, p. 93.
Actinophrys viridis
Ehrenberg Abh. Akad. Berlin, 1833, p. 228.
Acanthocystis turfacea
Carter Ann. Mag. Nat. Hist. (ser. 3) XII, 1863, p 263; *op. cit.* XIII, 1864, p. 36, pl. ii, f. 25.
Wailes Jrn. Linn. Soc. Zool. XXXII, 1912, p. 126.
Penard Héliozoaires, 1904, p. 235, figs.
A. viridis
Grenacher Zeitschr. wiss. Zool. XIX, 1869, p. 289, pl. xxiv, ff. 1–3.
A. pallida
Greeff Arch. mikr. Anat. V, 1869, p. 489, pl. xxvii, f. 19.
A. chætophora
Leidy Rep. U.S. Geol. Surv. XII, 1879, p. 264, pl. xliii, ff. 1–6.
West Jrn. Linn. Soc. Zool. XXVIII, 1901, p. 340.

Body spherical, with a double outer investment, the

inner one consisting of a single layer of oval silicious plates slightly imbricated, the outer one consisting of two kinds of silicious spines, one kind very numerous, long and slightly bifurcate at the extremities, the other kind less numerous, shorter, with widely bifurcate extremities, the basal ends of all the spines provided with flattened plates which form a continuous spherical investment; plasma usually coloured green by chlorophyll granules; endoplasm colourless, granular, eccentric; nucleus large, placed eccentrically, pyriform or irregular in shape, containing a large nucleolus; central granule present; pseudopodia long, not tenuous, slightly granuliferous; contractile vesicles absent except in colourless individuals.

Diameter of outer envelope usually 35 μ to 60 μ, but may attain 100 μ or more (150 μ Schaudinn); length of the shorter spines equal to about half the diameter of the body, that of the longer spines two to three times as much; pseudopodia equal in length to twice the diameter of the body or more.

Habitat.—Lakes, ponds and moorland pools; not common.

Distribution. — England. — Terrington, Yorkshire (*West*); Dunham, Cheshire (*Cash*); Easedale, Derbyshire and Sheffield district (*Brown*); Epping Forest, Essex (*Cash*); Bournemouth, Hants (*Wallington*); Barnes, Surrey (*G. S. West*).

Ireland.—? Wicklow (*Archer*); Clare Island and Achill Island, Mayo (*Wailes & Penard*).

The spines appear to be hollow and are attached together by the plates at their basal ends, which form a continuous outer investment enclosing a clear zone around the body proper; nearly midway in this zone is the second investment of oval discs; these however are usually indistinguishable until the outer spines have been removed.

The bifurcated ends of the spines are characteristic of the species and serve to identify it under abnormal

conditions, as for instance in the absence of the green corpuscles, under which aspect it was named by Greeff *A. pallida*; it is sometimes seen distended into an ovoid form by numerous large inclusions, which in some cases, at any rate, are ova belonging to a Rotifer of the genus *Proales*. Stokes watched a struggle in which an ingested Rotifer eventually succeeded in escaping by devouring a portion of the plasma, leaving, however, an egg behind.

In addition to internal parasites the exterior is often invested by a thick covering of microbes, which, however, do not appear to exercise any deleterious effects.

The central granule with its radiating lines and the nucleus are usually hidden by the green colouring matter; the nucleus is of a characteristic shape.

An account of the processes of multiplication in this genus has already been given (p. 11); occasionally the animal is found encysted; the cysts are formed inside the outer investment, and are spherical with a reticulated outer surface which is formed of small discs cemented together, their convex sides being turned outwards.

Young individuals as small as 10 μ in diameter occur and have the characteristics of the species.

2. **Acanthocystis erinaceus** Penard.

(Plate LXXI, fig. 2.)

Acanthocystis erinaceus
Penard Arch. Biol. IX. 1889, p. 455, pl. xxxi. ff. 23–27.
Penard Héliozoaires. 1904, p. 267, fig.
Wailes & Penard Proc. R. Irish Acad XXXI. pt. 65, 1911, p. 53.
A. albida
Penard Arch. Biol. IX, 1889, p. 458, pl. xxxi, ff. 28, 29.

Body small, spherical; the outer investment consisting of small silicious plates arranged tangentially in a thin layer of plasma having a membranous consistency and radial spines sharply pointed, curved, of moderate length with expanded bases; plasma yellowish in

colour, granular without a clearly defined endoplasm; nucleus not large, grey in colour, placed eccentrically; contractile vesicle large with a smaller one often present; pseudopodia long, tenuous, granuliferous.

Diameter of envelope without spines 18 μ to 23 μ; length of spines one fourth to one half the diameter of envelope.

Habitat.—Aquatic vegetation. Rare.

Distribution.—Scotland.—Isle of May (*Brown*).
Ireland.—Clare Island, Mayo (*Wailes & Penard*).

From *A. aculeata* and *A. brevicirrhis* this species is distinguished by its smaller size and much more delicate capsule as also by the curved radial spines which are quite distinctive.

3. **Acanthocystis spinifera** Greeff.

(Text-fig. 190.)

Acanthocystis spinifera
Greeff Arch. mikr. Anat. V, 1869, p. 493, pl. xxvii, ff. 20–23.
Archer Qrt. Jrn. Micr. Sci. X, 1870, p. 102; *op. cit.* XVI, 1876, p. 364, pl. xxi, f. 8.
Hertwig & Lesser Arch. mikr. Anat. X, 1874, Suppl. p. 195, pl. iv, f. 3, a, b; *non* Penard Héliozoaires, 1904, p. 245, fig.
? *A. pertyana*
Penard Héliozoaires, 1904, p. 248, fig.
Acanthocystis
? Leidy Rep. U.S. Geol. Surv. XII, 1879, p. 268, pl. xliii, ff. 7–13.

Body of medium size, spherical, with an outer investment formed by the enlarged bases of numerous, moderately long, straight, tenuous and sharply pointed spines placed radially; an inner investment also present formed of small elliptical scales; ectoplasm and endoplasm clearly differentiated, the former granular and frequently containing one or more yellow bodies or numerous green granules; the endoplasm containing a central granule and an eccentrically placed nucleus containing a nucleolus; contractile vesicles, one or more situated near the periphery, but often indistinguishable; pseudopodia long and very tenuous.

Diameter of envelope 40 μ to 60 μ; length of spines from one third to one half the diameter of the envelope.

Habitat.—Moorland pools and vegetation in still water.

Distribution. — England. — Sheffield district, W. Yorks.; Derbyshire (*Brown*).

Ireland.—? Wicklow (*Archer*).

In the original description of this species by Greeff the included yellow bodies were considered to be characteristic; they were also observed by Archer, but

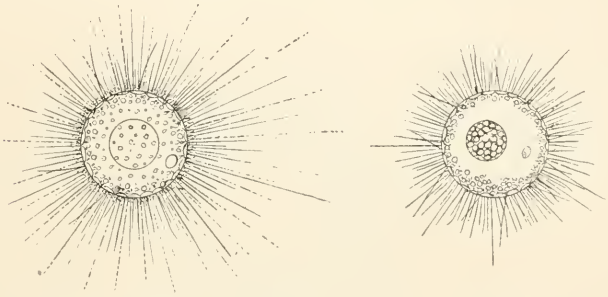

Fig. 190.—*Acanthocystis spinifera.* × 300. (After Greeff.)

Hertwig and Lesser did not find them, their place being taken by numerous "chlorophyll-green granules"; Archer also observed these and remarked that they occurred in "never the abundant quantity mostly characteristic of *A. chætophora*." The yellow globules Archer considered to be of an oily nature and agreed with Hertwig and Lesser in the supposition that their presence or absence was probably determined by the "varying degree of nutrition of the organism." This no doubt is correct if, as seems probable, they serve as a reserve supply of food.

The *A. spinifera* of Penard is a distinct species, but Penard's illustration and description of "*A. pertyana* Archer" show that he had probably this species under observation at the time.

4. **Acanthocystis brevicirrhis** (Perty).

(Plate LXIV, fig. 4, LXIX, fig. 1.)

Actinophrys brevicirrhis
Perty Zur Kennt. klein. Lebensformen, 1852, p. 159, pl. viii, f. 7.
Acanthocystis pertyana
Archer Qrt. Jrn. Micr. Sci. (N.S.) IX, 1869, p. 252, pl. xvi. f. 1; *non* Penard Héliozoaires, 1904, p. 248, fig.
Acanthocystis paludosa
West J. Linn. Soc. Zool. XXVIII, 1901, p. 340, pl. xxx. ff. 32, 33.
Acanthocystis ?
Leidy Rep. U.S. Geol. Surv. XII, 1879, p. 270, pl. xliii. ff. 14–16.

Body of medium size, spherical, having a double outer investment, the inner portion consisting of a thin layer of small silicious scales, the outer portion consisting of numerous, short, pin- or thorn-like spines attached by their enlarged bases either radially or divergently; plasma colourless or greyish, often containing numerous green chlorophyll cells, also numerous granules and food particles; endoplasm not clearly differentiated, placed eccentrically, containing a central granule; nucleus single, grey in colour, placed eccentrically, usually concealed from view by the plasma and its contents; contractile vesicle single, large; pseudopodia long, tenuous, granuliferous.

Diameter of envelope without the spines 30 μ to about 50 μ (Penard 18 μ to 40 μ). Length of spines 5 μ to 12 μ.

Habitat.—Lakes, ponds, ditches and quiet parts of rivers and streams.

Distribution.—England.—Shelf and Ilkley (*G. S. West*); Sheffield District (*Brown*); W. Yorkshire; Derbyshire (*Brown*); Hornsea Mere, Lincolnshire; Thames at Weybridge, Surrey.

Scotland.—Aberfoyle; Craigcaffie; Ben Ledi; Pt. Patrick (*Brown*).

Ireland.—Carrig Mt., Wicklow (*Archer*).

5. **Acanthocystis myriospina** Penard.

(Text-fig. 191.)

Acanthocystis myriospina
PENARD Jahrb. Nassau. Ver. Naturk. XLIII, 1890, p. 23; Héliozoaires, 1904, p. 230, fig.
Acanthocystis? sp.
LEIDY Rep. U.S. Geol. Surv. XII, 1879, p. 268, pl. xliii, ff. 8, 11, 13.
? Heterophrys pusilla
ZACHARIAS Zool. Anz. XXV, 1902, p. 665.

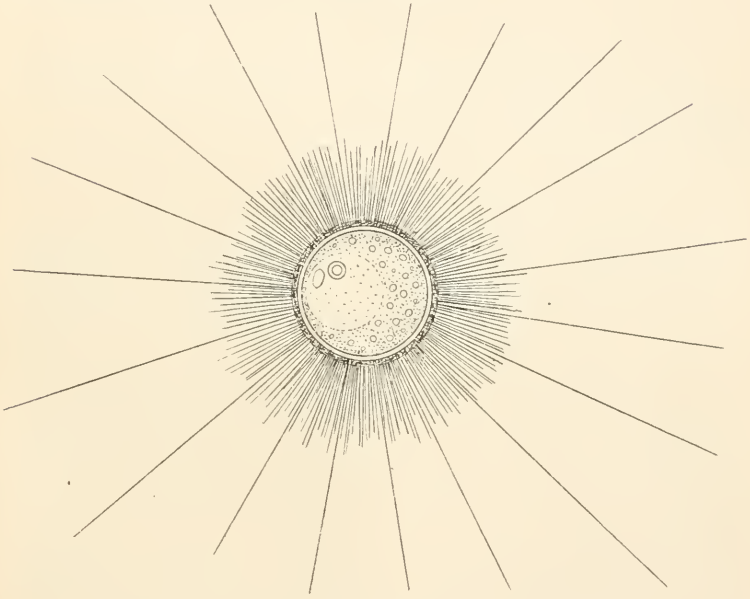

FIG. 191.—*Acanthocystis myriospina*. (After Penard.)

Body small, spherical; outer envelope composed of one or two layers of minute scales from which originate very numerous, delicate radial spines; ectoplasm, clear or of a blue or bluish-green tint, often containing yellow or dark-coloured food particles; endoplasm placed eccentrically; nucleus small, placed eccentrically; contractile vesicles one or more near the periphery; pseudopodia numerous, long, attenuate, granuliferous.

Diameter of body 12–20 μ, usually about 15 μ.

Spines about the diameter of the body in length.

Habitat.—Sediment of moorland pools and ditches.

Distribution.—England.—Derbyshire (*Wailes*).

The pseudopodia are so attenuated that they are often difficult to detect; when the skeleton is examined in a dry state the spines are seen to have enlarged bases shaped like pin-heads.

Sub-order IV. DESMOTHORACA Hertwig & Lesser.

Heliozoa with an envelope or capsule homogeneous, continuous and perforated, often provided with a pedicel or stalk.

Synopsis of British Freshwater Genera.

Capsule stalked, openings in it comparatively large and numerous. (10) *Clathrulina.*

Capsule stalked, openings in it minute and not so numerous. (11) *Hedriocystis.*

Genus 10. **CLATHRULINA** Cienkowsky.

Clathrulina Cienkowsky Arch. mikr. Anat. III, 1867, p. 311.
Podosphæra Archer Qrt. Jrn. Micr. Sci. (n.s.) VIII, 1868, p. 67.

Envelope spherical, homogeneous, pedunculate, provided with numerous openings usually regularly placed; plasma centrally placed, not filling the test; nucleus, except during division, single, placed centrally; pseudopodia numerous, tenuous, granuliferous, straight or forked.

The species *C. stuhlmanni* has an envelope pierced with very small openings and is provided with a very long stalk; it has up to the present been recorded from Africa only.

Synopsis of British Species.

Openings in envelope large. *C. elegans.*

Openings in envelope small. *C. cienkowskii.*

1. **Clathrulina elegans** Cienkowsky.

(Plate LXXIII, fig. 1. Text-fig. 192.)

Clathrulina elegans
Cienkowsky Arch. mikr. Anat. III, 1867, p. 311, pl. xviii, ff. 1–15.
Greeff Arch. mikr. Anat. V, 1869, p. 467, pl. xxvi, ff. 1–7.
Hertwig & Lesser Arch. mikr. Anat. X, 1874, Suppl. p. 227, pl. v, f. 4.
Leidy Rep. U.S. Geol. Surv. XII, 1879, p. 273, pl. xliv.
Foulke Proc. Acad. Nat. Sci. Philad. 1884, p. 17.
Penard Héliozoaires, 1904, p. 270, figs.
Wailes J. Linn. Soc. Zool. XXXII, 1912, p. 126.
Wailes & Penard Proc. R. Irish Acad. XXXI, pt. 65, 1911, p. 19.
Podosphæra hæckeliana
Archer Qrt. Jrn. Micr. Sci. (N.S.) VIII, 1868, p. 67.

Envelope spherical, homogeneous, colourless when young, becoming yellowish or brown with age, perforated by numerous comparatively large openings more or less circular or polygonal in shape; the envelope provided with a peduncle or stalk; body lobed, not filling the envelope, plasma colourless, granular; endoplasm not differentiated; nucleus single, placed centrally; contractile vesicles one or more; pseudopodia of moderate length, slender, tapering, granuliferous, without central axes, straight or forked.

Diameter of the envelope 60 μ to 90 μ (Leidy 30 μ to 44 μ); diameter of the openings in the envelope 6 μ to 10 μ; length of the stalk twice to four times the diameter of the envelope; diameter of the stalk 3 μ to 4 μ.

Habitat.—Ponds and moorland pools amongst aquatic vegetation; rare.

Distribution.—England.—Windermere, Westmoreland (*G. S. West*); N. Yorks; White Moss, Lancashire, Essex, Sussex (*Cash*).

Wales.—Llyn Ogwen (*G. S. West*); N. Wales (*Archer*).

Ireland.—Lough Neagh, Co. Armagh (*G. S. West*); Wicklow (*Archer*); Clare Island, Mayo (*Wailes & Penard*).

The envelope, which was formerly described as

composed of a silicious material, was found by Penard to be of a chitinous character, being readily dissolved in boiling sulphuric acid and destroyed by the heat from a blow-pipe.

The apertures in it are separated from each other by narrow bars having raised or thickened borders, and although the openings are usually somewhat polygonal in shape they always have the angles rounded.

The peduncle or stalk is hollow and either has an enlarged base or root-like filaments by which it is attached to some support; young individuals after emerging from the mother capsule frequently attach themselves to it and may again in their turn serve as supports for a younger generation; in this way chains and small colonies are formed consisting of two or three up to seven or eight individuals (Fig. 192); capsules are sometimes found devoid of stalks which become severed owing to a constriction that takes place close to the capsule, the animal thus regaining its freedom of movement.

The apices of cone-shaped expansions of the plasma usually give rise to the pseudopodia, two or three of which often diverge from a single orifice and a common point of origin; they are also frequently forked and appear devoid of any central axis.

The contractile vesicle is normally single in mature individuals, but is often or even usually indistinguishable; in young forms two or three can often be seen.

Various methods of propagation have been observed; simple division, either binary or multiple, up to six or seven in number, is the most common, the young emerging through an aperture of the capsule in an amœboid form, after which they either at once secrete first a stalk and then a fine pellicle which eventually becomes the capsule, or they may again divide or they may encyst; the cysts are spherical with a chitinous envelope covered with fine points or projections and have a single centrally placed nucleus. Mature individuals are often found encysted, and two cysts,

presumably the result of binary division, are not infrequently seen in one capsule.

The formation of zoospores is also of not uncommon occurrence. Miss Foulke has described the formation

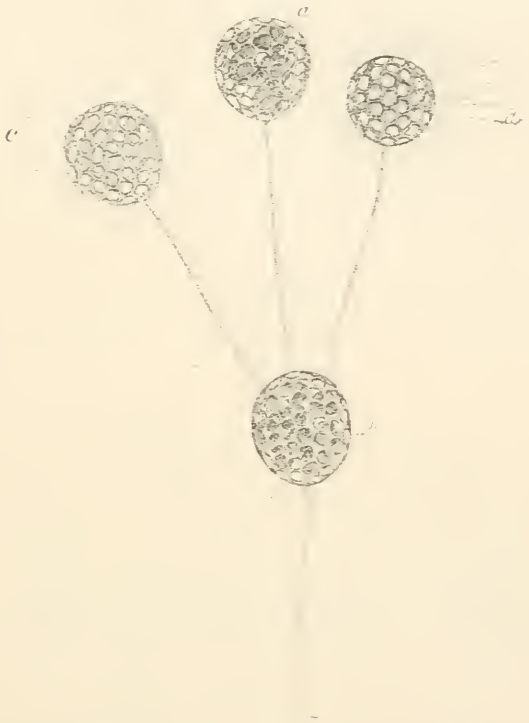

FIG. 192.—*Clathrulina elegans*. Colony of four individuals. *a*, *b*. Capsules containing embryos. *c*, *d*. Individuals with pseudopodia extended. (After Greeff.)

of free swimming "germs," which perhaps are swarm spores or gametes, and states that they are liberated from the capsule enclosed in thin sacs from which they quickly emerge.

Although normally uni-nuclear, individuals are often found with several nuclei, due to the animal being in process of division.

2. **Clathrulina cienkowskii** Mereschkowsky.

(Text-fig. 193.)

Clathrulina cienkowskii
Mereschkowsky Arch. mikr. Anat. XVI, 1879, p. 191, pl. x, f. 34.
Penard Héliozoaires, 1904, p. 276, figs.
Wailes & Penard Proc. R. Irish Acad. XXXI, pt. 65, 1911, p. 19.
Wailes J. Linn. Soc. Zool. XXXII, 1912, p. 126.

Body small, partially filling the capsule; capsule spherical, thick, pierced with numerous small circular apertures having raised borders forming an alveolar surface; pedicel long, tenuous; plasma greyish in colour, containing numerous granules and food par-

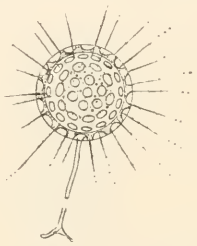

Fig. 193.—*Clathrulina cienkowskii.* × 375.

ticles; nucleus placed centrally, containing a large central nucleole; one or two contractile vesicles usually present; pseudopodia long, granuliferous.

Diameter of capsule 25 μ to 40 μ; the pedicel usually about five or six times the diameter of the capsule in length, but sometimes attaining 300 μ, with a diameter of about 2 μ; the apertures in the capsule 4 μ to 5 μ in diameter.

Habitat.—Aquatic vegetation. Rare.

Distribution.—Ireland.—Inishbofin, Galway (*Wailes & Penard*).

Propagation by simple binary and multiple division has been observed, also the formation of cysts, which differ from those of *C. elegans* by being without asperities on the surface.

Mereschkowsky's description of the species differs somewhat from that given above in so far as he describes the surface of the capsule as studded with short, blunt, spine-like projections arising from between the apertures. As suggested by Penard, this is probably an error of observation due to the boss-like appearance of the raised borders as seen in section under the microscope, and Mereschkowsky's original figures of the specimens he obtained from Lake Onega differ but little from the figure.

On the Continent of Europe Penard found this species usually varying from 26 μ to 33 μ in diameter, rarely attaining 40 μ, and clearly differentiated from *C. elegans* which he found to vary from 60 μ to 90 μ, but in N. America 40 μ in diameter is quite a usual size for *C. elegans* (Leidy gives 30 μ to 44 μ) and careful observation is necessary to distinguish between the two species.

Genus 11. **HEDRIOCYSTIS** Hertwig & Lesser.

Hedriocystis Hertwig & Lesser Arch. mikr. Anat. X, 1874, Suppl. p. 225.

Capsule or envelope pedicellate and pierced by minute pores surrounded by facets or ridges giving it a polyhedral form.

Only two species have been recorded up to now from Great Britain. *H. pellucida* Hertwig & Lesser forms colonies, but the other two species have been recorded only as solitary.

Synopsis of British Freshwater Species.

Facets of capsule bordered by ridges.	(1) *H. reticulata.*
Angles of capsule bearing spines.	(2) *H. spinifera.*

1. **Hedriocystis reticulata** Penard.

(Plate LXXIV, figs. 1–4.)

Hedriocystis reticulata
Penard Héliozoaires, 1904, p. 284, figs.
Brown Ann. Scot. Nat. Hist. 1911, p. 231.

Capsule stalked, transparent, thin, colourless or of a pale yellow, spherical with numerous facets more or less regularly polygonal and having raised borders; stalk of moderate length, straight, solid; body spherical, not filling the capsule; plasma bluish in colour, containing refringent granules and food particles; nucleus single placed sub-centrally; one contractile vesicle normally present and usually active; pseudopodia without axes, each issuing from a pore in the centre of a facet; habit solitary.

Diameter of capsule about 25 μ; stalk about 70 μ in length and 1 μ to 1·5 μ in diameter. Diameter of body about 12 μ.

Habitat.—Marshy pools. Rare.

Distribution.—Scotland.—Craigcaffie (*Brown*).

Both capsule and stalk are of a chitinous material, and the former is so transparent and colourless that only the ridges bounding its polygonal faces are apparent; the pores are indicated only by the pseudopodia that issue from them except when treated with acid when small bubbles of gas serve to localise them.

Division within the capsule has been observed, but the method of escape from it has not been recorded.

2. **Hedriocystis spinifera** Brown.

(Plate LXXIII, figs. 2–4.)

Hedriocystis spinifera
Brown Jrn. R. Micr. Soc. 1918, p. 172, ff. 5–7 on pl.

Capsule minute, similar to that of the preceding species, but furnished with spines arising at many of the junctions of the alveolar ridges; body spherical,

nearly filling the capsule; plasma bluish in colour, granular; nucleus single, placed sub-centrally; a single contractile vesicle normally present; pseudopodia long, radiating, straight, tenuous; habit solitary.

Diameter of capsule 8 μ to 12 μ.

Habitat.—Wet moss.

Distribution.—Scotland.—Isle of May (*Brown*).

Up till now no individuals have been found provided with a pedicel or stalk, but this may be due to these having been broken off during collection.

Four genera of Heliozoa have not yet been recorded from the British Isles, and it is thought that a brief diagnosis of each of the species included in them would be welcome.

The genus *Raphidocystis* comprises species usually similar to those included in the genus *Raphidiophrys*, but some or all of the investing spicules are of special shape.

Raphidocystis simplex (Schaudinn) Pen. (*Acanthocystis simplex* Schaudinn) is similar to an *Acanthocystis* in structure but has no envelope of tangential spines, the body being surrounded by a pellucid mucilaginous investment from which tapering spines, equal to the diameter of the body in length, radiate. Diameter 15 μ to 22 μ. Africa.

R. stellata Pen. has the mucilaginous investment crowded with small spherules; the radial spines are covered by plasma and thus form *permanent* axes to the pseudopodia. Diameter 12 μ to 19 μ without envelope.

R. tubifera Pen. The external envelope consists of numerous oval scales placed tangentially, and radial spicules of a funnel-shape. Diameter 18 μ without envelope.

R. lemani Pen. (*Acanthocystis lemani* Pen.). (Fig. 184, p. 28.) The thick transparent envelope of this species has embedded in it minute mushroom-shaped spicules, and protruding from it radially wineglass-shaped spicules and numerous long tubular spines. Diameter 18 μ to 25 μ without envelope.

R. glutinosa Pen. The pellucid mucilaginous envelope contains numerous Y-shaped spicules; no radial spines present. Diameter 12 μ to 13 μ without envelope.

The genus *Pinaciophora* Greeff contains one species, *P. fluviatilis* Greeff (Fig. 185, p. 28), in which the external envelope is formed of circular imbricated discs each per-

forated with nineteen minute pores; plasma reddish in colour. Diameter 45 μ to 50 μ.

The genus *Elaster* Grimm contains one species, *E. greeffi* Grimm, which has a perfectly smooth spherical capsule devoid of pedicel or projections and perforated by numerous small pores. Diameter 20 μ.

Choanocystis Pen. comprises one species, *C. lepidula* Pen., in which the perforations in the envelope are provided with conical borders, the smaller ends outwards; the orifices of these cones are provided with funnel-shaped extensions whose edges nearly touch one another. Diameter 13 μ.

PSEUDO-HELIOZOA.

This term has been applied by Penard to forms which are more or less closely allied to the Heliozoa, but at the same time have some of the characteristics of the Proteomyxa or Flagellata. They include the following species:—

Chondropus viridis Greeff, a form allied to the genus *Vampyrella*.

Nuclearia caulescens Pen., *Clathrella foreli* Pen., (Text-fig. 194), *Actinocoma ramosa* Pen., *Artodiscus saltans* Pen. are all species that assume a spherical form, but radial spines are wanting, the pseudopodia are radiating, without central axes and mostly bifurcated or branching. All the above appear to be most nearly allied to the Proteomyxa. *Myriophrys paradoxa* Pen. possesses radiating pseudopodia provided with stiff axes, but in addition the body is densely covered with vibratile cilia, whilst *Dimorpha mutans* Gruber has the typical Heliozoan pseudopodia, but only two flagella. The genus *Ciliophrys* Cienk. is another similar form, linking the Heliozoa with the Flagellata.

The genera *Pythelios* Frenzel, *Actinomonas* Kent, and *Monobia* Schneider also have a heliozoan-like appearance.

Minchin has the following remarks on this subject: "Especially remarkable are certain genera which indicate a close relationship between Heliozoa and

Flagellata. An account of several such forms is given by Penard, in addition to which the following may be noted: *Ciliophrys* Cienkowski has two phases; in the one it appears as a typical Heliozoon with stiff radiating pseudopodia; in the other it is a typical flagellate.

"In the process of transformation the Heliozoon-form retracts its pseudopodia, its body becomes amœboid and a flagellum grows out; finally the animal becomes a pear-shaped flagellate swimming by means of its flagellum (Schewiakoff; Caullery).

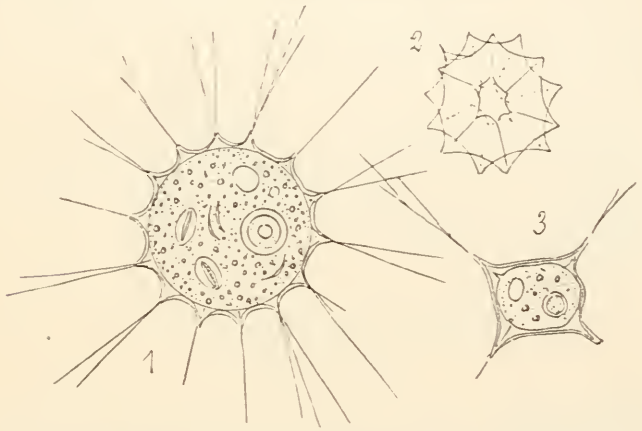

Fig. 194.—*Clathrella foreli*. 1. Usual appearance. 2. Envelope (partly diagrammatic). 3. Young individual. (After Penard.)

"*Ciliophrys* thus recalls *Pseudospora* in its two phases, and there can be little doubt that the two forms are closely allied."

After describing *Dimorpha mutans* the author proceeds: "These facts appear to indicate an origin for the Heliozoa from Flagellates such as those of the genus *Multicilia*, in which the body bears radiating flagella planted evenly over the surface; transformation of the flagella into stiff pseudopodia would produce the Heliozoon-type of organism. On such a view two peculiarities of the Heliozoan pseudopodia receive explanation; the power of nutation and bending which

they frequently possess; and their insertion on a 'central grain,' which would then represent the blepharoplast pure and simple of a flagellate. On this view the pseudopodia of the Heliozoa would appear to be structures quite different in nature from the similarly-named organs of Lobosa."

"On the other hand the Heliozoa also show affinities towards forms classed among the Reticulosa or 'Proteomyxa,' as already noted in the case of *Ciliophrys* and *Pseudospora*. Przesmycki has described a species, *Endophrys rotatorium*, parasitic in Rotifera, which he considers as a connecting-link between *Nuclearia* and *Vampyrella*. The exact systematic position of such genera must be considered at present an open question."

The species *Dimorpha mutans* having been recently recorded in Great Britain and being one of the most interesting of the flagellated type, a description of it with figures is added.

Dimorpha mutans Gruber.

(Text-fig. 195.)

Dimorpha mutans
GRUBER Zeitschr. wiss. Zool. XXXVI, 1881, p. 445, pl. xxix.
BLOCHMANN Biol. Centralbl. XIV, 1874, p. 197, f. 2.
SCHOUTEDEN Arch. Protistenk. IX, 1907, p. 108, f. 1.
Dimorpha nutans (sic).
MINCHIN Introd. Stud. Protozoa, 1912, p. 248.
Actinophrys ciliatum
NELSON English Mechanic, 27th Octr. 1916, p. 273, fig.

Body small, shape varying from spherical to ovoid; envelope smooth, membranous, pellucid; plasma pale blue in colour, containing pale green or yellow coloured granules, with a clear marginal zone usually present; nucleus single, placed eccentrically, containing a single hemispherical nucleolus; centrosome placed eccentrically, from which two flagella originate; pseudopodia long when fully extended, straight, tenuous, granuliferous, retractile, sometimes absent, each containing a

central axis originating from the centrosome; contractile vesicles two or more in number.

Diameter of body 11 μ to 15 μ ? ; flagella about one and a half times the diameter of the body in length.

Habitat.—Aquatic vegetation.

Distribution. — England. — Bournemouth, Hants (*Chaffey*).

Schouteden found his specimens on the branches of

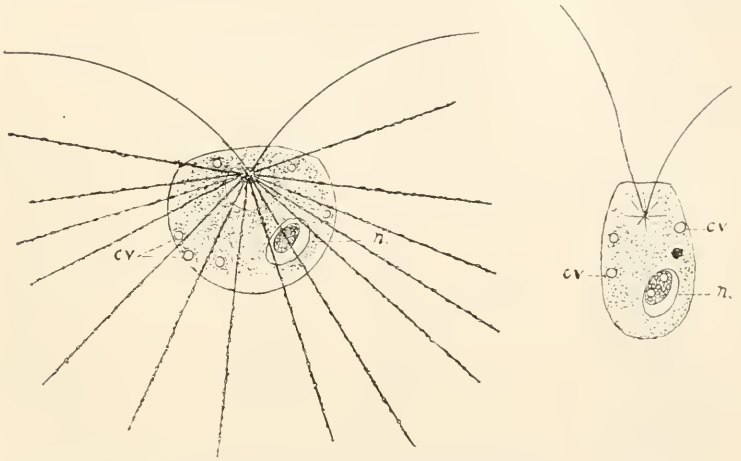

Fig. 195.—*Dimorpha mutans.* On the left, a specimen with pseudopodia extended. (After Schouteden.) On the right, an immature form without pseudopodia. (After Blochmann.) *c.v.* Contractile vesicles. *n.* Nucleus.

the colonial Flagellate *Anthophysa*, and states that one of the flagella may be used as an anchor; the animals were observed to feed on *Monas*; the contractile vesicles had a period of 25 seconds.

Gruber gives illustrations showing the Heliozoan state in which the body is spherical and the pseudopodia in various states of development, also of immature forms, both spherical and ovoid, in which the pseudopodia were absent, but in all one or both of the flagella are present.

The flagella of the individuals found near Bournemouth were in constant and rapid vibration.

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* The figures in heavy type indicate the pages on which the genera and species are defined or described.

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EXPLANATIONS OF THE PLATES.

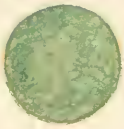
Plate 64

PLATE LXIV.

FIGS.

1. *Actinophrys sol* Ehrenb. (form *picta*).
2, 3. *Actinophrys sol* Ehrenb.
4. *Acanthocystis brevicirrhis* (Perty).
5, 6. *Pompholyxophrys punicea* Archer.

All from drawings by G. S. West. × 520.



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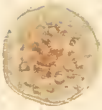

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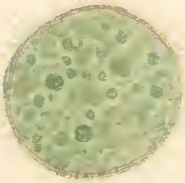

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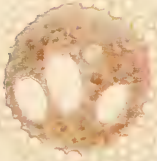

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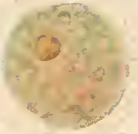

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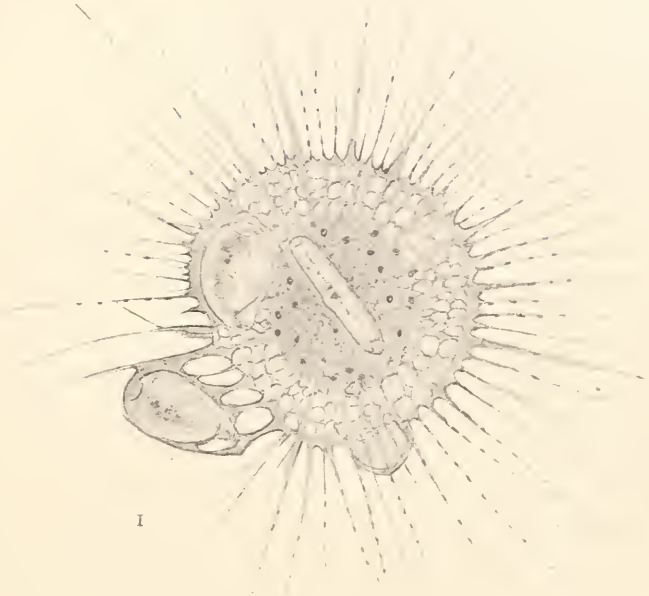
Plate 65

PLATE LXV.

FIGS.

1. *Actinosphærium eichhornii* (Ehrenb.). A small animal just captured by the pseudopodia is seen on the left. Other organisms ingested as food are lying in the plasma. × 100 (Cash.)
2. *A. eichhornii* (Ehrenb.). A portion further enlarged. *ps.* Pseudopodia. *ax.* Axis (West).



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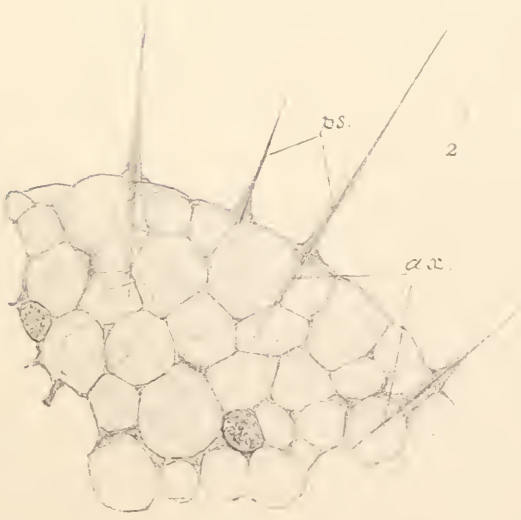

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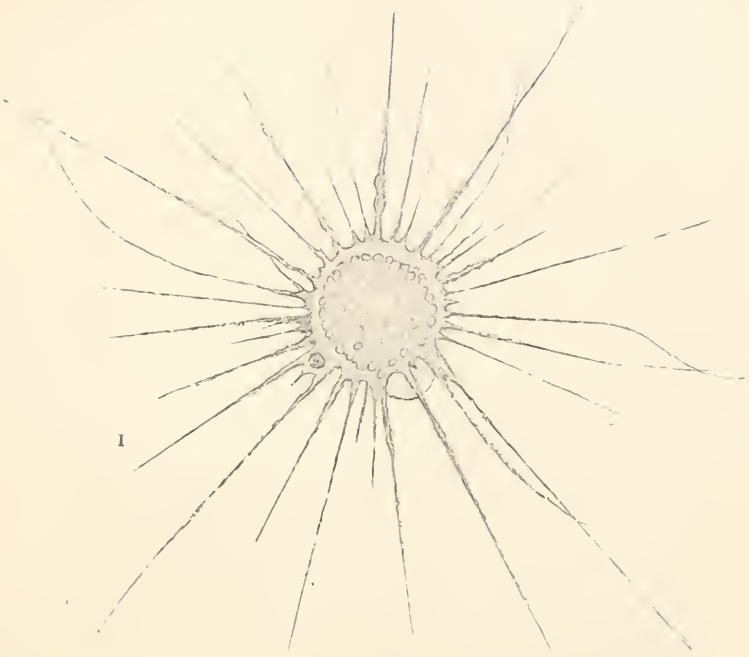
Plate 66

PLATE LXVI.

FIGS.

1. *Actinosphærium arachnoideum* Penard. × 455 (Cash).
2. *Actinophrys subalpina* West. × 520 (West).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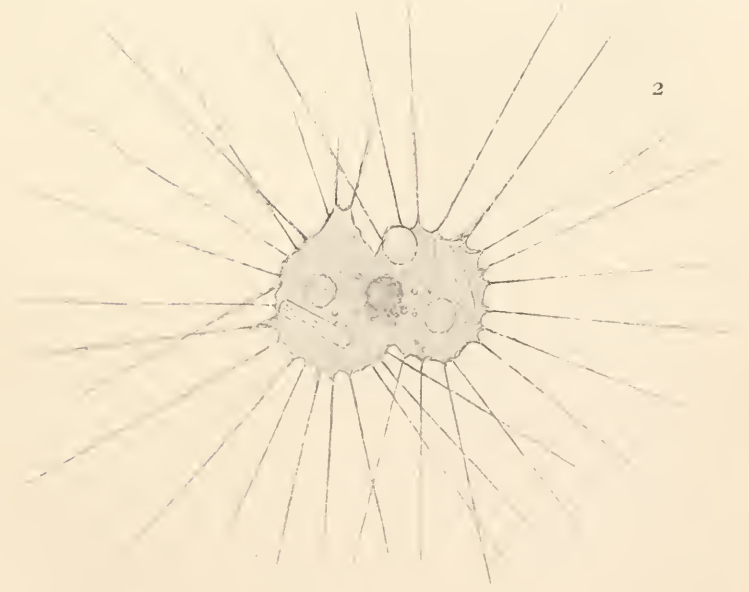
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Plate 67

PLATE LXVII.

FIGS.
1–6. *Actinophrys sol* Ehrenb. Figs. 1–4. × 800 (Cash). Figs. 5, 6. × 500 (West).


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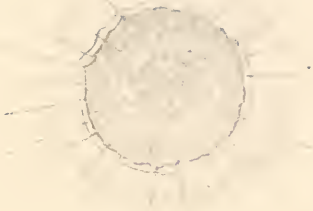
Plate 68

PLATE LXVIII.

FIGS.

1, 2. *Heterophrys myriopoda* Archer (Cash).
3. *H. fockei* Archer (Cash).
4. *H. radiata* West. × 520 (West).



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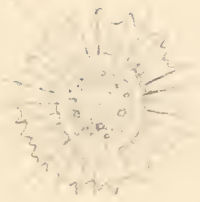

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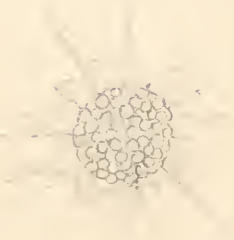

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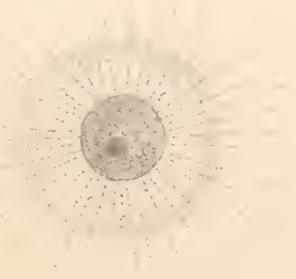

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PLATE LXIX.

FIGS.

1. *Raphidiophrys viridis* Archer.
2. *Acanthocystis brevicirrhis* (Perty).
3. *Heterophrys fockei* Archer.

4, 5. *Pompholyxophrys punicea* Archer.

All after Archer. × 250.

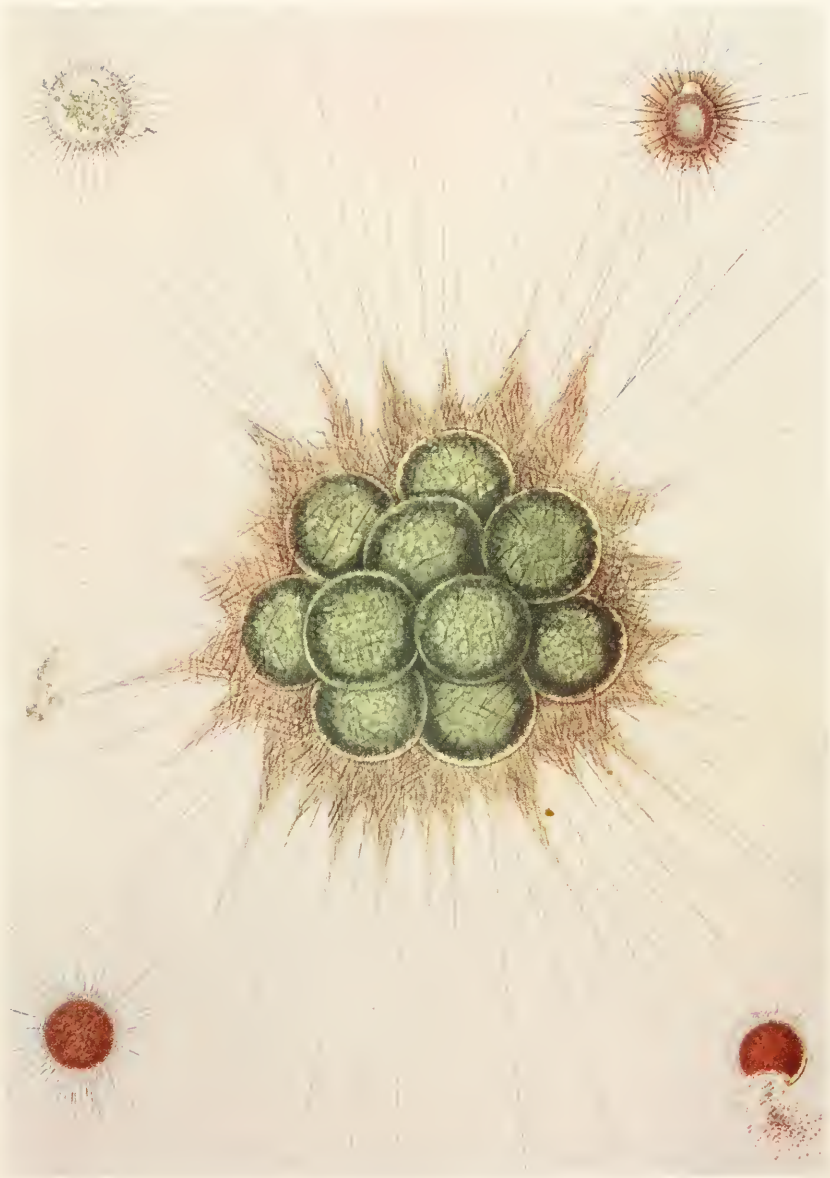
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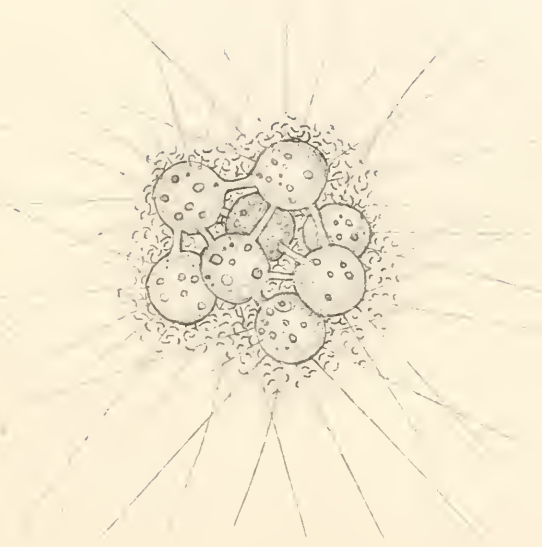
PLATE LXX.

FIGS.

1. *Raphidiophrys elegans* H. & L. × 400 (Cash).
2. *R. viridis* Archer. × 250 (Cash).
3. *R. pallida* Schulze. × 400 (Cash).

The spicules are shown much darker than they appear naturally.



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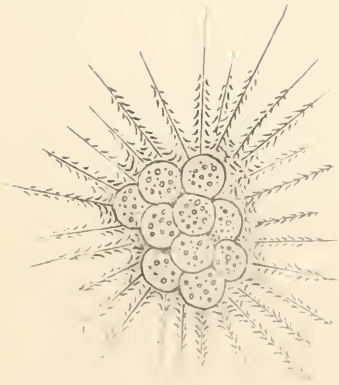

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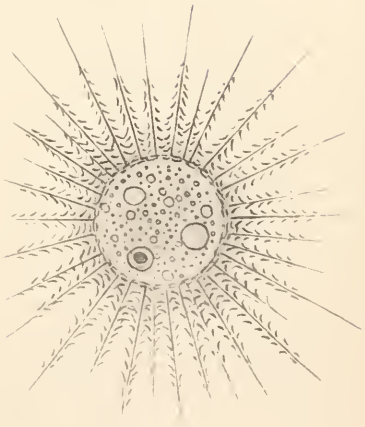

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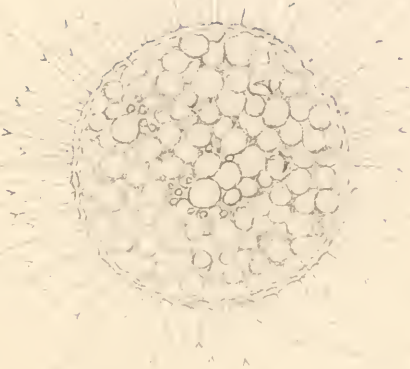
Plate 71

PLATE LXXI.

FIGS.

1. *Acanthocystis chætophora* (Schrank). × 500 (West).
2. *A. erinaceus* Penard. × 1200 (Brown).



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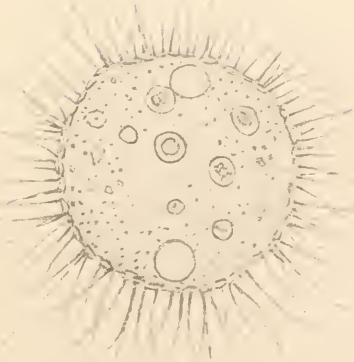

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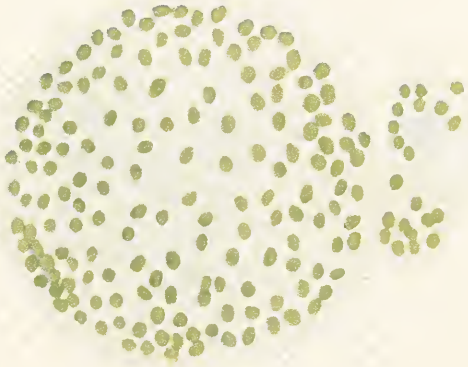
Plate 72

PLATE LXXII.

FIGS.

1. *Actinophrys sol* Ehrenb. × 400 (West).
2. *Acanthocystis chætophora* (Schrank). × 500 (West).

In both cases the structure is hidden by symbiotic algæ.



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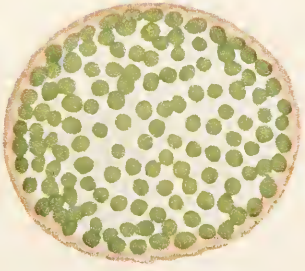

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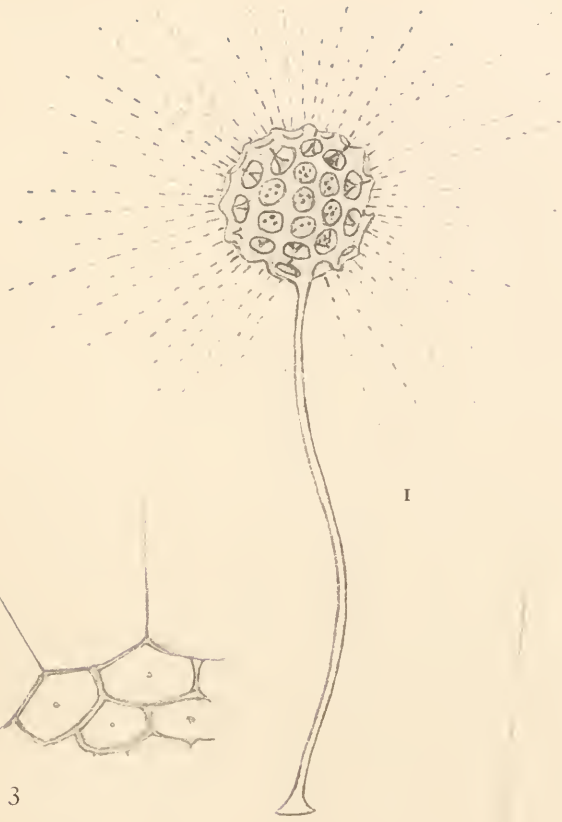
Plate 73

PLATE LXXIII.

FIGS.

1. *Clathrulina elegans* Cienk. × 300.
2. *Hedriocystis spinifera* Brown. × 2400.
3. *H. spinifera*, portion of test further enlarged. × 5000.
4. *H. spinifera*, optical section showing portion of capsule and plasma with nucleus and contractile vacuole. × 5000.

Figs. 2–4 from drawings by J. M. Brown.



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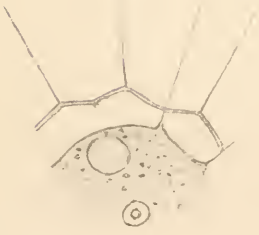

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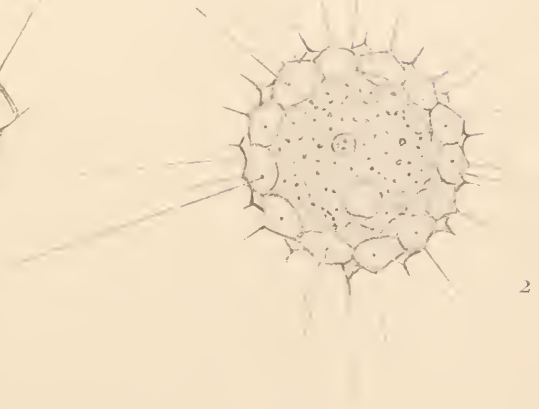


2

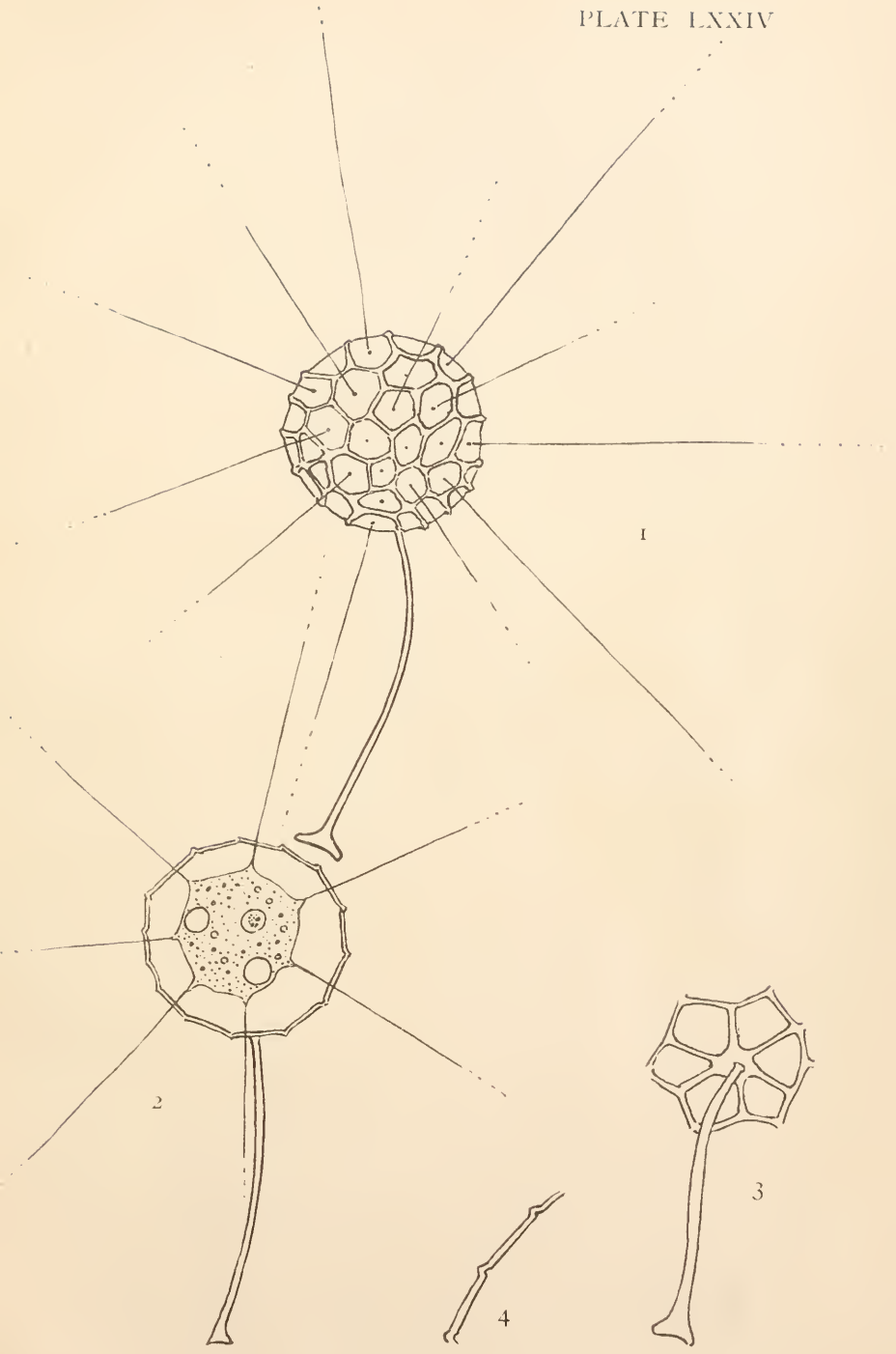
Plate 74

PLATE LXXIV.

FIGS.

1. *Hedriocystis reticulata* Penard. × 980.
2. *H. reticulata*, optical section.
3. *H. reticulata*, attachment of test to stalk.
4. *H. reticulata*, section of test, further enlarged.

All from drawings by J. M. Brown.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