Spencer resolves protoplasm into "physiological units," Haeckel into "plastidules," while Darwin accounts for heredity by reference to the properties of supposed "gemmules," Engelmann suggests the existence of "contractile units" (*inotagmata*), &c.; but these various hypotheses, framed mostly for special purposes, still await more general criticism. See (6).

§ 8. *Origin of Protoplasm.*—See ABIOGENESIS, BIOLOGY, REPRODUCTION, and (7).

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PROTOZOA

PROTOZOA is the name applied to the lowest grade of the animal kingdom, and originated as a translation of the German term "Urthiere." Whilst at first used some forty years ago in a vague sense, without any strict definition, so as to include on the one hand some simple organisms which are now regarded as plants and on the other some animals which are now assigned a higher place in the animal series, the term has within the last twenty years acquired a very clear signification.

The Protozoa are sharply and definitely distinguished from all the rest of the animal kingdom, which are known by the names "Metazoa" or "Enterozoa." They are those animals which are structurally single "cells" or single corpuscles of protoplasm, whereas the Enterozoa consist of many such units arranged definitely (in the first instance) in two layers—an endoderm or enteric cell-layer and an ectoderm or deric cell-layer—around a central cavity, the enteron or common digestive cavity, which is in open communication with the exterior by a mouth.

The Protozoa are then essentially unicellular animals. The individual or person in this grade of the animal kingdom is a single cell; and, although we find Protozoa which consist of aggregates of such cells, and are entitled to be called "multicellular," yet an examination of the details of structure of these cell-aggregates and of their life-history establishes the fact that the cohesion of the cells in these instances is not an essential feature of the life of such multicellular Protozoa but a secondary and non-essential arrangement. Like the budded "persons" forming, when coherent to one another, undifferentiated "colonies" among the Polyps and Corals, the coherent cells of a compound Protozoon can be separated from one another and live independently; their cohesion has no economic significance. Each cell is precisely the counterpart of its neighbour; there is no common life, no distribution of function among special groups of the associated cells, and no corresponding differentiation of structure. As a contrast to this we find even in the simplest Enterozoa that the cells are functionally and structurally distinguishable into two groups—those which line the enteron or digestive cavity and those which form the outer body wall. The cells of these two layers are not interchangeable; they are fundamentally different in properties and structure from one another. The individual Enterozoon is not a single cell; it is an aggregate of a higher order consisting essentially of a digestive cavity around which two layers of cells are disposed. The individual Protozoon is a single cell; a number of these individuals may, as the result of the process of fission (cell-division), remain in contact with one another, but the compound individual which they thus originate has not a strong character. The constituent cells are still the more important individualities; they never become differentiated and grouped in distinct layers differing from one another in properties and structure; they never become subordinated to the individuality of the aggregate produced by their cohesion; hence we are justified in calling even these exceptional aggregated Protozoa unicellular.

By far the larger number of Protozoa are absolutely single isolated cells, which, whenever they duplicate themselves by that process of division common to these units of structure (whether existing as isolated organisms or as constituents of the tissues of plants or of animals), separate at once into two distinct individuals which move away from one another and are thenceforward strangers.

Whilst it is easy to draw the line between the Protozoa and the Enterozoa or Metazoa which lie above them, on account of the perfectly definite differentiation of the cells of the latter into two primary tissues, it is more difficult to separate the Protozoa from the parallel group of unicellular plants.

Theoretically there is no difficulty about this distinction. There is no doubt that organisms present themselves to us in two great series starting in both cases from simple unicellular forms. The one series, the plants, can take up the carbon, hydrogen, oxygen, and nitrogen necessary to build up their growing protoplasm from mineral compounds soluble in water, compounds which constitute the resting stage of those elements in the present physical conditions of our planet. Plants can take their nitrogen in the form of ammonia or in the form of nitrates and their carbon in the form of carbonic acid. Accordingly they require no mouths, no digestive apparatus; their food being soluble in water and diffusible, they absorb at all or many points of their surface. The spreading diffuse form of plants is definitely related to this fact. On the other hand the series of organisms which we distinguish as animals cannot take the nitrogen, necessary to build up their protoplasm, in a lower state of combination than it presents in the class of compounds known as albumens; nor can they take carbon in a lower state of combination than it presents when united with hydrogen or with hydrogen and oxygen to form fat, sugar, and starch. Albumens and fats are not soluble in water and diffusible; they have to be seized by the animal in the condition of more or less solid particles, and by chemical processes superinduced in the living protoplasm of the animal by the contact of these particles they are acted upon, chemically modified, and rendered diffusible. Hence the animal is provided with a mouth and a digestive cavity, and with organs of locomotion and prehension by which it may search out and appropriate its scattered nutriment. Further the albumens, fats, sugars, and starch which are the necessary food of an animal are not found in nature excepting as the products of the life of plants or of animals; accordingly all animals are in a certain sense parasitic upon either plants or other animals. It would therefore seem to be easy to draw the line between even the most minute unicellular plants and the similarly minute unicellular animals—assigning those which feed on the albumens, &c., of other organisms by means of a mouth and digestive apparatus to the animal series, and those which can appropriate the elements of ammonia, nitrates, and carbonates to the plants.

Such absolute distinctions lending themselves to sharp definitions have, however, no place in the organic world; and this is found to be equally true whether we attempt to categorically define smaller groups in the classification of plants and animals or to indicate the boundaries of the great primary division which those familiar names imply. Closely allied to plants which are highly and specially developed as plants, and feed exclusively upon ammonia, nitrates, and carbonates, we find exceptionally modified kinds which are known as "insectivorous plants" and are provided with digestive cavities (the pitchers of pitcher-plants, &c.), and actually feed by acting chemically upon the albumens of insects which they catch in these digestive receptacles. No one would entertain for a moment the notion that these insectivorous plants should be considered as animals. The physiological definition separating plant from animal breaks down in their case; but the consideration of the probable history of their evolution as indicated by their various details of structure suffices at once to convince the most sceptical observer that they actually belong to the vegetable line of descent or family tree, though they have lost the leading physiological characteristic which has dominated the structure of other plants. In this extreme case it is made very obvious that in grouping organisms as plants or as animals we are not called upon to apply a definition but to consider the multifarious evidences of historical evolution. And we find in the case of the Protozoa and the Protophyta that the same principle holds good, although, when dealing with extremely simple forms, it becomes much more difficult to judge of the genetic relationship of an organism in proportion as the number of detailed points of possible agreement with and divergence from other forms to which it may be supposed to be related are few.

The feeding of plants upon carbonic acid is invariably accompanied by the presence of a peculiar green-colouring matter—chlorophyll. In virtue of some direct or indirect action of this chlorophyll the protoplasm of the plant is enabled to seize the carbon of the mineral world—the carbon which has sunk to the lowest resting stage of combination—and to raise it into combination with hydrogen and oxygen and ultimately with nitrogen. There are plants which have no chlorophyll and are thus unable to feed upon carbonic acid. They are none the less plants since they agree closely with particular chlorophyll-bearing plants in details of form and structure, mode of growth and reproduction. A large series of these are termed Fungi. Though unable to feed on carbonic acid, they do not feed as do animals. They can take their carbon from acetates and tartrates, which animals cannot do, and their nitrogen from ammonia. Even when it is admitted that some of these colourless plants, such as the Bacteria (Schizomycetes), can act upon albumens so as to digest them and thus nourish themselves, it is not reasonable to place the Bacteria among animals, any more than it would be reasonable so to place Nepenthes, Sarracenia, and Drosera (insectivorous Phanerogams). For the structure and mode of growth of the Bacteria is like that of well-known chlorophylligerous minute Algæ from which they undoubtedly differ only in having secondarily acquired this peculiar mode of nutrition, distinct from that which has dominated and determined the typical structure of plants.

So we find in a less striking series of instances amongst animals that here and there the nutritional arrangements which we have no hesitation in affirming to be the leading characteristic of animals, and to have directly and perhaps solely determined the great structural features of the animal line of descent, are largely modified or even altogether revolutionized. The green Hydra, the freshwater Sponge, and some Planarian worms produce chlorophyll corpuscles in the protoplasm of their tissues just as green plants do, and are able in consequence to do what animals usually cannot do—namely, feed upon carbonic acid. The possibilities of the protoplasm of the plant and of the animal are, we are thus reminded, the same. The fact that characteristically and typically plant protoplasm exhibits one mode of activity and animal protoplasm another does not prevent the protoplasm of even a highly developed plant from asserting itself in the animal direction, or of a thoroughly characterized animal, such as the green Hydra, from putting forth its chlorophylligenous powers as though it belonged to a plant.

Hence it is not surprising that we find among the Protozoa, notwithstanding that they are characterized by the animal method of nutrition and their forms determined by the exigencies of that method, occasional instances of partial vegetable nutrition such as is implied by the development of chlorophyll in the protoplasm of a few members of the group. It would not be inconsistent with what is observed in other groups should we find that there are some unicellular organisms which must, on account of their structural resemblances to other organisms, be considered as Protozoa and yet have absolutely given up altogether the animal mode of nutrition (by the ingestion of solid albumens) and have acquired the vegetable mode of absorbing ammonia, nitrates, and carbonic acid. Experiment in this matter is extremely difficult, but such "vegetable" or "holophytic nutrition" appears to obtain in the case of many of the green Flagellata, of the Dinoflagellata, and possibly of other Protozoa.

On the other hand there is no doubt that we may fall into an error in including in the animal line of descent all unicellular organisms which nourish themselves by the inception of solid nutriment. It is conceivable that some of these are exceptional creophagous Protophytes parallel at a lower level of structure to the insectivorous Phanerogams. In all cases we have to balance the whole of the evidence and to consider probabilities as indicated by a widely-reaching consideration of numerous facts.

The mere automatic motility of unicellular organisms was at one time considered sufficient indication that such organisms were animals rather than plants. We now know that not only are the male reproductive cells of ferns and similar plants propelled by vibratile protoplasm, but such locomotive particles are recognized as common products ("swarm-spores" and "zoospores") of the lowest plants.

The danger of dogmatizing erroneously in distinguish-

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ing Protozoa from Protophyta, and the insuperable difficulty in really accomplishing the feat satisfactorily, has led at various times to the suggestion that the effort should be abandoned and a group constituted confessedly containing both unicellular plants and unicellular animals and those organisms which may be one or the other. Haeckel has proposed to call this group the Protista (1).[1] On the whole, it is more satisfactory to make the attempt to discriminate those unicellular forms which belong to the animal line of descent from those belonging to the vegetable line. It is, after all, not a matter of much consequence if the botanist should mistakenly claim a few Protozoa as plants and the zoologist a few Protophyta as animals. The evil which we have to avoid is that some small group of unattractive character should be rejected both by botanist and zoologist and thus our knowledge of it should unduly lag. Bearing this in mind the zoologist should accord recognition as Protozoa to as wide a range of unicellular organisms as he can without doing violence to his conceptions of probability.

A very interesting and very difficult subject of speculation forces itself on our attention when we attempt to draw the line between the lowest plants and the lowest animals, and even comes again before us when we pass in review the different forms of Protozoa.

That subject is the nature of the first protoplasm which was evolved from not-living matter on the earth's surface. Was that first protoplasm more like animal or more like vegetable protoplasm as we know it to-day? By what steps was it brought into existence?

Briefly stated the present writer's view is that the earliest protoplasm did not possess chlorophyll and therefore did not possess the power of feeding on carbonic acid. A conceivable state of things is that a vast amount of albuminoids and other such compounds had been brought into existence by those processes which culminated in the development of the first protoplasm, and it seems therefore likely enough that the first protoplasm fed upon these antecedent steps in its own evolution just as animals feed on organic compounds at the present day, more especially as the large creeping plasmodia of some Mycetozoa feed on vegetable refuse. It indeed seems not at all improbable that, apart from their elaborate fructification, the Mycetozoa represent more closely than any other living forms the original ancestors of the whole organic world. At subsequent stages in the history of this archaic living matter chlorophyll was evolved and the power of taking carbon from carbonic acid. The "green" plants were rendered possible by the evolution of chlorophyll, but through what ancestral forms they took origin or whether more than once, *i.e.*, by more than one branch, it is difficult even to guess. The green Flagellate Protozoa (Volvocineæ) certainly furnish a connecting point by which it is possible to link on the pedigree of green plants to the primitive protoplasm; it is noteworthy that they cannot be considered as very primitive and are indeed highly specialized forms as compared with the naked protoplasm of the Mycetozoon's plasmodium.

Thus then we are led to entertain the paradox that though the animal is dependent on the plant for its food yet the animal preceded the plant in evolution, and we look among the lower Protozoa and not among the lower Protophyta for the nearest representatives of that first protoplasm which was the result of a long and gradual evolution of chemical structure and the starting point of the development of organic form.

The Protozoon Cell-Individual compared with the Typical Cell of Animal and Vegetable Tissues.

MORPHOLOGY.

The Protozoon individual is a single corpuscle of protoplasm, varying in size when adult from less than the $\frac{1}{10000}$th of an inch in diameter (some Sporozoa and Flagellata) up to a diameter of an inch (Nummulites), and even much larger size in the plasmodia of Mycetozoa. The substance of the Protozoa exhibits the same general properties—irritability, movement, assimilation, growth, and division—and the same irremediable chemical alteration as the result of exposure to a moderate heat, which are observed in the protoplasm constituting the corpuscles known as cells which build up the tissues of the larger animals and plants. There is therefore no longer any occasion to make use of the word "sarcode" which before this identity was established was very usefully applied by Dujardin (2) to the substance which mainly forms the bodies of the Protozoa. Like the protoplasm which constitutes the "cells" of the Enterozoa and of the higher plants, that of the Protozoon body is capable of producing, by chemical processes which take place in its substance (over and above those related merely to its nutrition), a variety of distinct chemical compounds, which may form a deposit in or beyond the superficial protoplasm of the corpuscle or may accumulate centrally. These products are therefore either ectoplastic or entoplastic. The chemical capacities of protoplasm thus exhibited are very diverse, ranging from the production of a denser variety of protoplasm, probably as the result of dehydration, such as we see in the nucleus and in the cortical substance of many cells, to the chemical separation and deposition of membranes of pure chitin or of cellulose or of shells of pure calcium carbonate or quasi-crystalline needles of silica.

NUCLEUS.—The nucleus is probably universally present in the Protozoon cell, although it may have a very simple structure and be of very small size in some cases. The presence of a nucleus has recently been demonstrated by means of appropriate staining reagents in some Protozoa (shell-bearing Reticularia or Foraminifera and many Mycetozoa) where it had been supposed to be wanting, but we are not yet justified in concluding absolutely that there are not some few Protozoa in which this central differentiation of the protoplasm does not exist; it is also a fact that in the young forms of some Protozoa which result from the breaking up of the body of the parent into many small "spores" there is often no nucleus present.

In contrast to this it is the fact that the cells which build up the tissues of the Enterozoa are all derived from the division of a nucleated egg-cell and the repeated division of its *nucleated* products, and are invariably nucleated. The same is true of tissue-forming plants,—though there are a *few* of the lowest plants, such as the Bacteria, the protoplasm of which presents no nucleus. In spite of recent statements (3) it cannot be asserted that the cells or protoplasmic corpuscles of the yeast-plant (Saccharomyces) and of the hyphæ of many simple moulds contain a true nucleus. We are here brought to the question "What is a true nucleus?" The nucleus which is handed on from the egg-cell of higher plants and Enterozoa to the cells derived from it by fission has lately been shown to possess in a wide variety of instances such very striking characteristics that we may well question whether every more or less distinctly outlined mass or spherule of protoplasm which can be brought into view by colouring or other reagents, within the protoplasmic body of a Protozoon or a Protophyte, is necessarily to be considered as quite the same thing as the nucleus of tissue-forming egg-cell-derived cells.

Researches, chiefly due to Flemming (4), have shown that the nucleus in very many tissues of higher plants and animals consists of a capsule containing a plasma of "achromatin" not deeply stained by reagents, ramifying in which is a reticulum of "chromatin" consisting of fibres which readily take a deep stain (Fig. I., A). Further it is demonstrated that, when the cell is about to divide into two, definite and very remarkable movements take place in the nucleus, resulting in the disappearance of the capsule and in an arrangement of its fibres first in the form of a wreath (Fig. I., D) and subsequently (by the breaking of the loops formed by the fibres) in the form of a star (E). A further movement within the nucleus leads to an arrangement of the broken loops in two groups (F), the position of the open ends of the broken loops being reversed

[1] These numbers refer to the bibliography at p. 866.

as compared with what previously obtained. Now the two groups diverge, and in many cases a striated appearance of the achromatin substance between the two groups of loops of chromatin is observable (H). In some cases (especially egg-cells) this striated arrangement of the achromatin substance precedes the separation of the loops (G). The striated achromatin is then termed a "nucleus-spindle," and the group of chromatin loops (Fig. I., G, *a*)

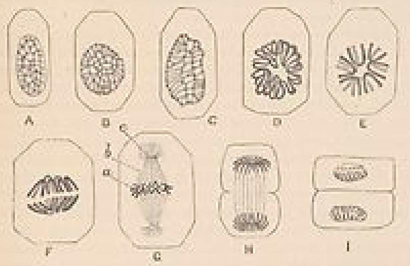

Fig. I.—Karyokinesis of a typical tissue-cell (epithelium of Salamander) after Flemming and Klein. The series from A to I represent the successive stages in the movements of the chromatin fibres during division, excepting G, which represents the "nucleus-spindle" of an egg-cell. A, resting nucleus; D, wreath-form; E, single star, the loops of the wreath being broken; F, separation of the star into two groups of U-shaped fibres; H, diaster or double star; I, completion of the cell-division and formation of two resting nuclei. In G the chromatin fibres are marked *a*, and correspond to the phase shown in F; they are in this case called the "equatorial plate"; *b*, achromatin fibres forming the nucleus-spindle; *c*, granules of the cell-protoplasm forming a "polar star." Such a polar star is seen at each end of the nucleus-spindle, and is not to be confused with the diaster H.

is known as "the equatorial plate." At each end of the nucleus-spindle in these cases there is often seen a star consisting of granules belonging to the general protoplasm of the cell (G, *c*). These are known as "polar stars." After the separation of the two sets of loops (H) the protoplasm of the general substance of the cell becomes constricted, and division occurs, so as to include a group of chromatin loops in each of the two fission products. Each of these then rearranges itself together with the associated achromatin into a nucleus such as was present in the mother-cell to commence with. This phenomenon is termed "karyokinesis," and has been observed, as stated above, in a large variety of cells constituting tissues in the higher animals and plants.

There is a tendency among histologists to assume that this process is carried out in all its details in the division of all cells in the higher plants and animals, and accordingly to assume that the structural differentiation of achromatin plasma and chromatin nucleus-fibres exists in the normal nucleus of every such cell. If this be true, it is necessary to note very distinctly that the nucleus of the Protozoon cell-individual by no means conforms universally to this model. As will be seen in the sequel, we find cases in which a close approach is made by the nucleus of Protozoa to this structure and to this definite series of movements during division (Fig. VIII. 3 to 12, and Fig. XXV.); and a knowledge of these phenomena has thrown light upon some appearances (conjugation of the Ciliata) which were previously misinterpreted. But there are Protozoa with a deeply-placed nucleus-like structure which does not present the typical structure above described nor the typical changes during division, but in which on the contrary the nucleus is a very simple homogeneous corpuscle or vesicle of more readily stainable protoplasm.

The difficulties of observation in this matter are great, and it is proportionately rash to generalize; but it appears that we are justified at the present moment in asserting that not all the cells even of higher plants and animals exhibit in full detail the structure and movement of the typical cell-nucleus above figured and described; and accordingly the fact that such structure and movement cannot always be detected in the Protozoon cell-nucleus must not be regarded as either an isolated phenomenon peculiar to such Protozoon cells, nor must it be concluded that we have only to improve our means of analysis and observation in order to detect this particular structure in all nuclei. It seems quite possible and even probable that nuclei may vary in these details and yet be true nuclei. Some nuclei which are observed in Protozoon cell-bodies may be regarded as being at a lower stage of differentiation and specialization than are those of the epithelial and embryonic cells of higher animals which exhibit typical karyokinesis. Others on the contrary, such as the nuclei of some Radiolaria (*vide infra*), are probably to be regarded as more highly developed than any tissue cell-nuclei, and will be found by further study to present special phenomena peculiar to themselves. In some of the highest Protozoa (the Ciliata) it has lately been shown that the nucleus may have no existence as such, but is actually dispersed throughout the protoplasm in the form of fine particles of chromatin-substance which stain on treatment with carmine but are in life invisible (84). This diffuse condition of the nuclear matter has no parallel, at present known, in tissue-cells, and curiously enough occurs in certain genera of Ciliata whilst in others closely allied to them a solid single nucleus is found. The new results of histological research have necessitated a careful study of the nucleus in its various stages of growth and division in the cell-bodies of Protozoa and a comparison of the features there observed with those established as "typical" in tissue-cells. Accordingly we have placed the figure and explanation of the typical cell-nucleus in the first place in this article for subsequent reference and comparison.

Cortical Substance.—The superficial protoplasm of an embryonic cell of an Enterozoon in the course of its development into a muscular cell undergoes a change which is paralleled in many Protozoa. The cortical layer becomes dense and highly refringent as compared with the more liquid and granular medullary substance. Probably this is essentially a change in the degree of hydration of the protoplasm itself, although it may be accompanied by the deposition of metamorphic products of the protoplasm which are not chemically to be regarded as protoplasm. The differentiation of this cortical substance (which is not a frequent or striking phenomenon in tissue-cells) may be regarded as an ectoplastic (*i.e.*, peripheral) modification of the protoplasm, comparable to the entoplastic (central) modification which produces a nucleus.

The formation of "cortical substance" in the Protozoa furnishes the basis for the most important division into lower and higher forms, in this assemblage of simplest animals. A large number (the Gymnomyxa) form no cortical substance; their protoplasm is practically (excepting the nucleus) of the same character throughout. A nearly equally large number (the Corticata) develop a complete cortical layer of denser protoplasm, which is distinct from the deeper medullary protoplasm. This layer is permanent, and gives to the body a definite shape and entails physiological consequences of great moment. The cortical protoplasm may exhibit further specialization of structure in connexion with contractile functions (muscular).

Ectoplastic Products chemically distinct from Protoplasm.—The protoplasm of all cells may throw down as a molecular precipitate distinct from itself chemical compounds, such as chitin and horny matter and other nitrogenized bodies, or again non-nitrogenous compounds, such as cellulose. Very usually these substances are deposited not external to but *in* the superficial protoplasm. They are then spoken of as cell-cuticle if the cell bounds the free surface of a tissue, or as matrix or cell-wall in other cases. The Protozoon cell-body frequently forms such "cuticles," sometimes of the most delicate and evanescent character (as in some Amœbæ), at other times thicker and more permanent. They may give indications (though proper chemical examination is difficult) of being allied in composition to chitin or gelatin, in other instances to cellulose, which is rare in animals and usual in plants. These cuticular deposits may be absent, or may form thin envelopes or in other cases jelly-like substance intimately mixed with the protoplasm (Radiolaria). They may take the form of hooks, tubercles, or long spines, in their older and more peripheral parts free from permeation by protoplasm, though deeply formed in and interpenetrated by it. Such pellicles and cuticles, the deeper layers (if not the whole) of which are permeated by protoplasm, lead insensibly to another category of ectoplastic products in which the material produced by the protoplasm is separated from it and can be detached from or deserted by the protoplasm without any rupture of the latter. These are—

Shells and Cysts.—Such separable investments are formed by the cell-bodies of many Protozoa, a phenomenon not exhibited by tissue-cells. Even the cell-walls of the protoplasmic corpuscles of plant tissues are permeated by that protoplasm, and could not be stripped off without rupture of the protoplasm. The shell and the cyst of the Protozoon are, on the contrary, quite free from the cell-protoplasm. The shell may be of soft chitin-like substance (Gromia, &c.), of cellulose (Labyrinthula, Dinoflagellata), of calcium carbonate (Globigerina, &c.), or of silica (Clathrulina, Codonella). The term "cyst" is applied to completely closed investments ("shells" having one or more apertures), which are temporarily produced either as a protection against adverse external conditions or during the breaking up of the parent-cell into spores. Such cysts are usually horny.

Stalks.—By a localization of the products of ectoplastic activity the Protozoon cell can produce a fibre or stalk of ever-increasing length, comparable to the seta of a Chætopod worm produced on the surface of a single cell.

ENTOPLASTIC PRODUCTS DISTINCT FROM PROTOPLASM.—Without pausing here to discuss the nature of the finest granules which are embedded as a dust-cloud in the hyaline matrix of the purest protoplasm alike of Protozoa and of the cells of higher animals and plants, and leaving aside the discussion of the generalization that all protoplasm presents a reticular structure, denser trabeculæ of extreme minuteness traversing more liquid material, it is intended here merely to point to some of the coarser features of structure and chemical differentiation, characteristic of the cell-body of Protozoa.

With regard to the ultimate reticular structure of protoplasm it will suffice to state that such structure has been shown to obtain in not a few instances (*e.g.*, Lithamœba, Fig. V.), whilst in most Protozoa the methods of microscopy at present applied have not yielded evidence of it, although it is not improbable that a recticular differentiation of the general protoplasm similar to that of the nucleus may be found to exist in all cells.

Most vegetable cells and many cells of animal tissues exhibit vacuolation of the protoplasm; *i.e.*, large spaces are present in the protoplasm occupied by a liquid which is not protoplasm and is little more than water with diffusible salts in solution. Such vacuoles are common in Protozoa. They are either permanent, gastric, or contractile.

Permanent vacuoles containing a watery fluid are sometimes so abundant as to give the protoplasm a "bubbly" structure (Thalamophora, Radiolaria, &c.), or may merely give to it a trabecular character (Trachelius, Fig. XXIV. 14, and Noctiluca, Fig. XXVI. 18). Such vacuoles may contain other matters than water, namely, special chemical secretions of the protoplasm. Of this nature are oil-drops, and from these we are led to those deposits within the cell-protoplasm which are of solid consistence (see below).

Gastric vacuoles occur in the protoplasm of most Protozoa in consequence of the taking in of a certain quantity of water with each solid particle of food, such ingestion of solid food-particles being a characteristic process bound up with their animal nature.

Contractile vacuoles are frequently but not universally observed in the protoplasm of Protozoa. They are not observed in the protoplasm of tissue-cells. The contractile vacuole whilst under observation may be seen to burst, breaking the surface of the Protozoon and discharging its liquid contents to the exterior; its walls, formed of undifferentiated protoplasm, then collapse and fuse. After a short interval it re-forms by slow accumulation of liquid at the same or a neighbouring spot in the protoplasm. The liquid is separated at this point by an active process taking place in the protoplasm which probably is of an excretory nature, the separated water carrying with it nitrogenous waste-products. A similar active formation of vacuoles containing fluid is observed in a few instances (Arcella, some Amœbæ) where the protoplasm separates a gas instead of liquid, and the gas vacuole so produced appears to serve a hydrostatic function.

Corpuscular and Amorphous Entoplastic Solids.—Concretions of undetermined nature are occasionally formed within the protoplasm of Protozoon cells, as are starch and nitrogenized concretions in tissue-cells (Lithamœba, Fig. V. *conc.*). But the most important corpuscular products after the nucleus, which we have already discussed, are chlorophyll corpuscles. These are (as in plants) concavo-convex or spherical corpuscles of dense protoplasm resembling that of the nucleus, which are impregnated superficially with the green-coloured substance known as chlorophyll. They multiply by fission, usually tetraschistic, independently of the general protoplasm. They occur in representatives of many different groups of Protozoa (Proteomyxa, Heliozoa, Labyrinthulidea, Flagellata, Ciliata), but are confined to a few species. Similar corpuscles or band-like structures coloured by other pigments are occasionally met with (Dinoflagellata).

Recently it has been maintained (Brandt, 5) that the chlorophyll corpuscles of Protozoa and other animals are parasitic Algæ. But, though it is true that parasitic Algæ occur in animal tissues, and that probably this is the nature of the yellow cells of Radiolaria, yet there seems to be no more justification for regarding the chlorophyll corpuscles of animal tissue-cells and of Protozoa as parasites than there is for so regarding the chlorophyll corpuscles of the leaves of an ordinary green plant.

Corpuscles of starch, paramylum, and other amyloïd substances are commonly formed in the Flagellata, whose nutrition is to a large extent plant-like.

Entoplastic Fibres.—A fibrillation of the protoplasm of the Protozoon cell-body may be produced by differentiation of less and more dense tracts of the protoplasm itself. But as distinct from this we find horny fibres occasionally produced within the protoplasm (Heliozoa) having definite skeletal functions. The threads produced in little cavities in the superficial protoplasm of many Ciliate Protozoa, known as trichocysts, may be mentioned here.

Entoplastic Spicules.—Needle-like bodies consisting either of silica or of a horny substance (acanthin) are produced in the protoplasm of many Protozoa (Heliozoa, Radiolaria). These are known as spicules; they may be free or held together in groups and arranged either radially or tangentially in reference to the more or less spherical body of the Protozoon. A similar production of siliceous spicules is observed in the tissue-cells of Sponges. Crystals of various chemical nature (silica, calcium carbonate, oxalate, &c.) are also frequently deposited in the protoplasm of the Protozoa, differing essentially from spicules in that their shape is due purely to crystallization.

General Form of the Protozoon Cell.—Those Protozoa which have not a differentiated cortical substance, and are known as Gymnomyxa, present very generally an extreme irregularity of contour. Their protoplasm, being liquid rather than viscous, flows into the most irregular shapes. Their fundamental form when at rest is in many cases that of the sphere; others are discoidal or may be monaxial, that is to say, show a differentiation of one region or "end" of the body from the other. Frequently the protoplasm is drawn out into long threads or filaments which radiate uniformly from all parts of the spherical or discoidal cell-body or originate from one region to the exclusion of other parts of the surface.

These non-corticate Protozoa can take solid particles of food into their protoplasm, there to be digested in an extemporized "gastric vacuole," at any part or most parts of their superficies. They have no permanent cell-mouth leading into the soft protoplasm since that soft protoplasm is everywhere freely exposed.

The corticate Protozoa have (with the exception of some parasites) one, and in the Acinetaria more than one, definite aperture in the cortical substance leading into the softer medullary protoplasm. This is the cell-mouth,—morphologically as distinct from the mouth of an Enterozoon as is the hole in a drain pipe from the front door of a house, but physiologically subserving the same distinctively animal function as does the mouth of multicellular animals. The general form of the body is in these Protozoa oblong, with either monaxial symmetry, when the mouth is terminal, or bilateral symmetry, when the body is oblong and flattened and the mouth is towards one end of what becomes by its presence the "ventral" surface. Though the protoplasm is not nakedly exposed in irregular lobes and long filaments in these corticate Protozoa so as to pick up at all points such food-particles as may fall in its way, yet the protoplasm does in most Corticata project in one or more peculiarly modified fine hair-like processes from the otherwise smooth surface of the cell-body. These processes are *vibratile cilia*, identical in character with the vibratile cilia of epithelial tissue-cells of Enterozoa. They are essentially locomotor and current-producing (therefore prehensile) organs, and, whilst unable to ingest solid food-particles themselves, serve to propel the organism in search of food and to bring food into the cell-mouth by the currents which they excite. Either a single vibratile filament is present, when it is called a flagellum, or a row or many rows of cilia are developed.

Constituent cells of the Enterozoa are well known which closely resemble some of the Gymnomyxa or non-corticate Protozoa in their general form. These are the colourless blood corpuscles or lymph corpuscles or phagocytes (Mecznikow, 6) which float freely in the blood and ingest solid particles at any part of their surface as do non-corticated Protozoa; they exhibit a similar irregularity and mutability of outline, and actually digest the particles which they take in. The endodermal digestive cells of some Enterozoa (Cœlentera and Planarians) are also naked protoplasmic corpuscles and can take in solid food-particles.

No tissue-cells are known which present any close parallel to the mouth-bearing corticate Protozoa. The differentiation of the structure of a single cell has in these forms reached a very high degree, which it is not surprising to find without parallel among the units which build up the individual of a higher order known as an Enterozoon. Cilia are developed on such cell-units (ciliated epithelium), but not used for the introduction of food-particles into the cell. In rare cases (the ciliated "pots" of the vascular fluid of Sipunculus) they act so as to freely propel the ciliated cell through the liquid "blood" of the Enterozoon, as the cilia of a Protozoon propel it through water. An aperture in the cortical substance (or in the cuticular product) of a tissue-cell is sometimes to be observed, but is never (?) used for the ingestion of food-particles. Such an aperture occurs in unicellular glands, where it serves as the outlet of the secretion.

Physiology.

Motion.—As has just been hinted, the movement of protoplasm, which in the tissue-cells of Enterozoa and higher plants is combined and directed so as to produce effects in relation to the whole organism built up of countless cells, is seen in the Protozoa in a different relation, namely, as subserving the needs of the individual cell of which the moving protoplasm is the main substance. The phenomena known in tissue-cells as "streaming" (*e.g.*, in the cells of the hairs of Tradescantia), as local contraction and change of form (*e.g.*, in the corpuscles of the cornea), as muscular contraction, and as ciliary movement are all exhibited by the protoplasm of the cell-body of Protozoa, with more or less constancy, and are intimately related to the processes of hunting, seizing, and ingesting food, and of the intercourse of the individuals of a species with one another and their evasion of hostile agencies. Granule streaming and the implied movement of currents in the protoplasm are seen in the filamentous protoplasm of the Heliozoa, Radiolaria, Reticularia, and Noctiluca, and in the cyclosis of the gastric vacuoles of Ciliata. Local contraction and change of form is seen best in the Amœbæ and some Flagellata, where it results in locomotion. Definite muscular contraction is exhibited by the protoplasmic band in the stalk of Vorticella, by the leg-like processes of the Hypotrichous Ciliata, and by the cortical substance of some large Ciliata. Ciliary movement ranging from the vibration of filaments of protoplasm temporarily evolved, up to the rhythmic beat of groups of specialized cilia, is observed in all groups of Protozoa in the young condition if not in the adult, and special varieties of ciliary movement and of cilia-like organs will be noted below. For an account of the conditions and character of protoplasmic movement generally which cannot be discussed in the present article the reader is referred to Engelmann (7).

The protoplasm of the cell-body of the Protozoa is drawn out into lobes and threads which are motile and are used as locomotive and prehensile organs. These processes are of two kinds, which are not present on the same cell and are not capable of transmutation, though there are exceptions to both of these statements. The one kind are termed "pseudopodia," and are either lobose or filamentous or branched and even reticular (Figs. IV. and IX.). The Protozoa which exhibit them are sometimes termed Myxopods. The other kind are cilia and flagella, and are simple threads which are alternately bent and straightened almost incessantly during the life of the organism. These Protozoa are termed Mastigopods. Whilst the cilia and flagella are permanent organs, the pseudopodia vary greatly in character; they are in some cases rapidly expanded and withdrawn in irregular form, and can hardly be said to be more than lobose protuberances of the flowing moving mass of protoplasm. In other cases they are comparatively permanent stiff threads of protoplasm which can be contracted and can fuse with one another but rarely do so (Heliozoa, Radiolaria). Between these extreme forms of "pseudopodia" there are numerous intermediate varieties, and the whole protoplasmic body of the Protozoon may even assume the form of a slowly changing network of threads of greater or less tenuity (Chlamydomyxa, Fig. VI.).

Nutrition.—Typically—that is to say, by determinate hereditary tendency—the Protozoa take solid food-particles into their protoplasm which form and occupy with the water surrounding them "gastric vacuoles" in the protoplasm. The food-particle is digested in this vacuole, by what chemical processes is not ascertained. It has been shown that the contents of the gastric vacuole give in some cases an acid reaction, and it is not improbable that free acid is secreted by the surrounding protoplasm. It is not known whether any ferment[1] is separated by the protoplasm, but it is probable from observations made on the digestive process of Cœlentera (Actiniæ) that the ferment is not separated, but that actual contact of the food-particle with the protoplasm is necessary for a "ferment influence" to be exerted. The digestion of a food-particle by a Protozoon is intra-cellular, and has been contrasted with the cavitary digestion of higher animals. In the latter, ferments and acids are poured out by the cells bounding the enteric cavity into that space, and digestion is extra-cellular. In the lowest Enterozoa (many Cœlentera and some Planarian worms) it has been shown that food-particles are actually taken up in a solid state by the soft protoplasm of the enteric cells and thus subjected to intra-cellular digestion. There appears to be a gradual transition from this process, in which close contact with living protoplasm is necessary that the solution of an albuminous food-particle may be effected, onwards to the perfectly free cavitary digestion by means of secretions accumulated in the enteron.

We have not yet any satisfactory observations on the chemistry of intra-cellular digestion either of Protozoa or of Cœlentera.

Certain Protozoa which are parasitic do not take solid food particles; they (like higher parasites, such as the Tapeworms) live in the nutritious juices of other animals and absorb these by their general surface in a liquid state. The Gregarinæ (Sporozoa), many Ciliata, &c., are in this case. Other Protozoa are known which are provided with chlorophyll corpuscles and do not take in solid food, but, apparently as a result of exceptional adaptation in which they differ from closely-allied forms, nourish themselves as do green plants. Such are the Volvocinean Flagellata and some of the Dinoflagellata. It has also been asserted that other Protozoa (viz., some Ciliata)—even some which possess a well-developed mouth—can (and experimentally have been made to) nourish themselves on nitrogenous compounds of a lower grade than albumens—such, for instance, as ammonium tartrate. Any such assertions must be viewed with the keenest scepticism, since experimental demonstration of the absence of minute albuminous particles (*e.g.*, Bacteria) from a solution of ammonium tartrate in which Ciliate Protozoa are flourishing is a matter of extreme difficulty and has not yet been effected.

Undigested food-remnants are expelled by the protoplasm of the Protozoon cell either at any point of the surface or by the cell-mouth or by a special cell-anus (some Ciliata, see Fig. XXIV. 22).

Respiration and Excretion.—The protoplasm of the Protozoa respires, that is, takes up oxygen and liberates carbonic acid, and can readily be shown experimentally to require a supply of oxygen for the manifestation of its activity. No special respiratory structures are developed in any Protozoa, and as a rule also the products of oxidation appear to be washed out and removed from the protoplasm without the existence of any special apparatus. The contractile vacuole which exists in so many Protozoa appears, however, to be an excretory organ. It has been shown to rapidly excrete in a state of solution colouring matters (anilin blue) which have been administered with food particles (**8**). No evidence has been adduced to show whether traces of nitrogenous waste-products are present in the water expelled by the contractile vacuole.

Chemical Metamorphosis.—The form which the various products of the activity of the Protozoon's protoplasm may assume has been noted above. It will be sufficient here to point out that the range of chemical capacities is quite as great as in the cells of the higher Enterozoa. Chitin, cellulose, silicon, calcium carbonate, fats, pigments, and gases can be both deposited and absorbed by it. Owing to the minuteness of the Protozoa, we are at present unable to recognize and do justice to the variety of chemical bodies which undoubtedly must play a part in their economy as the result of the manufacturing activity of their protoplasm. See, however, Zopf (**13**), p. 71.

Growth and Reproduction.—The Protozoon cell follows the same course as tissue-cells, in that by assimilation of nutriment its protoplasm increases in volume and reaches a certain bulk, when its cohesion fails and the viscid droplet divides into two. The coefficient of cohesion varies in different genera and species, but sooner or later the disrupting forces lead to division, and thus to multiplication of individuals or reproduction. The phenomena connected with the division of the nucleus (already alluded to) will be noticed in particular cases below.

Whilst simple binary division is almost without exception a chief method of reproduction among the Protozoa, it is also very usual, and probably this would be found if our knowledge were complete to have few exceptions, that under given conditions the Protozoon breaks up rapidly into many (from ten to a hundred or more) little pieces, each of which leads an independent life and grows to the form and size of its parent. It will then multiply by binary division, some of the products of which division will in their turn divide into small fragments. The small fragments are called "spores." Usually the Protozoon before breaking up into spores forms a "cyst" (see above) around itself. Frequently, but not as a necessary rule, two (rarely three or more) Protozoon cell-individuals come together and fuse into one mass before breaking up into spores. This process is known as "conjugation;" and there can be no doubt that the physiological significance of the process is similar to that of sexual fertilization, namely, that the new spores are not merely fragments of an old individual but are something totally new inasmuch as they consist of a combination of the substance of individuals who have had different life experiences.

Whilst spore-formation is not necessarily preceded by conjugation, conjugation is not necessarily followed by spore-formation. Among the Mycetozoa the young individuals produced from spores conjugate at a very early period of growth in numbers and form "plasmodia," and after a considerable interval of feeding and growth the formation of spores takes place. Still more remarkable is the fact observed among the Ciliata where two individuals conjugate and after a brief fusion and mixture of their respective protoplasm separate, neither individual (as far as certain genera at least are concerned) breaking up into spores, but simply resuming the process of growth and recurrent binary division with increased vigour.

There is certainly no marked line to be drawn between reproduction by simple fission and reproduction by spore-formation; both are a more or less complete dividing of the parent protoplasm into separate masses; whether the products of the first fission are allowed to nourish themselves and grow before further fission is carried out or not

[1] The digestive ferment pepsin has been detected by Krukenberg in the plasmodium of the Mycetozoon Fuligo (flowers of tan). See on this subject Zopf (13), p. 88.

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does not constitute an essential difference. The fission of the Ciliate Protozoon, Opalina (see below Fig. XXIV. 4–8), is a step from the ordinary process of delayed binary division towards spore-formation. In some Protozoa spores are produced after encystation by a perfectly regular process of cleavage (comparable to the cleavage of the egg-cell of Enterozoa)—first two, then four, then eight, sixteen, and thirty-two fission products being the result (see Fig. XX. 24, 25, &c.).

But more usually there is a hastening of the process, and in these cases it is by no means clear what part the parent cell-nucleus takes. An encysted Gregarina (or two conjugated Gregarinæ) suddenly breaks up into a number of equal-sized spores, which do not increase in number by binary division and have not been formed by any such process. This multicentral segregation of the parent protoplasm is a marked development of the phenomenon of sporulation and remote from ordinary cell-division. How it is related to ordinary cell-division is not known, inasmuch as the changes undergone by the nucleus in this rapid multicentral segregation of the parent protoplasm have not been determined. The spores of Protozoa may be naked or encased singly or in groups in little envelopes, usually of a firm horny substance (see Fig. XX. 23 to 26, and Fig. XXIV. 15 to 18). Whenever the whole or a part of a Protozoon cell divides rapidly into a number of equal-sized pieces which are simultaneously set free and are destined to reproduce the adult form, the term spore is applied to such pieces, but the details of their formation may vary and also those of their subsequent history. In typical cases each spore produced as the result of the fission of an encysted Protozoon (conjugated or single) has its own protective envelope, as in the Mycetozoa (Fig. III.) and the Sporozoa (Fig. XVIII.), from which the contained protoplasm escapes by "germination" as a naked corpuscle either flagellate or amœbiform. In some terminologies the word "spore" is limited to such a "coated" spore, but usually the naked protoplasmic particles which issue from such "coated" spores, or are formed directly by the rapid fission of the parent Protozoon, are also called "spores." The former condition is distinguished as a "chlamydospore," whilst the latter are termed "gymnospores." Many Protozoa produce gymnospores directly by the breaking up of their protoplasm, and these are either "flagellulæ" (swarm-spores) or "amœbulæ" (creeping spores). The production of coated spores is more usual among the lower plants than it is among Protozoa, but is nevertheless a characteristic feature of the Gregarinæ (Sporozoa) and of the Mycetozoa. The term "gemma" or "bud-spore" is applied to cases, few in number, where (as in Acinetaria, Fig. XXVI., Spirochona, Fig. XXIII. 10, and Reticularia, Fig. X. 8) the spores are gradually nipped off from the parent-cell one or more at a time. This process differs from ordinary cell-division only in the facts (1) that the products of division are of unequal size—the parent-cell being distinguishable as the larger and more complete in structure, and (2) that usually the division is not binary, but more than one bud-spore is produced at a time.

Whilst in the binary cell-division of the Protozoa the two products are usually complete in structure at the period of separation, spores and spore-buds are not only of small size and therefore subject to growth before attaining the likeness of the parent, but they are also very often of simple and incomplete structure. The gap in this respect between the young spore and its parent necessarily varies according to the complexity of the parental form.

In the case of the Radiolaria, of the Gregarinæ, of Noctiluca, and of the Acinetaria, for instance, the spore has before it a considerable process of development in structure and not merely of growth, before attaining the adult characters. Hence there is a possible embryology of the Protozoa, to the study of which the same principles are applicable as are recognized in the study of the embryology of Enterozoa. Embryonic forms of great simplicity of structure, often devoid of nucleus, and consisting of simple elongate particles of protoplasm, are hatched from the spore-cases of the Gregarinæ (Fig. XVII. 13, 14) These gradually acquire a differentiated cortical protoplasm and a nucleus. A very large number of Gymnomyxa produce spores which are termed "monadiform," that is, have a single or sometimes two filaments of vibratile protoplasm extended from their otherwise structureless bodies. By the lashing of these flagella the spores (swarm-spores or zoospores) are propelled through the water. The resemblance of these monadiform young (best called "flagellulæ") to the adult forms known as Flagellata has led to the suggestion that we have in them a case of recapitulative development, and that the ancestors of the Gymnomyxa were Protozoa similar to the Flagellata. Again the Acinetaria produce spores which are uniformly clothed with numerous vibratile cilia (Fig. XXVI.), although the adults are entirely devoid of such structures; this is accounted for by the supposition that the Acinetaria have been developed from ancestors like the Ciliata, whose characters are thus perpetuated in their embryonic stages. There can be little doubt that these embryological suggestions are on the whole justified, and that the nucleated Protozoa are the descendants of non-nucleated forms similar to the spores of Gymnomyxa and Sporozoa, whilst it seems also extremely probable that the ancestral Protozoa were neither exclusively amœboid in the movement of their protoplasm nor provided with permanent vibratile filaments (flagella and cilia); they were neither Myxopods nor Mastigopods (to use the terms which have been introduced to express this difference in the character of the locomotor processes), but the same individuals were capable of throwing out their protoplasm sometimes in the form of flowing lobes and networks, sometimes in the form of vibratile flagella. A few such undifferentiated forms exist at the present day among the Proteomyxa and in a little more advanced condition among the lowest Flagellata, *e.g.*, Ciliophrys.

Death.—It results from the constitution of the Protozoon body as a single cell and its method of multiplication by fission that death has no place as a natural recurrent phenomenon among these organisms. Among the Enterozoa certain cells are separated from the rest of the constituent units of the body as egg-cells and sperm-cells; these conjugate and continue to live, whilst the remaining cells, the mere carriers as it were of the immortal reproductive cells, die and disintegrate. There being no carrying cells which surround, feed, and nurse the reproductive cells of Protozoa, but the reproductive cell being itself and alone the individual Protozoon, there is nothing to die, nothing to be cast off by the reproductive cell when entering on a new career of fission. The bodies of the higher animals which die may from this point of view be regarded as something temporary and non-essential, destined merely to carry for a time, to nurse, and to nourish the more important and deathless fission-products of the unicellular egg. Some of these fission-products of the new individual developed from an egg-cell—namely, the egg-cells and sperm-cells—are as immortal as the unicellular Protozoon. This method of comparing the unicellular and the multicellular organism is exceedingly suggestive, and the conception we thus gain of the individuality of the Enterozoon throws light upon the phenomena of reproduction and heredity in those higher organisms.

Experiment and observation in this matter are extremely difficult; but we have no reason to suppose that there is any inherent limit to the process of nutrition, growth, and fission, by which continuously the Protozoa are propagated. The act of conjugation from time to time confers upon the protoplasm of a given line of descent new properties, and apparently new vigour. Where it is not followed by a breaking up of the conjugated cells into spores, but by separation and renewed binary fission (Ciliata), the result is described simply as "rejuvenescence." The protoplasm originated by the successive division of substance traceable to one parent cell has become specialized, and in fact too closely adapted to one series of life-conditions; a fusion of substance with another mass of protoplasm equally specialized, but by experience of a somewhat differing character, imparts to the resulting mixture a new combination of properties, and the conjugated individuals on separation start once more on their deathless career with renewed youth.

CLASSIFICATION OF THE PROTOZOA.

In attempting a scheme of classification it would be most in accordance with the accepted probabilities of the ancestral history of the Protozoa to separate altogether those forms devoid of a nucleus from those which possess one, and to regard them as a lower "grade" of evolution or differentiation of structure.

By some systematists, notably Bütschli (9), the presence or absence of a nucleus has not been admitted as a basis of classificatory distinction, whilst on the other hand both Haeckel (1) and Huxley (10) have insisted on its importance.

The fact is that during recent years many of those Protozoa which were at one time supposed to be devoid of nucleus even in a rudimentary form, and furnished therefore the tangible basis for a lowest group of "Protozoa Homogenea" or "Monera," have been shown by the application of improved methods of microscopic investigation to possess a nucleus, that is to say, a differentiated corpuscle of denser protoplasm lying within the general protoplasm, and capable when the organism is killed by alcohol or weak acids of taking up the colour of various dyes (such as carmine and hæmatoxylin) more readily and permanently than is the general protoplasm. In such cases the nucleus may be very small and exhibit none of the typical structure of larger nuclei. It is usually surrounded by a clear (*i.e.*, non-granular) halo of the general protoplasm which assists the observer in its detection. Nuclei have been discovered in many Reticularia (Foraminifera), a group in which they were supposed to be wanting, by Schultze (11) and the Hertwigs (12) and more recently in the Mycetozoa and in Vampyrella and Protomonas (Zopf, 13), where so excellent an observer as Cienkowski had missed them.

It seems therefore not improbable that a nucleus is present though not observed in Protomyxa, Myxastrum, and other similar forms which have been by Haeckel and others classed as "Monera" or "Homogenea." The recently described (14) Archerina (Fig. II. 8, 11) certainly possesses no nucleus in the usual sense of that term, but it is possible that the chlorophyll-coloured corpuscles of that organism should be considered as actually representing the nucleus. Whilst then refraining from asserting that there are no existing Protozoa devoid of nucleus corresponding in this character with non-nucleate Protophyta, such as the Bacteria, we shall not in our scheme of classification institute a group of Homogenea, but shall leave the taking of that step until it has been shown after critical examination that those forms now regarded by some observers as Homogenea are really so. In the meantime these forms will find their places alongside of the Nucleata most nearly allied to them in other characters.

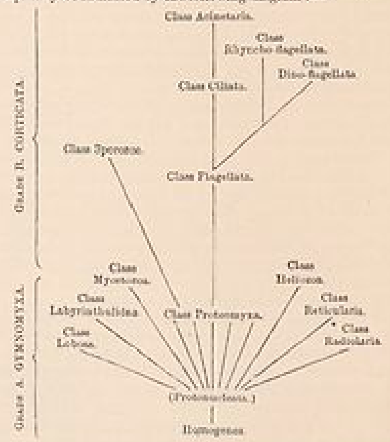
The Protozoa with a definite permanent cortical substance of differentiated protoplasm are undoubtedly to be regarded as evolved from forms devoid of such differentiation of their substance, and we accordingly take this feature as the indication of a primary division of the Protozoa.[1] The lower grade, the Gymnomyxa, afford in other respects evidence of their being nearly related to the ancestral forms from which the Corticata (the higher grade) have developed. The Gymnomyxa all or nearly all, whilst exhibiting amœboid movement and the flowing of their protoplasm into "pseudopodia" of very varied shapes, produce spores which swim by means of one or two flagella of vibratile protoplasm (monadiform young or flagellulæ). These flagellate young forms are closely related to the Flagellata, a group of the Corticata from which it seems probable that the Dinoflagellata, the Ciliata, and the Acinetaria have been derived. The Gymnomyxa themselves cannot, on account of the small number of structural features which they offer as indications of affinity and divergence in genetic relationships *inter se*, be classified with anything like confidence in a genealogical system. We are obliged frankly to abandon the attempt to associate some of the simpler forms with their nearest genetic allies and to content ourselves with a more or less artificial system, which is not, however, artificial in so far as its main groups are concerned. Thus the genetic solidarity of each of the large classes Heliozoa, Reticularia, Mycetozoa, and Radiolaria is not open to question. The Lobosa on the other hand appear to be a more artificial assemblage, and it is difficult to say that genetically there is any wide separation between them and the Mycetozoa or between the Mycetozoa and some of the simpler forms which we bring together under the class Proteomyxa.

The scheme of classification which we adopt is the following:—

PROTOZOA.

Sections.	GRADE A. *GYMNOMYXA.*
Proteana.	Class I. PROTEOMYXA.
	Ex. *Vampyrella*, *Protomyxa*, *Archerina*.
Plasmodiata.	Class II. MYCETOZOA.
	Ex. The *Eu-mycetozoa* of Zopf.
Lobosa.	Class III. LOBOSA.
	Ex. *Amœba*, *Arcella*, *Pelomyxa*.
Filosa.	Class IV. LABYRINTHULIDEA.
	Ex. *Labyrinthula*, *Chlamydomyxa*.
	Class V. HELIOZOA.
	Ex. *Actinophrys*, *Raphidiophrys*, *Clathrulina*.
	Class VI. RETICULARIA.
	Ex. *Gromia*, *Lituola*, *Astrorhiza*, *Globigerina*.
	Class VII. RADIOLARIA.
	Ex. *Thalassicolla*, *Eucyrtidium*, *Acanthometra*.
	GRADE B. *CORTICATA.*
Lipostoma.	Class I. SPOROZOA.
	Ex. *Gregarina*, *Coccidium*.
Stomatophora.	Class II. FLAGELLATA.
	Ex. *Monas*, *Salpingœca*, *Euglena*, *Volvox*.
	Class III. DINOFLAGELLATA.
	Ex. *Prorocentrum*, *Ceratium*.
	Class IV. RHYNCHOFLAGELLATA.
	Ex. *Noctiluca*.
	Class V. CILIATA.
	Ex. *Vorticella*, *Paramœcium*, *Stentor*.
	Class VI. ACINETARIA.
	Ex. *Acineta*, *Dendrosoma*.

The genetic relationships which probably obtain among these groups may be indicated by the following diagram:—



Literature.—Certain works of an older date dealing with microscopic organisms, and therefore including many Protozoa, have historical interest. Among these we may cite O. F. Müller, *Animalcula Infusoria*, 1786; Ehrenberg, *Infusionsthierchen*, 1838;

[1] The "exoplasm" and "endoplasm" described in Amœba, &c., by some authors are not distinct layers but one and the same continuous substance—what was internal at one moment becoming external at another, no really structural difference existing between them.

Dujardin, *Histoire naturelle des Infusoires*, 1841; Pritchard, *Infusoria*, 1857.

The general questions relating to protoplasm and to the constitution of the Protozoon body as a single cell are dealt with in the following more recent treatises:—Max Schultze, *Ueber den Organismus der Polythalamien*, 1854, and *Ueber das Protoplasma der Rhizopoden und Pflanzenzellen*, 1863; and Engelmann, article "Protoplasma" in Hermann's *Handwörterbuch der Physiologie*, 1880.

Special works of recent date in which the whole or large groups of Protozoa are dealt with in a systematic manner with illustrations of the chief known forms are the following:—Bütschli, "Protozoa," in Bronn's *Classen und Ordnungen des Thierreichs*, a comprehensive and richly illustrated treatise now in course of publication, forming the most exhaustive account of the subject matter of the present article which has been attempted (the writer desires to express his obligation to this work, from the plates of which a large proportion of the woodcut figures here introduced have been selected); W. S. Kent, *Manual of the Infusoria*, 1882—an exhaustive treatise including figures and descriptions of all species of Flagellata, Dinoflagellata, Ciliata, and Acinetaria; Stein, *Der Organismus der Infusionsthiere*, 1867–1882; Haeckel, *Die Radiolarien*, 1862; Archer, "Résumé of recent contributions to our knowledge of freshwater Rhizopoda," *Quart. Jour. of Microscopical Science*, 1876–77; Zopf, "Pilzthiere" (Mycetozoa), in *Encyklopädie der Naturwissenschaften*, Breslau, 1884.

We shall now proceed to consider the classes and orders of Protozoa in detail.

PROTOZOA.

Characters.—Organisms consisting of a single cell or of a group of cells not differentiated into two or more tissues; incapable of assimilating nitrogen in its diffusible compounds (ammonia or nitrates) or carbon in the form of carbonates, except in special instances which there is reason to regard as directly derived from allied forms not possessing this capacity. The food of the Protozoa is in consequence as a rule taken in the form of particles into the protoplasm either by a specialized mouth or by any part of the naked cell-substance, there to be digested and rendered diffusible.

Grade A. *GYMNOMYXA*, Lankester, 1878 (64).

Characters.—Protozoa in which the cell-protoplasm is entirely or partially exposed to the surrounding medium, during the active vegetative phase of the life-history, as a naked undifferentiated slime or viscous fluid, which throws itself into processes or "pseudopodia" of various form either rapidly changing or relatively constant. Food can be taken into the protoplasm in the form of solid particles at any point of its surface or at any point of a large exposed area. The distinction into so-called "exoplasm" and "endoplasm" recognized by some authors, is *not* founded on a permanent differentiation of substance corresponding to the cortical and medullary substance of Corticata, but is merely due to the centripetal aggregation of granules lying in a uniform undifferentiated protoplasm. The cell-individual exhibits itself under four phases of growth and development—(1) as a swarm-spore (monadiform young or flagellula); (2) as an amœba form; (3) as constituent of a plasmodium or cell-fusion or conjugation; (4) as a cyst, which may be a flagellula(Schwärme)-producing cyst, an amœbula-producing cyst, a covered-spore(chlamydospore)-producing cyst (sporocyst *sens. stric.*, Zopf), or a simple resting cyst which does not exhibit any fusion of its contents (hypnocyst). Any one of these phases may be greatly predominant and specialized whilst the others are relatively unimportant and rapidly passed through.

Class I. PROTEOMYXA, Lankester.

Characters.—Gymnomyxa which exhibit in the amœba phase various forms of pseudopodia often changing in the same individual, and do not produce elaborate spore cysts; hence they are not referable to any one of the subsequent six classes. Mostly minute forms, with small inconspicuous nucleus (absent in some?).

A division into orders and families is not desirable, the group being confessedly an assemblage of negatively characterized or insufficiently known forms.

Genera.—*Vampyrella*, Cienkowski (15); *Vampyrellidium*, Zopf (13); *Spirophora*, Zopf (= *Amœba radiosa*, Perty); *Haplococcus*, Zopf; *Leptophrys*, Hertwig and Lesser (16); *Endyonema*, Zopf; *Barbella*, Sorokin (17); *Myxastrum*, Haeckel (1); *Enteromyxa*, Cienkowski (18); *Colpodella*, Cienkowski (19); *Pseudospora*, Cienkowski (20); *Protomonas*, Cienkowski (15); *Diplophysalis*, Zopf (13); *Gymnococcus*, Zopf; *Aphelidium*, Zopf; *Pseudosporidium*, Zopf; *Protomyxa*, Haeckel (1); *Plasmodiophora*, Woronin (21); *Tetramyxa*, Göbel (22); *Gloidium*, Sorokin (23); *Gymnophrys*, Cienkowski (24); *Myxodictyum*, Haeckel (1); *Boderia*, Wright (25); *Biomyxa*, Leidy (92); *Protogenes*, Haeckel (1); *Protamœba*, Haeckel (1); *Nuclearia*, Cienkowski (26); *Monobia*, Aim. Schneider (27); *Archerina*, Lankester (14).

The forms here brought together include several genera (the first nineteen) referred by Zopf to the Mycetozoa, some again (Vampyrella, Myxastrum, Nuclearia, Monobia) which are by Bütschli associated with the Heliozoa, others (Protamœba, Gloidium) referred by the same authority to the Lobosa (Amœbæa) and others (Colpodella, Protomonas) which might be grouped with the lower Flagellata. By grouping them in the manner here adopted we are enabled to characterize those higher groups more satisfactorily and to give a just expression to our present want of that knowledge of the life-history both of these forms and of the higher Gymnomyxa which when it is obtained may enable us to disperse this heterogeneous class of Proteomyxa. The group has the same function in relation to the other classes of Gymnomyxa which the group Vermes has been made to discharge in relation to the better defined phyla of the Metazoa; it is a lumber-room in which obscure, lowly-developed, and insufficiently known forms may be kept until they can be otherwise dealt with.

It is true that, thanks to the researches of Continental botanists (especially Cienkowski and Zopf), we know the life-history of several of these organisms; but we are none the less unable to connect them by tangible characteristics with other Gymnomyxa.

Nearly all of the above-named genera are parasitic rather than "voracious," that is to say, they feed on the organized products of larger organisms both plants and animals (Haplococcus is parasitic in the muscles of the pig), into whose tissues they penetrate, and do not, except in a few cases (Protomyxa, Vampyrella), engulph whole organisms, such as Diatoms, &c., in their protoplasm. Many live upon and among the putrefying debris of other organisms (*e.g.*, rotting vegetable stems and leaves, excrements of animals), and like the Mycetozoa exert a digestive action upon the substances with which they come in contact comparable to the putrefying and fermentative activity of the Schizomycetes (Bacteria).

Fig. II. illustrates four chief genera of Proteomyxa.

Protomyxa aurantiaca was described by Haeckel (1), who found it on shells of Spirula on the coast of the Canary Islands, in the form of orange yellow flakes consisting of branching and reticular protoplasm nourishing itself by the ingestion of Diatoms and Peridinia. This condition is not a simple amœba phase but a "plasmodium" formed by the union of several young amœbæ. The plasmodium under certain conditions draws itself together into a spherical form and secretes a clear membranous cyst around itself, and then breaks up into some hundreds of flagellulæ or swarm-spores (Fig. II. 2). The diameter of the cyst is ·12 to ·2 millimetre. The flagellulæ subsequently escape (Fig. II. 3) and swim by the vibratile movement of one end which is drawn out in the form of a coarse flagellum. The swarm-spore now passes into the amœba phase (Fig. II. 4). Several of the small amœbæ creeping on the surface of the spirula-shell then unite with one another and form a plasmodium which continues to nourish itself by "voracious" inception of Diatoms and other small organisms. The plasmodia may attain a diameter of one millimetre and be visible by the naked eye.

A nucleus was not observed by Haeckel in the spores nor in the amœba phase, nor scattered nuclei in the plasmodium, but it is not improbable that they exist and escaped detection in the living condition, in consequence of their not being searched for by methods of staining, &c., which have since come into use. A contractile vacuole does not exist.

Vampyrella spirogyræ, Cienkowski (Fig. II. 5, 6, 7), is one of several species assigned to the genus Vampyrella, all of which feed upon the living cells of plants. The nucleus previously stated to be absent has been detected by Zopf (13). There is no contractile vacuole. The amœba phase has an actinophryd character (*i.e.*, exhibits fine radiating pseudopodia resembling those of the sun-animalcule, Actinophrys, one of the Heliozoa). This species feeds exclusively upon the contents of the cells of Spirogyra, effecting an entrance through the cell-wall (Fig. II. 5), sucking out the contents, and then creeping on to the next cell. In some species of Vampyrella as many as four amœba-individuals have been observed to fuse to form a small plasmodium. Cysts are formed which enclose in this species a single amœba-individual. The cyst often acquires a second or third inner cyst membrane by the shrinking of the protoplasmic body after the first encystment and the subsequent formation of a new membrane. The encysted protoplasm sometimes merely divides into four parts each of which creeps out of the cyst as an Actinophrys-like amœba (Fig. II. 7); in other instances it forms a dense spore, the product of which is not known.

Protogenes primordialis is the name given by Haeckel to a very simple form with radiating filamentous pseudopodia which he observed in sea-water. It appears to be the same organism as that described and figured by Max Schultze as *Amœba porrecta*. Schultze's figure is copied in Fig. II. 12. No nucleus and no contractile vacuole is observed in this form. It feeds voraciously on smaller organisms. Its life-history has not been followed over even a few steps. Hence we must for the present doubt altogether as to its true affinities. Possibly it is only a detached portion of the protoplasm of a larger nucleate Gymnomyxon. The same kind of doubt is justified in regard to Haeckel's *Protamoeba primitiva*, which was observed by him in pond water and differs from Protogenes in having lobose pseudopodia, whilst agreeing with it in absence of nuclei, contractile vacuoles, and other differentiation of structure.

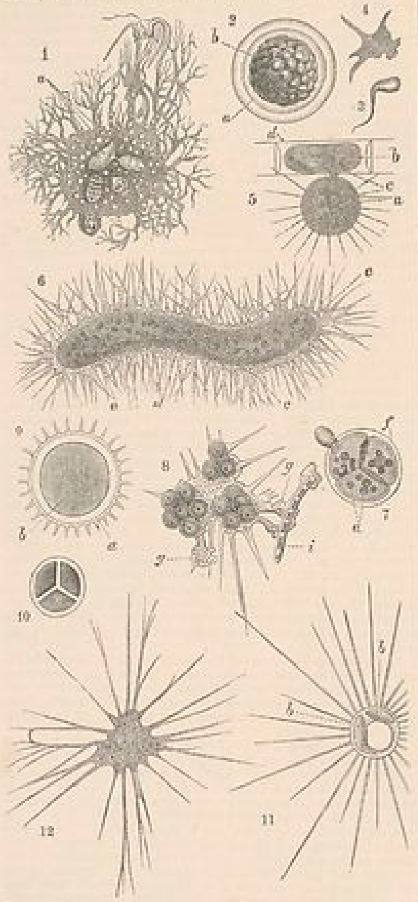


Fig. II.—Various **Proteomyxa.** 1. *Protomyxa aurantiaca*, Haeckel, plasmodium phase. The naked protoplasm shows branched, reticulate processes (pseudopodia), and numerous non-contractile vacuoles. It is in the act of engulfing a Ceratium. Shells of engulfed Ciliata (Tintinnabula) are embedded deeply in the protoplasm *a*. 2. Cyst phase of Protomyxa. *a*, transparent cyst-wall; *b*, protoplasm broken up into spores. 3. Flagellula phase of Protomyxa, the form assumed by the spores on their escape from the cyst. 4. Amoebula phase of the same, the form assumed after a short period by the flagellulae. 5. *Vampyrella spirogyrae*, Cienk., amoeba phase penetrating a cell of Spirogyra *b*, by a process of its protoplasm *c*, and taking up the substance of the Spirogyra cell, some of which is seen within the Vampyrella *a*. 6. Large individual of Vampyrella, showing pseudopodia *c*, and food particles *e*. The nucleus (though present) is not shown in this drawing. 7. Cyst phase of Vampyrella. The contents of the cyst have divided into four equal parts, of which three are visible. One is commencing to break its way through the cyst-wall *f*; *a*, food particles. 8. *Archerina Boltoni*, Lankester, showing lobose and filamentous protoplasm, and three groups of chlorophyll corpuscles. The protoplasm *g* is engulfing a Bacterium *i*. 9. Cyst phase of Archerina. *a*, spinous cyst-wall; *b*, green-coloured contents. 10. Chlorophyll corpuscle of Archerina showing tetraschistic division. 11. Actinophryd form of Archerina. *b*, chlorophyll corpuscles. 12. *Protogenes primordialis*, Haeckel (*Amoeba porrecta*, M. Schultze), from Schultze's figure.

The structureless protoplasmic network described by Haeckel from spirit-preserved specimens of Atlantic ooze and identified by him with Huxley's (**28**) Bathybius, as also the similar network described by Bessels (**29**) as Protobathybius, must be regarded for the present as insufficiently known.

It is possible that these appearances observed in the ooze dredged from great depths in the Atlantic are really due to simple Protozoa. On the other hand it has been asserted by Sir Wyville Thomson, who at one time believed in the independent organic nature of Bathybius, that the substance taken for protoplasm by both Huxley and Haeckel is in reality a gelatinous precipitate of calcium sulphate thrown down by the action of alcohol upon sea-water. Other naturalists have pointed to the possibility of the protoplasmic network which Bessels studied in the living condition on board ship being detached portions of the protoplasm of Reticularia and Radiolaria. The matter is one which requires further investigation.

Archerina Boltoni is the name given by Lankester (**14**) to a very simple Gymnomyxon inhabiting freshwater ponds in company with Desmids and other simple green Algae (Fig. II. 8 to 11). Archerina exhibits an amoeba phase in which the protoplasm is thrown into long stiff filaments (Fig. II. 11), surrounding a spherical central mass about $\frac{1}{1000}$th inch in diameter (actinophryd form). A large vacuole (non-contractile) is present, or two or three small ones. No nucleus can be detected by careful use of reagents in this or other phases. The protoplasm has been seen to ingest solid food particles (Bacteria) and to assume a lobose form. The most striking characteristic of Archerina is the possession of chlorophyll corpuscles. In the actinophryd form two oval green-coloured bodies (*b*, *b*) are seen. As the protoplasm increases by nutrition the chlorophyll corpuscles multiply by quaternary division (Fig. II. 10) and form groups of four or of four sets of four symmetrically arranged. The division of the chlorophyll corpuscles is not necessarily followed by that of the protoplasm, and accordingly specimens are found with many chlorophyll corpuscles embedded in a large growth of protoplasm (Fig. II. 8); the growth may increase to a considerable size, numbering some hundreds of chlorophyll corpuscles, and a proportionate development of protoplasm. Such a growth is not a plasmodium, that is to say, is not formed by fusion of independent amoeba forms, but is due to continuous growth. When nutrition fails the individual chlorophyll corpuscles separate, each carrying with it an investment of protoplasm, and then each such amoeba form forms a cyst around itself which is covered with short spines (Fig. II. 9). The cysts are not known to give rise to spores, but appear to be merely hypnocysts.

The domination of the protoplasm by the chlorophyll corpuscles is very remarkable and unlike anything known in any other organism. Possibly the chlorophyll corpuscles are to be regarded as nuclei, since it is known that there are distinct points of affinity between the dense protoplasm of ordinary nuclei and the similarly dense protoplasm of normal chlorophyll corpuscles.

Class II. MYCETOZOA, De Bary.

Characters.—Gymnomyxa which, as an exception to all other Protozoa, are not inhabitants of water but occur on damp surfaces exposed to the air. They are never parasitic, as are some of the Proteomyxa most nearly allied to them (Plasmodiophora, &c.), but feed on organic debris. They are structurally characterized by the fact that the amoeba forms, which develop either directly or through flagellulae from their spores, always form large, sometimes very large, *i.e.*, of several square inches area, fusion plasmodia (or rarely aggregation plasmodia), and that the spores are always chlamydospores (*i.e.*, provided with a coat) and are formed either in naked groups of definite shape (sori) or on the surface of peculiar columns (conidiophors) or in large fruit-like cysts which enclose the whole or a part of the plasmodium and develop besides the spores definite sustentacular structures (capillitium) holding the spores in a mesh-work.

Three orders of Mycetozoa are distinguishable according to the arrangement of the spores in more or less complex spore-fruits.

Order 1. SOROPHORA, Zopf.

Characters.—Mycetozoa which never exhibit a vibratile (monadiform) swarmspore or flagellula phase, but hatch from the spore as amoebae. A true fusion plasmodium is not formed, but an aggregation plasmodium by the contact without fusion of numerous amoeba forms. The spore fruit is a naked aggregation of definitely arranged encysted amoebae called a sorus, not enclosed in a common capsule; each encysted amoeba has the value of a single spore and sets free on germination a single amoebula. They inhabit the dung of various animals.

Genera.—*Copromyxa*, Zopf; *Cysthulina*, Cienk.; *Dictyostelium*, Brefeld; *Acrasis*, Van Tieghem; *Polysphondylium*, Brefeld.

Order 2. ENDOSPOREA, Zopf.

Characters.—Mycetozoa always passing through the flagellula phase and always forming true plasmodia by fusion of amoeba forms. The spore-fruit is in the form of a large cyst which encloses a quantity of the plasmodium; the latter then breaks up into (*a*) spores (one corresponding to each nucleus of the enclosed plasmodium) each of which has a cellulose coat, and (b) a capillitium of threads which hold the spores together. Each spore (chlamydospore) liberates on germination a single nucleated flagellula, which develops into an amœbula, which in turn fuses with other amœbulæ to form the plasmodium. The Endosporea are essentially dwellers on rotten wood and such vegetable refuse.

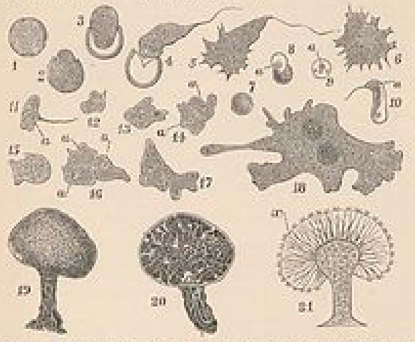


FIG. III.—**Mycetozoa** (after De Bary). 1-6, Germination of spore (1) of *Trichia varia*, showing the emerging "flagellula" (4, 5), and its conversion into an "amœbula" (6). 7-18, Series leading from spore to plasmodium phase of *Chondrioderma difforme*:—7, spore; 10, flagellula; 12, amœbula; 14, apposition of two amœbulæ; 15-17, fusions; 18, plasmodium. 19, 20, Spore-fruit (cyst) of *Physarum leucophæum*, Fr. (× 25), the former from the surface, the latter in section with the spores removed to show the sustentacular network or capillitium. 21, Section of the spore-cyst of *Didymium squamulosum*, with the spores removed to show the radiating capillitium *x* and the stalk.

Sub-order 1. PERITRICHEA, Zopf.

Fam. 1. CLATHROPTYCHIACEÆ, Rostafinski.
Genera.—*Clathroptychium*, Rost.; *Enteridium*, Ehr.
Fam. 2. CRIBRARIACEÆ.
Genera.—*Dictydium*, Pers.; *Cribraria*, Pers.

Sub-order 2. ENDOTRICHEA, Zopf.

Fam. 1. PHYSAREA.
Genera.—*Physarum*, Pers.; *Craterium*, Trentepol; *Badhamia*, Berkeley; *Leocarpus*, Link.; *Tilmadoche*, Fr.; *Fuligo* (*Æthalium*), Hall; *Æthaliopsis*, Z.
Fam. 2. DIDYMIACEÆ.
Genera.—*Didymium*; *Lepidoderma*, De Bary.
Fam. 3. SPUMARIACEÆ.
Genera.—*Spumaria*, Pers.; *Diachea*, Fries.
Fam. 4. STEMONITEA.
Genera.—*Stemonitis*, Gleditsch; *Comatricha*, Preuss; *Lamproderma*, Rost.
Fam. 5. ENERTHENEMEA.
Genera.—*Enerthema*, Bowman.
Fam. 6. RETICULARIACEÆ, Zopf.
Genera.—*Amaurochæte*, Rost.; *Reticularia*, Bull.
Fam. 7. TRICHIACEÆ.
Genera.—*Hemiarcyria*, Rost.; *Trichia*, Hall.
Fam. 8. ARCYRIACEÆ.
Genera.—*Arcyria*, Hall; *Cornuvia*, Rost.; *Lycogala*, Ehr.
Fam. 9. PERICHÆNACEÆ.
Genera.—*Perichæna*, Fries.; *Lachnobolus*, Fries.
Fam. 10. LICEACEÆ.
Genera.—*Licea*, Schrader; *Tubulina*, Pers.; *Lindbladia*, Fries.; *Tubulifera*, Zopf.

ORDER 3. EXOSPOREA, Zopf.

Characters.—The chlamydospore liberates an amœbula in the first instance, which develops into a flagellula. This subsequently returns to the amœba form, and by fusion with other amœbulæ it forms a true fusion plasmodium. The spores are not produced within a cyst but upon the surface of column-like up-growths of the plasmodium, each spore (conidium) forming as a little spherical outgrowth attached to the column (conidiophor) by a distinct pedicle. Sole Genus.—*Ceratium*. [This name must be changed, since it was already applied to a genus of Dinoflagellata, when Famintzin and Woronin gave it to this Mycetozoon.]

Further Remarks on Mycetozoa.—About two hundred species of Mycetozoa have been described. Botanists, and especially those who occupy themselves with Fungi, have accumulated the very large mass of facts now known in reference to these organisms; nevertheless the most eminent botanist who has done more than any other to advance our knowledge of Mycetozoa, namely, De Bary, has expressed the view that they are to be regarded rather as animals than as plants. The fact is that, once the question is raised, it becomes as reasonable to relegate all the Gymnomyxa without exception to the vegetable kingdom as to do so with the Mycetozoa. Whatever course we take with the latter, we must take also with the Heliozoa, the Radiolaria, and the Reticularia.

The formation of plasmodia, for which the Mycetozoa are conspicuous, appears to be a particular instance of the general phenomenon of cell-conjugation. Small plasmodia are formed by some of the Proteomyxa; but among the other Gymnomyxa, excepting Mycetozoa, and among Corticate Protozoa, the fusion of two individuals (conjugation *sensu stricto*) is more usual than the fusion of several. Zopf (13) has attempted to distinguish arbitrarily between conjugation and plasmodium formation by asserting that in the former the nuclei of the cells which fuse are also fused, whereas in the latter process the nuclei retain their independence. Both statements are questionable. What happens to the nucleus in such conjugations as those of the Gregarinæ has not yet been made out, whilst it is only quite recently that Strasburger (30) has shown that the plasmodia of Mycetozoa contain numerous scattered nuclei, and it is not known that fusion does not occur between some of these. There is no doubt that the nuclei of plasmodia multiply by fission, though we have no detailed account of the process.

The Sorophora are exceptional in that the amœbæ which unite to form a cell-colony in their case do not actually fuse but only remain in close contact; with this goes the fact that there are no large spore-cysts, but an identification of spore and spore-cyst. The amœbæ arrange themselves in stalked clusters (sori), and each becomes encysted: one may, in this case, consider the cyst equally as a spore or as a spore-cyst which produces but a single spore. The amœbæ described by various writers as inhabiting the alimentary canal and the dung of higher animals (including man) belong to this group. The form described by Cunningham in the *Quart. Jour. Micr. Sci.*, 1881, as *Protomycomyces coprinarius* is apparently related to the *Copromyxa* (*Guttulina*) *protea* of Fayod (31).

The spore-fruits of the Endosporea occur in various degrees of elaboration. Usually they are (1) spherical or pear-shaped cysts with or without an obvious stalk (Fig. III. 19, 20, 21), and often have a brilliant colour, and are of a size readily observed by the naked eye, the plasmodia which give rise to them being by no means microscopic. But they may present themselves (2) as irregular ridges growing up from the plasmodium, when they are termed serpula forms. Lastly, the cysts may be united side by side in larger or smaller groups instead of forming at various separate points of the plasmodium. These composite bodies are termed "fruit-cakes" or "æthalia," in view of the fact that the spore-cysts of Fuligo, also called Æthalium—the well-known "flowers of tan"—form a cake of this description.

The capillitium or network of threads which lies between the spores in the spore-cysts of Endosporea is a remarkable structure which exhibits special elaborations in detail in different genera, here not to be noticed for want of space. Although definite in form and structure, these threads are not built up by cells but are formed by a residual protoplasm (*cf.* Sporozoa) which is left in the cyst after the spores have been segregated and enclosed each in its special coat. They are often impregnated by calcium carbonate, and exhibit crystalline masses of it, as does also the cyst-wall.

The spores of the Mycetozoa are as a rule about the $\frac{1}{2000}$th inch in diameter. They are produced by millions in the large fruit-cakes of such forms as Fuligo. Often the spore-coat is coloured; it always consists of a substance which gives the cellulose reaction with iodine and sulphuric acid. This has been sometimes considered an indication of the vegetable nature of the Mycetozoa, but cannot be so regarded since many animals (especially the Tunicata and various Protozoa) produce substances giving this same reaction.

Dryness, low temperature, and want of nutriment lead to a dormant condition of the protoplasm of the plasmodium of many Mycetozoa and to its enclosure in cyst-like growths known as "sclerotia," which do not give rise to spores, but from which the protoplasm creeps forth unaltered when temperature, nutrition, and moisture are again favourable. The sclerotia are similar in nature to the hypnocysts of other Protozoa.

The physiological properties—chemical composition, digestive action, reaction to moisture, heat, light, and other physical influences—of the plasmodia of Mycetozoa have been made the subject of important investigations; they furnish the largest masses of undifferentiated protoplasm available for such study. The reader is referred to Zopf's admirable treatise (13) as to these matters, and also for a detailed account of the genera and species.

CLASS III. **LOBOSA**, Carpenter.

Characters.—Gymnomyxa in which (as in the succeeding four classes) the amœba-phase predominates over the others in permanence, size attained, and physiological importance. The pseudopodia are lobose, ranging in form from mere wave-like bulgings of the surface to blunt finger-like processes, but never having the character of filaments either simple, arborescent, or reticulate. Fusions of two individuals (conjugation) have been observed in a

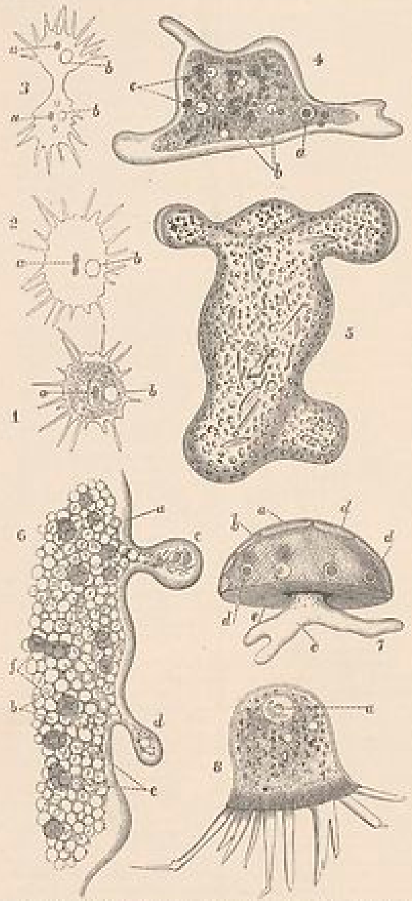


FIG. IV.—Various **Lobosa.** 1, 2, 3. *Dactylosphæra* (*Amœba*) *polypodia*, M. Schultze, in three successive stages of division; the changes indicated occupied fifteen minutes. *a*, nucleus; *b*, contractile vacuole (copied from F. E. Schultze, in *Archiv f. Mikrosk. Anat.*). 4. *Amœba princeps*, Ehr. (after Auerbach). *a*, nucleus; *b*, *c*, vacuoles (one or more contractile); the shaded granules are food-particles. 5. *Pelomyxa palustris*, Greeff (after Greeff), an example with comparatively few food-particles (natural size [illegible] inch in length). 6. Portion of a Pelomyxa more highly magnified. *a*, clear superficial zone of protoplasm (so-called "exoplasm"); *b*, vacuoles, extremely numerous; *c*, lobose pseudopodium; *d*, a similar pseudopodium; *e*, nuclei; *f*, "refractive bodies" (reproductive?); scattered about in the protoplasm are seen numerous cylindrical crystals. 7. *Arcella vulgaris*, Ehr. *a*, shell; *b*, protoplasm within the shell; *c*, extended protoplasm in the form of lobose pseudopodia; *d*, nuclei; *e*, contractile vacuole; the dark bodies unlettered are gas vacuoles. 8. *Cochliopodium pellucidum*, Hert. and Less. *a*, nucleus surrounded by a hyaline halo sometimes mistaken for the nucleus, whilst the latter is termed [illegible] nucleolus.

few cases, but not fusions of many individuals so as to form plasmodia; nevertheless the size attained by the naked protoplasm by pure growth is in some cases considerable, forming masses readily visible by the naked eye (Pelomyxa). The presence of more than one nucleus is a frequent character. A contractile vacuole may or may not be present. The formation of sporocysts and of chlamydospores (coated spores) has not been observed in any species, but naked spores (flagellulæ or amœbulæ) have been with more or less certainty observed as the product of the breaking up of some species (Amœba? Pelomyxa). The cyst phase is not unusual, but the cyst appears usually to be a hypnocyst and not a sporocyst. In the best observed case of spore-production (Pelomyxa) the spores were apparently produced without the formation of a cyst. Reproduction is undoubtedly most freely effected by simple fission (Amœba) and by a modified kind of bud-fission (Arcella). Fresh-water and marine. Two orders of the Lobosa are distinguished in accordance with the presence or absence of a shell.

ORDER 1. NUDA.

Characters.—Lobosa devoid of a shell.

Genera.—*Amœba*, Auct. (Fig. IV. 4); *Ouramœba*, Leidy (with a villous tuft at one end, Wallich's *A. villosa*); *Corycia*, Duj. (low, ridge-like pseudopodia); *Lithamœba*, Lankester (Fig. V.); *Dinamœba*, Leidy (32) (covered with short stiff processes); *Hyalodiscus*, H. and L.; *Plakopus*, F. E. Schultze; *Dactylosphæra*, H. and L. (Fig. IV. 1, 2, 3); *Pelomyxa*, Greeff (Fig. IV. 5, 6); *Amphizonella*, Greeff (forms a gelatinous case which is broken through by the pseudopodia).

ORDER 2. TESTACEA.

Characters.—Lobosa which secrete a shell provided with an aperture from which the naked protoplasm can be protruded. The shell is either soft and membranous, or strengthened by the inclusion of sand-particles, or is hard and firm.

Genera.—*Cochliopodium* (Fig. IV. 8), H. and L.; *Pyxidicula*, Ehr.; *Arcella*, Ehr. (Fig. IV. 7); *Hyalosphenia*, Stein; *Quadrula*, F. E. Schultze (shell membraneous, areolated); *Difflugia*, Leclerc (shell with adventitious particles).

Further remarks on the Lobosa.—The Lobosa do not form a very numerous nor a very natural assemblage. Undoubtedly some of the forms which have been described as species of Amœba are amœba forms of Mycetozoa; this appears to be most probably the case in parasitic and stercoricolous forms. But when these are removed, as also those Proteomyxa which have pseudopodia of varying character, at one time lobose and at another filamentous, we have left a certain small number of independent lobose Gymnomyxa which it is most convenient to associate in a separate group. We know very little of the production of spores (whether it actually obtains or not) or of developmental phases among these Lobosa. The common Amœbæ are referable to the species *A. princeps*, *A. lobosa*, *Dactylosphæra polypodia*, *Ouramœba villosa*. Of none of these do we know certainly any reproductive phenomena excepting that of fission (see Fig. IV. 1, 2, 3). Various statements have been made pointing to a peculiar change in the nucleus and a production of spores having the form of minute Amœbæ, arising from that body; but they cannot be considered as established. Whilst the observed cases of supposed reproductive phenomena are very few, it must be remembered that we have always to guard (as the history of the Ciliata has shown, see below) against the liability to mistake parasitic amœbulæ and flagellulæ for the young forms of organisms in which they are merely parasitic. The remarkable *Pelomyxa palustris* of Greeff (32) was seen by him to set free (without forming a cyst) a number of amœbulæ which he considers as probably its young. Mr Weldon of St John's College, Cambridge, has observed the same phenomenon in specimens of Pelomyxa which made their appearance in abundance in an aquarium in the Morphological Laboratory, Cambridge. It seems probable that the amœbulæ in this case are not parasites but spore-like young, and this is the best observed case of such reproduction as yet recorded in the group.

Arcella is remarkable for the production of bud-spores, which may be considered as a process intermediate between simple fission and the complete breaking up of the parent body into spores. As many as nine globular processes are simultaneously pinched off from the protoplasm extruded from the shell of the Arcella; the nuclei (present in the parent Arcella to the number of two or three) have not been traced in connexion with this process. The buds then become nipped off, and acquire a shell and a contractile vacuole (33).

The presence of more than one nucleus is not unusual in Lobosa, and is not due to a fusion of two or more uninuclear individuals, but to a multiplication of the original nucleus. This has been observed in some Amœbæ (*A. princeps*?) as well as Arcella. Pelomyxa (Fig. IV. 6) has a great number of nuclei like the Heliozoon, Actinosphærium (Fig. VIII.).

Pelomyxa is the most highly differentiated of the Lobosa. The highly vacuolated character of its protoplasm is exhibited in a less degree by Lithamœba and resembles that of Heliozoa and Radiolaria. Besides the numerous nuclei there are scattered in the protoplasm strongly refringent bodies (Fig. IV. 6, *f*), the significance of which has not been ascertained. The superficial protoplasm is free from vacuoles, hyaline, and extremely mobile. Occasionally it is drawn out into very short fine filaments. Scattered in the protoplasm are a number of minute cylindrical crystals, of unascertained composition. Pelomyxa is of very large size for a Protozoon, attaining a diameter of $\frac{1}{10}$th of an inch. It takes into its substance a quantity of foreign particles, both nutrient organic matter such as Rotifera and Diatoms and sand particles. It occurs not uncommonly in old

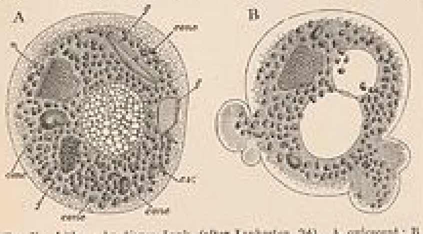


Fig. V.—*Lithamoeba discus*, Lank. (after Lankester, 34). A, quiescent; B, throwing out pseudopodia. c.v., contractile vacuole, overlying which the vacuolated protoplasm is seen; conc, concretions insoluble in dilute HCl and dilute KHO, but soluble in strong HCl; n, nucleus.

muddy ponds (such as duck-ponds), creeping upon the bottom, and has a white appearance to the naked eye. Lithamoeba (Fig. V.) is distinguished by its large size, disk-like form, the disk-like shape of its pseudopodia, the presence of specific concretions, the vacuolation of its protoplasm, and the block-like form and peculiar tessellated appearance of its large nucleus, which has a very definite capsule. In Lithamoeba it is easy to recognize a distinct pellicle or temporary cuticle which is formed upon the surface of the protoplasm, and bursts when a pseudopodium is formed. In fact it is the rupture of this pellicle which appears to be the proximate cause of the outflow of protoplasm as a pseudopodium. Probably a still more delicate pellicle always forms on the surface of naked protoplasm, and in the way just indicated determines by its rupture the form and the direction of the "flow" of protoplasm which is described as the "protrusion" of a pseudopodium.

The shells of Lobosa Testacea are not very complex. That of Arcella is remarkable for its hexagonal areolation, dark colour, and firm consistence; it consists of a substance resembling chitin. That of Difflugia has a delicate membranous basis, but includes foreign particles, so as to resemble the built-up case of a Caddis worm.

Arcella is remarkable among all Protozoa for its power of secreting gas-vacuoles (observed also in an Amoeba by Bütschli), which serve a hydrostatic function, causing the Arcella to float. The gas can be rapidly absorbed by the protoplasm, when the vacuole necessarily disappears and the Arcella sinks.

Class IV. LABYRINTHULIDEA.

Characters.—Gymnomyxa forming irregular heaps of ovoid nucleated cells, the protoplasm of which extends itself as a branching network or labyrinth of fine threads. The oval (spindle-shaped) corpuscles, consisting of dense protoplasm, and possessing each a well-marked nucleus (not observed in Chlamydomyxa), travel regularly and continuously along the network of filaments. The oval corpuscles multiply by fission; they also occasionally become encysted and divide into four spherical spores. The young forms developed from these spores presumably develop into colonies, but have not been observed.

Genera.—Two genera only of Labyrinthulidea are known:—*Labyrinthula*, Cienkowski; *Chlamydomyxa*, Archer.

Cienkowski (35) discovered Labyrinthula on green Algæ growing on wooden piles in the harbour of Odessa (marine). It has an orange colour and forms patches visible to the naked eye. Chlamydomyxa was discovered by Archer of Dublin (36) in the cells of Sphagnum and crawling on its surface; hence it is a freshwater form. Unlike Labyrinthula, the latter forms a laminated shell of cellulose (Fig. VI. 2, c), in which it is frequently completely enclosed, and indeed has rarely been seen in the expanded labyrinthine condition. The laminated cellulose shells are very freely secreted, the organism frequently deserting one and forming another within or adherent to that previously occupied. The network of Chlamydomyxa appears to consist of hyaline threads of streaming protoplasm, whilst that of Labyrinthula has a more horny consistence, and is not regarded by Cienkowski as protoplasm.

The spindle-shaped cells are much alike in form and size in the two genera; but no nucleus was detected by Archer in those of Chlamydomyxa. The encysting of the spindle-cells and their fission into spores has been seen only in Labyrinthula. Chlamydomyxa is often of a brilliant green colour owing to the presence of chlorophyll corpuscles, and may exhibit a red or mottled red and green appearance owing to the chemical change of the chlorophyll. It has been observed to take in solid nourishment, though Labyrinthula has not.

The Labyrinthulidea present strong resemblances to the Mycetozoa. The genus Dactylostelium (Sorophora) would come very close to Labyrinthula were the amoebæ of its aggregation plasmodium

Fig. VI.—**Labyrinthulidea.** 1. A colony or "cell-heap" of *Labyrinthula vitellina*, Cienk., crawling upon an Alga. 2. A colony or "cell-heap" of *Chlamydomyxa labyrinthuloides*, Archer, with fully expanded network of threads on which the oat-shaped corpuscles (cells) are moving. a is an ingested food particle; at c a portion of the general protoplasm has detached itself and become encysted. 3. A portion of the network of *Labyrinthula vitellina*, Cienk., more highly magnified. p, protoplasmic mass apparently produced by fusion of several filaments; p′, fusion of several cells which have lost their definite spindle-shaped contour; s, corpuscles which have become spherical and are no longer moving (perhaps about to be encysted). 4. A single spindle cell and threads of *Labyrinthula macrocystis*, Cienk. n, nucleus. 5. A group of encysted cells of *L. macrocystis*, embedded in a tough secretion. 6, 7. Encysted cells of *L. macrocystis*, with enclosed protoplasm divided into four spores. 8, 9. Transverse division of a non-encysted spindle-cell of *L. macrocystis*.

set upon a network of threads. Such a network, whether in the condition of soft protoplasm or hardened and horny, is represented in the higher Mycetozoa by the capillitium of the sporocysts.

The most important difference between Archer's Chlamydomyxa and Cienkowski's Labyrinthula is that in the former the threads

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of the network appear to consist of contractile protoplasm, whilst in the latter they are described as firm horny threads exuded by the spindle-cells. Neither form has been re-examined since its discovery; and it is possible that this apparent difference will be removed by further study.

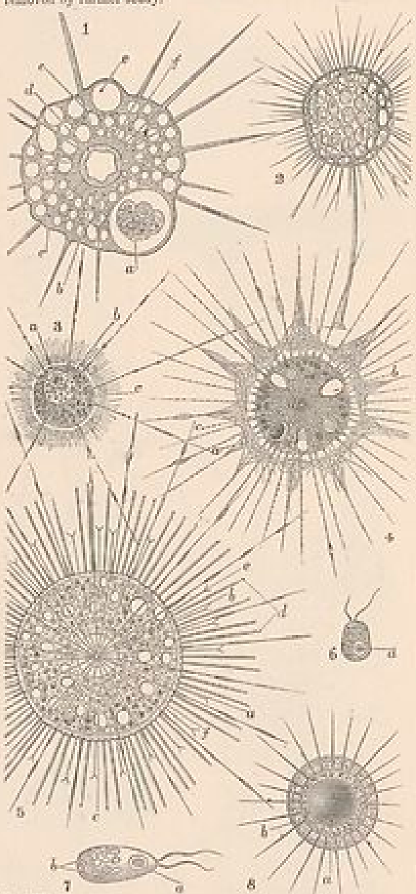

FIG. VII.—**Heliozoa.** 1. *Actinophrys sol*, Ehrb.; × 300. *a*, food-particle lying in a large food-vacuole; *b*, deep-lying finely granular protoplasm; *c*, axial filament of a pseudopodium extended inwards to the nucleus; *d*, the central nucleus; *e*, contractile vacuole; *f*, superficial much-vacuolated protoplasm. 2. *Clathrulina elegans*, Cienk.; × 200. 3. *Heterophrys marina*, H. and L. × 660. *a*, nucleus; *b*, clearer protoplasm surrounding the nucleus; *c*, the peculiar felted envelope. 4. *Raphidiophrys pallida*, F. E. Schultze; × 430. *a*, food-particle; *b*, the nucleus; *c*, contractile vacuole; *d*, central granule in which all the axis-filaments of the pseudopodia meet. The tangentially disposed spicules are seen arranged in masses on the surface. 5. *Acanthocystis turfacea*, Carter; × 240. *a*, probably the central nucleus; *b*, clear protoplasm around the nucleus; *c*, more superficial protoplasm with vacuoles and chlorophyll corpuscles; *d*, coarser siliceous spicules; *e*, finer forked siliceous spicules; *f*, finely granular layer of protoplasm. The long pseudopodia reaching beyond the spicules are not lettered. 6. Bi-flagellate "flagellula" of *Acanthocystis aculeata*. *a*, nucleus. 7. Ditto of *Clathrulina elegans*. *a*, nucleus. 8. *Astrodisculus ruber*, Greeff; × 320. *a*, red-coloured central sphere (? nucleus); *b*, peripheral homogeneous envelope.

CLASS V. **HELIOZOA**, Haeckel, 1866.

Characters.—Gymnomyxa in which the dominating amœba phase has the form of a spherical body from the surface of which radiate numerous isolated filamentous pseudopodia which exhibit very little movement or change of form, except when engaged in the inception of food-particles. The protoplasm of the spherical body is richly vacuolated; it may exhibit one or more contractile vacuoles and either a single central nucleus or many nuclei (Nuclearia, Actinosphærium). Skeletal products may or may not be present. Flagellulæ have been observed as the young forms of some species (Acanthocystis, Clathrulina), but very little has been as yet ascertained as to spore-formation or conjugation in this group, though isolated facts of importance have been observed. Mostly freshwater forms.

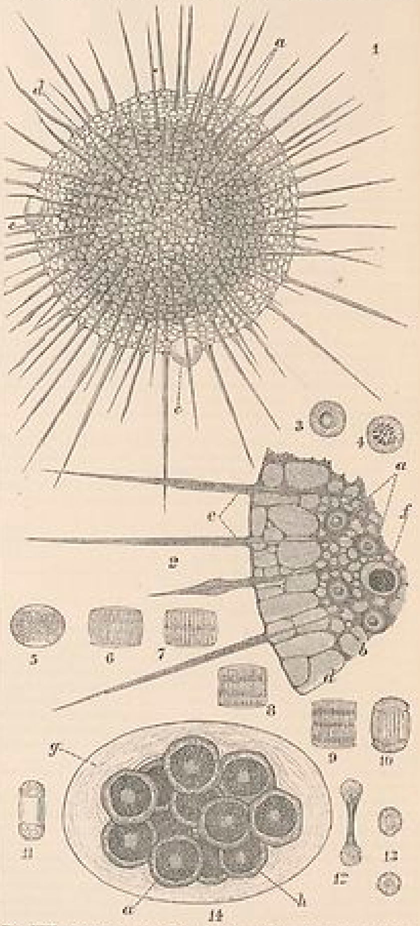

FIG. VIII.—**Heliozoa.** 1. *Actinosphærium Eichhornii*, Ehr.; × 200. *a*, nuclei; *b*, deeper protoplasm with smaller vacuoles and numerous nuclei; *c*, contractile vacuoles; *d*, peripheral protoplasm with larger vacuoles. 2. A portion of the same specimen more highly magnified and seen in optical section. *a*, nuclei; *b*, deeper protoplasm (so-called endosarc); *d*, peripheral protoplasm (so-called ectosarc); *e*, pseudopodia showing the granular protoplasm streaming over the stiff axial filament; *f*, food-particle in a food-vacuole. 3, 4. Nuclei of Actinosphærium in the resting condition. 5–12. Successive stages in the division of a nucleus of Actinosphærium, showing fibrillation, and in 7 and 8 formation of an equatorial plate of chromatin substance (after Hertwig). 14. Cyst-phase of *Actinosphærium Eichhornii*, showing the protoplasm divided into twelve chlamydospores, each of which has a siliceous coat; *a*, nucleus of the spore; *g*, gelatinous wall of the cyst; *h*, siliceous coat of the spore.

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ORDER 1. APHROTHORACA, Hertwig (56).

Characters.—Heliozoa devoid of a spicular or gelatinous envelope, excepting in some a temporary membranous cyst.

Genera.—*Nuclearia*, Cienk. (37) (many nuclei; many contractile vacuoles; body not permanently spherical, but amœboid); *Actinophrys*, Ehr. (Fig. VII. 1; body spherical; pseudopodia with an axial skeletal filament; central nucleus; one large contractile vacuole; often forming colonies; *A. sol*, the Sun-animalcule); *Actinosphærium*, Stein (Fig. VIII.; spherical body; pseudopodia with axial filament; nuclei very numerous; contractile vacuoles 2 to 14); *Actinolophus*, F. E. Schulze (stalked).

ORDER 2. CHLAMYDOPHORA, Archer (57).

Characters.—Heliozoa with a soft jelly-like or felted fibrous envelope.

Genera.—*Heterophrys*, Archer (Fig. VII. 3); *Sphærastrum*, Greeff; *Astrodisculus*, Greeff (Fig. VII. 5).

ORDER 3. CHALAROTHORACA, Hertw. and Lesser (58).

Characters.—Heliozoa with a loose envelope consisting of isolated siliceous spicules.

Genera.—*Raphidiophrys*, Archer (Fig. VII. 4; skeleton in the form of numerous slightly curved spicules placed tangentially in the superficial protoplasm); *Pompholyxophrys*, Archer; *Pinacocystis* H. and L.; *Pinaciophora*, Greeff; *Acanthocystis*, Carter (skeleton in the form of radially disposed siliceous needles; encysted condition observed, and flagellula young, Fig. VII. 6); *Wagnerella*, Merosch.

ORDER 4. DESMOTHORACA, Hertw. and Less.

Characters.—Heliozoa with a skeletal envelope in the form of a spherical or nearly spherical shell of silica preforated by numerous large holes.

Genera.—*Orbulinella*, Entz (without a stalk); *Clathrulina*, Cienk. (with a stalk, Fig. VII. 2).

Further remarks on the Heliozoa.—The Sun-animalcules, Actinophrys and Actinosphærium, were the only known members of this group when Carter discovered in 1863 Acanthocystis. Our further knowledge of them is chiefly due to Archer of Dublin, who discovered the most important forms, and figured them in the *Quart. Jour. Micr. Sci.* in 1867.

Some of the Proteomyxa (*e.g.*, Vampyrella) exhibit "heliozoon-like" or "actinophryd" forms, but are separated from the true Heliozoa by the fact that their radiant pseudopodia are not maintained for long in the stiff isolated condition characteristic of this group. It is questionable whether Nuclearia should not be relegated to the Proteomyxa on account of the mobility of its body, which in all other Heliozoa has a constant spherical form.

Actinophrys sol is often seen to form groups or colonies (by fission), and so also is Raphidiophrys. It is probable from the little that is known that reproduction takes place not only by simple fission but by multiple fission, producing flagellate spores which may or may not be preceded by encystment. Only Clathrulina, Acanthocystis, Actinosphærium, and Actinophrys have been observed in the encysted state, and only the first two have been credited with the production of flagellated young. The two latter genera form covered spores within their cysts, those of Actinosphærium being remarkable for their siliceous coats (Fig. VIII. 14), but their further development has not been seen.

CLASS VI. **RETICULARIA**, Carpenter, 1862.

(*Foraminifera*, Auct., *Thalamophora*, Hertwig).

Characters.—Gymnomyxa in which the dominating amœba-phase, often of great size (an inch in diameter), has an irregular form, and a tendency to throw out great trunks of branching and often anastomosing filamentous pseudopodia, and an equally strong tendency to form a shell of secreted membrane or secreted lime or of agglutinated sand particles (only in one genus of secreted silex) into which the protoplasm (not in all?) can be drawn and out of and over which it usually streams in widely spreading lobes and branches. One nucleus is present, or there are many. A contractile vacuole is sometimes, but not as a rule, present (or at any rate not described). Reproduction is by fission and (as in some other Protozoa) by the formation of peculiar bud-spores which remain for a time after their formation embedded in the parental protoplasm. No multiple breaking up into spores after or independent of the formation of a cyst is known. Marine and freshwater.

The Reticularia are divisible into several orders. The marked peculiarity of the shell structure in certain of these orders is only fitly emphasized by grouping them together as a sub-class Perforata, in contrast to which the remaining orders stand as a sub-class Imperforata. The distinction, however, is not an absolute one, for a few of the Lituolidea are perforate, that is, are sandy isomorphs of perforate genera such as Globigerina and Rotalia.

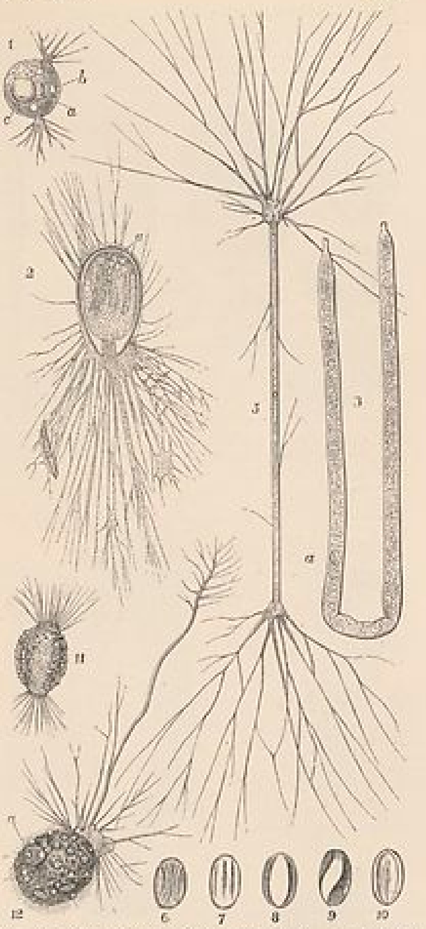

FIG. IX.—**Gromiidea (Reticularia membranosa).** 1. *Diplophrys Archeri*, Barker. *a*, nucleus; *b*, contractile vacuoles; *c*, the yellow oil-like body. Moor pools, Ireland. 2. *Gromia oviformis*, Duj. *a*, the numerous nuclei; near these the elongated bodies represent ingested Diatoms. Freshwater. 3. *Shepheardella taeniiformis*, Siddall (*Quart. Jour. Micr. Sci.*, 1880); × 30 diameters. Marine. The protoplasm is retracted at both ends into the tubular case. *a*, nucleus. 5. *Shepheardella taeniiformis*; × 15; with pseudopodia fully expanded. 6-10. Varying appearance of the nucleus as it is carried along in the streaming protoplasm within the tube. 11. *Amphitrema Wrightianum*, Archer, showing membranous shell encrusted with foreign particles. Moor pools, Ireland. 12. *Diaphorophodon mobile*, Archer. *a*, nucleus. Moor pools, Ireland.

SUB-CLASS A. **Imperforata.**

Characters.—Shell-substance not perforated by numerous apertures through which the protoplasm can issue, but provided with only one or two large apertures, or in branched forms with a few such apertures.

ORDER 1. GROMIIDEA, Brady.

Characters.—Shell or test membranous, in the form of a simple sac with a pseudopodial aperture either at one extremity or at both. Pseudopodia thread-like, long, branching, reticulated. Marine and freshwater.

FAM. 1. MONOSTOMINA, with a single aperture to the shell.

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Genera.—*Lieberkuehnia*, Clap. and Lach.; *Gromia*, Duj. (Fig. IX. 2); *Mikrogromia*, Hertw.; *Euglypha*, Duj. (shell built up of hexagonal siliceous plates); *Diaphorophodon*, Archer (38) (many foreign particles cemented to form shell; small pseudopodia issue between these, hence resembling Perforata, and large long ones from the proper mouth of the shell, Fig. IX. 12).

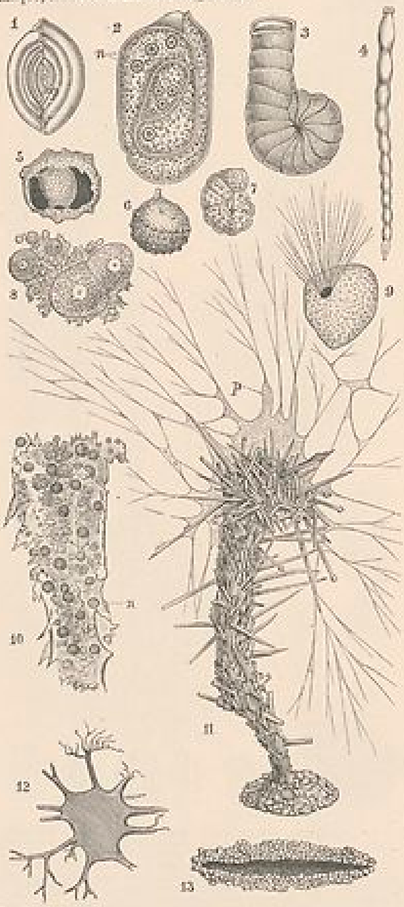

Fig. X.—**Imperforata.** 1. *Spiroloculina planulata*, Lamarck, showing five "cells"; porcellanous. 2. Young ditto, with shell dissolved and protoplasm stained so as to show the seven nuclei *n*. 3. Spirolina (Peneroplis); a sculptured imperfectly coiled shell; porcellanous. 4. Vertebralina, a simple shell consisting of chambers succeeding one another in a straight line; porcellanous. 5, 6. *Thurammina papillata*, Brady, a sandy form. 5 is broken open so as to show an inner chamber; recent, × 25. 7. *Lituola* (*Haplophragmium*) *canariensis*, a sandy form; recent. 8. Nucleated reproductive bodies (bud-spores) of Haliphysema. 9. *Squamulina laevis*, M. Schultze; × 40; a simple porcellanous Miliolide. 10. Protoplasmic core removed after treatment with weak chromic acid from the shell of *Haliphysema Tumanowiczii*, Bow. *n*, vesicular nuclei, stained with haematoxylin (after Lankester). 11. *Haliphysema Tumanowiczii*; × 25 diam.; living specimen, showing the wine-glass-shaped shell built up of sand-grains and sponge-spicules, and the abundant protoplasm *p*, issuing from the mouth of the shell and spreading partly over its projecting constituents. 12. Shell of *Astrorhiza limicola*, Sand.; × ½; showing the branching of the test on some of the rays usually broken away in preserved specimens (original). 13. Section of the shell of Marsipella, showing thick walls built of sand-grains.

Fam. 2. Amphistomina, with an aperture at each end of the shell.

Genera.—*Diplophrys*, Barker (Fig. IX. 1); *Ditrema*, Archer; *Amphitrema*, Archer (Fig. IX. 11); *Shepheardella*, Siddall (39) (membranous shell very long and cylindrical so as to be actually tubular, narrowed to a spout at each end, Fig. IX. 3; protoplasm extended from either aperture, Fig. IX. 5, and rapidly circulating within the tubular test during life, carrying with it the nucleus which itself exhibits peculiar movements of rotation, Fig. IX. 6, 7, 8, 9, 10).

Order 2. ASTRORHIZIDEA, Brady.

Characters.—Test invariably consisting of foreign particles; it is usually of large size and single-chambered, often branched or radiate with a pseudopodial aperture to each branch, the test often continued on to the finer branches of the pseudopodia (Fig. X. 12); never symmetrical. All marine.

Fam. 1. Astrorhizina, Brady. Walls thick, composed of loose sand or mud very slightly cemented.

Genera.—*Astrorhiza*, Sandahl (Fig. X. 12, very little enlarged); *Pelosina*, Brady; *Storthosphaera*, Brady; *Dendrophrya*, St. Wright; *Syringammina*, Brady.

Fam. 2. Pilulinina. Test single-chambered; walls thick, composed chiefly of felted sponge-spicules and fine sand, without calcareous or other cement.

Genera.—*Pilulina*, Carpenter; *Technitella*, Norman; *Bathysiphon*, Sars.

Fam. 3. Saccamminina. Chambers nearly spherical; walls thin, composed of firmly cemented sand grains.

Genera.—*Psammosphaera*, Schultze; *Sorosphaera*, Brady; *Saccammina*, M. Sars.

Fam. 4. Rhabdamminina. Test composed of firmly cemented sand-grains, often with sponge-spicules intermixed; tubular; straight, radiate, branched or irregular; free or adherent; with one, two, or more apertures; rarely segmented.

Genera.—*Jaculella*, Brady; *Marsipella*, Norman (Fig. X. 13); *Rhabdammina*, M. Sars; *Aschemonella*, Brady; *Rhizammina*, Brady; *Sagenella*, Brady; *Botellina*, Carp.; *Haliphysema*, Bowerbank (test wine-glass-shaped, rarely branched, attached by a disk-like base; generally beset with sponge-spicules, Fig. X. 11; pseudopodial aperture at the free extremity). This and Astrorhiza are the only members of this order in which the living protoplasm has been observed; in the latter it has the appearance of a yellowish cream, and its microscopic structure is imperfectly unknown (61). In Haliphysema the network of expanded pseudopodia has been observed by Saville Kent as drawn in Fig. X. 11. Lankester (59) discovered numerous vesicular nuclei scattered in the protoplasm (Fig. X. 10, *n*), and also near the mouth of the shell reproductive bodies (probably bud-spores) embedded in the protoplasm (Fig. X. 8). Haliphysema was described by Bowerbank as a Sponge, and mistaken by Haeckel (60) for a very simple two-cell-layered animal (Enterozoon), to which he assigned the class name of Physemaria.

Order 3. MILIOLIDEA, Brady.

Characters.—Test imperforate; normally calcareous and porcellanous, sometimes encrusted with sand; under starved conditions (*e.g.*, in brackish water) becoming chitinous or chitino-arenaceous; at abyssal depths occasionally consisting of a thin homogeneous, imperforate, siliceous film. The test has usually a chambered structure, being divided by septa (each with a hole in it) into a series of loculi which may follow one another in a straight line (Fig. X. 4) or the series may be variously coiled (Fig. X. 1 and 3). The chambering of the test does not express a corresponding cell-segmentation of the protoplasm; the latter, although growing in volume as the new shell-chambers are formed, remains one continuous cell-unit with many irregularly scattered nuclei (Fig. X. 2). The chambered and septate structure results in this group and in the other orders from the fact that the protoplasm, expanded beyond the last-formed chamber, forms a new test upon itself whilst it lies and rests upon the surface of the old test. The variations in such a formation are shown in Fig. XII. 1, 2, 3, 4.

Fam. 1. Nubecularina. Test free or adherent, taking various irregular asymmetrical forms, with variable aperture or apertures.

Genera.—*Squamulina*, Schultze (Fig. X. 9, showing the expanded pseudopodia); *Nubecularia*, Defrance.

Fam. 2. Miliolina. Shell coiled on an elongated axis, either symmetrically or in a single plane or inequilaterally; two chambers in each convolution. Shell aperture alternately during growth (addition of new chambers) at either end of the shell.

Genera.—*Biloculina*, D'Orb.; *Fabularia*, Defrance; *Spiroloculina*, D'Orb. (Fig. X. 1, 2); *Miliolina*, Williamson (Fig. XI.).

Fam. 3. Hauerinina. Shell dimorphous; chambers partly milioline, partly spiral or rectilinear.

Genera.—*Articulina*, D'Orb.; *Vertebralina*, D'Orb. (Fig. X. 4); *Ophthalmidium*, Kubler; *Hauerina*, D'Orb.; *Planispirina*, Seguenza.

Fam. 4. Peneroplidina. Shell planospiral or cyclical, sometimes crozier-shaped, bilaterally symmetrical.

Genera.—*Cornuspira*, Schultze; *Peneroplis*, Montfort (Fig. X. 3);

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Orbiculina, Lamarck; *Orbitolites*, Lamarck (by a division of the chambers regularly into chamberlets, and a cyclical mode of growth which results in shells of the size of a shilling, a very elaborate-looking structure is produced which has been admirably analysed by Carpenter (40), to whose memoir the reader is specially referred).

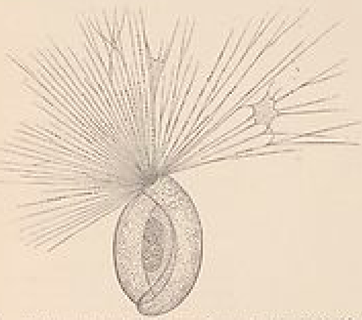


FIG. XI.—*Miliolina* (*Triloculina*) *tenera*. Young living animal with expanded pseudopodia (after Max Schultze). A single nucleus is seen in the innermost chamber.

Fam. 5. ALVEOLININA. Shell spiral, elongated in the line of the axis of the convolution; chambers divided into chamberlets.

Genus.—*Alveolina*, D'Orb.

Fam. 6. KERAMOSPHÆRINA. Shell spherical; chambers in concentric layers.

Genus.—*Keramosphæra*, Brady.

ORDER 4. LITUOLIDEA, Brady.

Characters.—Test arenaceous, usually regular in contour; septation of the many-chambered forms often imperfect, the cavity being labyrinthic. This order consists of sandy isomorphs of the simpler Miliolidea, and also of the simpler Perforata (Lagena, Nodosaria, Cristellaria, Globigerina, Rotalia, Nonionina, &c.); it also contains some peculiar adherent species.

Fam. 1. LITUOLINA. Test composed of coarse sand-grains, rough externally; often labyrinthic.

Genera.—*Reophax*, Montfort; *Haplophragmium*, Reuss (Fig. X. 7); *Coskinolina*, Stache; *Placopsilina*, D'Orb.; *Haplostiche*, Reuss; *Lituola*, Lamarck; *Bdelloidina*, Carter.

Fam. 2. TROCHAMMININA. Test thin, composed of minute sand-grains incorporated with calcareous and other organic cement, or embedded in a chitinous membrane; exterior smooth, often polished; interior smooth or rarely reticulated; never labyrinthic.

Genera.—*Thurammina*, Brady (test consisting typically of a single spherical chamber with several mammillate apertures, Fig. X. 5, 6); *Hippocrepina*, Parker; *Hormosina*, Brady; *Ammodiscus*, Reuss; *Trochammina*, Parker and Jones; *Carterina*, Brady; *Webbina*, D'Orb.

Fam. 3. ENDOTHYRINA. Test more calcareous and less sandy than in the other groups of Lituolidea; sometimes perforate; septation distinct.

Genera.—*Nodosinella*, Brady; *Polyphragma*, Reuss; *Involutina*, Terq.; *Endothyra*, Phillips; *Bradyina*, Möll.; *Stacheia*, Brady.

Fam. 4. LOFTUSINA. Test of relatively large size; lenticular, spherical, or fusiform; constructed either on a spiral plan or in concentric layers, the chamber cavities occupied to a large extent by the excessive development of the finely arenaceous cancellated walls.

Genera.—*Cyclammina*, Brady; *Loftusia*, Brady; *Parkeria*, Carpenter.

SUB-CLASS B. **Perforata.**

Characters.—Shell substance perforated by numerous minute apertures, through which as well as from the main aperture the protoplasm can issue.

ORDER 5. TEXTULARIDEA, Brady.

Characters.—Tests of the larger species arenaceous, either with or without a perforate calcareous basis; smaller forms hyaline and conspicuously perforated. Chambers arranged in two or more alternating series, or spiral or confused; often dimorphous.

Fam. 1. TEXTULARINA. Typically bi- or tri-serial; often bi-rarely tri-morphous.

Genera.—*Textularia* Defrance; *Cuneolina*, D'Orb.; *Verneuilina*, D'Orb.; *Tritaxia*, Reuss; *Chrysalidina*, D'Orb.; *Bigenerina*, D'Orb.; *Pavonina*, D'Orb.; *Spiroplecta*, Ehr.; *Gaudryina*, D'Orb.; *Valvulina*, D'Orb.; *Clavulina*, D'Orb.

Fam. 2. BULIMININA. Typically spiral; weaker forms more or less regularly biserial; aperture oblique, comma-shaped or some modification of that form.

Genera.—*Bulimina*, D'Orb.; *Virgulina*, D'Orb.; *Bifarina*, Parker and Jones; *Bolivina*, D'Orb.; *Pleurostomella*, Reuss.

Fam. 3. CASSIDULINA. Test consisting of a Textularia-like series of alternating segments more or less coiled upon itself.

Genera.—*Cassidulina*, D'Orb.; *Ehrenbergina*, Reuss.

ORDER 6. CHILOSTOMELLIDEA, Brady.

Characters.—Test calcareous, finely perforate, many-chambered. Segments following each other from the same end of the long axis, or alternately at the two ends, or in cycles of three, more or less embracing. Aperture a curved slit at the end or margin of the final segment.

Genera.—*Ellipsoidina*, Seguenza; *Chilostomella*, Reuss; *Allomorphina*, Reuss.

ORDER 7. LAGENIDEA, Brady.

Characters.—Test calcareous, very finely perforated; either single-chambered, or consisting of a number of chambers joined in a straight, curved, spiral, alternating, or (rarely) branching series. Aperture simple or radiate, terminal. No interseptal skeleton nor canal system.

Fam. 1. LAGENINA. Shell single-chambered.

Genera.—*Lagena*, Walker and Boys; *Nodosaria*, Lamk.; *Lingulina*, D'Orb.; *Frondicularia*, Defrance; *Rhabdogonium*, Reuss; *Marginulina*, D'Orb.; *Vaginulina*, D'Orb.; *Rimulina*, D'Orb.; *Cristellaria*, Lamk.; *Amphicoryne*, Schlumb.; *Lingulinopsis*, Reuss; *Flabellina*, D'Orb.; *Amphimorphina*, Neugeb.; *Dentalinopsis*, Reuss.

Fam. 2. POLYMORPHININA. Segments arranged spirally or irregularly around the long axis; rarely biserial and alternate.

Genera.—*Polymorphina*, D'Orb.; *Dimorphina*, D'Orb.; *Uvigerina*, D'Orb.; *Sagrina*, P. and J.

Fam. 3. RAMULININA. Shell branching, composed of spherical or pyriform chambers connected by long stoloniferous tubes.

Genus.—*Ramulina*, Rupert Jones.

ORDER 8. GLOBIGERINIDEA, Brady.

Characters.—Test free, calcareous, perforate; chambers few, inflated, arranged spirally; aperture single or multiple, conspicuous. No supplementary skeleton nor canal system. All the larger species pelagic in habit.

Genera.—*Globigerina*, D'Orb. (Fig. XII. 6); *Orbulina*, D'Orb. (Fig. XII. 8); *Hastigerina*, Wy. Thomson (Fig. XII. 5); *Pullenia*, P. and J.; *Sphæroidina*, D'Orb.; *Candeina*, D'Orb.

ORDER 9. ROTALIDEA, Brady.

Characters.—Test calcareous, perforate; free or adherent. Typically spiral and "rotaliform" (Fig. XII. 2), that is to say, coiled in such a manner that the whole of the segments are visible on the superior surface, those of the last convolution only on the inferior or apertural side, sometimes one face being more convex sometimes the other. Aberrant forms evolute, outspread, acervuline, or irregular. Some of the higher modifications with double chamber-walls, supplemental skeleton, and a system of canals. The nature of this supplemental skeleton is shown in Fig. XII. 2 and 10.

Fam. 1. SPIRILLININA. Test a complanate, planospiral, non-septate tube; free or attached.

Genus.—*Spirillina*, Ehr.

Fam. 2. ROTALINA. Test spiral, rotaliform, rarely evolute, very rarely irregular or acervuline.

Genera.—*Patellina*, Williamson; *Cymbalopora*, Hay; *Discorbina*, P. and J.; *Planorbulina*, D'Orb.; *Truncatulina*, D'Orb.; *Anomalina*, P. and J.; *Carpenteria*, Gray (adherent); *Rupertia*, Wallich; *Pulvinulina*, P. and J.; *Rotalia*, Lamk.; *Calcarina*, D'Orb. [Shell rotaliform; periphery furnished with radiating spines; supplemental skeleton and canal system largely developed. This form is shown in a dissected condition in Fig. XII. 10. Outside and between the successive chambers with finely perforated walls a^2, a^3, a^4 a secondary shell-substance is deposited by the protoplasm which has a different structure. Whilst the successive chambers with their finely perforate walls (resembling dentine in structure) are formed by the mass of protoplasm issuing from the mouth of the last-formed chamber, the secondary or supplemental-shell substance is formed by the protoplasm which issues through the fine perforations of the primary shell substance; it is not finely canaliculated, but is of denser substance than the primary shell and traversed by coarse canals (occupied by the protoplasm) which make their way to the surface of the test (c', c). In Calcarina a large bulk of this secondary shell-substance is deposited around each chamber and also forms the heavy club-like spines.]

Fam. 3. TINOPORINA. Test consisting of irregularly heaped chambers with (or sometimes without) a more or less distinctly spiral primordial portion; for the most part without any general pseudopodial aperture.

Genera.—*Tinoporus*, Carpenter; *Gypsina*, Carter; *Aphrosina*, Carter; *Thalamopora*, Roemer; *Polytrema*, Risso. [Shell parasitic, encrusting, or arborescent; surface areolated, coloured pink or white, Fig. XII. 9. Interior partly occupied by small chambers, arranged in more or less regular layers, and partly by non-segmented canal-like spaces, often crowded with sponge-spicules. No true canal system. This is one of the most important types as exhibiting the arborescent and encrusting form of growth. It is fairly abundant.]

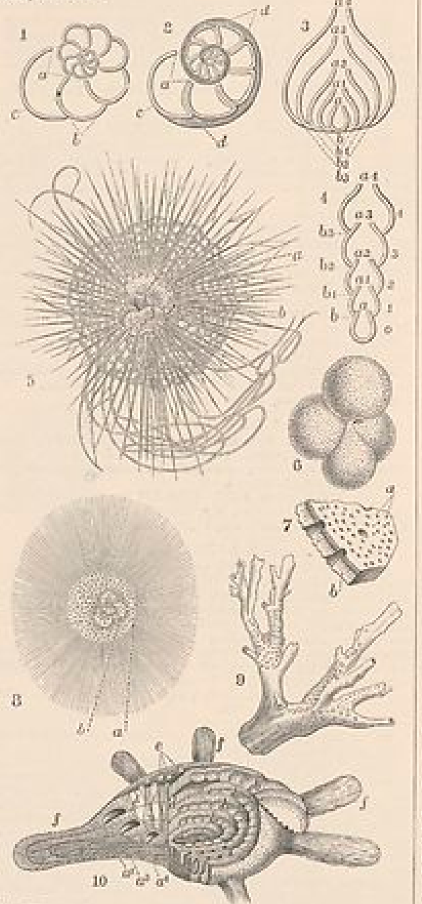


Fig. XII.—**Perforata.** 1. Spiral arrangement of simple chambers of a Reticularian shell. 2. Ditto, with double septal walls, and supplemental shell-substance (shaded). 3. Diagram to show the mode in which successively-formed chambers may completely embrace their predecessors. 4. Diagram of a simple straight series of non-embracing chambers. 5. *Hastigerina* (*Globigerina*) *Murrayi*, Wyv. Thomson. a, bubbly (vacuolated) protoplasm, enclosing b, the perforated Globigerina-like shell (conf. central capsule of Radiolaria). From the peripheral protoplasm project, not only fine pseudopodia, but hollow spines of calcareous matter, which are set on the shell, and have an axis of active protoplasm. Pelagic; drawn in the living state. 6. *Globigerina bulloides*, D'Orb., showing the punctiform perforations of the shell and the main aperture. 7. Fragment of the shell of Globigerina, seen from within, and highly magnified. a, fine perforations in the inner shell substance; b, outer (secondary) shell substance. Two coarser perforations are seen in section, and one lying among the smaller. 8. *Orbulina universa*, D'Orb. Pelagic example, with adherent radiating calcareous spines (hollow), and internally a small Globigerina shell. It is uncertain whether Orbulina is merely a developmental phase of Globigerina. a, Orbulina shell; b, Globigerina shell. 9. *Polytrema miniaceum*, Lin.; × 12. Mediterranean. Example of a branched adherent calcareous perforate Reticularian. 10. *Calcarina Spengleri*, Gmel.; × 38. Tertiary, Sicily. Shell dissected so as to show the spiral arrangement of the chambers, and the copious secondary shell substance. a^1, a^2, a^3, chambers of three successive cells in section, showing the thin primary wall (finely tubulated) of each; b, b, b, b, perforate surfaces of the primary wall of four tiers of chambers, from which the secondary shell substance has been cleared away; c, c', secondary or intermediate shell substance in section, showing coarse canals; d, section of secondary shell substance at right angles to c'; e, tubercles of secondary shell substance on the surface; f, f, club-like processes of secondary shell substance.

Order 10. NUMMULINIDEA, Brady.

Characters.—Test calcareous and finely tubulated; typically free, many-chambered, and symmetrically spiral. The higher modifications all possess a supplemental skeleton, and canal system of greater or less complexity.

Fam. 1. Fusulinina. Shell bilaterally symmetrical; chambers extending from pole to pole; each convolution completely enclosing the previous whorls. Shell-wall finely tubulated. Septa single or rarely double; no true interseptal canals. Aperture a single elongated slit, or a row of small rounded pores, at the inner edge of the final segment.

Genera.—*Fusulina*, Fischer; *Schwagerina*, Möller.

Fam. 2. Polystomellina. Shell bilaterally symmetrical, nautiloid. Lower forms without supplemental skeleton or interseptal canals; higher types with canals opening at regular intervals along the external septal depressions.

Genera.—*Nonionina*, D'Orb.; *Polystomella*, Lamarck.

Fam. 3. Nummulitina. Shell lenticular or complanate; lower forms with thickened and finely tubulated shell-wall, but no intermediate skeleton; higher forms with interseptal skeleton and complex canal system.

Genera.—*Archædiscus*, Brady; *Amphistegina*, D'Orb.; *Operculina*, D'Orb.; *Heterostegina*, D'Orb.; *Nummulites*, Lamarck; *Assilina*, D'Orb.

Fam. 4. Cycloclypeina. Shell complanate, with thickened centre, or lenticular; consisting of a disk of chambers arranged in concentric annuli, with more or less lateral thickening of laminated shell substance, or acervuline layers of chamberlets. Septa double and furnished with a system of interseptal canals.

Genera.—*Cycloclypeus*, Carpenter; *Orbitoides*, D'Orb.

Fam. 5. Eozoonina. Test forming irregular, adherent, acervuline masses.

Genus.—*Eozoon*, Dawson.

Further remarks on the Reticularia.—The name Thalamophora, pointing to the peculiar tendency which the larger members of the group have to form chamber after chamber and so to build up a complex shell, has been proposed by Hertwig (56) and adopted by many writers. The old name Foraminifera (which did not refer to the fine perforations of the Perforata but to the large pseudopodial aperture leading from chamber to chamber) has also been extended by some so as to include the simpler Gromia-like forms. On the whole Carpenter's term Reticularia (62) seems most suitable for the group, since they all present the character indicated. It has been objected that the Radiolaria are also reticular in their pseudopodia, but if we except the pelagic forms of Reticularia (Globigerina, Orbulina, &c.), we find that the Radiolaria are really distinguishable by their stiffer, straighter, radiating pseudopodia. No doubt the Labyrinthulid Chlamydomyxa and the plasmodia of some Mycetozoa are as reticular in their pseudopodia as the Reticularia, but they possess other distinctive features which serve, at any rate in an artificial system, to separate them.

The protoplasm of the majority of the Reticularia is unknown, or only very superficially observed; hence we have made a point of introducing among our figures as many as possible which show this essential part of the organism. It is only recently (1876) that nuclei have been detected in the calcareous-shelled members of the group, and they have only been seen in a few cases.

The protoplasm of the larger shell-making forms is known to be often strongly coloured, opaque, and creamy, but its minute structure remains for future investigation. Referring the reader to the figures and their explanation, we would draw especial attention to the structure of the protoplasmic body of Hastigerina (one of the Globigerinidæ) as detected by the "Challenger" naturalists. It will be seen from Fig. XII. 5 that the protoplasm extends as a relatively enormous "bubbly" mass around the shell which is sunk within it; from the surface of this "bubbly" (vacuolated or alveolated) mass the pseudopodia radiate.

The reader is requested to compare this with Fig. XIII., representing the "bubbly" protoplasmic body of Thalassicolla. It then becomes obvious that the perforated central capsule CK of the latter holds the same relation to the mass of the protoplasm as does the central perforated shell of Globigerina (Hastigerina). The extreme vacuolation of the protoplasm in both cases (the vacuoles being filled with sea-water accumulated by endosmosis) and the stiff radiating pseudopodia are directly correlated with the floating pelagic life of the two organisms. All the Radiolaria are pelagic, and many exhibit this vacuolation; only a few of the Reticularia are so, and their structural correlation to that habit has only lately been ascertained.

The Reticularia are almost exclusively known by their shells, which offer a most interesting field for study on account of the very great complexity of form attained by some of them, notwithstanding the fact that the animal which produces them is a simple unicellular Protozoon. Space does not permit the exposition here of the results obtained by Carpenter in the study of the complex shells of Orbitolites, Operculina, Nummulites, &c.; it is essential that his work *Introduction to the Study of the Foraminifera* (Ray Society, 1862) should be consulted, and in reference to the sandy-shelled forms the monograph by Brady, in the *Challenger Reports*, vol. ix., 1883; and it must be sufficient here to point out the general principles of the shell-architecture of the Reticularia. Let us suppose that we have an ever-growing protoplasmic body which tends to produce a calcareous shell on its surface, leaving an aperture for the exit of its pseudopodia. It will grow too large for its shell and accumulate outside the shell. The accumulated external mass may then secrete a second chamber, resting on the first as chamber 1 rests on chamber 0 in Fig. XII. 4. By further growth a new chamber is necessitated, and so is produced a series following one another in a straight line, each chamber communicating with the newer one in front of it by the narrow pseudopodial aperture (a, a^1, a^2, a^3). Now it is possible for these chambers to be very variously arranged instead of simply as in Fig. XII. 4. For instance, each new chamber may completely enclose the last, as in Fig. XII. 3, supposing the protoplasm to spread all over the outside of the old chamber before making a new deposit. Again the chambers need not succeed one another in a straight line, but may be disposed in a spiral (Fig. XII. 1). And this spiral may be a flat coil, or it may be a helicine spiral with a rising axis; further it may be close or open. All these forms in various degrees of elaboration are exhibited by Miliolidea and various Perforata.

But the Perforata in virtue of their perforate shell-walls introduce a new complication. The protoplasm issues not only from the mouth of the last-formed chamber, but from the numerous pores in the wall itself. This latter protoplasm exerts its lime-secreting functions; it gathers itself into coarse branching threads which remain uncalcified, whilst all around a dense deposit of secondary or supplemental shell-substance is thrown down, thus producing a coarsely canalicular structure. The thickness and amount of this secondary shell and the position it may occupy between and around the chambers of primitive shell-substance vary necessarily in different genera according to the mode in which the primitive chambers are arranged and connected with one another. Calcarina is a fairly typical instance of an abundant secondary shell-deposit (Fig. XII. 10), and it is the existence of structure resembling the chambers of Calcarina with their surrounding primary and secondary shell-substances which has rendered it necessary to regard Eozoon (41) as the metamorphosed encrusting shell of a pre-Cambrian Reticularian.

The division of the Reticularia into Imperforata and Perforata which is here maintained has no longer the significance which was once attributed to it. It appears, according to the researches of Brady, that it is not possible to draw a sharp line between these sub-classes, since there are sandy forms which it is difficult to separate from Imperforate Lituolidea and are nevertheless perforate, in fact are "sandy isomorphs of Lagena, Nodosaria, Globigerina, and Rotalia." It does not appear to the present writer that there can be any insurmountable difficulty in separating the Lituolidea into two groups—those which are sandy isomorphs of the porcellanous Miliolidea, and those which are sandy isomorphs of the hyaline Perforata. The two groups of Lituolidea thus formed might be placed in their natural association respectively with the Imperforata and the Perforata.

The attempt to do this has not been made here, but the classification of Brady has been adopted. In Bütschli's large work on the Protozoa (9) the breaking up of the Lituolidea is carried out to a logical conclusion, and its members dispersed among the Miliolidea on the one hand and the various orders of Perforata on the other hand.

The calcareous shell-substance of the Miliolidea being opaque and white has led to their being called "Porcellana," whilst the transparent calcareous shells of the smaller Perforata has gained for that group the synonym of "Hyalina."

The shells of the calcareous Reticularia and of some of the larger arenaceous forms are found in stratified rocks, from the Palæozoic strata onwards. The Chalk is in places largely composed of their shells, and the Eocene Nummulitic limestone is mainly a cemented mass of the shells of Nummulites often as large each as a shilling. The Atlantic ooze is a chalky deposit consisting largely of the shells of Globigerina, &c.

Class VII. **RADIOLARIA**, Haeckel, 1862 (63) (*Polycystina*, Ehr.).

Characters.—Gymnomyxa in which the protoplasmic body of the dominant amœba phase has the form of a sphere or cone from the surface of which radiate filamentous pseudopodia, occasionally anastomosing, and encloses a spherical (homaxonic) or cone-shaped (monaxonic) perforated shell of membranous consistence known as the central capsule, and probably homologous with the perforated shell of a Globigerina. The protoplasm within the capsule (intracapsular protoplasm) is continuous through the pores or apertures of the capsule with the outer protoplasm. Embedded in the former lies the large and specialized nucleus (one or more). Gelatinous substance is frequently formed peripherally by the extracapsular protoplasm, constituting a kind of soft mantle which is penetrated by the pseudopodia. A contractile vacuole is never present.

Usually an abundant skeleton, consisting of spicules of silica or of a peculiar substance called acanthin arranged radially or tangentially, loose or united into a basket-work, is present. Oil globules, pigment, and crystals are found in greater or less abundance in the protoplasm.

In most but not all Radiolaria peculiar nucleated yellow corpuscles are abundantly present, usually regarded as parasitic Algæ. Reproduction by fission has been observed, and also in some few species a peculiar formation of swarm-spores (flagellulæ) within the central capsule, in which the nucleus takes an important part. All the Radiolaria are marine. The Radiolaria are divided into two sub-classes according to the chemical nature of their spicular skeleton, and into orders according to the nature and the disposition of the apertures in the wall of the central capsule.

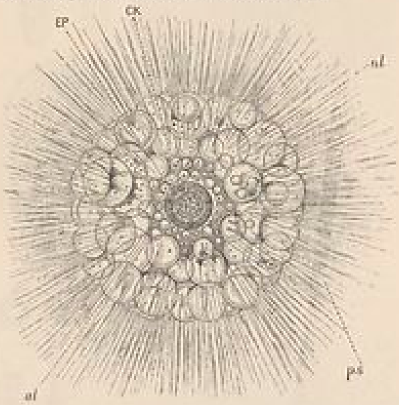


Fig. XIII.—*Thalassicolla pelagica*, Haeckel; × 25. CK, central capsule; EP, extracapsular protoplasm; *al*, alveoli, liquid-holding vacuoles in the protoplasm similar to those of Heliozoa, Pelomyxa, Hastigerina, &c.; *ps*, pseudopodia. The minute unlettered dots are the "yellow cells."

Sub-class I. **Silico-Skeleta**, Lankester.

Characters.—A more or less elaborate basket-work of tangential and radial elements consisting of secreted silica is present; in rare exceptions no skeleton is developed.

Order 1. PERIPYLÆA, Hertwig.

Characters.—Silico-skeletal Radiolaria in which the central capsule is uniformly perforated all over by fine pore-canals; its form is that of a sphere (homaxonic), and to this form the siliceous skeleton primarily conforms, though it may become discoid, rhabdoid, or irregular. The nucleus is usually single, but numerous nuclei are present in each central capsule of the Polycyttaria.

Fam. 1. Sphærida, Haeck. Spherical Peripylæa with a spherical basket-work skeleton, sometimes surrounded by a spongy outer skeleton, sometimes simple, sometimes composed of many concentric spheres (never discoid, flattened, or irregular). The central capsule sometimes encloses a part of the spherical skeleton, and often is penetrated by radiating elements.

Genera (selected).—*Ethmosphæra*, Haeck.; *Xiphosphæra*, Haeck.; *Staurosphæra*, Haeck.; *Heliosphæra*, Haeck. (Fig. XIV. 14); *Astrosoma*, Haeck.; *Haliomma*, Haeck.; *Actinomma*, Haeck. (Fig. XIV. 17; note the sphere within sphere, the smallest lying in the nucleus, and the whole series of spherical shells connected by radial spines); *Arachnosphæra*, Haeck.; *Plegmosphæra*, Haeck.; *Spongosphæra*, Haeck. (Fig. XVI. 8).

Fam. 2. Discida, Haeck. Discoid Peripylæa; both skeleton and central capsule flattened.

Genera (selected).—*Phacodiscus*, Haeck.; *Heliodiscus*, Haeck.; *Spongodiscus*, Haeck.; *Spongurus*, Haeck.

FAM. 3. THALASSICOLLIDA. Peripylæa devoid of a skeleton, or with a skeleton composed of loose siliceous spicules only. Nucleus single; central capsule and general protoplasm spherical.

Genera (selected).—*Thalassicolla*, Huxley (Fig. XIII., Fig. XIV. 1); *Thalassosphæra*, Haeck.; *Physematium*, Haeck.

FAM. 4. POLYCYTTARIA. Peripylæa consisting of colonies of many central capsules united by their extracapsular protoplasm. Central capsules multiplying by fission. Nuclei in each central capsule numerous. Siliceous skeleton either absent, or of loose spicules, or having the form of a spherical fenestrated shell surrounding each central capsule.

Genera (selected).—*Collosphæra*, Müller (with fenestrated globular skeleton); *Sphærozoum*, Haeck. (skeleton of numerous loose spicules which are branched); *Raphidozoum*, Haeck. (spicules simple); *Collozoum*, Müller (devoid of skeleton, Fig. XIV. 2, 3, 4, 5).

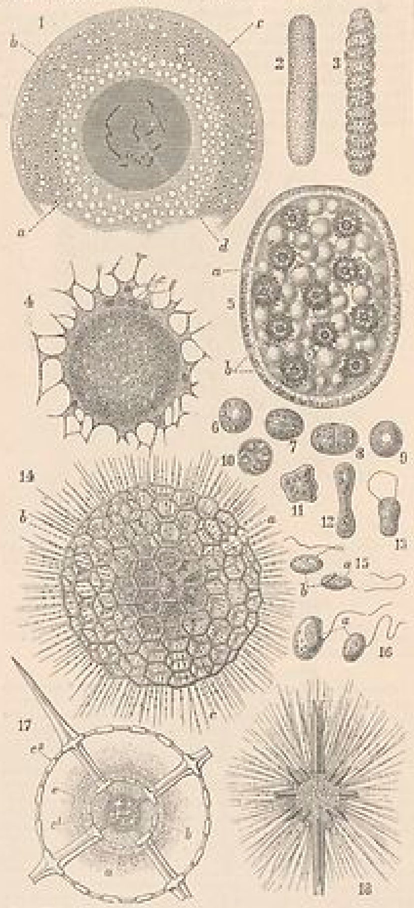


FIG. XIV.—**Radiolaria.** 1. Central capsule of *Thalassicolla nucleata*, Huxley, in radial section. *a*, the large nucleus (Binnenbläschen); *b*, corpuscular structures of the intracapsular protoplasm containing concretions; *c*, wall of the capsule (membranous shell), showing the fine radial pore-canals; *d*, nucleolar fibres (chromatin substance) of the nucleus. 2, 3. *Collozoum inerme*, J. Müller, two different forms of colonies, of the natural size. 4. Central capsule from a colony of *Collozoum inerme*, showing the intracapsular protoplasm and nucleus, broken up into a number of spores, the germs of swarm-spores or flagellula; each encloses a crystalline rod. *c*, yellow cells lying in the extracapsular protoplasm. 5. A small colony of *Collozoum inerme*, magnified 25 diameters. *a*, alveoli (vacuoles) of the extracapsular protoplasm; *b*, central capsules, each containing besides protoplasm a large oil-globule. 6-13. Yellow cells of various Radiolaria:—6, normal yellow cell; 7, 8, division with formation of transverse septum; 9, a modified condition according to Brandt; 10, division of a yellow cell into four; 11, amœboid condition of a yellow cell from the body of a dead Sphærozoum; 12, a similar cell in process of division; 13, a yellow cell the protoplasm of which is creeping out of its cellulose envelope. 14. *Heliosphæra inermis*, Haeck., living example; × 400. *a*, nucleus; *b*, central capsule; *c*, siliceous basket-work skeleton. 15. Two swarm-spores (flagellulæ) of *Collozoum inerme*, set free from such a central capsule as that drawn in 4; each contains a crystal *b* and a nucleus *a*. 16. Two swarm-spores of *Collozoum inerme*, of the second kind, viz., devoid of crystals, and of two sizes, a macrospore and a microspore. They have been set free from central capsules with contents of a different appearance from that drawn in 4. *a*, nucleus. 17. *Actinomma asteracanthion*, Haeck.; × 200; one of the Peripylæa. Entire animal in optical section. *a*, nucleus; *b*, wall of the central capsule; *c*, innermost siliceous shell enclosed in the nucleus; c^2, middle shell lying within the central capsule; c^3, outer shell lying in the extracapsular protoplasm. Four radial siliceous spines, holding the three spherical shells together are seen. The radial striation of the protoplasm and the fine extracapsular pseudopodia are to be noted. 18. *Amphilonche messanensis*, Haeck.; × 200; one of the Acanthometridea. Entire animal as seen living.

ORDER 2. MONOPYLÆA, Hertwig.

Characters.—Silico-skeletal Radiolaria in which the central capsule is not spherical but monaxonic (cone-shaped), with a single perforate area (pore-plate) placed on the basal face of the cone; the membrane of the capsule is simple, the nucleus single; the skeleton is extracapsular, and forms a scaffold-like or bee-hive-like structure of monaxonic form.

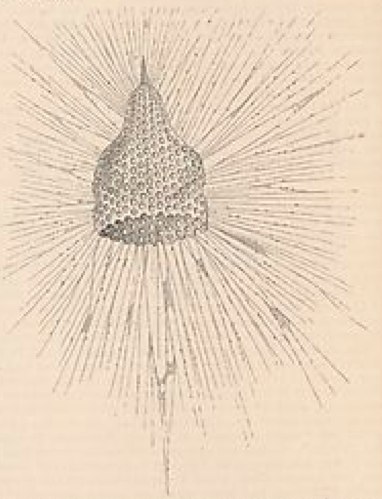


FIG. XV.—*Eucyrtidium cranioides*, Haeck.; ×150; one of the Monopylæa. Entire animal as seen in the living condition. The central capsule is hidden by the bee-hive-shaped siliceous shell within which it is lodged.

FAM. 1. PLECTIDA, Haeck. Skeleton formed of siliceous spines loosely conjoined.

Genera (selected).—*Plagiacantha*, Haeck.; *Plegmatium*, Haeck.

FAM. 2. CYRTIDA, Haeck. Skeleton a monaxonic or triradiate shell, or continuous piece (bee-hive-shaped).

Genera (selected).—*Halicalyptra*, Haeck.; *Eucyrtidium*, Haeck. (Fig. XV.); *Carpocanium*, Haeck. (Fig. XVI. 3).

FAM. 3. BOTRIDA, Haeck. Irregular forms; the shell composed of several chambers agglomerated without definite order; a single central capsule.

Genera.—*Botryocyrtis*, Haeck.; *Lithobotrys*, Haeck.

FAM. 4. SPYRIDA, Haeck. Geminate forms, with shell consisting of two conjoined chambers; a single central capsule.

FAM. 5. STEPHIDA, Haeck. Skeleton cricoid, forming a single siliceous ring or several conjoined rings.

Genera (selected).—*Acanthodesmia*, Haeck.; *Zygostephanus*, Haeck.; *Lithocircus*, Haeck. (Fig. XVI. 1).

ORDER 3. PHÆODARIA, Haeck. (*Tripylæa*, Hertwig).

Characters.—Silico-skeletal Radiolaria in which the central

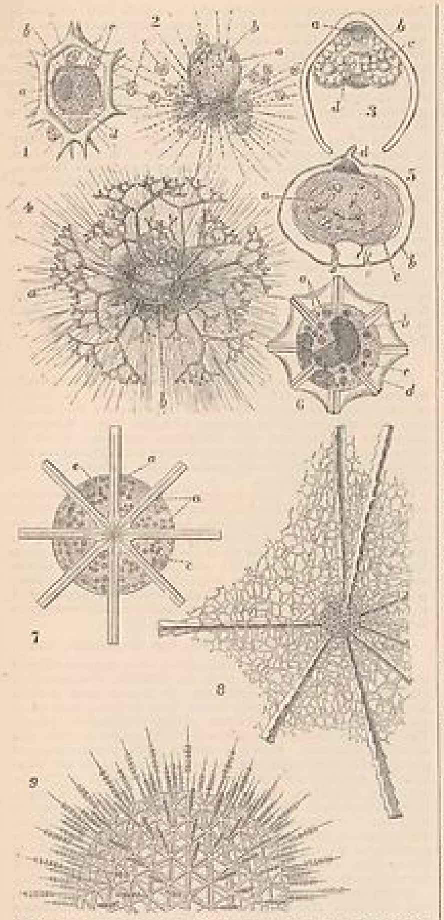


Fig. XVI.—**Radiolaria.** 1. *Lithocircus annularis*, Hertwig; one of the Monopylea. Whole animal in the living state (optical section). *a*, nucleus; *b*, wall of the central capsule; *c*, yellow cells; *d*, perforated area of the central capsule (Monopylean). 2. *Cystidium inerme*, Hertwig; one of the Monopylea. Living animal. An example of a Monopylean destitute of skeleton. *a*, nucleus; *b*, capsule-wall; *c*, yellow cells in the extracapsular protoplasm. 3. *Carpocanium diadema*, Haeck.; optical section of the bee-hive-shaped shell to show the form and position of the protoplasmic body. *a*, the tri-lobed nucleus; *b*, the siliceous shell; *c*, oil-globules; *d*, the perforate area (pore-plate) of the central capsule. 4. *Coelodendrum gracillimum*, Haeck.; living animal, complete; one of the Tripylea. *a*, the characteristic dark pigment (phaeodium) surrounding the central capsule *b*. The peculiar branched siliceous skeleton, consisting of hollow fibres, and the expanded pseudopodia are seen. 5. Central capsule of one of the Tripylea, isolated, showing *a*, the nucleus; *b*,*c*, the inner and the outer laminae of the capsule-wall; *d*, the chief or polar aperture; *e*,*e*, the two secondary apertures. 6, 7. *Acanthometra Claparedei*, Haeck. 7 shows the animal in optical section, so as to exhibit the characteristic meeting of the spines at the central point as in all Acanthometridea; 6 shows the transition from the uninuclear to the multinuclear condition by the breaking up of the large nucleus. *a*, small nuclei; *b*, large fragments of the single nucleus; *c*, wall of the central capsule; *d*, extracapsular jelly (not protoplasm); *e*, peculiar intracapsular yellow cells. 8. *Spongosphaera streptacantha*, Haeck.; one of the Peripylea. Siliceous skeleton not quite completely drawn on the right side. *a*, the spherical extra-capsular shell (compare Fig. XIV. 17), supporting very large radial spines which are connected by a spongy network of siliceous fibres. 9. *Aulosphaera elegantissima*, Haeck.; one of the Phaeodaria. Half of the spherical siliceous skeleton.

capsule has a double membrane and more than one perforate area, viz., one chief "polar aperture," and one, two, or more accessory apertures (Fig. XVI. 5). The nucleus is single. Around the central capsule is an abundant dark brown pigment (phaeodium of Haeckel). The siliceous skeleton exhibits various shapes regular and irregular, but is often remarkable for the fact that it is built up of hollow tubes.

Fam. 1. Phaeocystida, Haeck. The siliceous skeleton is either entirely absent or consists of hollow needles which are disposed outside the central capsule, regularly or irregularly.

Genera (selected).—*Aulacantha*, Haeck.; *Thalassoplancta*, Haeck.

Fam. 2. Phaeogromida, Haeck. The siliceous skeleton consists of a single fenestrated shell, which may be spherical, ovoid, or often dipleuric, but always has one or more large openings.

Genera (selected).—*Challengeria*, Wy. Thomson; *Lithogromia*, Haeck.

Fam. 3. Phaeosphaerida. The siliceous skeleton consists of numerous hollow tubes which are united in a peculiar way to form a large spherical or polyhedral basket-work.

Genera (selected).—*Aulosphaera*, Haeck. (Fig. XVI. 9); *Auloplegma*, Haeck.; *Cannosphaera*, Haeck.

Fam. 4. Phaeoconchida. The siliceous skeleton consists of two separate fenestrated valves, similar to a mussel's shells; often there are attached to the valves simple or branched hollow tubes of silex.

Genera (selected).—*Conchidium*, Haeck.; *Coelodendrum*, Haeck. (Fig. XVI. 4).

Sub-class II. **Acanthometridea**, Lankester (= *Acanthino-skeleta*).

Characters.—Radiolaria in which the skeleton is composed of a peculiar horny substance known as acanthin (rarely of silica). The central capsule is uniformly perforate (Peripylea type). A divided or multiple nucleus is present in the capsule; the capsule-wall is single. The skeleton always has the form of spines which radiate from a central point within the capsule where they are all fitted to one another. Rarely a fenestrated tangential skeleton is also formed.

Fam. 1. Acanthonida, Haeck. Skeleton consisting of twenty spines of acanthin disposed in five parallel zones of four spines each, meeting one another at the central point of the organism; never forming a fenestrated shell.

Genera (selected).—*Acanthometra*, J. Müller (Fig. XVI. 6, 7); *Astrolonche*, Haeck.; *Amphilonche*, Haeck. (Fig. XIV. 18).

Fam. 2. Diploconida, Haeck. Skeleton a double cone.

Genus unicum.—*Diploconus*, Haeck.

Fam. 3. Dorataspida, Haeck. The twenty acanthin spines of the skeleton form by transverse outgrowths a spherical fenestrated shell.

Genera (selected).—*Stauraspis*, Haeck.; *Dorataspis*, Haeck.

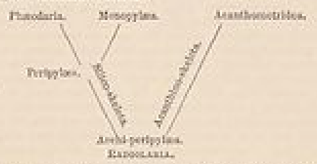
Fam. 4. Sphaerocapsida, Haeck. The twenty acanthin spines are joined together at their free apices by a simple perforate shell of acanthin.

Genus unicum.—*Sphaerocapsa*.

Fam. 5. Litholophida. Skeleton of many needles of acanthin radiating from a single point without definite number or order.

Genera.—*Litholophus*, Haeck.; *Astrolophus*, Haeck.

Further remarks on the Radiolaria.—It has not been possible in the systematic summary above given to enumerate the immense number of genera which have been distinguished by Haeckel (**42**) as the result of the study of the skeletons of this group. The important differences in the structure of the central capsule of different Radiolaria were first shown by Hertwig, who also discovered that the spines of the Acanthometridea consist not of silica but of an organic compound. In view of this latter fact and of the peculiar numerical and architectural features of the Acanthometrid skeleton, it seems proper to separate them altogether from the other Radiolaria. The Peripylea may be regarded as the starting point of the Radiolarian pedigree, and have given rise on the one hand to the Acanthometridea, which retain the archaic structure of the central capsule whilst developing a peculiar skeleton, and on the other hand to the Monopylea and Phaeodaria which have modified the capsule but retained the siliceous skeleton.



The occasional total absence of any siliceous or acanthinous skeleton does not appear to be a matter of classificatory importance, since skeletal elements occur in close allies of those very few forms

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which are totally devoid of skeleton. Similarly it does not appear to be a matter of great significance that some forms (Polycyttaria) form colonies, instead of the central capsules separating from one another after fission has occurred.

It is important to note that the skeleton of silex or acanthin does not correspond to the shell of other Gymnomyxa, which appears rather to be represented by the membranous central capsule. The skeleton does, however, appear to correspond to the spicules of Heliozoa, and there is an undeniable affinity between such a form as Clathrulina (Fig. VII. 2) and the Sphærid Peripylæa (such as Heliosphæra, Fig. XIV. 11). The Radiolaria are, however, a very strongly marked group, definitely separated from all other Gymnomyxa by the membranous central capsule sunk in their protoplasm. Their differences *inter se* do not affect their essential structure. The variations in the chemical composition of the skeleton and in the perforation of the capsule do not appear superficially. The most obvious features in which they differ from one another relate to the form and complexity of the skeleton, a part of the organism so little characteristic of the group that it may be wanting altogether. It is not known how far the form-species and form-genera which have been distinguished in such profusion by Haeckel as the result of a study of the skeletons are permanent (*i.e.*, relatively permanent) physiological species. There is no doubt that very many are local and conditional varieties of a single Protean species. The same remark applies to the species discriminated among the shell-bearing Reticularia. It must not be supposed, however, that less importance is to be attached to the distinguishing and recording of such forms because we are not able to assert that they are permanent species.

The *yellow cells* (of spherical form, ·005 to 0·15 of a millimetre in diameter) which occur very generally scattered in the extra-capsular protoplasm of Radiolaria were at one time regarded as essential components of the Radiolarian body. Their parasitic nature is now rendered probable by the observations of Cienkowski (43), Brandt (44), and Geddes (45), who have established that each cell has a cellulose wall and a nucleus (Fig. XIV. 6 to 13), that the protoplasm is impregnated by chlorophyll which, as in Diatoms, is obscured by the yellow pigment, and that a starch-like substance is present (giving the violet reaction with iodine). Further, Cienkowski showed, not only that the yellow cells multiply by fission during the life of the Radiolarian, but that when isolated they continue to live; the cellulose envelope becomes softened; the protoplasm exhibits amœboid movements and escapes from the envelope altogether (Fig. XIV. 13) and multiplies by fission. Brandt has given the name *Zooxanthella nutricola* to the parasitic unicellular Alga thus indicated. He and Geddes have shown that a similar organism infests the endoderm cells of Anthozoa and of some Siphonophora in enormous quantities, and the former has been led, it seems erroneously, to regard the chlorophyll corpuscles of *Hydra viridis*, Spongilla, and Ciliata as also parasitic Algæ, for which he has coined the name Zoochlorella. The same arguments which Brandt has used to justify this view as to animal chlorophyll would warrant the creation of a genus "Phytochlorella" for the hypothetical Alga which has hitherto been described as the "chlorophyll corpuscles" of the cells of ordinary green plants.

Zooxanthella nutricola does not, for some unknown reason, infest the Acanthometridea, and it is by no means so universally present in the bodies of the Silico-skeleta as was supposed before its parasitic nature was recognized.

The *streaming of the granules of the protoplasm* has been observed in the pseudopodia of Radiolaria as in those of Heliozoa and Reticularia; it has also been seen in the deeper protoplasm; and granules have been definitely seen to pass through the pores of the central capsule from the intracapsular to the extracapsular protoplasm. A feeble vibrating movement of the pseudopodia has been occasionally noticed.

The *production of swarm-spores* has been observed only in Acanthometra and in the Polycyttaria and Thalassicollidæ, and only in the two latter groups have any detailed observations been made. Two distinct processes of swarm-spore production have been observed by Cienkowski (43), confirmed by Hertwig (46)—distinguished by the character of the resulting spores which are called "crystalligerous" (Fig. XIV. 15) in the one case, and "dimorphous" in the other (Fig. XIV. 16). In both processes the nucleated protoplasm within the central capsule breaks up by a more or less regular cell-division into small pieces, the details of the process differing a little in the two cases. In those individuals which produce crystalligerous swarm-spores, each spore encloses a small crystal (Fig. XIV. 15). On the other hand, in those individuals which produce dimorphous swarm-spores, the contents of the capsule (which in both instances are set free by its natural rupture) are seen to consist of individuals of two sizes "macrospores" and "microspores," neither of which contain crystals (Fig. XIV. 16). The further development of the spores has not been observed in either case. Both processes have been observed in the same species, and it is suggested that there is an alternation of sexual and asexual generations, the crystalligerous spores developing directly into adults, which in their turn produce in their central capsules dimorphous swarm-spores (macrospores and microspores), which in a manner analogous to that observed in the Volvocinean Flagellata copulate (permanently fuse) with one another (the larger with the smaller) before proceeding to develop. The adults resulting from this process would, it is suggested, produce in their turn crystalligerous swarm-spores. Unfortunately we have no observations to support this hypothetical scheme of a life-history.

Fusion or conjugation of adult Radiolaria, whether preliminary to swarm-spore-production or independently of it, has not been observed—this affording a distinction between them and Heliozoa, and an agreement, though of a negative character, with the Reticularia.

Simple fission of the central capsule of adult individuals and subsequently of the whole protoplasmic mass has been observed in several instances, and is probably a general method of reproduction in the group.

The siliceous shells of the Radiolaria are found abundantly in certain rocks. They furnish, together with Diatoms and Sponge-spicules, the silica which has been segregated as flint in the Chalk formation. They are present in quantity (as much as 10 per cent.) in the Atlantic ooze, and in the celebrated "Barbados earth" (a Tertiary deposit) are the chief components.

GRADE B. *CORTICATA*, Lankester, 1878 (64).

Characters.—Protozoa in which the protoplasm of the cell-body, in its adult condition, is permanently differentiated into two layers, an outer denser cortical substance and an inner more fluid medullary substance (not to be confused with the merely temporary distinction of ectoplasm and endoplasm sometimes noted in Gymnomyxa, which is not structural but due to the gravitation and self-attraction of the coarser granules often embedded in the uniformly fluid protoplasm).

Since the Corticata have developed from simple Gymnomyxa exhibiting both amœboid and flagellate phases of form and activity, it results (1) that the forms of the body of many Corticata are traceable to modifications of these primitive forms; (2) that the young stages of the Corticata are in the lower classes of that group typical flagellulæ or amœbulæ; and (3) that there are certain archaic forms included in those lower classes whose position there is doubtful, and which might be with almost equal propriety assigned to the Gymnomyxa, since they are transitional from that lower grade to the higher grade of Corticata.

CLASS I. **SPOROZOA**, Leuckart (47); Syn. *Gregarinida*, Auct.

Characters.—Corticata parasitic in almost all classes and orders of animals, imbibing nutriment from the diffusible albuminoids of their hosts and therefore mouthless. In typical cases there is hatched from a chlamydospore one or more modified nucleate or non-nucleate flagellulæ (falciform young, drepanidium phase). The flagellula increases in size and differentiates cortical and medullary substance. Fission is common in the younger stages of growth. The movements now become neither vibratile nor amœboid but definitely restrained, and are best described as "eugle-noid" (*cf.* Flagellata, Fig. XX. 27, 28). The nucleus is single, large, and spherical. No contractile vacuole and rarely any vacuole is present. A size of $\frac{1}{2}$th inch may be attained in this phase, which may be definitely spoken of as the euglena phase corresponding to the amœba phase of Gymnomyxa. It is usually of oblong form, with sac-like contractile wall of cortical substance, but may be spherical (Coccidiidea) or even amœboid (Myxosporidia).

Conjugation, followed directly or after an interval by sporulation, may now ensue. The conjugated individuals (two), or sometimes a single individual, become encysted. The contents of the cysts now rapidly divide (by a process the details of which are unknown) into minute ovoid nucleated (?) bodies; sometimes a portion of the protoplasm is not converted into spores but may form sporoducts (*cf.* capillitium of Mycetozoa). Each piece acquires a special chitin-like colourless coat, and is then a chlamydospore. Rarely one spore only is formed from the whole contents of a cyst. The spore-coat is usually thick, and remarkable for processes and other accessory developments. The included protoplasm of the chlamydospore frequently divides into several pieces before hatching. These usually, when set free from the spore-coat, have the form of modified nucleated flagellulæ, *i.e.*, flagellulæ in which the protoplasm is not drawn out into a thread-like flagellum but exhibits an elongate form, uniformly endowed with vibratile activity. With few (if any) exceptions, the falciform young thus characterized penetrates a cell of some tissue of its host and there undergoes the first stages of its growth (hence called Cytozoa). In some forms the pre-cystic phase never escapes from its cell host. In other cases it remains connected with the hospitable cell long after it has by growth exceeded by many hundred times the bulk of its quondam entertainer; often it loses all connexion with its cell host and is carried away to some other part of the infested animal before completing its growth and encysting.

The Sporozoa are divided into four sub-classes, differing from one another according to the form and development attained by the euglena phase. We shall place the most highly developed first, not only because our knowledge about it is most complete, but because it is possible that one at least of the other sub-classes is derived by degeneration from it.

Sub-class I. Gregarinidea, Bütschli (9).

Characters.—Sporozoa in which the euglena phase is dominant, being relatively of large size, elongate in form, definitely shaped, having contractile but not viscid cortex, and exhibiting often active nutritional and locomotor phenomena. Though usually if not invariably cell-parasites in early youth, they become free before attaining adult growth, and inhabit either the body-cavity or the intestine of their hosts. Many spores are produced in the encysted phase. The spores have an oblong, sometimes caudate coat, and produce each one or several falciform young. At present only known as parasites of Invertebrata.

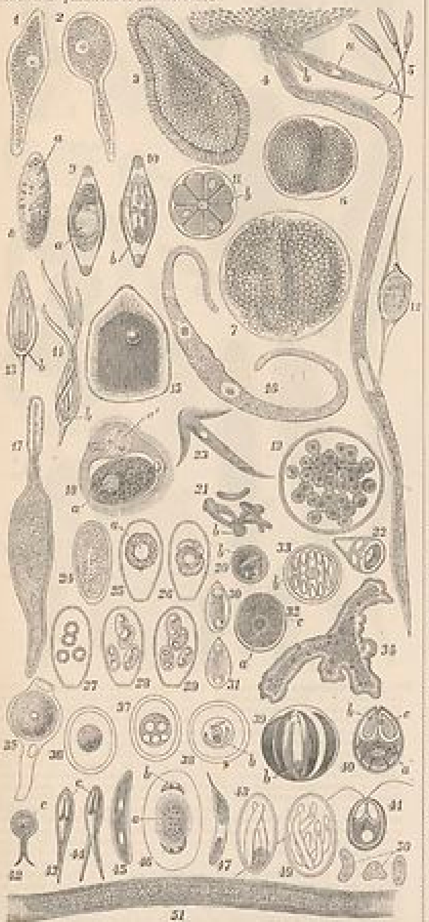

Fig. XVII.—**Sporozoa.** 1, 2. *Monocystis agilis*, Stein; × 250; from the testis of the Earthworm. Two phases of movement—a ring-like contraction passing along the body from one end to the other. 3. Individual of the same species which has penetrated in the young stage a sperm-cell of the Earthworm, and is now clothed as it were with spermatoblasts. 4. *Monocystis magna*, A. Schmidt, from the testis of the Earthworm (*L. terrestris*, L.). Two individuals, which are implanted by one extremity at *b* in two epithelial cells of the rosette of the spermatic duct. *a*, nucleus of the Monocystis. 5. Tailed chlamydospores of *Monocystis tenax*, Köll. 6. Two *M. agilis* encysted, spores forming on the surface of the protoplasm. 7. A similar cyst further advanced in spore-formation (see Fig. XVIII.). 8. Spore of *M. agilis*, now elongated but still naked. *a*, nucleus. × 1000. 9. The spore has now encased itself in a navicula-shaped coat. *a*, nucleus. 10. The spore protoplasm has now divided into several falciform swarm-spores, leaving a portion of the protoplasm unused. *b*, Schneider's residual core. 11. Optical transverse section of a completed spore. *b*, Schneider's residual core. 12. Chlamydospore of *Klossia chitonis*, nov. sp., from the liver of Chiton (original.) 13, 14. Chlamydospore of *Monocystis nemertis*, Köll., liberating falciform young. *b*, Schneider's residue. 15. *Monocystis pellucida*, Köll. (from Nereis); × 150; to show the very thick cortical substance and its fibrillation (after Lankester, **54**). 16. *Monocystis tenax*, Köll., two individuals adhering to one another (a syzygium). For spores see 5. 17. *Monocystis aphroditæ*, Lankester (**55**); × 60; remarkable among Monocystids for its long proboscis resembling the epimerite of some Septata. 18. *Klossia helicina*, Aim. Schn., from the kidney of *Helix hortensis*. A single cell of the renal epithelium in which a full-grown Klossia is embedded. *a*, nucleus of the Klossia; *a'*, nucleus of the renal cell. 19. Cyst of *Klossia helicina*, the contents broken up into spherical chlamydospores. 20. Single spore from the last, showing falciform young and a Schneider's residue *b*. 21. The contents of the same spore. 22. A small renal cell of Helix containing two of the youngest stage of Klossia. 23. *Monocystis sagittata*, Leuck., from the intestine of *Capitella capitata*; × 200. 24 to 31. *Coccidium oviforme*, Leuck., from the liver of the Rabbit:—24, adult individual encysted; 25, the protoplasm contracted—*a*, nucleus; 26, 27, division into four spores, as yet naked; 28, 29, the spores have acquired a covering, *i.e.*, are chlamydospores, and each contains a single falciform young; 30, 31, two views of a chlamydospore more highly magnified so as to show the single falciform young (from Leuckart). 32. *Klossia octopiana*, Aim. Schn., from Cephalopoda. *a*, nucleus; *b*, cyst-membrane. × 200 diam. 33. Single spherical spore of the same; × 1400 diam.; showing numerous falciform young, and *b*, Schneider's residue. 34. *Myxidium Lieberkühnii*, Bütschli, one of the Myxosporidia, from the bladder of the Pike (Esox); creeping euglena phase, showing strongly lobed amœboid character (pseudopodia and undifferentiated (?) cortex); × 60 diam. 35–39. *Eimeria falciformis*, Eimer sp., from the Mouse:—35, an adult non-encysted individual inhabiting an epithelial cell of the intestine of the mouse; 36, encysted phase; 37, clear corpuscles appear in the encysted protoplasm; 38, the protoplasm now forms a single spore containing several falciform young; *b*, Schneider's residue; 39, isolated spore showing falciform young, and *b*, Schneider's residue. 40. Chlamydospore of *Myxobolus Mülleri*, Bütschli, one of the Myxosporidia from the gills of Cyprinoid Fishes. *a*, nucleus; *b*, refringent corpuscle; *c*, polar body or thread-capsule. 41. A similar chlamydospore which has ejected the filaments from its thread capsules. 42. Chlamydospore of a Myxosporidium infesting the kidney of *Lota vulgaris*. *c*, polar body (psorosperm of authors). 43, 44. Chlamydospores of a Myxosporidium from the gills of Perca (psorosperm of authors). Compare with the tailed chlamydospore of *Monocystis tenax*, 5. 45–47. *Drepanidium ranarum*, Lankester, the falciform young of an unascertained Coccidiide infesting the Frog (supposed by Gaule to be produced by the blood corpuscles):—45, specimen stained by iodine; 46, red-blood corpuscle of Frog, showing *b*, two contained Drepanidia, and *a*, the nucleus of the blood corpuscle; 47, living Drepanidium. 48. Chlamydospore of Lieberkühn's Coccidium of the Frog's kidney, perhaps belonging to the life-cycle of *Drepanidium ranarum*. The spore contains two falciform young (Drepanidia?) and a Schneider's residue. 49. Chlamydospore of *Monocystis thalassemæ*, Lankester, containing numerous falciform young. 50, 51, *Sarcocystis Miescheri*, Lankester:—50, falciform young escaped from chlamydospores; 51, adult euglena phase inhabiting a striated muscle fibre of the Pig.

Order 1. HAPLOCYTA, Lankester.

Characters.—Gregarinidea in which there is never at any time a partition of the medullary substance into two or more chambers. The euglenoid is always a single contractile sac with one mass of medullary substance in which floats the large vesicular transparent nucleus. Spores larger than in the next group, each producing several falciform young.

Genus unicum.—*Monocystis*, Stein, 1848. The various generic subdivisions proposed by Aim. Schneider (**48**), and accepted by Bütschli, appear to the present writer to have insufficient characters, and serve to complicate rather than to organise our knowledge of the subject. We do not yet know enough of the sporulation and subsequent development of the various monocystic Gregarinidea to justify the erection of distinct genera.

Monocystis agilis, Stein, Fig. XVII. 1, 2, 3, 6, 7, 8, 9, 10, 11, and Fig. XVIII. is the type. The other species of Monocystis occur chiefly (and very commonly) in marine Annelids, Platyhelminthes, Gephyrea, and Tunicata; not in Arthropoda, Mollusca, nor Vertebrata. The only definite differences which they present of possibly more than specific worth, as compared with *M. agilis*, are in the form of the chlamydospores, which are sometimes tailed, as in *M. tenax* (Fig. XVII. 5), and in *M. nemertis* (Fig. XVII. 13) and *M. sipunculi*, and further also certain differences in the general form, as for instance the anchor-like *M. sagittata* (Fig. XVII. 23), and the proboscidiferous *M. aphroditæ* (Fig. XVII. 17). The fine parallel striation of the cuticle in some species (*M. serpulæ*, &c.) might also be made the basis of a generic or subgeneric group.

On the whole it seems best to leave all the species for the present in the one genus Monocystis, pending further knowledge. It seems probable that more than one species (at least two, *M. agilis* and *M. magna*) infest the common Earthworm.

Order 2. SEPTATA, Lankester.

Characters.—Gregarinidea in which in the adult the medullary substance is separated into two chambers—a smaller anterior (the protomerite) and a larger posterior (the deutomerite), in which lies the nucleus. There is frequently if not always present, either in early growth or more persistently, an anterior proboscis-like appendage (the epimerite) growing from the protomerite. The epimerite serves to attach the parasite to its host, and may for that purpose carry hooklets. It is always shed sooner or later. The phase in which it is present is called a "cephalont," the phase after it has broken off a "sporont" (see Fig. XIX. 22, 23). The spores are smaller than in the preceding group, often very minute, and sometimes the cyst is complicated by the formation of sporoducts, and by a kind of "capillitium" of residual protoplasm (Fig. XIX. 2). Spores producing each only a single (?) falciform young.

Genera.—*Gregarina*, Dufour; *Hoplorhynchus*, Von Carus.

[The numerous genera which have been proposed at different times by Hammerschmidt and others, and more recently by Aimé Schneider, appear to the present writer to be unserviceable, owing to the fact that our knowledge is as yet very incomplete. A good basis for generic or family distinctions might probably be found in the greater or less elaboration of the cyst and the formation or not of sporoducts. But of the majority of Septata we do not know the cysts or the history of sporulation; we merely know that some have simple cysts with complete sporulation leaving no residue of protoplasm, and that others form cysts with double walls and elaborate tubular ducts, whilst a part of the protoplasm is not sporulated but forms a capillitium (Fig. XIX. 2).

Another possible basis for generic division of the Septata may be found in the characters of the epimerite. This may be present or absent altogether. It may exist only in the young condition or persist until growth is completed. It may be simple, short, elongate, or provided with hooklets. The presence of hooklets on the epimerite is the only character which at present seems to serve conveniently for generic distinction. With regard to the other points mentioned we are not sufficiently informed, since we know the complete history of development from the young form set free from the spore in only one or two cases.]

The Septata are found exclusively in the alimentary canals of Arthropoda (Insects, Myriapods, Crustacea, not Arachnida). See Fig. XIX. for various examples of the group.

FIG. XVIII.—Cyst of *Monocystis agilis*, the common Gregarinide of the Earthworm; × 750 diam.; showing ripe chlamydospores and complete absence of any residual protoplasm or other material in the cyst (original).

SUB-CLASS II. **Coccidiidea**, Bütschli (9).

Sporozoa in which the euglena phase remains of relatively minute size, of spherical shape and simple egg-cell-like structure. It is not locomotive, but continues, until the cyst is formed, to inhabit a single cell of the host. Many, few, or one single chlamydospore are formed in the cyst. One or more falciform young escape from each spore, and exhibit active movements (flagellula-like) leading to a penetration of a tissue-cell by the young form as in Gregarinidea. Many are parasites of Vertebrata.

ORDER 1. MONOSPOREA, Aim. Schn.

Characters.—The whole content of the cyst forms but a single spore.

Genus unicum.—*Eimeria* (in the intestinal epithelium of Triton, Frog, Sparrow, Mouse, and the Myriapods Lithobius and Glomeris, Fig. XVII. 35 to 39).

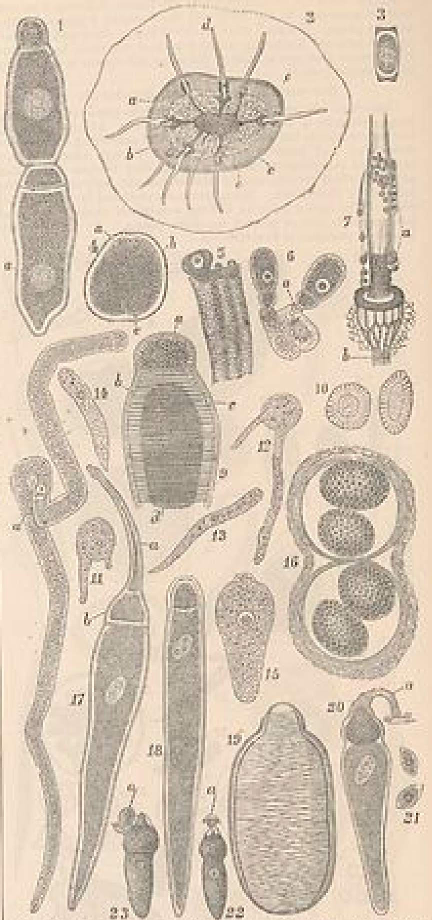

FIG. XIX.—Sporozoa (Septata). 1. *Gregarina blattarum*, Siebold, from the intestine of *Blatta orientalis*; × 80. A syzygium of two individuals. Each animal consists of a small anterior chamber, the protomerite, and a large posterior chamber, the deutomerite, in which is the nucleus *a*. 2. Over-ripe cyst of *Gregarina blattarum*, with thick gelatinous envelope *e*, and projecting sporoducts *d*. The spores have been nearly all discharged, but a mass of them still lies in the centre of the cyst *b*. The specimen has been treated with dilute KHO, and the granular contents of the cyst dissolved. Around the central mass of spores is rendered visible the network of protoplasmic origin in which the ejected spores were embedded. This distinctly resembles in origin and function the capillitium of Mycetozoa (Fig. III.). *a*, the plasmatic channels leading to the everted sporoducts; *b*, the still remaining spores; *c*, the proper cyst-wall; *d*, the everted sporoducts; *e*, the gelatinous envelope. 3. A ripe spore (chlamydospore) of *Gregarina blattarum*, a long time after its escape from the cyst; × 1600 diam. 4. Commencing encystment of a syzygium of *G. blattarum*. *a*, protomerite of one individual; *b*, gelatinous envelope; *c*, protomerite of the second individual. 5. Three epithelial cells of the mid-gut of *Blatta orientalis*, into the end of each of which an extremely young *Gregarina blattarum* has made its way. 6. Further development of the young Gregarina; only the epimerite *a* is now buried in the substance of the epithelial cell, and this will soon break off and set the Gregarina free. It is now a "cephalont"; it will then become a "sporont." 7. Basal part of an everted sporoduct of *Gregarina blattarum*. *a*, granular-fibrous mass investing the base of the duct; *b*, commencement of the plasmatic channel in the interior of which the sporoduct was produced as an invaginated cuticular formation before its eversion. 8. *Gregarina gigantea*, E. Van Ben., from the intestine of the Lobster; × 150. *a*, nucleus.

9. Anterior end of the same more highly magnified. *a*, protomerite; *b*, layer of circular fibrillæ lying below the cuticle; *c*, cortical substance of the deutomerite; *d*, medullary substance of the deutomerite. 10. Two spores of *Gregarina gigantea* (after Bütschli), showing the very thick coat of the spore. 11-15. Stages in the development of *Gregarina gigantea*:—11, recently escaped from the spore-coat, no nucleus; 12, still no nucleus, one vibratile and one motionless process; 13, the two processes have divided; one here drawn has developed a nucleus; 14, further growth; 15, the deutomerite commences to develop. 16. Cysts of *Gregarina gigantea*, from the rectum of the Lobster. The double contents are believed by Ed. Van Beneden to be due not to conjugation previous to encystment but to subsequent fusion. 17, 18. *Gregarina longicollis*, Stein, from the intestine of *Blaps mortisaga*:—17, cephalont phase, with a long proboscis-like epimerite *a*, attached to the protomerite *b*; 18, sporont phase, the epimerite having been cast preliminarily to syzygy and encystment. 19. *Gregarina Munieri*, Aim. Schneider, from the intestine of *Timarcha tenebricosa*, to show the network of anastomosing fibres beneath the cuticle, similar to the annular fibrillæ of *G. gigantea* shown in 9. 20. *Gregarina (Hoplorhynchus) oligacanthus*, Stein, from the intestine of the larva of Agrion. Cephalont with spine-crowned epimerite *a*. 21. Spores of *Gregarina oligacanthus*. 22, 23. *Gregarina (Hoplorhynchus) Dujardini*, Aim. Schneider, from the intestine of *Lithobius forficatus*:—22, specimen with epimerite *a*, therefore a "cephalont"; 23, specimen losing its epimerite by rupture and becoming a "sporont."

ORDER 2. OLIGOSPOREA, Aim. Schn.

Characters.—The cyst-content develops itself into a definite and constant but small number of spores.

Genus unicum.—*Coccidium*, Leuck. (in intestinal epithelium and liver of Mammals, and some Invertebrates, Figs. XVII. 24 to 31).

ORDER 3. POLYSPOREA.

Characters.—The cyst-content develops itself into a great number of spores (sixty or more).

Genus unicum.—*Klossia*, Aim. Schn. Three species of Klossia are found in Mollusca—viz., in Helix, in Cephalopods, and in Chiton. Schneider's genus, Adelea, from Lithobius, appears to belong here. Kloss (49) discovered the parasite of the renal cells of *Helix hortensis* represented in Fig. XVII. 18, 19, 20, 21, and 22; Schneider that of Cephalopods, Fig. XVII. 32, 33. In Chiton Dr Tovey has discovered a third species with very remarkable spores, which are here figured for the first time (Fig. XVII. 12).

The *Drepanidium Ranarum* (Fig. XVII. 45, 46, 47), discovered by Lankester (50) in the Frog's blood, is probably the falciform young of a Coccidium parasitic in the Frog's kidney, and discovered there by Lieberkühn (51). A spore of this Coccidium is shown in Fig. XVII. 48; whilst in 46 two Drepanidia which have penetrated a red-blood corpuscle of the Frog are represented.

The Polysporous Coccidiidea come very close to the Gregarinide genus Monocystis, from which they may be considered as being derived by an arrest of development. The spores and falciform young of the Coccidiidea are closely similar to those of Monocystis, and the young in both cases penetrate the tissue-cells of their host; but in Monocystis this is only a temporary condition, and growth leads to the cessation of such "cell-parasitism." On the other hand, growth is arrested in the Coccidiidea, and the organism is permanently a cell-parasite.

Since the parasitism is more developed in the case of a cell-parasite than in the case of a parasite which wanders in the body cavity, it seems probable that the Coccidiidea have been derived from the Gregarinidea rather than that the reverse process has taken place.

SUB-CLASS III. **Myxosporidia**, Bütschli.

Characters.—Sporozoa in which the euglena-phase is a large multinucleate amœba-like organism (Fig. XVII. 34). The cysts are imperfectly known, but appear to be simple; some attain a diameter of two lines. The spores are highly characteristic, having each a thick coat which is usually provided with a bifurcate process or may have thread capsules (like nematocysts) in its substance (Fig. XVII. 40, 41, 42, 43, 44).

The spores contain a single nucleus, and are not known to produce falciform young, but in one case have been seen to liberate an amœbula. The further development is unknown. The Myxosporidia are parasitic beneath the epidermis of the gills and fins, and in the gall-bladder and urinary bladder of Fishes, both freshwater and marine.

Genera.—*Myxidium*, Bütschli (Pike, Fig. XVII. 34); *Myxobolus*, Bütschli (Cyprinoids); *Lithocystis*, Giard (the Lamellibranch Echinocardium).

The Myxosporidia are very imperfectly known. They present very close affinities to the Mycetozoa, and are to be regarded as a connecting link between the lower Gymnomyxa and the typical Sporozoa. Possibly their large multinucleate amœba phase is a plasmodium formed by fusion of amœbulæ set free from spores, though it is possible that the many nuclei are the result of a division of an original single nucleus, preparatory to sporulation.

Their spores are more elaborate in structure than those of any other Protozoa, and are more nearly paralleled by those of some species of Monocystis than by those of Mycetozoa. The thread-capsules of the spores are identical in structure with those of Hydrozoa, and probably serve as organs of attachment, as do the furcate processes of the spore-case. It is not certain that a definite cyst is always or ever formed, but as occurs rarely in some Gregarinidea, the spores may be formed in a non encysted amœba form.

Although pseudopodia, sometimes short and thread-like, have been observed in the amœba phase, yet it is also stated that a distinction of cortical and medullary substance obtains.

The "psorosperms" of J. Müller are the spores of Myxosporidia.

SUB-CLASS IV. **Sarcocystidia**, Bütschli.

(This division is formed by Bütschli for the reception of Sarcocystis, parasitic in the muscular fibres of Mammals, and of Amœbidium, parasitic in Crustacea. Both are very insufficiently known, but have the form of tubular protoplasmic bodies in which numerous ovoid spores are formed from which falciform young escape.)

Genera.—*Sarcocystis*, Lankester; *Amœbidium*, Cienkowski (52). Sarcocystis (Fig. XVII. 50, 51, *S. Miescheri*, Lank.), was first observed by Miescher in the striated muscle-fibres of the Mouse; then by Rainey in a similar position in the Pig, and taken by him for the youngest stage in the development of the cysts of *Tænia solium*; subsequently studied by Beale and others in connexion with the cattle-plague epidemic, and erroneously supposed to have a causal connexion with that disease. It is common in healthy butcher's meat. See Leuckart (47).

Further remarks on the Sporozoa.—The Sporozoa contrast strongly with the large classes of Gymnomyxa, the Heliozoa, Reticularia, and Radiolaria, as also with the Ciliate and Tentaculiferous Corticata, by their abundant and rapidly recurrent formation of spores, and agree in this respect with some Proteomyxa, with Mycetozoa, and some Flagellata. Their spores are remarkable for the firm, chitin-like spore-coat and its varied shapes, contrasting with the cellulose spherical spore-coat of Mycetozoa and with the naked spores of Radiolaria and Flagellata.

The protoplasm of the more highly developed forms (Gregarinidea) in the euglenoid phase exhibits considerable differentiation. Externally a distinct cuticle may be present, marked by parallel rugæ (*Monocystis serpula*) or by fine tubercles (*Monocystis sipunculi*). A circlet of hooks may be formed by the cuticle at one end of the body. Below the cuticle is sometimes developed a layer of fibrils running transversely to the long axis of the body (Fig. XIX. 9 and 19), which have been regarded as contractile, but are probably cuticular. The cortical layer of protoplasm below these cuticular structures is dense and refringent and sometimes fibrillated (*Monocystis pellucida*, Fig. XVII. 15). It is the contractile substance of the organism, and encloses the finely granular more liquid medullary substance. The granules of the latter have been shown by Bütschli (9) to give a starch-like reaction with iodine, &c. Probably the protoplasm in which they lie is finely reticulate or vacuolar, and when the granules are few it is actually seen to be so. No contractile vacuole is ever present. In Myxosporidia the medullary protoplasm is coloured yellow by hæmatoidin derived from the blood of its host or by absorbed bile-pigment, and also contains small crystals.

The nucleus of the Gregarinidea is a large clear capsule, with a few or no nucleolar granules. It has never been seen in a state of division, and it is not known what becomes of it during sporulation, though sporulating Gregarinidea have been observed with many minute nuclei scattered in their protoplasm, presumably formed by a breaking up of the single nucleus.

The habit of attaching themselves in pairs which is common in Gregarinidea is perhaps a reminiscence of a more extensive formation of aggregation plasmodia (compare Mycetozoa). The term "syzygium" is applied to such a conjunction of two Gregarinidea; it is not accompanied by fusion of substance. The formation of cysts is not connected with this pairing, since the latter occurs in young individuals long before encystment. Also cysts are formed by single Gregarinidea, as is always the case in the non-motile Coccidiidea.

The encystment always leads to the formation of spores, but in rare cases sporulation has been observed in unencysted Gregarinidea, and it occurs perhaps normally without true cyst-formation in the Myxosporidia.

The cell-parasitism of the young Sporozoa, and their flagellula-like (falciform) young and active vibratile movement, are points indicating affinity with the lower Gymnomyxa, and especially with those Proteomyxa, such as Vampyrella and Plasmodiophora, which are cell-parasites. Indeed it is probable that we have in this fact of cell-parasitism, and especially of parasitism in animal cells, a basis for the theoretical association of several unicellular organisms. The Haplococcus of Zopf (regarded by him as a Mycetozoon) is parasitic in the muscular cells of the Pig, and is probably related to Sarcocystis. Recently Von Lendenfeld (53) has described in Australia an amœba-like organism as parasitic in the skin of Sheep, which will probably be found to be either a Sporozoon or referable to those parasitic spore-producing Proteomyxa which are separated from Sporozoa only by their negative characters (see previous remarks on the negative characters of Proteomyxa).

The application of the name "Gregarines" has sometimes been made erroneously to external parasitic organisms, which have nothing in common with the Sporozoa. This was the case in regard to a fungoid growth in human hair—the so-called "chignon Gregarine." The Silk-worm disease known as "pebrine" has also been attributed to a Gregarine. It seems probable that the parasitic organism which causes that disease is (as is also the distinct parasite causing the disease known as "flaccidezza" in the same animals) one of the Schizomycetes (Bacteria). No disease is known at present as due to Sporozoa, although (e.g., the *Klossia chitonis*) they may lead to atrophy of the organs of the animals which they infest, in consequence of their enormous numbers. Coccidia and Sarcocystis are stated to occur in Man.

Class II. FLAGELLATA,[1] Ehrenberg.

Characters.—Corticata in which the dominant phase in the life-history is a corticate flagellula, that is, a nucleated cell-body provided with one or a few large processes of vibratile protoplasm. Very commonly solid food particles are ingested through a distinct cell-mouth or aperture in the cortical protoplasm, though in some an imbibition of nutritive matter by the whole surface and a nutritional process chemically resembling that of plants (holophytic), chlorophyll being present, seems to occur.

Conjugation followed by a breaking up into very numerous minute naked spores is frequent in some; as also a division into small individuals (microgonidia), which is followed by their conjugation with one another or with big individuals (macrogonidia) and subsequent normal growth and binary fission.

Many have a well-developed cuticle, which may form collar-like outgrowths or stalk-like processes. Many produce either gelatinous or chitin-like shells (cups or cortex), which are connected so as to form spherical or arborescent colonies; in these colonies the protoplasmic organisms themselves produce new individuals by fission, which separate entirely from one another but are held together by the continuity, with those already existing, of the new shells or jelly-houses or stalk-like supports produced by the new individuals. A single well-marked spherical nucleus, and one or more contractile vacuoles, are always present in the full-grown form.

Often, besides ingested food-particles, the protoplasm contains starch granules (amylon nucleus), paramylum corpuscles, chromatophores and chlorophyll corpuscles, some of which may be so abundant as to obscure the nucleus. One or two pigment spots (stigmata or so-called eye-spots) are often present at the anterior end of the body.

Sub-class I. Lissoflagellata, Lankester.

Never provided with a collar-like outgrowth around the oral pole.

Order 1. MONADIDEA, Bütschli.

Characters.—Lissoflagellata of small or very small size and simple structure; often naked and more or less amoeboid, sometimes forming tests. Usually colourless, seldom with chromatophors. With a single anterior large flagellum or sometimes with two additional paraflagella. A special mouth-area is often wanting, sometimes is present, but is never produced into a well-developed pharynx.

Fam. 1. Rhizomastigina, Bütschli. Simple mouthless forms with 1 to 2 flagella; either permanently exhibiting a Gymnomyxa-like development of pseudopodia or capable of passing suddenly from a firm-walled into a Gymnomyxa-like condition, when the flagella may remain or be drawn in. Ingestion of food by aid of the pseudopodia.

Genera.—*Mastigamoeba*, F. E. Schultze; *Ciliophrys*, Cienkowski (65); *Dimorpha*, Gruber; *Actinomonas*, Kent; *Trypanosoma*, Gruby (parasitic in the blood of Frogs and other Amphibia and Reptiles, Fig. XX. 21, 22). The Rhizomastigina might all be assigned to the Proteomyxa, with which they closely connect the group of Flagellata. The choice of the position to be assigned to such a form as Ciliophrys must be arbitrary.

Fam. 2. Cercomonadina, Kent. Minute oblong cell-body which posteriorly may exhibit amoeboid changes. One large anterior flagellum. Mouth at the base of this organ. Reproduction by longitudinal fission and by multiple fission producing spores in the encysted resting state.

Genera.—*Cercomonas*, Duj. (Fig. XX. 32, 33); *Herpetomonas*, S. Kent; *Oikomonas*, Kent (=*Monas*, James Clark; *Pseudospora*, Cienkowski, Fig. XX. 29, 30, 31); *Ancyromonas*, S. K.

Fam. 3. Codonoecina, Kent. Small colourless monads similar to Oikomonas in structure, which secrete a fixed gelatinous or membranous envelope or cup.

Genera.—*Codonoeca*, James Clark; *Platytheca*, Stein.

Fam. 4. Bikoecina, Stein. Distinguished from the last family by the fact that the monad is fixed in its cup by a contractile thread-like stalk; cup usually raised on a delicate stalk.

Genera.—*Bicosoeca*, J. Cl.; *Poteriodendron*, Stein.

[1] Bütschli's work (B) has been pretty closely followed in the diagnosis of the groups of Flagellata and the enumeration of genera here given.

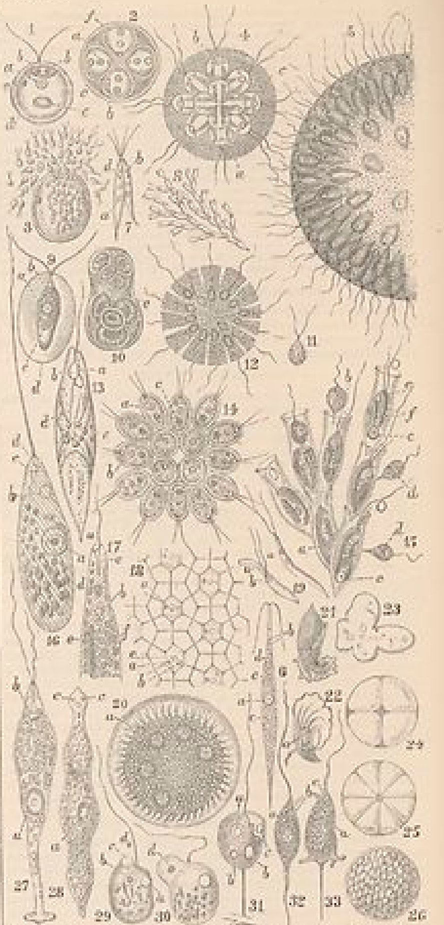

Fig. XX.—**Flagellata.** 1. *Chlamydomonas pulvisculus*, Ehr. (=*Zygoselmis*, Fresen.); one of the Phytomastigoda; free-swimming individual. *a*, nucleus; *b*, contractile vacuole; *c*, starch corpuscle; *d*, cellulose investment; *e*, stigma (eye-spot). 2. Resting stage of the same, with fourfold division of the cell-contents. Letters as before. 3. Breaking up of the cell-contents into minute biflagellate swarm-spores, which escape, and whose history is not further known. 4. *Syncrypta volvox*, Ehr.; one of the Phytomastigoda. A colony enclosed by a common gelatinous test *c*. *a*, stigma; *b*, vacuole (non-contractile). 5. *Uroglena volvox*, Ehr.; one of the Monadidea. Half of a large colony, the flagellates embedded in a common jelly. 6. *Chlorogonium euchlorum*, Ehr.; one of the Phytomastigoda. *a*, nucleus; *b*, contractile vacuole; *c*, starch grain; *d*, eye-spot. 7. *Chlorogonium euchlorum*, Ehr., one of the Phytomastigoda. Copulation of two liberated microgonidia. *a*, nucleus; *b*, contractile vacuole; *d*, eye-spot (so-called). 8. Colony of *Dinobryon sertularia*, Ehr.; × 200; one of the Monadidea. 9. *Haematococcus palustris*, Girod (= *Chlamydococcus*, Braun, *Protococcus* Cohn), one of the Phytomastigoda; ordinary individual with widely separated test. *a*, nucleus; *b*, contractile vacuole; *c*, amylon nucleus (pyrenoid). 10. Dividing resting stage of the same, with eight fission products in the common test *c*. 11. A microgonidium of the same. 12. *Phalansterium consociatum*, Cienk.; one of the Choanoflagellata; × 325. Disk-like colony. 13. *Euglena viridis*, Ehr.; × 300; one of the Euglenoidea. *a*, pigment spot (stigma); *b*, clear space; *c*, paramylum granules; *d*, chromatophor (endochrome plate). 14. *Gonium pectorale*, O. F. Müller; one of the Phytomastigoda. Colony seen from the flat side, × 300. *a*, nucleus; *b*, contractile vacuole; *c*, amylon nucleus. 15. *Dinobryon sertularia*, Ehr.; one of the Monadidea. *a*, nucleus; *b*, contractile vacuole; *c*, amylum-nucleus; *d*, free colourless flagellates, probably not belonging to Dinobryon; *e*, stigma (eye-speck); *f*, chromatophore. 16. *Peranema trichophorum*, Ehr., (one of the Euglenoidea), creeping individual seen from the back; × 140. *a*, nucleus; *b*, contractile vacuoles; *c*, pharynx; *d*, mouth. 17. Anterior end of *Euglena acus*, Ehr., in profile. *a*, mouth; *b*, contractile vacuoles; *c*, pharynx; *d*, stigma (eye-speck); *e*, paramylum-body; *f*, chlorophyll corpuscles. 18. Part of the surface of a colony of *Volvox globator*, L. (Phytomastigoda), showing the intercellular connective fibrils. *a*, nucleus; *b*, contractile vacuole; *c*, amylum granule. 19. Two microgonidia of *Volvox globator*, L. *a*, nucleus; *b*, contractile vacuole. 20. Ripe asexually produced daughter-individual of *Volvox minor*, Stein, still enclosed in the cyst of the partheno-gonidium. *a*, young partheno-gonidia. 21, 22. *Trypanosoma sanguinis*, Gruby; one of the Heteromastigoda, from the blood of *Rana esculenta*. *a*, nucleus. × 500. 23–26. Reproduction of *Bodo caudatus*, Duj. (one of the Heteromastigoda), after Dallinger and Drysdale:—23, fusion of several individuals (plasmodium); 24, encysted fusion-product dividing into four; 25, later into eight; 26, cyst filled with swarm-spores. 27. *Astasia tenax*, O. F. Müll. (Proteus); one of the Euglenoidea; × 440. Individual with the two flagella, and strongly contracting hinder region of the body. *a*, nucleus; *b*, contractile vacuole close to the pharynx. 28. The same devoid of flagella. *a*, nucleus; *c*, *c*, the two dark pigment spots (so-called eyes) near the mouth. 29. *Oikomonas termo* (*Monas termo*) Ehr.; one of the Monadidea. *a*, nucleus; *b*, contractile vacuole; *c*, food-ingesting vacuole; *d*, food-particle. × 440. 30. The food-particle *d* has now been ingested by the vacuole. 31. *Oikomonas mutabilis*, Kent (Monadidea), with adherent stalk. *a*, nucleus; *b*, contractile vacuole; *c*, food-particle in food vacuole. 32, 33. *Cercomonas crassicauda*, Duj. (Monadidea), showing two conditions of the pseudopodium-protruding tail. *a*, nucleus; *b*, contractile vacuoles; *c*, mouth.

Fam. 5. Heteromonadina, Bütschli. Small colourless or green monads which possess, besides one chief flagellum, one or two smaller paraflagella attached near it, often forming colonies secreting a common stalk.

Genera.—*Monas* (Ehr.), Stein; *Dendromonas*, Stein; *Cephalothamnium*, Stein; *Anthophysa*, Bory d. Vinc. (Fig. XXI. 12, 13); *Dinobryon*, Ehr. (Fig. XX. 8 and 15); *Epipyxis*, Ehr.; *Uroglena*, Ehr. (Fig. XX. 5).

Order 2. EUGLENOIDEA, Bütschli.

Characters.—Generally somewhat large and highly developed monoflagellate forms, of monaxonic or slightly asymmetrical build. Cuticle present; cortical substance firm, contractile, and elastic; some forms quite stiff, others capable of definite annular contraction and worm-like elongation. At the base of the flagellum a small or large mouth leading into a more or less distinct pharyngeal tube. Near this is always the contractile vacuole. Rarely a pair of flagella instead of one.

Fam. 1. Coelomonadina. Coloured Euglenoidea, with numerous small chlorophyll corpuscles or 1 to 2 large plate-like green or brown chromatophors. Mouth and pharynx inconspicuous; nutrition probably largely vegetal (holophytic).

Genera.—*Coelomonas*, Stein; *Gonyostomum*, Dies.; *Vacuolaria*, Cienk.; *Microglena*, Ehr.; *Chromulina*, Cienk.; *Cryptoglena*, Ehr.

Fam. 2. Euglenina, Stein. Body monaxonic, elongated, hinder end pointed. Spirally striated cuticle. A fine mouth-aperture leads into the well-developed tubular pharynx. Flagellum usually single, sometimes paired, often cast off. Near the pharynx is the "reservoir" of the contractile vacuoles and several of the latter. A single (sometimes two) stigma or colour-speck near the same spot. Chromatophors nearly always present, generally bright green. A large nucleus in the middle of the body. Multiplication by longitudinal fission. Encysted condition and attendant fission imperfectly studied. Copulation doubtful.

Genera.—(*a*) With flexible cuticle:—*Euglena*, Ehr. (Fig. XX. 13, 17; this is probably Priestley's "green matter," from which he obtained oxygen gas; though one of the very commonest of all Protozoa, its life-history has yet to be worked out); *Colacium*, Ehr.; *Eutreptia*, Perty.

(*b*) With stiff, shell-like cuticle:—*Ascoglena*, Stein; *Trachelomonas*, Ehr.; *Lepocinclis*, Perty; *Phacus*, Nitzsch.

Fam. 3. Menoidina, Bütschli. Similar to the Euglenina, but devoid of chlorophyll, a deficiency connected with the saprophytic mode of life. Stigma always absent.

Genera.—(*a*) With flexible cuticle:—*Astasiopsis*, Bütschli; *Astasiades*, Bütschli.

(*b*) With stiff cuticle and non-contractile body:—*Menoidium*, Perty; *Atractonema*, Stein; *Rhabdomonas*, Fresenius.

Fam. 4. Peranemina. Very contractile (metabolic) colourless Euglenoids. Mouth and pharynx large; inception of solid nutriment certainly observed.

Genera.—*Peranema*, Duj. (Fig. XX. 16); *Urceolus*, Mereschk.

Fam. 5. Petalomonadina. Colourless, non-metabolic forms. Mouth opening at the base of the single large flagellum.

Genera.—*Petalomonas*, Stein.

Fam. 6. Astasina. Colourless, metabolic, or stiff Euglenoids, differing from the rest in having a small or large paraflagellum in addition to the chief one. Nutrition partly saprophytic partly animal.

Genera.—*Astasia*, Ehr. emend. Stein (Fig. XX. 27, 28); *Heteronema*, Duj.; *Zygoselmis*, Duj.; *Sphenomonas*, Stein; *Tropidoscyphus*, Stein.

Order 3. HETEROMASTIGODA, Bütschli.

Characters.—Small and large monads. Naked and even amoeboid or with stiff cuticle. Two flagella at the anterior end differing in size: the smaller directed forwards subserves the usual locomotor function; the larger is directed backwards and trailed, without movement. Sometimes two backwardly directed flagella are present. Always a mouth and animal nutrition. Always colourless.

Fam. 1. Bodonina, Bütschli. Size of the two flagella not very different.

Genera.—*Bodo*, Ehb. emend. Stein (Fig. XX. 23 to 26, and Fig. XXI. 10; the hooked monad and the springing monad of Dallinger and Drysdale (66); *Heteromita* of Dujardin and Kent); *Phyllomitus*, Stein; *Colponema*, Stein; *Dallingeria*, Kent; *Trimastix*, Kent.

Fam. 2. Anisonemina, Kent. Large forms with cuticle; difference of the two flagella considerable. Mouth, pharynx, and animal nutrition.

Genera.—*Anisonema*, Duj.; *Entosiphon*, Stein.

Order 4. ISOMASTIGODA, Bütschli.

Characters.—Small and middle-sized forms of monaxonic rarely bilateral shape. Fore-end with 2, 4, or seldom 5 equal-sized and similar flagella. Some are coloured, some colourless; naked or with strong cuticle or secreting an envelope. Mouth and pharynx seldom observed; nutrition generally holophytic (*i.e.*, like a green plant), but in some cases, nevertheless, holozoic (*i.e.*, like a typical animal).

Fam. 1. Amphimonadina. Small, colourless, biflagellate Isomastigoda.

Genera.—*Amphimonas*, Duj. (?*Pseudospora*, Cienk.).

Fam. 2. Spongomonadina, Stein. Small colourless oval forms with two closely contiguous flagella. Chief character in the union of numerous individuals in a common jelly or in branched gelatinous tubes, the end of each of which is inhabited by a single and distinct individual.

Genera.—*Spongomonas*, Stein; *Cladomonas*, Stein; *Rhipidomonas*, Stein.

[Group **Phytomastigoda**, Bütschli. The following three families, viz., Chrysomonadina, Chlamydomonadina, and Volvocina, are so closely related to one another as to warrant their union as a sub-order. They are typical Isomastigoda, but have chlorophyll corpuscles and holophytic nutrition with correlated deficient mouth and pharynx. They are usually regarded by botanists as belonging to the unicellular Algae.]

Fam. 3. Chrysomonadina, Bütschli. Single or colony-forming; seldom an envelope. Spherical free-swimming colonies may be formed by grouping of numerous individuals around a centre. With two or rarely one brown or greenish brown chromatophor; a stigma (eye-speck) at the base of the flagella.

Genera.—*Stylochrysalis*, Stein; *Chrysopyxis*, Stein; *Nephroselmis*, Stein; *Synura*, Ehr.; *Syncrypta*, Ehr. (Fig. XX. 4).

Fam. 4. Chlamydomonadina. Fore-end of the body with two or four (seldom five) flagella. Almost always green in consequence of the presence of a very large single chromatophor. Generally a delicate shell-like envelope of membranous consistence. 1 to 2 contractile vacuoles at the base of the flagella. Usually one eye-speck. Division of the protoplasm within the envelope may produce four, eight, or more new individuals. This may occur in the swimming or in a resting stage. Also by more continuous fission microgonidia of various sizes are formed. Copulation is frequent.

Genera.—*Hymenomonas*, Stein; *Chlorangium*, Stein; *Chlorogonium*, Ehr. (Fig. XX. 6, 7); *Polytoma*, Ehr.; *Chlamydomonas*, Ehr. (Fig. XX. 1, 2, 3); *Haematococcus*, Agardh (=*Chlamydococcus*, A. Braun, Stein; *Protococcus*, Cohn, Huxley and Martin; *Chlamydomonas*, Cienkowski); *Carteria*, Diesing; *Spondylomorum*, Ehr.; *Coccomonas*, Stein; *Phacotus*, Perty.

Fam. 5. Volvocina. Colony-building Phytomastigoda, the cell-individuals standing in structure between Chlamydomonas and Haematococcus, and always biflagellate. The number of individuals united to form a colony varies very much, as does the shape of the colony. Reproduction by the continuous division of all or of only certain individuals of the colony, resulting in the production of a daughter colony (from each such individual). In some, probably in all, at certain times copulation of the individuals of distinct sexual colonies takes place, without or with a differentiation of the colonies and of the copulating cells as male and female. The result of the copulation is a resting zygospore (also called zygote or oo-spermospore or fertilized egg-cell), which after a time develops itself into one or more new colonies.

Genera.—*Gonium*, O. F. Müller (Fig. XX. 14); *Stephanosphaera*, Cohn; *Pandorina*, Bory de Vinc.; *Eudorina*, Ehr.; *Volvox*, Ehr. (Fig. XX. 18, 20).

[The sexual reproduction of the colonies of the Volvocina is one of the most important phenomena presented by the Protozoa. In some families of Flagellata full-grown individuals become amoeboid, fuse, encyst, and then break up into flagellate spores which develop simply to the parental form (Fig. XX. 23 to 26). In the Chlamydomonadina a single adult individual by division produces small individuals, so-called "microgonidia." These copulate with one another or with similar microgonidia formed by other adults (as in Chlorogonium, Fig. XX. 7); or more rarely in certain genera a microgonidium copulates with an ordinary individual (macrogonidium). The result in either case is a "zygote," a cell formed by fusion of two which divides in the usual way to produce new individuals. The microgonidium in this case is the male element and equivalent to a spermatozoon; the macrogonidium is the female and equivalent to an egg-cell. The zygote is a fertilized egg-cell, or oo-spermospore. In the colony-building forms we find that only certain cells produce by division microgonidia; and, regarding the colony as a multicellular individual, we may consider these cells as testis-cells and their microgonidia as spermatozoa. In some colony-building forms the microgonidia copulate with ordinary cells of the colony which, when thus fertilized, become encysted as zygotes, and subsequently separate and develop by division into new colonies. In Volvox the macrogonidia are also specially-formed cells (not merely any of the ordinary vegetative cells), so that in a sexually ripe colony we can distinguish egg-cells as well as sperm mother-cells. Not only so, but in some instances (Eudorina and some species of Volvox) the colonies which produce sexual cells can not merely be distinguished from the asexual colonies (which reproduce parthenogenetically), but can be distinguished also *inter se* into male colonies, which produce from certain of their constituent cell-units spermatozoa or microgonidia only, and female colonies which produce no male cells, but only macrogonidia or egg-cells which are destined to be fertilized by the microgonidia or spermatozoa of the male colonies.

The differentiation of the cell-units of the colony into neutral or merely carrying cells of the general body on the one hand and special sexual cells on the other is extremely important. It places these cell-colonies on a level with the Enterozoa (Metazoa) in regard to reproduction, and it cannot be doubted that the same process of specialization of the reproductive function, at first common to all the cells of the cell-complex, has gone on in both cases. The perishable body which carries the reproductive cells is nevertheless essentially different in the two cases, in the Volvocina being composed of equipollent units, in the Enterozoa being composed of units distributed in two physiologically and morphologically distinct layers or tissues, the ectoderm and the endoderm.

The sexual reproduction of the Vorticellidæ may be instructively compared with that of the Phytomastigoda; see below.]

Fam. 6. Tetramitina. Symmetrical, naked, colourless, somewhat amœboid forms, with four flagella or three and an undulating membrane. Nutrition animal, but mouth rarely seen.

Genera.—*Collodictyon*, Carter; *Tetramitus*, Perty (Fig. XXI. 11, 14; calycine monad of Dallinger and Drysdale (66)); *Monocercomonas*, Grassi; *Trichomonas*, Donné; *Trichomastix*, Blochmann.

Fam. 7. Polymastigina. Small, colourless, symmetrical forms. Two flagella at the hinder end of the body and two or three on each side in front. Nutrition animal or saprophytic.

Genera.—*Hexamitus*, Duj. (Fig. XXI. 5); *Megastoma*, Grassi; *Polymastix*, Bütschli.

Fam. 8. Trepomonadina, Kent. As Polymastigina, but the lateral anterior flagella are placed far back on the sides.

Genera.—*Trepomonas*, Duj., described recently without name by Dallinger (67).

Fam. 9. Cryptomonadina. Coloured or colourless, laterally compressed, asymmetrical forms; with two very long anterior flagella, placed a little on one side springing from a deep atrium-like groove or furrow (*cf.* Dinoflagellata and Noctiluca, to which these forms lead).

Genera.—*Cyathomonas*, From.; *Chilomonas*, Ehr.; *Cryptomonas*, Ehr.; *Oxyrrhis*, Duj.

Fam. 10. Lophomonadina. A tuft of numerous flagella anteriorly.

Genus.—*Lophomonas*, Stein (Fig. XXI. 9, connects the Flagellata with the Peritrichous Ciliata).

Sub-class II. **Choanoflagellata**, Saville Kent.

Flagellata provided with an upstanding collar surrounding the anterior pole of the cell from which the single flagellum springs, identical in essential structure with the "collared cells" of Sponges. Single or colony-building. Individuals naked (*Codosiga*), or inhabiting each a cup (*Salpingoeca*), or embedded in a gelatinous common investment (*Proterospongia*).

Order 1. NUDA, Lankester.

Characters.—Individuals naked, secreting neither a lorica (cup) nor a gelatinous envelope.

Genera.—*Monosiga*, S. Kent (solitary stalked or sessile); *Codosiga*, James Clark (united socially on a common stalk or pedicle, Fig. XXI. 3, 4); *Astrosiga*, S. Kent; *Desmarella*, S. Kent.

Order 2. LORICATA, Lankester.

Characters.—Each individual collared-cell unit secretes a horny cup or shell.

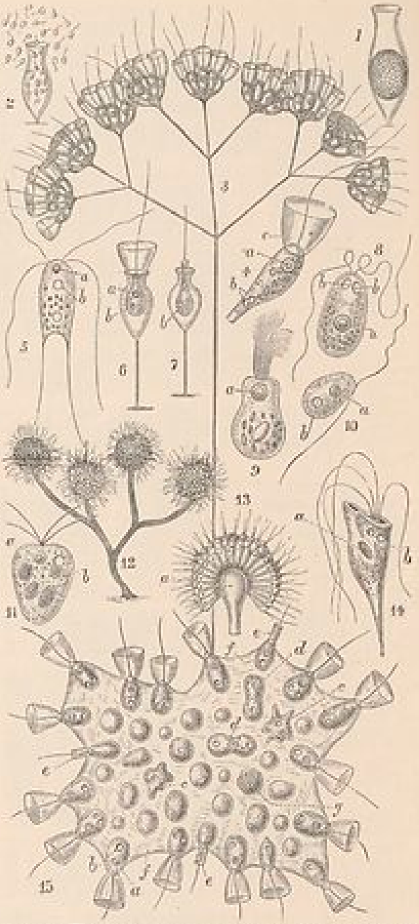

Fig. XXI.—**Flagellata.** 1. *Salpingoeca fusiformis*, S. Kent; one of the Choanoflagellata. The protoplasmic body is drawn together within the goblet-shaped shell, and divided into numerous spores. × 1500. 2. Escape of the spores of the same as monoflagellate and swarm-spores. 3. *Codosiga umbellata*, Tatem; one of the Choanoflagellata; adult colony formed by dichotomous growth; × 625. 4. A single zooid of the same; × 1250. *a*, nucleus; *b*, contractile vacuole; *c*, the characteristic "collar" formed by cuticle on the inner face of which is a most delicate network of naked streaming protoplasm. 5. *Hexamita inflata*, Duj.; one of the Isomastigoda; × 850; normal adult; showing *a*, nucleus, and *b*, contractile vacuole. 6, 7. *Salpingoeca urceolata*, S. Kent; one of the Choanoflagellata;—6, with collar extended; 7, with collar retracted within the stalked cup. *a*, nucleus; *b*, contractile vacuole. 8. *Polytoma uvella*, Müll. sp.; one of the Phytomastigoda. *a*, nucleus; *b*, contractile vacuole. × 800. 9. *Lophomonas blattarum*, Stein; one of the Isomastigoda, from the intestine of *Blatta orientalis*. *a*, nucleus. 10. *Bodo lens*, Müll.; one of the Heteromastigoda; × 800. *a*, nucleus; *b*, contractile vacuole; the wavy filament is a flagellum, the straight one is an immobile trailing thread. 11. *Tetramitus sulcatus*, Stein; one of the Isomastigoda; × 430. *a*, nucleus; *b*, contractile vacuole. 12. *Anthophysa vegetans*, O. F. Müller; one of the Monadidea; × 300. A typical, erect, shortly-branching colony stock with four terminal monad-clusters. 13. Monad cluster of the same in optical section (× 800), showing the relation of the individual monads or flagellate zooids to the stem *a*. 14. *Tetramitus rostratus*, Perty; one of the Isomastigoda; × 1000. *a*, nucleus; *b*, contractile vacuole. 15. *Proterospongia Haeckeli*, Saville Kent; one of the Choanoflagellata; × 800. A social colony of about forty flagellate zooids. *a*, nucleus; *b*, contractile vacuole; *c*, amœbiform zooid sunk

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within the common jelly or test (compared by S. Kent to the mesoderm-cells of a sponge-colony); *d*, similar zooid multiplying by transverse fission; *e*, normal zooids with their collars contracted; *f*, hyaline mucilaginous common test or zoothecium; *g*, individual contracted and dividing into minute flagellate spores (microgonidia) comparable to the spermatozoa of a Sponge.

Genera.—*Salpingoeca*, James Clark (sedentary, Fig. XXI. 6, 7); *Lagenoeca*, S. Kent (free swimming); *Polyoeca*, S. Kent (cups united socially to form a branching zooecium as in Dinobryon).

ORDER 3. GELATINIGERA, Lankester.

The cell-units secrete a copious gelatinous investment and form large colonies.

Genera.—*Phalansterium*, Cienk. (Fig. XX. 12); *Proterospongia*, Saville Kent (Fig. XXI. 15).

[The Choanoflagellata were practically discovered by the American naturalist James Clark (68), who also discovered that the ciliated chambers of Sponges are lined by collared cells of the same peculiar structure as the individual Choanoflagellata, and hence was led to regard the Sponges as colonies of Choanoflagellata. Saville Kent (69) has added much to our knowledge of the group, and by his discovery of Proterospongia (see Fig. XXI. 15, and description) has rendered the derivation of the Sponges from the Flagellata a tenable hypothesis.]

Further remarks on the Flagellata.—Increased attention has been directed of late years to the Flagellata in consequence of the researches of Cienkowski, Bütschli, James Clark, Saville Kent, and Stein. They present a very wide range of structure, from the simple amoeboid forms to the elaborate colonies of Volvox and Proterospongia. By some they are regarded as the parent-group of the whole of the Protozoa; but, whilst not conceding to them this position, but removing to the Proteomyxa those Flagellata which would justify such a view, we hold it probable that they are the ancestral group of the mouth-bearing Corticata, and that the Ciliata and Dinoflagellata have been derived from them. One general topic of importance in relation to them may be touched on here, and that is the nature of the flagellum and its movements. Speaking roughly, a flagellum may be said to be an isolated filament of vibratile protoplasm, whilst a cilium is one of many associated filaments of the kind. The movement, however, of a flagellum is not the same as that of any cilium; and the movement of all flagella is not identical. A cilium is simply bent and straightened alternately, its substance probably containing, side by side, a contractile and an elastic fibril. A flagellum exhibits lashing movements to and fro, and is thrown into serpentine waves during these movements. But two totally distinct kinds of flagella are to be distinguished, viz., (*a*) the pulsellum, and (*b*) the tractellum. An example of the pulsellum is seen in the tail of a spermatozoon which drives the body in front of it, as does the tadpole's tail. Such a "pulsellum" is the cause of the movement of the Bacteria. It is never found in the Flagellata. So little attention has been paid to this fact that affinities are declared by recent writers to exist between Bacteria and Flagellata. The flagellum of the Flagellata is totally distinct from the pulsellum of the Bacteria. It is carried in front of the body and draws the body after it, being used as a man uses his arm and hand when swimming on his side. Hence it may be distinguished as a "tractellum." Its action may be best studied in some of the large Englenoidea, such as Astasia. Here it is stiff at the base and is carried rigidly in front of the animal, but its terminal third is reflected and exhibits in this reflected condition swinging and undulatory movements tending to propel the reflected part of the flagellum forward, and so exerting a traction in that direction upon the whole animal. It is in this way (by reflexion of its extremity) that the flagellum or tractellum of the Flagellata also acts so as to impel food-particles against the base of the flagellum where the oral aperture is situated.

Many of the Flagellata are parasitic (some hæmatozoic, see Lewis, 70); the majority live in the midst of putrefying organic matter in sea and fresh waters, but are not known to be active as agents of putrefaction. Dallinger and Drysdale have shown that the spores of Bodo and others will survive an exposure to a higher temperature than do any known Schizomycetes (Bacteria), viz., 250° to 300° Fahr., for ten minutes, although the adults are killed at 180°.

CLASS III. DINOFLAGELLATA, Bütschli.

Characters.—Corticate Protozoa of a bilaterally asymmetrical form, sometimes flattened from back to ventral surface (Diplopsalis, Glenodinium), sometimes from the front to the hinder region (Ceratium, Peridinium), sometimes from right to left (Dinophysis, Amphidinium, Prorocentrum)—the anterior region and ventral surface being determined by the presence of a longitudinal groove and a large flagellum projecting from it. In all except the genus Prorocentrum (Fig. XXII. 6) there is as well as a longitudinal groove a transverse groove (hence Dinifera) in which lies horizontally a second flagellum (Klebs and Bütschli), hitherto mistaken for a girdle of cilia. The transverse groove lies either at the anterior end of the body (Dinophysis, Fig. XXII. 3, 4; Amphidinium) or at the middle. In Gymnodinium it takes a spiral course. In Polykrikos (a compound metameric form) there are eight independent transverse grooves.

The Dinoflagellata are either enclosed in a cuticular shell (Ceratium, Peridinium, Dinophysis, Diplopsalis, Glenodinium, Prorocentrum, &c.) or are naked (Gymnodinium and Polykrikos). The cuticular membrane (or shell) consists of cellulose or of a similar substance (*cf.* Labyrinthulidea) and not, as has been supposed, of silica, nor of chitin-like substance; it is either a simple cyst or perforated by pores, and may be built up of separate plates (Fig. XXII. 10).

The cortical protoplasm contains trichocysts in Polykrikos.

The medullary protoplasm contains often chlorophyll and also diatomin and starch or other amyloid substance. In these cases (Ceratium, some species of Peridinium, Glenodinium, Prorocentrum, *Dinophysis acuta*) nutrition appears to be holophytic. But in others (Gymnodinium and Polykrikos) these substances are absent and food-particles are found in the medullary protoplasm which have been taken in from the exterior through a mouth; in these nutrition is holozoic. In others which are devoid of chlorophyll and diatomin, &c., there is found a vesicle and an orifice connected with the exterior near the base of the flagellum (*cf.* Flagellata) by which water and dissolved or minutely granular food-matter is introduced into the medullary protoplasm (*Protoperidinium pellucidum*, *Peridinium divergens*, *Diplopsalis lenticula*, *Dinophysis laevis*). It is important to note that these divergent methods of nutrition are exhibited by different species of one and the same genus, and possibly by individuals of one species in successive phases of growth (!).

No contractile vacuole has been observed in Dinoflagellata.

The nucleus is usually single and very large, and has a peculiar labyrinthine arrangement of chromatin substance.

Transverse binary fission is the only reproductive process as yet ascertained. It occurs either in the free condition (Fig. XXII. 2) or in peculiar horned cysts (Fig. XXII. 8). Conjugation has been observed in some cases (by Stein in Gymnodinium).

Mostly marine, some freshwater. Many are phosphorescent.

The Dinoflagellata are divisible into two orders, according to the presence or absence of the transverse groove.

ORDER 1. ADINIDA, Bergh.

Characters.—Body compressed laterally; both longitudinal and transverse flagellum placed at the anterior pole; a transverse groove is wanting; a cuticular shell is present.

Genera.—*Prorocentrum*, Ehr. (Fig. XXII. 6, 7); *Exuviella*, Cienk. (= *Dinopyxis*, Stein; *Cryptomonas*, Ehr.).

ORDER 2. DINIFERA, Bergh.

Characters.—A transverse groove is present and usually a longitudinal groove. The animals are either naked or loricate.

Fam. 1. DINOPHYIDA, Bergh. Body compressed; the transverse groove at the anterior pole; the longitudinal groove present; longitudinal flagellum directed backwards; loricate.

Genera.—*Dinophysis*, Ehr. (Fig. XXII. 3, 4); *Amphidinium*, Cl. & L.; *Amphisolenia*, Stein; *Histioneis*, Stein; *Citharistes*, Stein; *Ornithocercus*, Stein.

Fam. 2. PERIDINIDA, Bergh. Body either globular or flattened; transverse groove nearly equatorial; longitudinal groove narrow or broad; loricate.

Genera.—*Protoperidinium*, Bergh; *Peridinium* (Ehr.), Stein (Fig. XXII. 1, 2); *Protoceratium*, Bergh; *Ceratium*, Schrank (Fig. XXII. 15); *Diplopsalis*, Bergh; *Glenodinium*, Ehr.; *Heterocapsa*, Stein; *Gonyaulax*, Diesing; *Goniodoma*, Stein; *Blepharocysta*, Ehr.; *Podolampas*, Stein; *Amphidoma*, Stein; *Oxytoxum*, Stein; *Ptychodiscus*, Stein; *Pyrophacus*, Stein; *Ceratocorys*, Stein.

Fam. 3. GYMNODINIDA, Bergh. As Peridinida but no lorica (cuticular shell).

Genera.—*Gymnodinium* (Fig. XXII. 5), Stein; *Hemidinium*, Bergh.

Fam. 4. POLYDINIDA, Bütschli. As Gymnodinida, but with several independent transverse grooves.

Genus.—*Polykrikos*, Bütschli.

Further Remarks on the Dinoflagellata.—This small group is at the moment of the printing of the present article receiving a large amount of attention from Bergh (81), Klebs (83), and Bütschli (82), and has recently been greatly extended by the discoveries of Stein (80),—the last work of the great illustrator of the Ciliate Protozoa before his death. The constitution of the cell-wall or cuticle from cellulose, as well as the presence of chlorophyll and diatomin, and the holophytic nutrition of many forms recently demonstrated by Bergh, has led to the suggestion that the Dinoflagellata are to be regarded as plants, and allied to the Diatomaceae and Desmidiaceae. Physiological grounds of this kind have, however, as has been pointed out above, little importance in determining the affinities of Protozoa. Bütschli (82) in a recent very important article has shown in confirmation of Klebs that the Dinoflagellata do not

possess a girdle of cilia as previously supposed, but that the structure mistaken for cilia is a second flagellum which lies horizontally in the transverse groove. Hence the name Ciliofiagellata is superseded by Dinoflagellata (Gr. dinos, the round area where oxen tread out on a threshing floor).

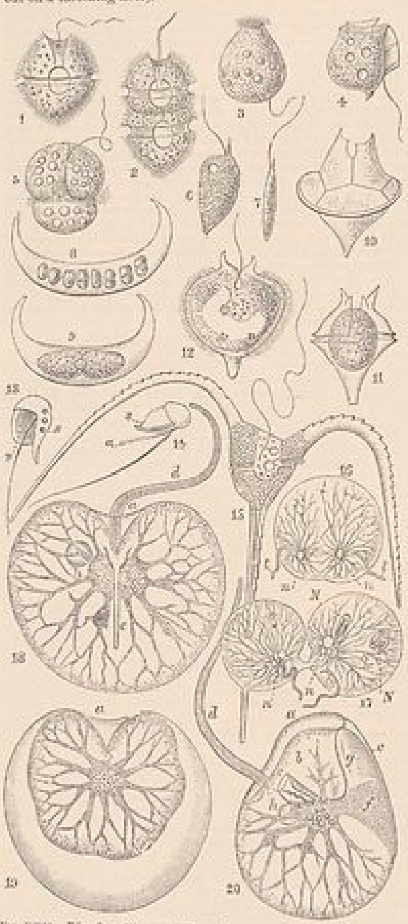

Fig. XXII.—**Dinoflagellata and Rhynchoflagellata.** *N.B.* In all these figures the apparent girdle of cilia is, according to Klebs and Bütschli's recent discovery, to be interpreted as an encircling flagellum lying in the transverse groove. 1. *Peridinium uberrimum*, Allman; ×300 (fresh-water ponds, Dublin). Probably (according to Bütschli) the processes on the surface are not cilia nor flagellum. Both the longitudinal and the transverse groove are well seen. 2. The same species in transverse fission. 3. *Dinophysis ovata*, Cl. and L.; ×350 (salt water, Norwegian coast). 4. *Dinophysis acuminata*, Cl. and L.; ×350 (salt water, Norwegian coast). 5. *Gymnodinium*, sp.; ×600. 6. *Prorocentrum micans*, Ehr.; ×300 (salt water). 7. Dorsal aspect of the same species. 8, 9. Cysts of Peridinia; the contents of a divided into eight minute naked Peridinia; ×300. 10. Empty cuirass of *Ceratium divergens*, Cl. and L.; ×500; showing the form and disposition of its component plates. 11. The same species with the animal contracted into a spherical form. The transverse groove well seen. 12. The same species in the normal state. The apparent girdle of cilia is really an undulating flagellum lying in the transverse groove. 13, 14. Young stages of *Noctiluca miliaris*. *n*, nucleus; *s*, the so-called spine (superficial ridge of the adult); *t*, the big flagellum; the unlettered filament is a flagellum which becomes the oral flagellum of the adult. 15. *Ceratium tripos*, Müll. The transverse groove well seen. The cilia really are a single horizontal flagellum. 16, 17. Two stages in the transverse fission of *Noctiluca miliaris*, Suriray. *n*, nucleus; *N*, food-particles; *t*, the muscular flagellum. 18. *Noctiluca miliaris*, viewed from the aboral side (after Allman, *Quart. Jour. Mic. Sci.*, 1872). *a*, the entrance to the atrium or flagellar fossa (=longitudinal groove of Dinoflagellata); *c*, the superficial ridge; *d*, the big flagellum (=the flagellum of the transverse groove of Dino-flagellata); *h*, the nucleus. 19. The animal acted upon by iodine solution, showing the protoplasm like the "primordial utricle" of a vegetable cell shrunk away from the structureless firm shell or cuirass. 20. Lateral view of Noctiluca, showing *a*, the entrance to the groove-like atrium or flagellar fossa in which *b* is placed; *c*, the superficial ridge; *d*, the big flagellum; *e*, the mouth and gullet, in which is seen Krohn's oral flagellum (=the chief flagellum or flagellum of the longitudinal groove of Dino-flagellata); *f*, broad process of protoplasm extending from the superficial ridge *c* to the central protoplasm; *g*, duplicature of the shell in connexion with the superficial ridge; *h*, nucleus.

Bütschli further suggests that the Dinoflagellata with their two flagella and their ⊥-shaped combination of longitudinal and transverse grooves may be derived from the Cryptomonadina (see p. 858). In the latter a groove-like recess is present in connexion with the origin of the two flagella. Bütschli thinks the large proboscis-like flagellum of Noctiluca (Rhynchoflagellata) represents the horizontal flagellum of Dinoflagellata, whilst the prominent longitudinal flagellum of the Dinoflagellata is represented in that animal by the small flagellum discovered by Krohn within the gullet (see Fig. XXII. 20, *e*). The young form of Noctiluca (Fig. XXII. 14) has the longitudinal flagellum still of large size.

The phosphorescence of many Dinoflagellata is a further point of resemblance between them and Noctiluca.

Bergh has shown that there is a considerable range of form in various species of Dinoflagellata (Ceratium, &c.), and has also drawn attention to the curious fact that the mode of nutrition (whether holophytic or holozoic) differs in allied species. Possibly it may be found to differ according to the conditions of life in individuals of one and the same species.

The drawings in Fig. XXII. were engraved before the publication of Bütschli's confirmation of Klebs's discovery as to the non-existence of cilia in the transverse groove. The hair-like processes figured by Allman (91) external to the transverse groove in his *Peridinium uberrimum* (Fig. XXII. 1, 2) cannot, however, be explained as a flagellum. Bütschli inclines to the opinion that their nature was misinterpreted by Allman, although the latter especially calls attention to them as cilia, and as rendering his *P. uberrimum* unlike the Peridinium of Ehrenberg, in which the cilia (horizontal flagellum) are confined to the transverse groove.

Class IV. **RHYNCHOFLAGELLATA**, Lankester.

Characters.—Corticate Protozoa of large size ($\frac{1}{50}$th inch) and globular or lenticular form, with a firm cuticular membrane and highly vacuolated (reticular) protoplasm. In Noctiluca a deep groove is formed on one side of the spherical body, from the bottom of which springs the thick transversely striated proboscis or "big flagellum." Near this is the oral aperture and a cylindrical pharynx in which is placed the second or smaller flagellum (corresponding to the longitudinal flagellum of Dinoflagellata).

Nutrition is holozoic. No contractile vacuole is present; granule-streaming is observed in the protoplasm. An alimentary tract and anus have been erroneously described. The nucleus is spherical and not proportionately large (see for details Fig. XXII. 18 to 20).

Reproduction by transverse fission occurs, also conjugation and, either subsequently to that process or independently of it, a formation of spores (Cienkowski, 87), the protoplasm gathering itself, within the shell-like cuticular membrane, into a cake which divides rapidly into numerous flagellated spores (flagellulæ). These escape and gradually develop into the adult form (Fig. XXII. 13, 14).

The proboscis-like large flagellum is transversely striated, and exhibits energetic but not very rapid lashing movements.

Noctiluca is phosphorescent, the seat of phosphorescence being, as determined by Allman (86), the cortical layer of protoplasm underlying the cuticular shell or cell-wall as the primordial cuticle of a vacuolated vegetable cell underlies the vegetable cell-wall.

Genera.—Only two genera (both marine) are known:—*Noctiluca*, Suriray (90) (Fig. XXII. 17-20); *Leptodiscus*, Hertwig (88).

Further Remarks on the Rhynchoflagellata.—The peculiar and characteristic feature of Noctiluca appears to be found in its large transversely-striated flagellum, which, according to Bütschli, is not the same as the longitudinal flagellum of the Dinoflagellata, but probably represents the horizontal flagellum of those organisms in a modified condition; hence the name here proposed—Rhynchoflagellata.

Noctiluca is further remarkable for its large size and cyst-like form, and the reticular arrangement of its protoplasm, like that of a vegetable cell. This is paralleled in *Trachelius ovum* among the Ciliata (Fig. XXIV. 14), where the same stiffening of the cuticle allows the vacuolation of the subjacent protoplasm to take place. The remarkable *Leptodiscus medusoides* of R. Hertwig (88) appears to be closely related to Noctiluca.

It would no doubt be not unreasonable to associate the Dino-

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flagellata and the Rhynchoflagellata with the true Flagellata in one class. But the peculiarities of the organization of the two former groups is best emphasized by treating them as separate classes derived from the Flagellata. Neither group leads on to the Ciliata or to any other group, but they must be regarded as forming a lateral branch of the family tree of Corticata. The relationship of Noctiluca to Peridinium was first insisted upon by Allman, but has quite recently been put in a new light by Bütschli, who identifies the atrial recess of Noctiluca (Fig. XXII. 20, *b*) with the longitudinal furrow or groove of the Dinoflagellata, and the large and minute flagella of the former with the transverse and longitudinal flagella respectively of the latter. The superficial ridge *c* of Noctiluca appears to represent the continuation of the longitudinal groove.

The phosphorescence of the sea, especially on northern coasts, is largely caused by Noctiluca, but by no means exclusively, since Medusæ, Crustaceans, Annelids, and various Protozoa often take part in the phenomenon. Not unfrequently, however, the phosphorescence on the British coasts seems to be solely due to Noctiluca, which then occurs in millions in the littoral waters.

FIG. XXIII. **Ciliata.**—1. *Spirostomum ambiguum*, Ehr.; one of the Heterotricha; × 150. Observe on the right side the oral groove and special heterotrichous band of long cilia. *a*, moniliform nucleus; *b*, contractile vacuole. 2. *Stentor polymorphus*, Müller; one of the Heterotricha; × 50; group of individuals with the area fringed by the heterotrichous cilia expanded trumpet-wise. 3. *Tintinnus lagenula*, C. and L.; one of the Heterotricha; × 300. 4. *Strombidium Claparedii*, S. K.; one of the Peritricha; × 200. 5. Empty shell of *Codonella campanella*, Haeck.; one of the Heterotricha; × 180. 6, 7. *Torquatella typica*, Lankester. *p*, the supra-oral lobe seen through the membranous collar. 8, 9. View of the base and of the side of *Trichodina pediculus*, Ehr.; one of the Peritricha; × 300. *a*, nucleus; *c*, corneous collar; *d*, mouth. 10. *Spirochona gemmipara*, Stein; one of the Peritricha; × 350. *a*, nucleus; *g*, bud. 11. *Vorticella citrina*, Ehr.; × 150 (Peritricha). At *d* multiple fission of an individual cell to form "microgonidia." 12. *Vorticella microstoma*, Ehr. (Peritricha); × 300. At *a* eight "microgonidia" formed by fission of a single normal individual. 13. Same species, binary fission. *a*, elongated nucleus. 14. *Vorticella nebulifera*, Ehr.; free-swimming zooid resulting from fission in the act of detaching itself and swimming away, possessing a posterior circlet of cilia. *e*, ciliated disk; *f*, pharynx. 15. *Vorticella microstoma*, Ehr.; normal zooid with two microgonidia (or microzooids) *c*, *d*, in the act of conjugation. *a*, nucleus; *b*, contractile vacuole; *e*, ciliated disk; *f*, pharynx. 16. *Vorticella microstoma*, Ehr., with stalk contracted and body enclosed in a cyst. *a*, nucleus. 17. *Vorticella nebulifera*, Ehr. *a*, nucleus; *b*, contractile vacuole; *c*, muscular region of the body continuous with the muscle of the stalk; *d*, pharynx (the basal continuation of the oral vestibule which receives at a higher point the fæcal excreta and the ejected liquid from the contractile vacuole). 18. *Carchesium spectabile*, Ehr.; retractile colony; × 50. 19. Trichocysts of *Epistylis flavicans*, Ehr., as figured by Greeff. 20. *Opercularia stenostoma*, Stein; × 200; a small colony. Observe the ciliation of the oral vestibule and the upstanding ciliate disk (opercular-like). 21, 22. *Pyxicola affinis*, S. K.; one of the stalked loricate Peritricha, in expanded and retracted states. *x*, the true operculum. 23, 24. *Gyrocoris oxyura*, Stein; one of the free-swimming Peritricha, with spiral equatorial cilia-band; × 250. *b*, contractile vacuole. 25, 26. *Thuricola valvata*, Str. Wright; one of the sessile tubicolous Peritricha. Two individuals are as a result of fission temporarily occupying one tube; *v*, the valve attached to the tube, like the door of the trap-door spider's nest and the valve of the Gasteropod Clausilium.

CLASS V. **CILIATA**, Ehrenberg (*Infusoria* sensu stricto).

Characters.—Corticata of relatively large size, provided with either a single band of cilia surrounding the anteriorly placed oral aperture or with cilia disposed more numerously over the whole surface of the body. The cilia are distinguished from the flagella of Flagellata by their smaller size and simple movements of alternate flexion and erection; they serve always at some period of growth as locomotor organs, and also very usually as organs for the introduction of food particles into the mouth. Besides one larger oblong nucleus a second (the paranucleus) is invariably (?) present (Fig. XXV. 2), or the nucleus may be dispersed in small fragments. Conjugation of equal-sized individuals, not resulting in permanent fusion, is frequent. The conjugated animals separate and their nuclei and paranuclei undergo peculiar changes; but no formation of spores, either at this or other periods, has been decisively observed (Fig. XXV. 8 to 15). Multiplication by transverse fission is invariably observed in full-grown individuals (Fig. XXV. 16), and conjugation appears to take place merely as an interlude in the fissiparous process; consequently young or small Ciliata are (with few exceptions) unknown. Possibly spore-formation may hereafter be found to occur at rare intervals more generally than is at present supposed (Fig. XXIV. 15, 18). A production of microgonidia by rapid fission occurs in some Peritricha (Fig. XXIII. 11, 12, 14, 15), the liberated microgonidia conjugating with the normal individuals, which also can conjugate with one another.

The Ciliata, with rare exceptions (parasites), possess one or more contractile vacuoles (Fig. XXV. 3). They always possess a delicate cuticle and a body-wall which, although constant, in form is elastic. They may be naked and free-swimming, or they may form horny (Fig. XXIII. 21, 25) or siliceous cup-like shells or gelatinous envelopes, and may be stalked and form colonies like those of Choanoflagellata, sometimes with organic connexion of the constituent units of the colony by a branching muscular cord (Vorticellidæ). Many are parasitic in higher animals, and of these some are mouthless. All are holozoic in their nutrition, though some are said to combine with this saprophytic and holophytic nutrition.

The Ciliata are divisible into four orders according to the distribution and character of their cilia. The lowest group (the Peritricha) may possibly be connected through some of its members, such as Strombidium (Fig. XXIII. 4), with the Flagellata through such a form as Lophomonas (Fig. XXI. 9).

In the following synopsis, chiefly derived from Saville Kent's valuable treatise (71), the characters of the families and the names of genera are not given at length owing to the limitation of our space.

ORDER 1. PERITRICHA, Stein (79).

Characters.—Ciliata with the cilia arranged in one anterior circlet or in two, an anterior and a posterior; the general surface of the body is destitute of cilia.

Sub-order 1. NATANTIA (animals never attached).

Fam. 1. TORQUATELLIDÆ.
Genus.—*Torquatella*, Lankester, like *Strombidium*, but the cilia adherent so as to form a vibratile membranous collar (Fig. XXIII. 6, 7).
Fam. 2. DICTYOCYSTIDÆ. Animals loricate.
Fam. 3. ACTINOBOLIDÆ. Illoricate, with retractile tentacula.

FAM. 4. HALTERIIDÆ.

Genera.—*Strombidium*, Cl. & L. (Fig. XXIII. 4); *Halteria*, Dujard., with a supplementary girdle of springing hairs; *Didinium*, Stein, (Fig. XXIV. 19).

FAM. 5. GYROCORIDÆ.

Genera.—*Gyrocoris*, Stein, with an equatorial ciliary girdle spirally disposed (Fig. XXIII. 23, 24); *Urocentrum*, Nitzsch, girdle annular.

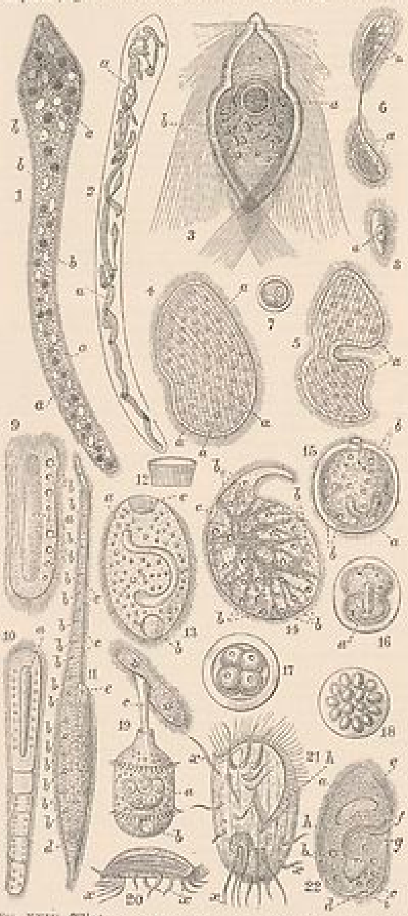

FIG. XXIV. **Ciliata.**—1. *Opalinopsis sepiolae*, Foett.; a parasitic Holotrichous mouthless Ciliate from the liver of the Squid. *a*, nuclei; *b*, vacuoles (non-contractile). 2. A similar specimen treated with picro-carmine, showing a remarkably branched and twisted nucleus; *a*, in place of several nuclei. 3. *Trichonympha agilis*, Leidy; parasitic in the intestine of the Termites (White Ants); × 600. *a*, nucleus; *b*, granules (food?). 4. *Opalina ranarum*, Purkinje; a Holotrichous mouthless Ciliate parasitic in the Frog's rectum; adult; × 200. *a*, *a*, the numerous regularly-dispersed nuclei. 5. The same; an individual in process of binary fission. *a*, nuclei. 6. The same; the process of fission has now reduced the individuals to a relatively small size. 7. Smallest fission-produced fragment encysted, expelled from the Frog in this state and swallowed by Tadpoles. 8. Young uninucleate individual which has emerged from the cyst within the Tadpole, and will now multiply its nuclei and grow to full size before in turn undergoing retrogressive fission. 9. *Anoplophrya naidos*, Duj.; a mouthless Holotrichous Ciliate parasitic in the worm Nais; × 200. *a*, the large axial nucleus; *b*, contractile vacuoles. 10. *Anoplophrya prolifera*, C. and L.; from the intestine of Clitellio. Remarkable for the adhesion in a metameric series of incomplete fission-products. *a*, nucleus. 11. *Amphileptus gigas*, C. and L.; one of the Holotricha; × 100. *b*, contractile vacuoles; *c*, trichocysts (see Fig XXIII. 19); *d*, nucleus; *e*, pharynx. 12, 13. *Prorodon niveus*, Ehr.; one of the Holotricha; × 75. *a*, nucleus; *b*, contractile vacuole; *c*, pharynx with horny fascicular lining. 12. The fasciculate cuticle of the pharynx isolated. 14. *Trachelius ovum*, Ehr. (Holotricha); × 80; showing the reticulate arrangement of the medullary protoplasm. *b*, contractile vacuoles; *c*, the cuticle-lined pharynx. 15, 16, 17, 18. *Ichthyophthirius multifiliis*, Fouquet; one of the Holotricha; × 120. Free individual and successive stages of division to form spores. *a*, nucleus; *b*, contractile vacuoles. 19. *Didinium nasutum*, Müll.; one of the Peritricha; × 200. The pharynx is everted and has seized a Paramoecium as food. *a*, nucleus; *b*, contractile vacuole; *c*, everted pharynx. 20. *Euplotes charon*, Müll.; one of the Hypotricha; lateral view of the animal when using its great hypotrichous processes, *x*, as ambulatory organs. 21. *Euplotes harpa*, Stein (Hypotricha); × 150. *h*, mouth; *x*, hypotrichous processes (limbs). 22. *Nyctotherus cordiformis*, Stein; a Heterotrichous Ciliate parasitic in the intestine of the Frog. *a*, nucleus; *b*, contractile vacuole; *c*, food particle; *d*, anus; *e*, heterotrichous band of large cilia; *f*, *g*, mouth; *h*, pharynx; *i*, small cilia.

FAM. 6. URCEOLARIIDÆ.

Genera.—*Trichodina*, Ehr.; two ciliate girdles; body shaped as a pyramid with circular sucker-like base, on which is a toothed corneous ring (Fig. XXIII. 8, 9); *Licnophora*, Clap.; *Cyclochæta*, Hat. Jacks.

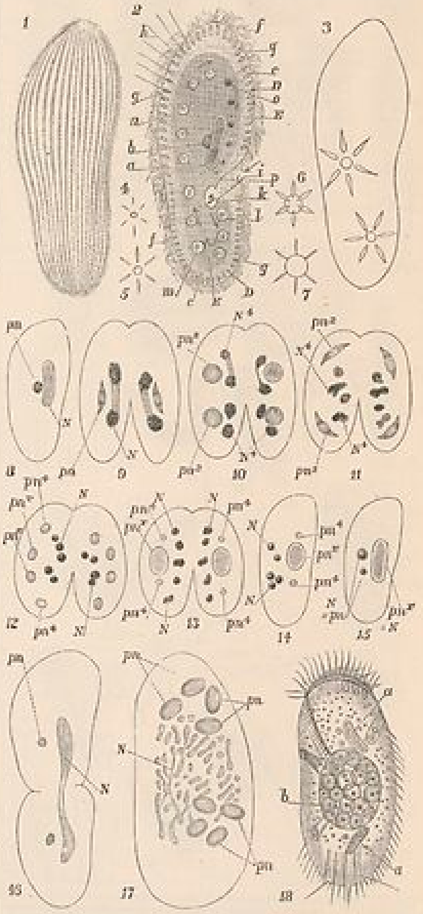

FIG. XXV. **Ciliata** (conjugation, &c.). 1. Surface view of Holotrichous Ciliate, showing the disposition of the cilia in longitudinal rows. 2.

Diagrammatic optical section of a Ciliate Protozoon, showing all structures except the contractile vacuoles. a, nucleus; b, paranucleus (so-called nucleolus); c, cortical substance; D, extremely delicate cuticle; E, medullary (more fluid) protoplasm; f, cilia; g, trichocysts; h, filaments ejected from the trichocysts; i, oral aperture; k, drop of water containing food-particles, about to sink into the medullary substance and form a food-vacuole; l, m, n, o, food-vacuoles, the successive order of their formation corresponding to the alphabetical sequence of the letters; the arrows indicate the direction of the movement of rotation of the medullary protoplasm; p, pharynx. 2. Outline of a Ciliate (Paramecium), to show the form and position of the contractile vacuoles. 4-7. Successive stages in the periodic formation of the contractile vacuoles. The ray-like vacuoles discharge their contents into the central vacuole, which then itself bursts to the exterior. 8-15. Diagrams of the changes undergone by the nucleus and paranucleus of a typical Ciliate during and immediately after conjugation:—N, nucleus; pn, paranucleus; 8, condition before conjugation; 9, conjugation effected; both nucleus and paranucleus in each animal elongate and become fibrillated; 10, two spherical paranuclei pn^1 in each, two dividing or divided nuclei N^1; 11, the spherical paranuclei have become fusiform; 12, there are now four paranuclei in each (pn^1 and pn^2), and a nucleus broken into four or even more fragments; 13, the two paranuclei marked pn^1 in 12 have united in each animal to form the new nucleus pn^3; the nuclear fragments are still numerous; 14, after cessation of conjugation the nuclear fragments N and the two unfused paranuclear pieces pn^2 are still present; 15, from a part or all of the fragments pn^2 the new paranucleus is in process of formation, the new nucleus (pn^3 = N) is large and elongated. 16. Diagram of a Ciliate in process of transverse fission. 17. Condition of the nucleus N, and of the paranucleus pn in *Paramecium aurelia* after cessation of conjugation as observed by Bütschli. 18. *Stylonichia mytilus* (one of the Hypotricha), showing endoparasitic unicellular organisms h, formerly mistaken for spores; a, nuclei (after conjugation and breaking up).

FAM. 7. OPHRYOSCOLECIDÆ.
Genera.—*Astylozoon*, Engelm.; *Ophryoscolex*, Stein.

Sub-order 2. SEDENTARIA, animals always attached or sedentary during the chief part of the life-history.

FAM. 1. VORTICELLIDÆ. Animals ovate, campanulate, or sub-cylindrical; oral aperture terminal, eccentric, associated with a spiral fringe of adoral cilia, the right limb of which descends into the oral aperture, the left limb encircling a more or less elevated protrusible and retractile ciliary disk.

Sub-family 1. Vorticellinæ: animalcules naked.

α.—Solitary forms.

Genera.—*Gerda*, Cl. and L.; *Scyphidia*, Dujard.; *Spirochona*, Stein (sessile with peristome in the form of a spirally convolute membranous expansion, Fig. XXIII. 10); *Pyxidium*, Kent (with a non-retractile stalk); *Vorticella*, Linn. (with a hollow stalk in which is a contractile muscular filament).

β.—Forming dendriform colonies.

Genera.—*Carchesium*, Ehr. (Fig. XXIII. 18, with contractile stalks); *Zoothamnium*, Ehr. (contractile stalks); *Epistylis*, Ehr. (stalk rigid); *Opercularia*, Stein (stalk rigid, ciliated disk oblique; an elongated peristomial collar, Fig. XXIII. 20).

Sub-family 2. Vaginicolinæ: animalcules secreting firm cup-like or tube-like membranous shells.

Genera.—*Vaginicola*, Lamarck (no internal valve); *Thuricola*, Kent (with a door-like valve to the tube, Fig. XXIII. 25, 26); *Cothurnia*, Ehr. (lorica or shell pediculate; no operculum); *Pyxicola*, Kent (lorica pedunculate, animal carrying dorsally a horny operculum, Fig. XXIII. 21, 22).

Sub-family 3. Ophrydina: animalcules secreting a soft gelatinous envelope.

Genera.—*Ophionella*, Kent; *Ophrydium*, Ehr.

ORDER 2. HETEROTRICHA, Stein.

Characters.—A band or spiral or circlet of long cilia is developed in relation to the mouth (the heterotrichous band) corresponding to the adoral circlet of Peritricha; the rest of the body is uniformly beset with short cilia.

α.—Heterotrichal band circular.

Genera (selected).—*Tintinnus*, Schranck (Fig. XXIII. 3); *Tricholinopsis*, Cl. and L.; *Codonella*, Haeck. (with a peri-oral fringe of lappet-like processes); *Calceolus*, Diesing.

β.—Heterotrichal band spiral.

Genera (selected).—*Stentor*, Oken (Fig. XXIII. 2); *Blepharisma*, Perty (with an undulating membrane along the oral groove); *Spirostomum*, Ehr. (oral groove linear and elongate, Fig. XXIII. 1); *Leucophrys*, Ehr. (oral groove very short).

γ.—Heterotrichal band in the form of a simple straight or oblique adoral fringe of long cilia.

Genera (selected).—*Bursaria*, Müller; *Nyctotherus*, Leidy (with well-developed alimentary tract and anus, Fig. XXIV. 22); *Balantidium*, Cl. and L. (*B. coli* parasitic in the human intestine).

ORDER 3. HOLOTRICHA, Stein.

Characters.—There is no special adoral fringe of larger cilia, nor a band-like arrangement of cilia upon any part of the body; short cilia of nearly equal size are uniformly disposed all over the surface. The adoral cilia sometimes a little longer than the rest.

α.—With no membraniform expansion of the body wall.

Genera.—*Paramecium*, Ehr. (Fig. XXV. 1, 2); *Prorodon*, Ehr. (Fig. XXIV. 13); *Coleps*, Ehr.; *Enchelys*, Ehr.; *Trachelocerca*, Ehr.; *Trachelius*, Ehr.; *Amphileptus*, Ehr.; *Ichthyophthirius*, Fouquet (Fig. XXIV. 15).

β.—Body with a projecting membrane, often vibratile.

Genera.—*Ophryoglena*, Ehr.; *Colpidium*, Stein; *Lembus*, Cohn; *Trichonympha*, Leidy (an exceptionally modified form, parasitic, Fig. XXIV. 3).

γ.—Isolated parasitic forms, devoid of a mouth.

Genera.—*Opalina*, Purkinje (nuclei numerous, no contractile vacuole, Fig. XXIV. 4 to 8); *Benedenia*, Foett.; *Opalinopsis*, Foett. (Fig. XXIV. 1, 2); *Anoplophrya*, Stein (large axial nucleus, numerous contractile vacuoles in two linear series, Fig. XXIV. 9 10); *Haptophrya*, Stein; *Hoplitophrya*, Stein.

ORDER 4. HYPOTRICHA, Stein.

Characters.—Ciliata in which the body is flattened and the locomotive cilia are confined to the ventral surface, and are often modified and enlarged to the condition of muscular appendages (setæ so-called). Usually an adoral band of cilia, like that of Heterotricha. Dorsal surface smooth or provided with tactile hairs only. Mouth and anus conspicuously developed.

α.—Cilia of the ventral surface uniform, fine, and vibratile.

Genera.—*Chilodon*, Ehr.; *Loxodes*, Ehr.; *Dysteria*, Huxl.; *Huxleya*, Cl. and L.

β.—Cilia of the ventral surface variously modified as setæ (muscular appendages), styles, or uncini.

Genera.—*Stylonichia*, Ehr. (Fig. XXV. 18); *Oxytricha*, Ehr.; *Euplotes*, Ehr. (Fig. XXIV. 20, 21).

Further remarks on the Ciliata.—The Ciliata have recently formed the subject of an exhaustive treatise by Mr Saville Kent (71) which is accessible to English readers. On the other hand Prof. Bütschli has not yet dealt with them in his admirable critical treatise on the Protozoa. Hence a large space has not been devoted in this article to the systematic classification and enumeration of their genera. See (79) and (93).

One of the most interesting features presented by the group is the presence in many of a cell anus as well as a cell mouth (Fig. XXIV. 22, *d*). In those devoid of an anus the undigested remnants of food are expelled either by a temporary aperture on the body-surface or by one opening into the base of the pharynx. In many parasitic Ciliata, as in higher animal parasites, such as the Cestoid worms, a mouth is dispensed with, nutriment being taken by general imbibition and not in the solid form. Many Ciliata develop chlorophyll corpuscles of definite biconcave shape, and presumably have so far a capacity for vegetal nutrition. In *Vorticella viridis* the chlorophyll is uniformly diffused in the protoplasm and is not in the form of corpuscles (72).

The formation of tubes or shells and in connexion therewith of colonies is common among the Peritricha and Heterotricha. The cuticle may give rise to structures of some solidity in the form of hooks or tooth-like processes, or as a lining to the pharynx (Fig. XXIV. 12).

The phenomena connected with conjugation and reproduction are very remarkable, and have given rise to numerous misconceptions. They are not yet sufficiently understood. It cannot be surely asserted that any Ciliate is at the present time known to break up, after encystment or otherwise, into a number of spores, although this was at one time supposed to be the rule. Ichthyophthirius (Fig. XXIV. 15 to 18) and some Vorticellæ (76) have been stated, even recently, to present this phenomenon; but it is not impossible that the observations are defective. The only approach to a rapid breaking up into spores is the multiple formation (eight) of microgonidia or microzooids in Vorticellidæ (Fig. XXIII. 11, 12); otherwise the result of the most recent observations appears to be that the Ciliata multiply only by binary fission, which is very frequent among them (longitudinal in the Peritricha, transverse to the long axis in the others).

Several cases of supposed formation of spores within an adult Ciliate and of the production endogenously of numerous "acinetiform young" have been shown to be cases of parasitism, minute unicellular parasites, *e.g.*, parasitic Acinetæ (such as Sphærophrya described and figured in Fig. XXVI.) being mistaken for the young.

The phenomenon of conjugation is frequent in the Ciliata, and is either temporary, followed by a separation of the fused individuals, as in most cases, or permanent, as in the case of the fertilization of normal individuals by the microgonidia of Vorticellidæ.

Since the process of conjugation or copulation is not followed by a formation of spores, it is supposed to have merely a fertilizing effect on the temporarily conjoined individuals, which nourish themselves and multiply by binary fission more actively after the process than before (hence termed "rejuvenescence)."

Remarkable changes have been from time to time observed in the nuclei of Ciliata during or subsequently to conjugation, and these were erroneously interpreted by Balbiani (73) as indicating the formation of spermatozoa and ova. The nuclei exhibit at one period great elongation and a distinct fibrillation, as in the dividing

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nuclei of tissue cells (compare Fig. I. and Fig. XXV. 9, 11, 17). The fibrillæ were supposed to be spermatozoids, and this erroneous view was confirmed by the observation of rod-like Bacteria (Schizomycetes) which in some instances infest the deeper protoplasm of large Ciliata.

The true history of the changes which occur in the nuclei of conjugating Ciliata has been determined by Bütschli (74) in some typical instances, but the matter is by no means completely understood. The phenomena present very great obstacles to satisfactory examination on account of their not recurring very frequently and passing very rapidly from one phase to another. They have not been closely observed in a sufficiently varied number of genera to warrant a secure generalization. The following scheme of the changes passed through by the nuclei must be regarded as necessarily referring to only a few of the larger Heterotricha, Holotricha, and Hypotricha, and is only probably true in so far as details are concerned, even for them. It is at the same time certain that some such series of changes occurs in all Ciliata as the sequence of conjugation.

In most of the Ciliata by the side of the large oblong nucleus is a second smaller body (or even two such bodies) which has been very objectionably termed the nucleolus (Fig. XXV. 8), but is better called the "paranucleus" since it has nothing to do with the nucleolus of a typical tissue-cell. When conjugation occurs and a "syzygium" is formed, both nucleus and paranucleus in each conjugated animal elongate and show fibrillar structure (Fig. XXV. 10). Each nucleus and paranucleus now divides into two, so that we get two nuclei and two paranuclei in each animal. Elongation and fibrillation are then exhibited by each of these new elements and subsequently fission, so that we get four nuclei and four paranuclei in each animal (11, 12). The fragments of the original nucleus (marked N in the figures) now become more dispersed and broken into further irregular fragments. Possibly some of them are ejected (so-called "cell excrement"); possibly some pass over from one animal to the other. Two of the pieces of the four-times-divided paranucleus now reunite (Fig. XXV. 13), and form a largish body which is the new nucleus. The remaining fragments of paranucleus and the broken down nucleus now gradually disappear, and probably as a remnant of them we get finally a few corpuscles which unite to form the new paranucleus (14, 15). The conjugated animals which have separated from one another before the later stages of this process are thus reconstituted as normal Ciliata, each with its nucleus and paranucleus. They take food and divide by binary fission until a new period of conjugation arrives, when the same history is supposed to recur.

The significance of the phenomena is entirely obscure. It is not known why there should be a paranucleus or what it may correspond to in other cells—whether it is to be regarded simply as a second nucleus or as a structurally and locally differentiated part of an ordinary cell-nucleus, the nucleus and the paranucleus together being the complete equivalent of such an ordinary nucleus. An attempt has been made to draw a parallel between this process and the essential features of the process of fertilization (fusion of the spermatic and ovicell nuclei) in higher animals; but it is the fact that concerning neither of the phenomena compared have we as yet sufficiently detailed knowledge to enable us to judge conclusively as to how far any comparison is possible. Whilst there is no doubt as to the temporary fusion and admixture of the protoplasm of the conjugating Ciliata, it does not appear to be established that there is any transference of nuclear or paranuclear matter from one individual to the other in the form of solid formed particles.

Conjugation resulting merely in rejuvenescence and ordinary fissive activity is observed in many Flagellata as well as in the Ciliata.

A noteworthy variation of the process of binary fission occurring in the parasite Opalina deserves distinct notice here, since it is intermediate in character between ordinary binary fission and that multiple fission which so commonly in Protozoa is known as spore-formation. In Opalina (Fig. XXIV. 4) the nucleus divides as the animal grows; and we find a great number of regularly disposed separate nuclei in its protoplasm. (The nuclei of many other Ciliata have recently been shown to exhibit extraordinary branched and even "fragmented" forms; compare Fig. XXIV. 2.) At a certain stage of growth binary fission of the whole animal sets in, and growth ceases. Consequently the products of fission become smaller and smaller (Fig. XXIV. 6). At last the fragments contain each but two, three, or four nuclei. Each fragment now becomes encased in a spherical cyst (Fig. XXIV. 7). If this process had occurred rapidly, we should have had a uninucleate Opalina breaking up at once into fragments (as a Gregarina does), each fragment being a spore and enclosing itself in a spore-case. The *Opalina ranarum* lives in the rectum of the Frog, and the encysted spores are formed in the early part of the year. They pass out into the water and undergo no change unless swallowed by a Tadpole, in the intestine of which they forthwith develop. From each spore-case escapes a uninucleate embryo (Fig. XXIV. 8), which absorbs nourishment and grows. As it grows its nucleus divides, and so the large multinucleate form from which we started is reattained.

This history has important bearings, not only on the nature of sporulation, but also on the question of the significance of the multinucleate condition of cells. Here it would seem that the formation of many nuclei is merely an anticipation of the retarded fissive process.

It is questionable how far we are justified in closely associating Opalina, in view of its peculiar nuclei, with the other Ciliata. It seems certain that the worm-parasites sometimes called Opalinæ, but more correctly Anaplophrya, &c., have no special affinity with the true Opalina. They not only differ from it in having one large nucleus, but in having numerous very active contractile vacuoles (75).

Recently it has been shown, more especially by Gruber (84), that many Ciliata are multinucleate, and do not possess merely a single nucleus and a paranucleus. In Oxytricha the nuclei are large and numerous (about forty), scattered through the protoplasm, whilst in other cases the nucleus is so finely divided as to appear like a powder or dust diffused uniformly through the medullary protoplasm (Trachelocerca, Choenia). Carmine staining, after treatment with absolute alcohol, has led to this remarkable discovery. The condition described by Foettinger (85) in his Opalinopsis (Fig. XXIV. 1, 2) is an example of this pulverization of the nucleus. The condition of pulverization had led in some cases to a total failure to detect any nucleus in the living animal, and it was only by the use of reagents that the actual state of the case was revealed. Curiously enough, the pulverized nucleus appears periodically to form itself by a union of the scattered particles into one solid nucleus just before binary fission of the animal takes place; and on the completion of fission the nuclei in the two new individuals break up into little fragments as before. The significance of this observation in relation to the explanation of the proceedings of the nuclei during conjugation cannot be overlooked. It also leads to the suggestion that the animal cell may at one time in the history of evolution have possessed not a single solid nucleus but a finely molecular powder of chromatin-substance scattered uniformly through its protoplasm, as we find actually in the living Trachelocerca.

Some of the Ciliata (notably the common Vorticellæ) have been observed to enclose themselves in cysts; but it does not appear that these are anything more than "hypnocysts" from which the animal emerges unchanged after a period of drought or deficiency of food. At the same time there are observations which seem to indicate that in some instances a process of spore-formation may occur within such cysts (76).

The differentiation of the protoplasm into cortical and medullary substance is very strongly marked in the larger Ciliata. The food-particle is carried down the gullet by ciliary currents and is forced together with an adherent drop of water into the medullary protoplasm. Here a slow rotation of the successively formed food-vacuoles is observed (Fig. XXV. 2, *l*, *m*, *n*, *o*), the water being gradually removed as the vacuole advances in position. It was the presence of numerous successively formed vacuoles which led Ehrenberg to apply to the Ciliata the not altogether inappropriate name "Polygastrica." The chemistry of the digestive process has not been successfully studied, but A. G. Bourne (8) has shown that, when particles stained with water-soluble anilin blue are introduced as food into a Vorticella, the colouring matter is rapidly excreted by the contractile vacuole in a somewhat concentrated condition.

The differentiation of the protoplasm of Ciliata in some special cases as "muscular" fibre cannot be denied. The contractile filament in the stalk of Vorticella is a muscular fibre and not simple undifferentiated contractile protoplasm; that is to say, its change of dimensions is definite and recurrent, and is not rhythmic, as is the flexion of a cilium. (Perhaps in ultimate analysis it is impossible to draw a sharp line between the contraction of one side of a cilium which causes its flexion and the rhythmical contraction of some muscular fibres.) The movements of the so-called "setæ" of the Hypotricha are also entitled to be called "muscular," as are also the general contractile movements of the cortical substance of large Ciliata. Haeckel (77) has endeavoured to distinguish various layers in the cortical substance; but, whilst admitting that, as in the Gregarinæ, there is sometimes a distinct fibrillation of parts of this layer, we cannot assent to the general distinction of a "myophane" layer as a component of the cortical substance.

Beneath the very delicate cuticle which, as a mere superficial pellicle of extreme tenuity, appears to exist in all Ciliata we frequently find a layer of minute oval sacs which contain a spiral thread; the threads are everted from the sacs when irritant reagents are applied to the animal (Fig. XXV. 2, *g*, *h*). These were discovered by Allman (78), and by him were termed "trichocysts." They appear to be identical in structure and mode of formation with the nematocysts of the Cœlentera and Platyhelmia. Similar trichocysts (two only in number) are found in the spores of the Myxosporidia (see *ante*, page 855).

The comparative forms of the nucleus and of the contractile vacuoles, as well as of the general body-form, &c., of Ciliata may be learnt from an examination of Figs. XXIII., XXIV., XXV., and the explanations appended to them.

Class VI. **ACINETARIA**, Lankester (*Tentaculifera*, Huxley).

Characters.—Highly specialized Corticate Protozoa, probably derived from Ciliata, since their young forms are provided with a more or less complete investment of cilia. They are distinguished by having no vibratile processes on the surface of the body in the adult condition, whilst they have few or many delicate but firm tentacle-like processes, which are either simply adhesive or tubular and suctorial. In the latter case they are provided at their extremity with a sucker-disk and have contractile walls, whereas in the former case they have more or less pointed extremities. The Acinetaria are sedentary in habit, even if not, as is usual, permanently fixed by a stalk. The nucleus is frequently arboriform. Reproduction is effected by simple binary fission, and by a modified fission (bud-fission) by which (as in Reticularia and Arcella) a number of small bud-like warts containing a portion of the branched parental nucleus are nipped off from the parent, often simultaneously (Fig. XXVI. 8). These do not become altogether distinct, but are for a time enclosed by the parental cell each in a sort of vacuole or brood-chamber, where the young Acinetarian develops a coat or band of cilia and then escapes from the body of its parent (Fig. XXVI. 10, 17). After a brief locomotive existence, it becomes sedentary, develops its tentacles, and loses its cilia.

The Acinetaria have one or more contractile vacuoles. Their nutrition is holozoic.

The surface of the body in some cases is covered only by a delicate cuticle, but in other cases a definite membranous shell or cup (often stalked) is produced. Freshwater and marine. See Fraipont (89).

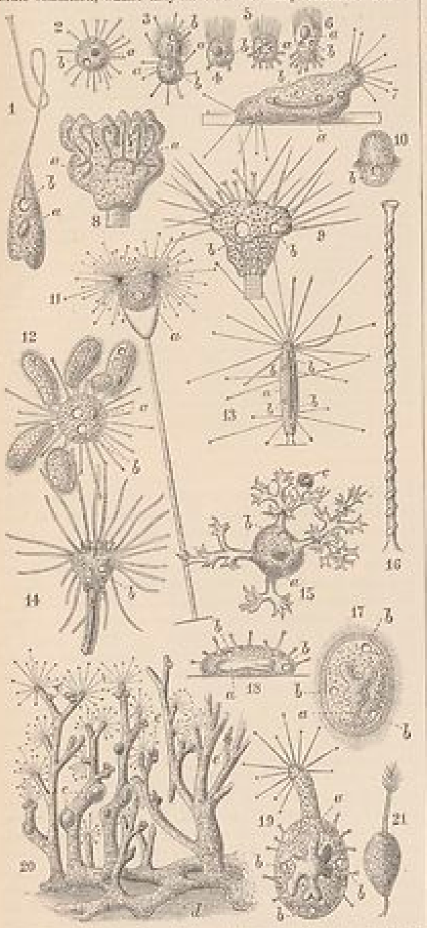

Fig. XXVI.—**Acinetaria.** 1. *Rhyncheta cyclopum*, Zenker. *a*, nucleus; *b*, contractile vacuole; only a single tentacle, and that suctorial; × 150. Parasitic on Cyclops. 2. *Sphaerophrya urostylae*, Maupas; normal adult; × 200. *a*, nucleus; *b*, contractile vacuole. Parasitic in Urostyla. 3. The same dividing by transverse fission, the anterior moiety with temporarily developed cilia. *a*, nucleus; *b*, contractile vacuole. 4, 5, 6. *Sphaerophrya stentorea*, Maupas; × 200. Parasitic in Stentor, and at one time mistaken for its young. 7. *Trichophrya epistylidis*, Cl. and L.; × 150. *a*, nucleus; *b*, contractile vacuole. 8. *Hemiophrya gemmipara*, Hertwig; × 400. Example with six buds, into each of which a branch of the nucleus *a* is extended. 9. The same species, showing the two kinds of tentacles (the suctorial and the pointed), and the contractile vacuoles *b*. 10. Ciliated embryo of *Podophrya Steinii*, Cl. and L.; × 200. 11. *Acineta grandis*, Saville Kent; × 100; showing pedunculated lorica, and animal with two bunches of entirely suctorial tentacles. *a*, nucleus. 12. *Sphaerophrya magna*, Maupas; × 300. It has seized with its tentacles, and is in the act of sucking out the juices of six examples of the ciliate *Colpoda parvifrons*. 13. *Podophrya elongata*, Cl. and L.; × 150. *a*, nucleus; *b*, contractile vacuole. 14. *Hemiophrya Benedenii*, Fraip.; × 200; the suctorial tentacles retracted. 15. *Dendrocometes paradoxus*, Stein; × 300. Parasitic on *Gammarus pulex*. *a*, nucleus; *b*, contractile vacuole; *c*, captured prey. 16. A single tentacle of Podophrya; × 800. (Saville Kent.) 17-20. *Dendrosoma radians*, Ehr.—17, free-swimming ciliated embryo, × 600; 18, earliest fixed condition of the embryo, × 600; 19, later stage, a single tentaculiferous process now developed, × 600; 20, adult colony; *c*, enclosed ciliated embryos; *d*, branching stolon; *e*, more minute reproductive (?) bodies. 21. *Ophryodendron pedicellatum*, Hincks; × 300.

Order 1. SUCTORIA, Kent.

A greater or less proportion or often all of the tentacles are suctorial and terminated with sucker-like expansions.

Genera.—*Rhyncheta*, Zenker (stalkless, naked, with only one tentacle; epizoic on Cyclops; Fig. XXVI. 1); *Urnula*, C. and L.; *Sphaerophrya*, C. and L. (naked, spherical, with distinctly capitate tentacles only; never with a pedicle; parasitic within Ciliata, supposed young; Fig. XXVI. 2-6, 12); *Trichophrya*, C. and L. (as *Sphaerophrya*, but oblong and temporarily fixed without a pedicle); *Podophrya*, Ehr. (naked, solitary, globose, ovate or elongate, fixed by a pedicle; tentacles all suctorial, united in fascicles or distributed irregularly; Fig. XXVI. 10, 13, 16); *Hemiophrya*, S. Kent (as *Podophrya*, but the tentacles are of the two kinds indicated in the definition of the group; Fig. XXVI. 8, 9, 14); *Podocyathus*, S. Kent (secreting and inhabiting stalked membranous cups or loricæ; tentacles of the two kinds); *Solenophrya*, C. and L. (with a sessile lorica; tentacles only suctorial); *Acineta*, Ehr. (as *Solenophrya*, but the lorica is supported on a pedicle; Fig. XXVI. 11); *Dendrocometes*, Stein (cuticle indurated; solitary, sessile, discoid; tentacles peculiar, viz., not contractile, more or less branched, root-like, and perforated at the extremities and suctorial in function; Fig. XXVI. 15). *Dendrosoma*, Ehr. (forming colonies of intimately fused individuals, with a basal adherent protoplasmic stolon and upstanding branches the termination of which bear numerous capitate suctorial tentacles only; Fig. XXVI. 17-20).

Order 2. NON-SUCTORIA, Lankester (=*Actinaria*, Kent).

Characters.—Tentacles filiform, prehensile, not provided with a sucker.

Genera.—*Ephelota*, Str. Wright (solitary, naked, pedunculate, with many flexible inversible tentacles); *Actinocyathus*, S. Kent; *Ophryodendron*, C. and L. (sessile, with a long, extensile, anterior proboscis bearing numerous flexible tentacles at its distal extremity; Fig. XXVI. 21); *Acinetopsis*, Robin (ovate, solitary, secreting a stalked lorica; from the anterior extremity of the animal is developed a proboscis-like organ which does not bear tentacles).

Further remarks on the Acinetaria.—The independence of the Acinetaria was threatened some years ago by the erroneous view of Stein (79) that they were phases in the life-history of Vorticellidæ. Small parasitic forms (Sphaerophrya) were also until recently regarded erroneously as the "acinetiform young" of Ciliata.

They now must be regarded as an extreme modification of the Protozoon series, in which the differentiation of organs in a unicellular animal reaches its highest point. The sucker-tentacles of the Suctoria are very elaborately constructed organs (see Fig. XXVI. 16). They are efficient means of seizing and extracting the juices of another Protozoon which serves as food to the Acinetarian. The structure of Dendrosoma is remarkable on account of its multicellular character and the elaborate differentiation of the reproductive bodies.

The ciliation of the embryos or young forms developed from the buds of Acinetaria is an indication of their ancestral connexion with the Ciliata. The cilia are differently disposed on the young of the various genera (see Fig. XXVI. 10, 17).

Bibliography.—[illegible] (E. R. L.)

PROUDHON, PIERRE JOSEPH (1809–1865), a well-known revolutionary writer, was born in 1809 at Besançon, France, the native place also of the socialist Fourier. His origin was of the humblest, his father being a brewer's cooper; and the boy herded cows and followed other simple pursuits of a like nature. But he was not entirely self-educated; at sixteen he entered the college of his native place, though his family was so poor that he could not procure the necessary books, and had to borrow them from his mates in order to copy the lessons. There is a story of the young Proudhon returning home laden with prizes, but to find that there was no dinner for him. At nineteen he became a working compositor; afterwards he rose to be a corrector for the press, reading proofs of ecclesiastical works, and thereby acquiring a very competent knowledge of theology. In this way also he came to learn Hebrew, and to compare it with Greek, Latin, and French; and it was the first proof of his intellectual audacity that on the strength of this he wrote an "Essai de grammaire générale." As Proudhon knew nothing whatever of the true principles of philology, his treatise was of no value. In 1838 he obtained the *pension Suard*, a bursary of 1500 francs a year for three years, for the encouragement of young men of promise, which was in the gift of the academy of Besançon. In 1839 he wrote a treatise "On the Utility of Keeping the Sunday," which contained the germs of his revolutionary ideas. About this time he went to Paris, where he lived a poor, ascetic, and studious life,—making acquaintance, however, with the socialistic ideas which were then fomenting in the capital. In 1840 he published his first work *Qu'est-ce que la Propriété?* His famous answer to this question, "La propriété, c'est le vol," naturally did not please the academy of Besançon, and there was some talk of withdrawing his *pension*; but he held it for the regular period. For his third memoir on property, which took the shape of a letter to the Fourierist, M. Considérant, he was tried at Besançon but was acquitted. In 1846 he published his greatest work, the *Système des Contradictions économiques ou Philosophie de la Misère*. For some time Proudhon carried on a small printing establishment at Besançon, but without success; afterwards he became connected as a kind of manager with a commercial firm at Lyons. In 1847 he left this employment, and finally settled in Paris, where he was now becoming celebrated as a leader of innovation. He regretted the sudden outbreak of the revolution of February (1848), because it found the social reformers unprepared. But he threw himself with ardour into the conflict of opinion, and soon gained a national notoriety. He was the moving spirit of the *Représentant du Peuple* and other journals, in which the most advanced theories were advocated in the strongest language; and as member of assembly for the Seine department he brought forward his celebrated proposal of exacting an impost of one-third on interest and rent, which of course was rejected. His attempt to found a bank which should operate by granting gratuitous credit was also a complete failure; of the five million francs which he required only seventeen thousand were offered. The violence of his utterances led to an imprisonment at Paris for three years, during which he married a young working woman. As Proudhon aimed at economic rather than political innovation, he had no special quarrel with the second empire, and he lived in comparative quiet under it till the publication of his work, *De la Justice dans la Révolution et dans l'Église* (1858), in which he attacked the church and other existing institutions with unusual fury. This time he fled to Brussels to escape imprisonment. On his return to France his health broke down, though he continued to write. He died at Passy in 1865.