

## Chapter 2

### Probiontics (= Cytode Science)

#### **The task of *probiontics***

The deep gap, which both in the older, and in the later much more extended view of Nature, separates the living bodies from the non-living, and the organisms from the inorganic, has been effectively filled by the important discoveries of 1904. On one side the *rheo-crystals*, the “living liquid crystals”, and on the other side the probionts, as *cytodes*, as simple “non-nuclear cells”, act as the real connecting bridge between the two so-called “kingdoms” of the lifeless and of the living Nature. Because of this, these probionts, which hitherto have been the “simplest life-forms”, much neglected by theory, now deserve the most intensive study. For the unbiased critical comparison of these, on one hand with the *rheo-crystals* and on the other with the true nucleated cells, opens for us not only the locked door to a unitary physical understanding of the whole of nature. It also solves immediately the great riddle of the “Lebenswunder”<sup>1</sup>, the natural appearance of the simplest organisms from inorganic materials, the much-disputed problem of abiogenesis (*archigony*). For this it appears to be necessary to take that special branch of natural science which makes its task the deeper recognition of these probionts, to emphasise it as *probiontics*, and to place it midway between inorganic (chemistry) and biology.

#### **Probionts (“pre-cellular organisms”, precursors of organic life; “Lebenswunder”, 1904, chapter 9, p. 217)**

The real character of these most simple and primitive “organisms” which live today on our Earth, resides in the fact that they have no organisation of their own; their living bodies show no assembly from separate organs, of morphologically independent components of differing physiological significance. The whole organism of these probionts remains in the simplest case and throughout its life, as a homogeneous, original, spherical plasma grain, not essentially different from a *rheo-crystal*, for example, from a myelin sphere. Like the latter, it grows through extensive food transport and divides, when it has reached a determined size, by “transgressive growth” into two halves (*hemitomy*). With this the whole life cycle of the probiont is completed. The original spherical form of the structure-less plasma grain is often changed; and also during its life activities many kinds of components formed secondarily become separate in the homogeneous substance. But the cell nucleus is lacking, and with it the essential character of a cell, and the sexuality connected with it. Such simple probionts live still today widely distributed on our Earth, in the three classes of Monera, Chromacea and Bacteria.

#### **Problematic Monera**

In the exposition of the very controversial concept of Monera in the fifth chapter of my “General Morphology”, I was led by observations to a nucleus-less rhizopod, whose whole

organism showed a structureless plasma body of the simplest sort, from the surface of which moving and changeable processes radiated. In 1854 Max Schultze had already showed, in his work on Polythalmia, a nucleus-less Amoeba porrecta. In 1864, I myself observed in Naples a related naked organism which I described as *Protogenes primordialis*. Another, amoeboid form, which propagates itself by simple division, I found repeatedly in fresh water around Jena: *Protamoeba primitiva*; it is pictured in the *Natürlichen Schöpfungsgeschichte*. Related forms have also been recently described by other observers, for example, the impressive *Pelomyxa pallida* of Gruber<sup>2</sup>. Here the questions arise, as for the nucleus-less Chromacea and Bacteria, of what do the hypothetical cell nuclei in these Monera, which are not sexually differentiated and propagate themselves by simple division, serve for? In a wider sense are all these probionts to be reckoned as real Monera (in accordance with my original definition “organisms without organs” of 1866)? In the narrower sense it seems however now more practical to confine this concept to those really nucleus-less rhizopoda, namely to the LoboMonera (*Protamoeba*, *Gloidium*) with cloth-like forms and rhizo-Monera (*Pelomyxa*, *Protomyxa*) with root-like pseudopodia. Nonetheless, as these contentious questions are resolved, the simplest Chromacea (*Chroococcus*) will retain the character of Monera like the true Bacteria (*Micrococcus*).

**Plasma (= “Living substance”—“Lebenswunder”, 1904, pp. 137–164)**

From the most important general results of innumerable investigations on living substances which have been presented in the last half century, with the improved techniques of modern microscopy and chemistry, a few general consequences will be presented. For all organisms in general, a colloidal or liquid substance, of the chemical group of the proteins, serves as a material substrate—plasma in the widest sense (earlier usually called “protoplasm”). Since I have laid out in detail my personal assessment of the physical and chemical properties of this fundamental “material of life” already in chapter 6 of the “Lebenswunder” and have also criticised the various differences of outlook on its structure and on its products and *diffacts* (products of differentiation), I will confine myself here to the exposition of those most important points, which are of significance for the foregoing treatment. In this I will support myself with the extensive investigations of my own, which I have carried out over more than sixty years on the microscopic relations of cellular life, in particular, on the single cell Radiolaria and other protists. It has emerged from these studies, in agreement with the observations of the most recent histologists, that the pure plasma, cleaned of inclusions, possesses no perceptible structure, but exhibits a glutinous homogeneous fluidity. The many “plasma structures” which have been described by numerous authors as threads, granulets, foam, frameworks etc., do not belong to the elementary structure of the pure natural plasma. They are not causes of its life activity, but consequences of it. Some are inner or outer plasma products, parts are *diffacts*, or “products of differentiation”, for example, separation of the hyaline membrane (hyaloplasma) and the grainy border membrane (polioplasma). All these multiform modifications can be combined into the concept of metaplasma (of secondarily resulting plasma), in contradistinction to the pure essential protoplasm. From this it emerges that the concept of plasma is purely chemical and not morphological. The essential primary protoplasm is quite homogeneous in relation to chemistry and is without visible structure, like the myelin and lecithin of the *rheo-crystals*. It may well have a very well-developed invisible molecular

structure<sup>3</sup>, for the comparative chemistry of the endless variety of plasmas has led us to the conviction that the plasma molecules are extraordinarily big, most being composed of more than a thousand atoms. Their boundless variability can be ascribed to this. The detailed environment of a single atom or atomic group in the complex structure of the plasma molecule or *plastidule* is sufficient to alter more or less significantly, the whole configuration and its morphological and physiological properties<sup>4</sup>.

### ***Plastids***

In the ninth chapter of the “Generelle Morphologie” (Vol. I, pp. 269–289) I had, in 1866, made the first attempt to determine the morphological individuality of the organism more sharply and thus established the “*plastidules*” or “creators” as the primary level or order. By this general concept of “individuals of the first order” I distinguish the *cytodes* as “nucleus-less plasma bodies” from the true (nucleated) cells. As fundamental components of the “active cell substance” (indispensable for the cell concept), the plasma (or protoplasm) and the nucleus karyon) should be contrasted with the passive plasma products. I have already characterised the physiological significance of these two essential cell organelles—“the inner nucleus of the inheritance of hereditary characters, the external plasma, has to take care of adaptation to the conditions of the external world” (“Generelle Morphologie”, p. 288). Since at present this hypothesis is highly valued by most biologists, and the nucleus is often designated as the “organelle of heredity”, it should be mentioned that just this hypothesis had already been formulated by me in 1866. Only eight years later it found its empirical foundation through the careful observations of the brothers Hertwig, Strasburger, Bütschli, van Beneden and others.

### ***Plastidules (= Plasma molecules)***

In the simplest Monera, in the most primitive forms of *plastids*, the whole organisation of the *cytode* consists of a homogeneous liquid plasma. Each molecule in this is equivalent to every other, as long as self-differentiation does not enter through the activities of life. The plasma molecules, which I have called *plastidules*, behave also in the whole (originally spherical) *cytodes* in the way that the same kinds of chemically identical crystal molecules do in the individual crystal<sup>5</sup>. In a related sense, Max Verworn (1903) interpreted these plasma molecules as the elementary factors of the processes of life and called them “*biogenes*”, but with the difference that he conceived of *biogenes* as “a group of chemical compounds” (Allgemeine Physiologie, Kap. 6). According to the micellar-hypothesis of Naegli (1884), these life units are not homogeneous plasma molecules, but are groups of molecules each composed of many kinds of molecules. He ascribes to these micelles a crystalline structure and assumes that they are bound in chains to the “micellar cords”, just as in the catenated coenobia the Schizophytes of the *cytodes* are arranged in chains. These chains can ramify further and can form numerous kinds of higher aggregates. The “ice flowers” on the frozen window panes, and the tree-like ramified crystal composites of dendrites, may serve as coarse models of this invisible micellar structure.

The theoretical essay of Naegli on “Forces and Morphogenesis in the realm of molecules”, a supplement to his Mechanical-Physiological Theory of Inheritance (1884), contains further physical and chemical discussions on his micellar hypothesis and related problems. His emphasis on the crystal structure of micelles is the more remarkable since

the “living crystals” of Lehmann (first fully described in 1904) were then still unknown. Recently this interpretation has won more validity, in that all morphological events are based upon crystallisation. Provided that the time and the opportunity are given to the molecules, they will order themselves regularly (following the *molethyn*). Only when these conditions are lacking (for example, in the formation of glasses, the over-rapid solidification of liquids) do amorphous masses result. For the understanding of these elementary ordering processes, it seems to me that the connection of *crystalloitics* with the *psychomatics*, expressed more concisely as “the crystal psyche” is of fundamental significance.

### **Schizophytes (Schizophyceae and Schizomycetaceae)**

(“Cleavage plants”). These, the lowest known organisms, are distinguished most fundamentally from other protists by two negative characteristics, by the absence of a cell nucleus and of sexual differentiation. The whole organism is, in the simplest case, a nucleus-less *plastid*, which grows by assimilation and multiplies by simple division. If the two equivalent division products (daughter *cytodes*) remain together, and multiply further, embedded in the same mass of jelly, then coenobia of the simplest kind result (*syntodia*). The two classes of these primitive bionts are to be distinguished in that, the older differently coloured Schizophyceae of “cleavage algae” (Chromaceae) are autotrophic and grow by the assimilation of carbon, while the younger, almost colourless Schizomycetes or “cleavage fungi” (Bacteria) are mostly allotrophic and nourish their plasma from other organisms. The former are really physiological plasma farmers (*plasmadomes*) and the latter plasma eaters (plasmaphages)<sup>6</sup>.

### **The nuclear question**

The contentious question, as to whether there are really “nuclear-less cells” is, in retrospect, in many ways of great significance in principle. It is a real “nuclear question” not only in the histological and cytological senses but also in the general biological and philosophical senses. An extensive literature has most recently developed around this question. Since especially the Schizophytes are cited as first line evidence to its solution, here only those writings can be quoted briefly, in which, according to my views, the lack of nuclei and the *cytode* nature, can be proved most decisively on the basis of the most recent observations. In 1904 there appeared simultaneously valuable works on “the cells of cyanophores” by Zacharias (Hamburg), Alfred Fischer (Marburg) and Jean Massart (Brussels). They contain more detailed establishment and illustration of the outlooks on the absence of cell nuclei, which earlier (since 1890) had been expressed by these botanists. Massart emphasises particularly energetically, in his prize-winning writing (on the protoplasma of the Schizophytes, 1900) the quite isolated position of the nucleus-less Schizophytes, which have no affinity whatever with any other class of organisms and which really exhibit only the first and simplest initial level of organisation.

### **Chroococcus (Chroococcaceae)**

As the simplest and lowest of all known organisms, one whose great significance so far has not been sufficiently appreciated, we ought to deal with the Chroococcus, a structureless homogeneous plasma sphere, which propagates itself by division and possesses no smaller levels of organisation. The family of the true Chroococci is still to be

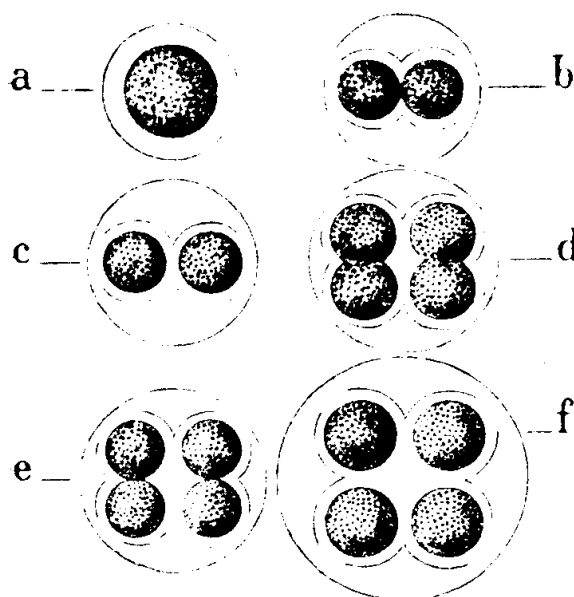


Fig. 23. *Chroococcus pallidus* in several stages of division. The basic form of the Chromacea (or Cyanophyceae), greatly magnified. The spherical cytodes contain no nuclei, but only a homogeneous, quite structure-less of finely dotted plasma; it is surrounded by a delicate structure-less gelatinous shell, (a) to (f) show repeated hemitomy.

found today widely distributed in fresh water and in the sea, on damp hills and on the bark of trees. In the most recent botanical textbooks they are introduced as the first family (or order) of Schizophytes. Their first exact description was given by Naegli nearly sixty years ago in his treatise on “Gattungeneinzelliger Algen” (1849). The genera *Chroococcus*, *Gloeocapsa* and *Alphanocapsa* will be characterised here as being related in that “their cells divide alternately in the three (mutually perpendicular) directions of space”. The most exact microscopic investigations of recent times have established that the homogeneous, green or orange coloured plasma bodies of this spherical *cytode*, often also containing chlorophyll, possess no kind of visible structure; a cell nucleus is completely absent. In most chromococci the plasma sphere is enclosed in a thin membrane. In many there is also a structure-less, often impressively thick gelatinous cover, as an excretion. But in others, as Naegli emphasised, “the extremely thin cell wall, almost a line, is to be remarked”. This beginning of “membration” is still not “organisation”; it must be treated more as a purely physical product of “surface tension”.

When one compares without bias the homogeneous *cytodes* of the *Chroococci* on one hand with the similarly formed spherical individuals of many *rheo-crystals* (for example of a simple myelin sphere) and on the other hand with the true nucleated cells of the simplest protophytes (Algalia), then they seem to be more nearly related to the former than to the latter. But one can also relate them to the chloroplasts of “chlorophyll grains” inside the true plant cells, which grow and multiply themselves by division<sup>7</sup>.

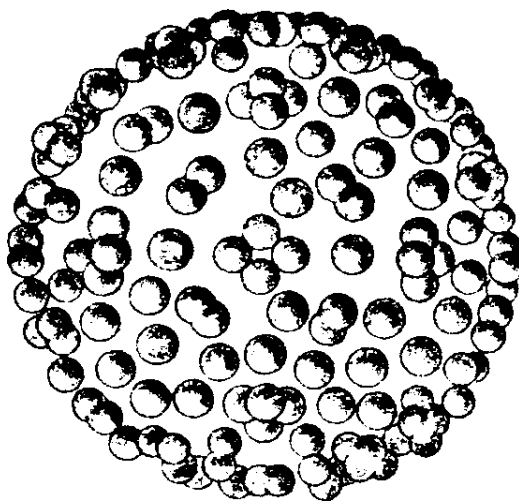


Fig. 24. *Coelosphaerium kützingianum*. A spherical cytode-union (coenobium) much magnified. In the soft gelatinous sphere numerous round cytodetes are embedded. They form a loose spherical sheet under the smooth surface and multiply by repeated division. The single cytodetes are structure-less bright green plasma spheres (like *Chroococcus*, Fig. 23) without nuclei.

**Chromacea (Phycochromacea or Cyanophyceae)<sup>8</sup> (“Systematische Phylogenie”, 1894, Vol. I, p. 101)**

While the simplest forms of Chromacea, the Chroococci, live as *monobionts*, as isolated round plasma grains, which after division, separate and grow separately, the *cytodetes* remain united, in the great majority of Cyanophyceae, unified in the common structureless gelatinous shells, and form, as in *coenobionts*, primitive “cell unions or cell families”—real *cytode* hordes (*syncytodia*). One of the simplest of this kind of coenobium is *Coelosphaerium*, a sphere of jelly, in the surface of which a layer of social plasma spheres is embedded, (as in the flagellate *Volvox*). By far the commonest form of these social unions is the catenal-coenobium, the *cytode* chain; as in the families of *Oscillatoria*, *Nostocaceae*, *Rivularia*, etc. universally distributed in fresh water. The essential spherical form of *cytodetes* passes over here into the form of a circular disc (a flattened cylinder). Since the halves produced by its division always continually divide in one direction, and the single discs lie one on another, like the separate coins in a roll of coins, long fibres thus result, which remain simple, sometimes branching and sometimes lying on each other in a bundle. In the *cytodetes* of this coenobium also, no cell nucleus is to be found, as the careful investigations of Hieronymus, Alfred Fischer, Otto Kirchner and others (1904) has recently established beyond doubt, and as I can confirm through observations on *Trichodesmium* and related *Oscillaria*<sup>9</sup>.

**Ecology of the chromacea**

These lowest probionts call in many ways for our special attention, not merely in morphological but also in physiological and ecological connections. Many kinds live

parasitically in the organs of plants, even inside single plant cells. Many live as symbionts deeply united with fungi (as plasmodome “gonads”) and thus build the special symbiotic forms of lichen. Other Chromacea are very much independent of outside influences and live under conditions of existence which no other organisms could sustain. Some kinds exist in hot thermal springs at temperatures of 70–75 deg. C. Many develop with rapidly repeated division of the *cytodes*, so massively that in a short time that a coherent slimy cover is formed on the surface of seas and lakes (“water bloom”). Thus in Spring a pond is often coloured bright green by *Oscillaria*. The Red Sea on the coast of Egypt and the Yellow Sea on the coast of China get their names from the astonishing mass development of fibre formed red or yellow coenobia, which belong to the *Trichodesmium* and *Xanthodesmium* of the genus *Oscillaria*. When I crossed the Equator on 10 March 1901 (on the journey back from Java to Ceylon), our steamer travelled for hours through a calm sea, which was covered with a thick red or orange layer of slime. After I had pulled a little of this red plankton on board and had isolated it in a glass vessel, it seemed to the naked eye in reflected light to be like finely chopped yellow straw or pieces of fluff heaped together. Under the microscope each piece of fluff showed itself to be composed of a felt of thickly woven, crossed fibre bundles, glued by jelly, and each fibre was a simple chain of disc-like *cytodes* like a roll of coins. For the red *Trichodesmium*<sup>10</sup> the fibres are stretched out and lie in each bundle parallel to each other. In the orange or straw-yellow *Xanthodesmium* the fibres are bent and are wound spirally round each other, like the fibres of a rope. Another closely related form of plankton is the “sun-like” *Heliotrichum*. Here uncountable straight fibres radiate from a common centre and form a golden star, like the *Actissa* (Fig. 25). While, however, in this Radiolarian each ray is a structureless and continuous plasma fibre, each ray in the *Heliotrichum* consists, on the other hand, of a simple chain of very small homogeneous *cytodes*.

### **Coccogonia and Hormogonia**

The physiological phenomena of the Chromacea are of the highest phylogenetic and philosophical interest as the oldest beginnings of organic life. Among these is the primitive mode of their asexual propagation. For the correct evaluation of these it is well to distinguish between the two orders of this class, the lower coccogonia and the higher hormogonia. The primitive coccogonia (*Chroococcus* and its relatives) are the simplest form of organic life conceivable, primitive *cytodes*, which permanently live independently or are united only in loose aggregates, gelatinous-type coenobia. They have no free movement and build no hormogonias. Their whole life activity is contracted to autotrophic growth, and if this exceeds a certain limit, the spherical *cytodes* divide through repeated halving into 2, 4, 8 etc. plastids. Among the *coenobionts* a structureless jelly is excreted which holds the generations together. These simplest coccogonia of all can be directly compared with the spherical *rheo-crystals* (myelin spheres).

The hormogonia, however, build mostly catenal-coenobia, thread-like chains or pearl necklaces, encompassing a larger number of more highly developed Chromacea. Through continual division into two, the *cytodes* in one direction develop cylindrically jointed threads which often lie in bundles on each other and which are surrounded with structureless gelatinous borders. Their propagation results from hormogonia or “nuclear threads”. The growing threads break up into pieces of thread, which have independent creeping or waving

motions, the origin of which is unknown. After a space of time these come to rest and sooner or later grow further. Further, the hormogonia implant themselves through “lasting cells” (or “spores”). These loosen themselves from the chains and shed a rigid shell. After a longer time they divide and build either hormogonia or young threads. Moreover, these so-called “lasting cells” or “spores” are not true nucleus-containing “cells”, but nucleus-less *cytodes*. To these belong the Oscillatoria, among which on one side there are the well-known Nostocacea, and on the other side come the Rivularia. For these more highly organised hormogonia differentiation appears (also further in connection with the finer *cytode* structure), which is still lacking for the older coccogonia.

### **Cyanophycin (Chromacea pigment)**

The conspicuous colour of the Chromacea of “Cyanophyceae”, from which this class of probionts takes their names, is caused by the deposition of pigment in the external plasma sheet of the *cytode*, which surrounds the colourless central nucleus. This dye, called Cyanophycin, belongs to the chemical group of the albumens or proteins and is closely related to chlorophyll; like this, the process of *plasmodomy* or “carbon assimilation” has the highest physiological significance. In the usual widely distributed Chromacea of fresh water, and also for most Chroococcacea, which live on damp stones, rocks, tree bark, etc., the pigment is blue-green or green, and thus the class has received the trivial names of “blue seaweed” or “blue-green algae” (Cyanophyceae). But besides the blue-green, blue or violet colours there are present also the most different other colours, in all shades of green to yellow, orange and violet. The remarkable Chromacea from the sea, mentioned earlier, which cover the surface of the open ocean in immense masses, are overwhelmingly yellow-, orange- or red-coloured (Trichodesmium) in the tropical zone and in the arctic zone red-brown or brown-black (Procytella). Since the colours of related Chromacea are often very different and can also change for one and the same kind according to the conditions, this colour is as little characteristic as is the green, toned down in many ways, of the foliage of the higher plants. Here in Autumn the changing green passes through all tones of the colour scale from yellow-green to orange, red and purple, but oppositely in the tropics, for the foliage of many trees their leaves begin with purple and then red and orange and finally become dark-green.

### **Thallus of the Cyanophyceae**

The trivial name “Cyanophyceae” for our *plasmodomic* probionts is also on other grounds erroneous and reprehensible. For the concept “phyceae” or “tangle” ought to be applied only to those true algae (in the stronger sense) which build a real thallus, the four classes of green algae (Chlorophyceae), moss algae (Charophyceae), brown algae (Phaeophyceae) and red algae (Rhodophyceae)<sup>11</sup>. For all these true algae, which belong to the kingdom of tissue-plants (metaphyta), exists the developed thallus or Lagerbau of differentiated tissues, which are built of numerous nucleus-containing cells; and which also possess sexual propagation. None of these characteristics are to be found for our Chromacea. They are nucleus-less *cytodes*, which multiply by division in the simplest asexual way, and have no tissue and no differentiated organs (in the morphological sense). Thus, the designations Schizophyceae and Phycochromacea should be discarded and the more suit-



able term Chromacea should be substituted. When their bodies are still often described as thallus and ascribed to the true thallus of the algae (or phycea), this lack of logic can only cause confusion; for a “single-cell thallus” is a “contradictio in adjecto”—also applied to a nucleus-less *cytode*, which is not a real “cell”.

### Chromatelles (Chromatophores)

The characteristic dyes of the Chromacea are, in the homogeneous plasma bodies of their *cytodes*, rarely diffused or are only bound to a thin wall-layer (lying inside the membrane). More often the Cyanophycin (just as the closely related chlorophyll) is mostly separated in a solid form from the plasma and builds special pigment grains; chromatelles or chromatophores<sup>12</sup>. As a result of the very exact investigations of these, made recently by Zacharias, Hieronymus and Alfred Fischer (loc. cit.), these “Chromatophores” have stimulated increased interest, both from a physiological point of view (as the “*plasmodome*” organelles for the assimilation of carbon) and on account of their morphological connections with crystals. In most Chromacea the Cyanophycin is first shed in the form of small spheres. When these spherocrystals become larger, the essential crystal form becomes a cube or a regular octahedron, the basic form in the cubic crystal system. For Tolypothrix and other hormogonia, Hieronymus found often in each *cytode* an impressively large crystal cube and near it a large number of spherulites of equal size (loc. cit. plate 18, figure 28). Often the former grew at the expense of the latter, which it “consumed”, as also happens in the growth of *sterro-crystals* and bio-crystals. The small *spherocrystals*, which are often distributed in very great numbers in the plasma of the *cytodes*, order themselves in numerous different ways. Often, with ordering into chains, they build long pearl necklaces, and these chains themselves build inside the plasma sphere many kinds of often symmetrical figures. The form of the single spherocrystal passes over, through uniaxial growth, from the sphere into the ellipsoid or cylinder, by flattening of the lens or disc. These shapes, which these rodlets take up inside the plasma sphere through, movement, bending or layer-formation, often remind one of the related forms and storage appearances of chromosomes during the division of the nuclei of the true nucleated cells. It is also possible that in a part of the Chromacea already there are transitions from the nucleus-less *cytodes* (= “ancestral cells”) to true cells (= “nucleus cells”) and that these rod-like chromatelles are precursors of chromosomes. Only a true morphologically independent nucleus is then lacking for the Chromacea as for the Bacteria and all true Monera. The colourless spherical “central core” at the centre of the plasma sphere is still not a real nucleus! What should it do here, where the whole life activity as “growth” occurs in the simplest form and all trace of sexual differentiation is lacking? Moreover it was also found by Alfred Fischer that in the simplest forms of the coccogonia the whole chromatophore is a thin-walled hollow sphere, which passes, without sharp boundaries, into the colourless “central core”. As is widely the case for all these simplest life processes, the “crystal psyche” of the chromatelles or the “cell psyches” of the plastids is involved. There remain wider *psychomatic* researches to be done. It should be noted, however, that for many Chromacea the polyhedral protein crystals are permeable to water and as *collo-crystals* can increase or decrease their volumes. In any case they arise essentially as *chromo-crystals* by crystallisation from the plasma.

**Bacteria (“Lebenswunder”, 1904, chapter 9, p. 227)**

The smallest and most simply built forms of life, which as Bacteria have recently become the leading area as a speciality of biological science, namely bacteriology, include in many connections the above mentioned Chromacea. In Bacteria also the living individual is, in the simplest case (*Micrococcus*), a homogeneous, spherical plasma grain of very limited size, without an inner core—a nucleus-less *cytode* and not a true nucleus-containing cell. Here also propagation takes place by simple division, without any sexual differentiation. If the two halves remain together and afterwards divide repeatedly, simple coenobia result through continual hemitomy. These result in the formation of chains (catenal-coenobia) if the divisions are in a straight line; tabular (tabular-coenobia) if they divide in a plane in two directions; packet-shaped, cubic (cubic coenobia) if this happens in three mutually perpendicular directions (*sarcina*).

**Bacterial forms**

In the newer, very comprehensive literature of bacteriology very numerous (over a thousand) kinds of these lowest organisms are described. Their distinction is mostly based on their ecological or *bionomic* relationships with other organisms, their significance as causes of fermentation, putrefaction, many diseases, etc. In contrast to this their morphological properties are the most simple, insofar as the external form partakes of the inner structure. At the same time, above all, the individuality of the solitary and the social Bacteria must be distinguished.

**Cytodes of Bacteria**

The fundamental forms of the individual, the so-called “Bacterial cell”, more correctly the nucleus-less *cytode*, are really of only two different shapes. The spherical Bacteria (*Coccacea* or sphero-Bacteria) have *cytodes* of the purely sphere shape (isoaxial, without different axes). For the rodlet Bacteria on the other hand (*Rhabdo-bacteria* or bacilli in the wider sense) the sphere goes over into the uniaxial form of the cylinder, with an emphasised main axis. This rodlet is either stretched out straight (eu-bacilli) or is bent into a sickle-shape or is helically extended (spirillae or spiro-Bacteria). The forms with weaker screw tendencies are distinguished as the vibrios, and others with many thicker screw turns as spirochaetes.

**Bacterial psyches**

The inner structure of the Bacteria has been subjected to the most careful study for a long time on account of their great importance as instigators of the most dangerous diseases (cholera, typhoid, tuberculosis, anthrax, etc.) as well as the causes of putrefaction and fermentation. Special attention has been paid to the investigation of the cell nucleus and other physiologically important organelles in the homogeneous plasma. The results of these basic researches, which have been carried out with all the most refined apparatus of modern microscopy and chemistry, remain wholly negative. From this the knowledge follows with certainty, what was long assumed by thoughtful bacteriologists, that the remarkable physiological and pathological significance of the Bacteria rests uniquely and alone on their chemical properties, on the complex composition of their homogeneous plasma from very numerous plastidules. Their physiological behaviour is only to be

explained further by the specific feelings which we must assume towards their spontaneous movements as attributes of Bacterial psyches. Since the thousands of types of Bacteria have, for aeons, produced the multiform illnesses of human beings, animals, plants and protists, they must in the course of hundreds of millions of years in adjustment of their family histories have developed correspondingly, and these phyletic metamorphoses can only exist in invisible chemical changes of their plastidule composition.

### Organelles of Bacteria

The homogeneous plasma core of the Bacterial *cytode* unites in itself the properties which, in the true nucleated cells are divided between the karyoplasma of the cell core and the cytoplasm of the cell body. It was thus in vain, that some researchers, wished to reckon the Bacterial plasma, on the basis of staining properties different from those of the nuclear substance, as being other than cell substance. It is best to designate this as *archiplasma* (or also as "*plasmon*"). As special organelles, which first developed secondarily from simple *cytodes*, are to be reckoned, among the higher Bacteria, the especially thin *cytode* shells and the flagellae, which serve many for locomotion. The external cythecium is usually only a very delicate membrane developed through surface tension, not composed of cellulose. In many Bacteria a structure-less gelatinous shell is shed on the outside. Among the social Bacteria numerous individuals, resulting from continual division, remain enclosed in a common mass of gel (*zoogloea*). The delicate flagellae which, sometimes singly and sometimes in groups, grow out of the *cytodes* of many Bacteria and permit them to swim, can be treated as organelles of the *cytode*. These recall, on one hand the movable continuations of many "vermiform" *rheo*-crystals, and on the other hand the flagellae of flagellates. The simplest forms of the latter include in other connections those Bacteria possessing flagellae, but distinguished by having true cell nuclei.

### Bacteria and Chromacea

The close relationships between these two classes—as well in morphological as in physiological aspects—are clear, but they are judged to be very different. The same goes for their phylogenetic relationships with other protists. Phylogenetically regarded, doubtless the Bacteria first appear by alteration of the metabolism (*metsitismus*) from the older Chromacea. The most essential difference between the two classes lies in metabolism. The older Chromacea are *plasmodome*; they possess the chemical facility of assimilating carbon and build themselves from inorganic substances, from water, carbon dioxide and ammonia, new carbohydrates and plasma; and thus they are to be judged as plants: *Phytomonera*<sup>13</sup>. The youngest Bacteria here are mostly plasmophages (with the exception of the interesting nitro-Bacteria). These manage without that capacity and must take their nourishment from other organisms; thus they must be seen as animals: *Zoomonera*. Thus Gottfried Ehrenberg 1838, in his great fundamental work: "Die Infusionstiere als vollkommene Organismen", excluded the Bacteria from the Infusoria. In a consequent recognition of that important, physiological-chemical contradiction, in my "Systematischen Phylogenie der Protisten" (1894) I also separated the Bacteria from the Protozoa and put them with the nucleus-less rhizopodia (*Lobomonera* and *Rhizomonera*) in the group of archezoa. This antagonism loses its schematic value if we treat the nitro-Bacteria as transitional forms between the two classes and also emphasise their common *cytode*

character. From this it seems expedient to unite the two classes as probionts and to contrast them with the other nucleated protists.

### Hemitomy

(= dividing into two or *dimidation*) = division of an individual body into two equal halves.

The simplest and most primitive form of propagation, occurring in the same way in the *rheo-crystals* as in the lowest organisms, is an event of significance in principle in many connections. *Hemitomy* is also, as all other kinds of *monogony* (or the “asexual propagation”) to be traced back to “excessive growth”. This “transgressive growth” is chiefly distinguished essentially in that both the new individuals resulting from the division of individuals are completely the same in size and properties; neither of the halves can be regarded as being older (parental) or newer (filial). Thus one cannot really speak of this as “heredity”. Neither of the two new individuals has taken on the role as the descendant of the halved unity but this has taken place by the formation of equivalent individuals of equal content. Thus it is also illogical to speak of the “immortality of the single cell”. Herein lies the essential difference between division into two and budding (gemmation), where a smaller (filial) part emerges from the greater (parental) part and must complete itself first by growth as a young *singulate* in order to reach the position of the parental part.

### Molethyn-action<sup>14</sup>

In the excellent treatment of the “conjunction of single cell algae” with which, in 1849, Karl Naegli laid the ground for our knowledge of these most interesting and lowest-level plants, he had already with special emphasis indicated the various phenomena of division, which is the single kind of propagation shown in this lowest “nucleus-less” cell. This distinction now wins for us a quite different significance, where we can compare the probionts with the crystals. For the *molethyn*—“the molecular directing forces”—which determine the parallel ordering of the molecules endowed with psyches and fix their physical “anisotropy”, are just as active in the repeated division of the *cytodes* of probionts as in Chromacea as Bacteria. The same molecular tropisms<sup>15</sup> or molecular ordering laws, which govern the division here and also in many single cell protists, and are determined solely by the *psychomatic* activity of the individual plastids, they turn about in the cell division in the tissue of *histone*, here with the essential difference that they are dependent on the complex law of the conservation and progressive inheritance of the socially connected tissue cells.

When we compare in this connection, the psychomatic action of the *molethyn* in the three directions of space during the *hemitomy* of the probionts, with the same during crystallisation (in the *sterro-crystals* and in the *rheo-crystals*), then we can distinguish four outstanding main forms:

I. *Polythyn hemitomy*: Division of the plastids in all directions of space; coenobia are amorphous or spherical. The same divisibility in all directions, recurs in the growth of many tissues.

II. *Cubothyn hemitomy*: Division of the plastids in the three mutually perpendicular directions of space; along the “three coordinate axes”; the coenobia are round or cubic. This form of division is repeated in the multiplication of many protists by equal cleavage; it recurs in the growth on many “parenchyma cells” of the *histones*.

III. *Plakothyn hemitomy*: Division of the plastids in a plane, in two mutually perpendicular directions on space. The coenobia are tabular, often quadratic or polygonal plates. The same form is repeated in the flat “germ discs” (Keimscheibe) of many metazoa with discoidal egg-division, as also in the growth of single-sheet epithelia.

IV. *Hormothyn hemitomy*: Division of the plastids repeated in a single direction of space (chain-building or catenation); the coenobia are catenal (in the form of chains or pearl necklaces, catenes or *hormae*). This form of social catenation, typical for the fibrous probionts and thread-algae (confervals (???)) recurs in the most diverse forms of the “hairs” of plants and animals, as well as in many fibres and tissues.

### **Erotics (sexuality)**

The most important physiological characteristic of the probionts is the lack of sexual differentiation and *amphigony*. This negative feature stands in direct causal relationship with their most important morphological character, the absence of the cell nucleus. All true probionts are *monogonic*, completely sexless; they lack Eros, the “loves” of the two different sexes, the meaningful contrast of male and female principles. When one considers what an infinitely important role in the life of organisms *amphigony*, sexual differentiation with all its erotic consequences, plays, then one must recognise that the probionts in this connection stand nearer to crystals than to organisms. This consideration takes an especially great weight if we hold the psychomatic meaning of Eros clearly in view—the deep correlation between the soul-life and the sexual life of the animals and plants. Among the higher animals, particularly the families of vertebrates and articulates, just as for human beings, the “marriage”, the actual commencement of sexual activity, is the “high time”<sup>16</sup> of the individual life. This high point of existence, the highest pleasure, has not only the greatest physiological meaning, because through it alone the preservation of species in the succession of generations is made possible; but also it is the source of multiform psychological and morphological differentiations, especially the entangled formation of “secondary sexual characteristics” of family life (upbringing of offspring). Quite related to the higher animals (Metazoa) in this way are the higher plants (metaphytes) and we should with confidence assume that also for these this culminating point of individual existence—the “blooming” of life—is connected with the highest pleasure. When in flowers the long pollen tube must find its way through the canal of the pistil to reach the semen bud, when in the same way the in ferns and mosses the motile sperm cell of the anthers must penetrate the narrow neck of the *archegonia* in order to reach the egg cell there, so this physiological event of fertilisation is also a consequence of erotic chemotropism<sup>17</sup>, the specific sexual mind activity. The origin of this sexual differentiation becomes quite clear to us through the comparison of the higher and the lower plants. For in the case of many single-cell protophytes and also for the lowest algae, there is still today isogamy, the copulation of two germ-cells (gametes) of the same kind; only when these separate, when the larger macrospores become egg-cells, the mobile smaller microspores sperm-cells, does real sexuality result.

### **Probiotics and geology**

The critical unbiassed comparison of the probionts, on one side with the *rheo-crystals*, and on the other side with the single-celled lowest protists, has led us to the conviction,

that these nucleus-less *cytodes*—as really “organisms without organisation”—represent a complete bridge between the two kingdoms of inorganic and organic Nature. This connecting mid-point between the lifeless inorganic and the life-endowed organisms is valid not only in morphological and physiological, in chemical and physical relations, but also in historical respects. Accordingly, the modern geology in the life-history of our planet can be divided into the following four periods:

I. The inorganic history of the Earth, from the *singulation* of the planets (by detachment from the Sun) up to the emergence of liquid water and later of the more complex carbon compounds.

II. The probiontic history of the Earth: the formation of plasma, the first “living substance”, through the catalysis of colloidal carbon compounds; and *singulation* through the building of *cytodes* (without nuclei and without sex); propagation by simple division.

III. The protistic history of the Earth; the emergence of the oldest cells (nucleated plastids) by separation of the primary plasma into external cell body (cytoplasm) and inner cell core (karyoplasma). The older plasmodome protophytes, which emerged as for the younger plasmophage Protozoa—from the latter through metasitism (circulation of matter)—lived initially isolated, built later cell colonies (coenobia). Multiplication through division as well as through isogamy (copulation of two equal cells: gametes). In that an opposition between the two copulating gametes developed, they transformed themselves (through sexual division of labour), the greater macrospores into egg-cells and the smaller microspores into the sperm cells. With this sexual antagonism there developed the important psychomatic property of “love”, the most powerful compulsion to higher mental (soul) development.

IV. The *histic* history of the Earth; the formation of tissues through the close amalgamation of cell communities (coenobia) and the differentiation of the growing cells. Two different kingdoms of fabrics (*histones*) developed diverging on one side to the *plasmodome* tissue plants (metaphytes) and on the other side to the plasmophage tissue-animals (metazoa). In both kingdoms the progress of erotics took a similar course—and with it the higher building of the *psychomatic*.

## Notes

1. Haeckel's book of 1904.
2. *Haeckel's note: Monera.* I gave an intensive exposition of this and other nucleus-less rhizopods in 1870 in my "Studien über Moneren und andere Protisten". At that time we did not have the important stains with which the cell nuclei could be most easily distinguished from the enclosing cytoplasmic bodies. Only twenty years later was the existence of a true cell nucleus in many cells hitherto regarded as without nuclei and its great significance for the processes of cell division (caryokinesis) realised by means of refined new staining methods. Now it has been shown that indeed a cell nucleus exists in many of the protists earlier described by me as without nuclei. This is not the case for all those lower protists which I had earlier distinguished as "zoö-monera" in my "Systematic phylogeny of the protists" (1894, pp. 138, 144). Recent reliable observers have also since looked in vain for a nucleus in many non-nucleated rhizopods, even with the help of the most subtle nuclear stains. For the considerable, *Pelomyxa pallida* of Gruber, living in the Mediterranean (close to my *protogenes*), numerous exceptionally small, powder-like particles have been detected as chromatids or nuclear particles in the structure-less and formless plasma bodies. This interpretation has not, however, been established sufficiently firmly.
3. Indeed it does! Haeckel has grossly under-estimated the complexity which the cell plasma is now found to have. From "Nature", 20 Nov. 1997, we learn that the genome of *Bacillus subtilis* comprises 4100 protein-coding genes with 4,214,810 base pairs and all the consequent structural complexity.
4. *Haeckel's note:* See my "Beiträge zur Plastiden-Theorie", 1870. Janaische Zeitschrift für Naturwiss., Bd. V, S. 492.
5. *Haeckel's note:* In my treatise on the "Perigenesis of Plastidules" (1875) I have clearly distinguished my outlook on the nature of these smallest particles of life and the important role which they play as carriers of heredity in propagation. See my "Gesammelten Vorträge über Entwicklungslehre", 2nd. Ed., Vol. II, (Bonn, 1902).
6. *Haeckel's note:* Hitherto the schizophytes have been mostly included with the algae in the textbooks, while the schizomycetes are put with the mushrooms. Only very recently have the systematic botanists decided to abandon this unnatural ordering and to give the two classes of schizophytes their deserved independent position, as unique most primitive organisms, on the lowest level of the plant kingdom. See the new "Handbuch der Systematischen Botanik" by Wettstein (1910), the "Lehrbuch der Botanik" by Strasburger (1915) and the "Syllabus der Pflanzenfamilien" by Engler (1909).
7. *Haeckel's note:* These and other important connections of the Chromacea have been suitably reviewed in the ninth chapter of the "Lebenswunder".
8. *Haeckel's note:* Cyanophyceae. The most important of our works on the structure of chromacea are: Zacharias, 1904 (and earlier 1900 and 1890); Jahrbuch der Hamburger Wissenschaftlichen Anstalten, Bd. XXI.—Hieronymus, 1892 (in Cohns "Beiträgen zur Biologie der Pflanzen", 1902, Breslau, S. 461. Taf. 17, 18, with exceptional illustrations).—Alfred Fischer, "Die Zelle der Cyanophyceen", 1905, in Botanische Zeitung, Heft 4 bis 6, Taf. 4, 5.—Jean Massart, "Sur la protoplasme der Schizophytes", 1900, Bruxelles (Gekrönte Preisschrift der belgischen Akademie). Many good pictures of schizophytes and of bacteria with detailed systematic and ecological description (by Kirchner and Migula) are to be found in: Engler, "Die natürlichen Pflanzenfamilien", I. Teil: Schizophyta. Leipzig, 1900.
9. *Haeckel's note:* Just in these Chromacea the defenders of the "cell dogma" have taken all pains, through chemical and physical experiments, and through observations with the most powerful microscopes, to prove the existence of a true cell nucleus in the homogeneous plasma bodies of the *cytodes*, but in vain. In these, as also in other recent cytological experiments, it is to be concluded that, by the deeply operating chemical and mechanical operations in the simple structure of the plastids, artificial changes were produced and structural properties were generated, which do not exist in the living bodies of the plastids.
10. *Haeckel's note:* Trichodesmium. See my "Malayischen Reisebriefe: aus Insulinde" (Leipzig, 1901, p. 246).
11. *Haeckel's note:* "Systematische Phylogenie der Pflanzen" (Berlin, 1894); Thallus, S. 295, System der Algen S. 302, Stammbaum S. 303.
12. *Haeckel's note:* Chromatellen. "Systematische Phylogenie der Pflanzen". 1894. S. 298. The concept "chromatophore" is, in zoology, long naturalised for the independent pigment cells; only much later has it been applied by botanists for the designation of single cell parts.
13. *Haeckel's note:* "Systematische Phylogenie der Protisten" (Berlin, 1894), pp. 93–97. Protophytes; pp. 133–

- 137, Protozoa—Archephyta, p. 98, Archezoa p. 137.
14. “Molethynen”—inter-molecular orienting forces.
  15. We expand Haeckel’s coinage: *moletropism*.
  16. In German “wedding” is Hochzeit-high time.
  17. *Haeckel’s note*: For erotic chemotropism and sexual elective affinity see my “Anthropogenie” (Evolutionary history of mankind) 1874; 6th. Ed., 1910, 29. Lecture, p. 875.