R.S.

NOTICE.

The Council of the Ray Society regret that the illness of their artist, Mr. Wing, and other circumstances, have prevented the publication of the last part of Messrs. Alder and Hancock's work on the Nudibranchiate Mollusca, and the second volume of Mr. Darwin's work on the Cirripedes. These, with the last volume of the Bibliography, are now in the press, and will shortly be issued together.

The volume now sent, 'Botanical and Physiological Memoirs,' is part of the issue for 1853.

22, Burlington Street;
April 12th, 1854.

THE

RAY SOCIETY.

INSTITUTED MDCCCXLIV.

LONDON.

MDCCCLIII.

BOTANICAL AND PHYSIOLOGICAL MEMOIRS,

CONSISTING OF

I.—THE PHENOMENON OF REJUVENESCENCE IN NATURE,

ESPECIALLY IN

THE LIFE AND DEVELOPMENT OF PLANTS.

BY DR. A. BRAUN.

TRANSLATED BY A. HENFREY, F.R.S., ETC.

II.—ON THE ANIMAL NATURE OF THE DIATOMEÆ,

WITH AN

ORGANOGRAPHICAL REVISION OF THE GENERA

ESTABLISHED BY KÜTZING.

BY PROFESSOR G. MENEGHINI.

TRANSLATED BY CHRISTOPHER JOHNSON, M.R.C.S.E.

III.—AN ABSTRACT OF THE NATURAL HISTORY OF PROTOCOCCUS PLUVIALIS.

BY DR. FERDINAND COHN.

BY GEORGE BUSK, F.R.S., ETC.

EDITED BY

ARTHUR HENFREY, F.R.S., F.L.S.

LONDON:

PRINTED FOR THE RAY SOCIETY.

MDCCCLIII.

J. E. ADLARD, PRINTER, BARTHOLOMEW CLOSE.

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REFLECTIONS

ON

THE PHENOMENON

OF

REJUVENESCENCE IN NATURE,

ESPECIALLY IN

THE LIFE AND DEVELOPMENT OF PLANTS.

By Dr. ALEXANDER BRAUN,

PROFESSOR OF BOTANY IN THE UNIVERSITY OF BERLIN,
&c. &c.

(Leipsic, 1851.)

TRANSLATED BY

ARTHUR HENFREY, F.R.S., F.L.S., etc.

TO THE READER.

The present Treatise 'On the Phenomenon of Rejuvenescence in Nature, especially in the Life and Development of Plants,' was issued to a small circle in May of last year, from the High School of Freiburg, in the Breisgau, to which the Author at that time belonged, and for which it was especially composed, as a Prorectorate Address; its publication to wider circles of the Scientific world has been delayed by many circumstances, partly connected with the change of residence of the Author, through his call to the High School of Giessen; partly in consequence of the events which afflicted the country with dissensions, and obstructed the calm progress of scientific undertakings. Nevertheless, the Author hopes that the substance of the Essay, which contains an attempt to combine the special branches of Botanical research more intimately together and with the entire body of Science, by means of certain connecting ideas, and to grasp and trace out the old questions under a new point of view, has not meanwhile grown out of date, so that he may venture to comply with friendly requisitions from many quarters, and deliver over his little work to more general diffusion. May the reader receive it kindly, as a little nail in the great structure which Natural Science has to erect, to which each labourer seeks to add his contribution in his own way, and to work for which, with voice and pen, is the endeavour, the life, and the happiness of the Naturalist

THE AUTHOR.

GIESSEN; *February*, 1851.

Since the original of this work was published, the Author has been chosen to succeed the late Professor Link in the University of Berlin; and now occupies a position commensurate with his numerous and elaborate contributions to Science. Modestly as he speaks of this remarkable work, the Translator has no hesitation in designating it one of the most important of modern contributions to the Philosophy of Botany. Without entering into the discussion of the curious speculations indicated in the title, attention is especially to be called to the lucid exposition of the Morphology of Plants, and to the definite establishment and full illustration of the laws of this branch of botanical science; to the section upon Cell-formation, again, which constitutes a body of fact and theory of the utmost importance to Physiology, Animal as well as Vegetable, since, bringing together and completing the various recent publications on the subject of cell-development, it clearly demonstrates the necessity of reforming the older views of the character of cellular structures, and, in showing the incontestible evidence now existing as to the essentially primary nature of the cell-contents or protoplasmic structures, at once levels the new field of investigation in Plants, and affords a basis for the clearing up of the analogies existing between the Animal and Vegetable tissues.

The Translator has confined himself to a careful rendering of the text and a slight amplification of the references, especially in cases where English translations exist of the works quoted. To have revised, in accordance with the present condition of knowledge, certain of the speculations which are now a little out of date, would have been interfering too far with the Author; but the sources are indicated whence the more recent facts may be obtained.

A. H.

LONDON; *September*, 1853.

SUMMARY OF THE CONTENTS.

ADDENDUM. At page 9, line 5, insert after

" *Rheum* with 6, outer, shorter, and 3 inner, longer ;" " in *Polygonum* with 5, outer, shorter, and 3 inner, longer."

PREFACE.

THE idea carried out in the following treatise, namely, of grouping together the phenomena of the graduated organisation of plants, and those of their reproduction, under a common point of view, as processes of Rejuvenescence, and of subjecting them to a minute examination under this point of view, was awakened in my mind several years ago, through an investigation of *Hydrodictyon*, and aroused anew at the end of that autumn of 1848 through the discovery of the mode of reproduction of *Pediastrum*, a genus of most elegant little Algæ, which are still included by many authors in the Animal Kingdom. At the Annual meeting of our local Association for the advancement of the Natural Sciences, on the 4th of December of the same year, I endeavoured, in a public lecture, *apropos* to the description of the course of formation and reproduction of the genus of Algæ just named, to develope this idea, and to show that it is the power of Rejuvenescence which principally distinguishes organic from inorganic existence, since it is to this that we must ascribe, both the graduated progression of the development of the individual organism, and the repetition of individuals by reproduction. When in the spring of last year, the confidence of my colleagues, and the grace of his Royal

Highness the Grand-Duke, the most serene Rector of our High School, conferred the Prorectorate upon me, I determined to make this subject, which appeared both capable of a profound treatment and of general interest, the basis of the Introductory Programme which, in accordance with the good old custom, the Prorector delivers in honour of the birthday of the exalted Patron and Rector of the High School, our beloved native Prince. The main thoughts were soon arranged, and the outlines traced; the illustrative examples added to the text were to be worked out during the printing of the essay, and the natural history of some of the genera of Algæ more particularly remarkable in reference to the subject, (*Pediastrum*, *Characium*, *Hydrodictyon*, *Ascidium*, *Sciadium*, *Palmoglæa*, &c.) was to be given in an appendix. But the storm of the revolution, which broke out in May, and shook our blessed fatherland to the very foundations of its existence, soon interrupted the incipient labours; for our High School was threatened by the tempestuous waves, and it was at the cost of care and severe effort alone, that the threads of scientific activity were protected from total disruption in the midst of the session. But, in the ever-memorable days of July, when the fermenting elements of social dissolution, which we at length saw gathered within our walls, had vanished before the helpful Brother-hand, strong in the spirit of order, like the shades of night before the sun's light; when in the following month our beloved ruler was enabled to return to his blinded people, who, ungrateful for his beneficence, had risen in opposition to him; the season was too far advanced, for the projected discourse to be properly carried out in time, on the basis which had been previously laid down. Consequently, to avoid offering anything hasty and unworthy of the High School, and yet to avoid withdrawing this essay from the destination to which it had been as a labour of love devoted, there remained nothing else, but to make it follow the invitation to the celebration of the Royal birthday, as a subsequent secondary tribute. The reasons why it has been delayed until now, lie partly in the manifold retardations through current official duties, and partly in the nature of the subject itself, which claimed more time and space in the elaboration of the details, than could be guessed in the original project. For, in the publication of phenomena as yet little known, the examples cited could not well be mentioned without an exact account of personal observations, which rendered necessary repeated diffusive episodes, in which both the votaries of the Morphology and Anatomy of Plants, and Physiologists in particular, will find many novelties. Where I have depended on the observations of others, the sources are conscientiously mentioned; I connected with this point also the design, to point out to the young who are just entering the realms of Science, who, moreover, were especially kept in view throughout the whole exposition of the chosen subject, the authors who deserve confidence, and from whose writings may be discerned, not only the present state of Scientific Botany, but the problems growing out of this, which will next require to be solved. I had greatly desired to be able to add numerous illustrative plates to this treatise, but I have omitted doing so, in order to avoid further delaying its publication. For the same reason I am obliged to give up, for the present, the appendix which formed part of the original plan, and which is referred to more than once in the text; a separate treatment of this will the sooner enable me to publish, with a certain degree of completeness, my observations on the natural history of various fresh-water Algæ, in particular on many genera belonging to the debateable region between the Vegetable and Animal Kingdoms, as well as those that produce active gonidia.

After these remarks, which may explain the delay in the appearance of these pages, I feel compelled to add a word of justification in reference to the direction of the researches which form the basis of the following observations, and which will doubtless be regarded in many quarters as antiquated, and leading away from the strict scientific path. A vivid conception of Nature, such as is here attempted, which tries to find in natural objects, the expression of living action, and not merely the effects of dead forces, does not lead, as some think, to baseless air-castles, for it does not set itself to study the life of nature, in any other way than in its revelation through phenomena; and just as little does it exclude rigid investigation of the laws, governing all natural phenomena; for it is exactly by the investigation of the laws within which, and the forces through which life acts, that it hopes to arrive at a perception of what is given to life, according to the difference of its stages. The justification of the effort to comprehend all the phenomena of nature, not only in their external reactions, but also in their inner connection, as the data for an universal history of living nature, lies in the very nature of the human soul, in its connection, not merely external but inward and essential, with living nature. As the study of nature originally arose from the feeling of the intimate relationship between external nature and human nature, it is also its aim to grasp and bring to perception, the furthest depths of this connection.

Partly during the printing of these pages, partly after its conclusion, I met with various literary novelties, of which I could have wished to have availed myself in passages on which they bore, in particular, Mettenius's '*Beiträge zur Botanik*' (Heidelberg, 1850), in which occurs an exact description of the discovery of spermatozoids in *Isoëtes*, mentioned cursorily at page 144 from information derived from a letter from the author.* Gærtner's important work, on the Production of hybrids in the Vegetable Kingdom, (*Die Bastardzeugung im Pflanzenreich*, Stuttgart, 1849), first reached me after my observations on *Cytisus Adami*, p. 316, were printed. There is no absolute decision there even, whether this remarkable intermediate species is a hybrid, produced by fertilisation from *Cyt. Laburnum*, and *C. purpureus*, or not; on the other hand various notices on the same subject had been published, which I had overlooked, especially the information of Schnittspahn's paper, in the third Year's publication of the Horticultural Society of the Grand-duchy of Hesse, (*Mitth. des Gartenvereins im Grossherz. Hess.*, Darmstadt, 1842, p. 38,) that Adam obtained his plant, by budding *C. purpureus* upon *C. alpinus*.† During the first year the grafted buds remained undeveloped, but many inequalities of the surface displayed themselves around

* These points are further referred to in editorial notes.—A. H.

† This probably means *C. alpinus*, Lamk., the same as *C. Laburnum*, L., and not *C. alpinus*, Mill., for the *C. Adami* of gardens returns on all hands into *C. Laburnum*, L., and not into *C. alpinus*, Mill.

them, which were gradually developed into buds, and these were developed in the second year into shoots, all but one of which, were *C. purpureus.* This one shoot had grown much thicker, and exhibited a form intermediate between *C. alpinus* and *C. purpureus;* this shoot was the parent of the *C. Adami* of gardens. Unfortunately, this report does not state from what source H. Schnittspahn himself derived his knowledge of these circumstances attending the origin of *C. Adami.* Since *C. Adami* possesses undoubtedly the nature of a hybrid, if Schnittspahn's information be correct, this plant will furnish the extraordinary case of a hybridation in a vegetative way, (conceivable as occurring through a fertilising action of the cells of the graft upon the primitive cell of an adventitious bud,) and its return into the two parent species, within the vegetative region, would then correspond to the vegetative origin. That hybridation is not in any way unusual in the genus *Cytisus,* is proved by a magnificent hybrid, between *C. purpureus* and *C. elongatus,* which is now, while I write these lines, in most beautiful blossom in the Botanical garden of our High School. It was obtained from the brothers Baumann of Bollwiller, in whose catalogue for 1847, it is given as "*C. purpureo-elongatus* (nobis), une nouvelle hybride superbe." In form and hairiness of the leaves it resembles *C. elongatus;* in the form of the calyx, more *C. purpureus.* The colour of the flowers is a mixture of light-yellow and pale rose-red, the standard being of the latter colour, the wings and keel of the former; when withered or dry, the red colour becomes stronger and almost like that of *Cytisus Adami.* The blossoms keep fresh a long time, but set no fruit. Messrs. Baumann were kind enough to furnish me, by letter, with the following particulars concerning the origin of this fine hybrid. "Our *C. purpureo-elongatus* was produced from our own sowing, but not by means of artificial fertilisation; the mother of this plant is *C. elongatus*, from which we gathered the seeds; but near this stood a *C. purpureus*, and probably the hybrid was produced by insects conveying the pollen from the latter plant to the former. We have never observed in this plant such a change of form as occurs in *C. Adami*." After all this, we look with so much the greater impatience for positive elucidation, based on repeated experiments, of the mode of origin of *C. Adami*, and in this for the establishment of several most important physiological facts. In regard to the return of *Cytisus Laburnum quercifolius*, into the common Laburnum with entire leaflets, mentioned at p. 315, I shall only mention here, in addition, that I have observed the same phenomenon lately in the Botanic garden of this town, and here the transition to the parent species took place by a marked separation from the variety and not through graduated intermediate stages.

Since this Preface is at the same time a Postscript, and as regards the first part of the Treatise a tolerably late one, it affords an opportunity of adding a few more complementary observations on the subjects touched upon in the text. In the first place, in regard to the mode of growth of the Vine, described at p. 46, I must report that the examination of fresh seedlings obtained last autumn, after that passage had been printed, did not confirm the conjecture expressed in the note, that the seedlings would behave like root-suckers; for they were totally devoid of tendrils at the summit, and displayed in the axils of the ordinary leaves, resting buds, which had *two* bud-scales, and therefore resembled, in this respect, not the "*Geitzen*," but the "*Lotten*." The derivation of the "*Lotten*" from the "*Geitzen*" in the way described, does not occur until the later degrees of ramification.

To the examples mentioned in the note, p. 114 of Fern leaves, with the apex of the leaf constantly undeveloped, or only unrolled after long interspaces and in steps, belongs also the genus *Neurolepis*, the larger species of which, related to *N. exaltata*, develope their slender pinnate leaves, which often attain a length of 4 or 5 feet, in several annual stages or lengths, which are marked in the developed leaf as contracted places, furnished with shorter pinnæ. In *N. neglecta*, Künze., the commonest species of our gardens, I found four such sections, of which, however, two often appear to be developed in one year. With this mode of development is connected the fact that the leaves of the species of *Neurolepis* ordinarily exhibit a little rolled-up knob at the end, and only rarely their proper leaf-point, running out into a terminal pinna.

I have to give a short postscript to the natural history of the Chlamidomonada, relating to the "resting stage" of *Chlamidomonas tingens* (p. 215). The said species appeared in great abundance this spring in little rain pools, close to the town, colouring the water bright green. When the "rest" commenced, the cells collected together in pulverulent, partly floating masses, exhibited a globular form, a diameter of from $\frac{1}{150}$ to $\frac{1}{75}$ of a millim., granular-punctate, green contents, and one larger vesicle. When the pools dried up in the month of May, crust-like, pale brick-red coats were found on the ground, the cells, formerly green, having assumed a pale reddish colour, the vesicle at the same time becoming indistinct, while the remainder of the contents became coarsely granulated, (through the formation of oil?). The plants have remained in this state ever since, not altering even when the pools were refilled by rain. The resting, but still green condition, seemed to me to correspond to *Protococcus Felisii*, Kütz., that which had turned red through desiccation, to *Pr. Orsinii*, Kütz., at least, according to the specimens sent to me by De Brébisson as a small variety of that species.

Herewith, I deliver these pages to the Fathers of our High School, my honoured colleagues, with the petition for a friendly reception, as a memorial of the efforts and expansions in Science and in Life, we have shared in an eventful year; I deliver it to the Academic Youth, in the hope that they may find therein the threads which connect the separate fragments of knowledge into a whole, and that the perception of this connection may encourage them to follow, with double zeal, undistracted, through good and evil times, the study of the material so abundant in all branches of science, and thus to enter more and more into the sacred workshops, in which are hewn the stones for building the great Dome of human knowledge. To the wider scientific public, lastly, I deliver these pages, with the consciousness of having therein published many results of conscientious research which will find their place in the building of Science, even if the connection in which I have here sought to place them, should shape itself very differently in a future, higher stage of development of Natural History

DR. A. BRAUN.

FREIBURG, BRIESGAU; *May*, 1850.

CONSIDERATIONS

ON THE

PHENOMENON

OF

REJUVENESCENCE IN NATURE,

ESPECIALLY IN

THE LIFE AND DEVELOPMENT OF PLANTS.

SCIENTIFIC investigation of the laws of Organic Nature advances, in our times, in two distinct directions, one of which may be called the *physiological*, the other the *morphological*. Each, followed in a one-sided manner, has led to multiplied contradiction in theory, which can only be solved by a more profound biological method of contemplation. Both directions hasten towards a profounder comprehension of this kind; the former in a negative manner, since, considering vital phenomena only in their external physical conditions, it is led, at the conclusion of every investigation, to a ground of the phenomenon inexplicable on this side; the latter in the positive way, since, regarding the forms, in connexion with the history of development, as becoming, changing and passing away, it must recognise a specific and individual vital unity, running through all the changes of form, unless the temporary products of development are to dissolve away into inessential appearance, and to lose all internal connexion. The investigation of development, in the smallest as in the largest circle, is, therefore, the most profitable and most promising field of action in natural history; and the remarks offered here belong to this field, for they discuss a general question which is not foreign to any special history of development.

Among the most essential and general characters of every course of development of a natural object, are *commencement* and *term*, and, connected with these, *youth* and *age*. Youth and Age, although falling within the sphere of ordinary human direct experience of life, do not appear to me, in reality, so easily or simply comprehensible in their true meaning and their contrasted relations, as might seem from a mere abstract consideration. Answers to the questions, so readily presenting themselves—How are youth and age distinguished? When does youth cease, and age begin? How do they pass into one another? Which is the more perfect condition of life? —would penetrate deeply into the interconnection existing among the totality of cosmical ideas. The purpose of the present Essay only extends to a few reflections, based on experience, on the changing relation of youth and age in the course of the life-time of the individual.

Youth and age are not mere periods of time, into which life may be divided so as to allow us to say,—Youth, ceases here and Age begins; and one does not pass gradually and continuously into the other, so that youth decreases in the same ratio as age increases; a glance into life rather demonstrates to us that the phenomena of youth go through life side by side with those of age, in the most varied conditions of exchange, not merely presenting themselves simultaneously in various departments of life, but crowding into the same region, and contending there. Even the child has *old* teeth, destined to early destruction (the milk-teeth), and *young* teeth (wisdom teeth) appear even at a late age. Many organs have already become old and lost their vitality before birth, such as the gills of the Mammalia, the teeth of the whale,* &c.; lizards and snakes form a young skin

* See Stannius, 'Lehrb. der Vergleich. Anatomie,' p. 411, on the teeth

annually, throwing off the old one; the crab changes even his old stomach for a young one, every year. The cotyledons, and even the radical leaves, as they are termed, have already yielded to age in the *Œnothera*, the rape, and many other plants, at a time when the flowers still remain in a young condition of buds, and, on the other hand, the floral envelopes have perished when the fruit is only in the commencement of its process of maturation. In the pupa of the grasshopper, all the external organs are fully developed, at a time when the wings are just beginning to be formed. So may Man be a mere child in mental development, when already old in bodily respects. We see youth and age, therefore, presenting themselves alternately in one and the same course of development; we see youth break forth in age, and enter into the midst of the process, for the purpose of completing or metamorphosing the structures. This is the phenomenon of *Rejuvenescence* (Verjüngung), which is repeated in infinitely varied ways in all domains of life, but nowhere asserted more distinctly and more accessibly to investigation, than in the Vegetable kingdom. Without Rejuvenescence there can be no progressive development; only the lifeless creation, or rather, that dying in the moment of production, the mineral, is devoid of the power of Rejuvenescence; whence it is also deprived of development and propagation.

Rejuvenescence appears, in the first place, as a return to an earlier condition of life, whereby is obtained a point of departure for renewed progress; or, in the extreme case, as a retrogression to the commencement of the entire course of development, to attain the aim in a repetition of the development. The former we see in the Rejuvenescences of the individual within the course of its individual development, the latter in the Rejuvenescence of the species through the succession of individuals. The retrogression just mentioned, introducing the Rejuve-

in the fœtus of the whale. According to Eschericht the fœtus of *Balænoptera longimana* has 102 teeth in the upper, and 84 in the lower jaw.

nescence, is either morphological, the structure returning actually from a higher stage into a lower formation; as we see, for example, in annual Rejuvenescence of many herbaceous perennials (*plantæ redivivæ*), as also in most woody plants, in the buds, which commence the rejuvenised course of life with leaves of the lowest stage of formation, the bud-scales belonging to the "cataphyllary" (*nieder-blatt*) formation;* or the retrogression is merely physiological, a chemical decomposition and dissolution in the structure already existent, whereby this becomes capable of a Rejuvenescence of its form, combined with a more or less distinct metamorphosis. Such it is in the interchange of materials in animals, with which are connected their more gradual and imperceptible, as well as the more sudden and surprising transformations. That the like is not wanting in plants, will be demonstrated in the succeeding examination of the phenomena of Rejuvenescence in Cell-life.

We have consequently to distinguish a descending and an ascending direction in the Rejuvenescence, one retrogressive, the other advancing with new impetus, one undoing the old and existent, the other shaping out the new. Both directions are necessarily related to that renewal of the vital movement to which we have applied the term "Rejuvenescence," and it is their alternation which maintains life in vibration and guards it against untimely rest. The smaller the vibrations in which it occurs, the more *constant* will the formative process appear to be, as for example in the processes completing the structure of a cell not destined to division; but even

* There arises great difficulty in rendering these terms applied to the different orders of leaves, since we have none corresponding to them in English. They are so frequently used, not only in a substantive but an adjective way, both in this treatise and in other recent German works, and have such a definite meaning, that we venture to invent new words and to use them in this translation. The word "*nieder-blatt*," (lower leaf), signifying cotyledons, the bud-scales at the base of branches, or the scales of rhizomes, is rendered by *cataphyll*; "*laub-blatt*," (leafy-leaf), stem leaves generally, by *euphyll*; "*hoch-blatt*," (high leaf), leaves belonging to the inflorescence, by *hysophyll*.—A. H.

here the lamellar deposition of the coat of the cell betrays the internal vibration of the formative activity. On the other hand, the phenomena of Rejuvenescence appear so much the more striking and surprising, the deeper the depression of life preceding the new upraising; and the more distinct, consequently, the separation of the new lease of life from the old, the more perfect the consumption and breaking through of the old structure by the new. The metamorphoses of insects furnish most beautiful examples.

Inquiring into the causes of the phenomena of Rejuvenescence, we recognise that external Nature, amid which special life displays itself, acts in calling and awakening through the influences which the seasons of the year, nay even the hours of the day, bring forth; but the proper internal cause can only be found in the tendency towards completion, which is present in every existence according to its kind, and drives it to subordinate to itself ever more completely the foreign and external world, to shape itself within it, as independently as the specific Nature allows. At the same time, however, a term is set to the task, beyond which the phenomena of Rejuvenescence do not proceed. As in mental life there is a time of maturity, when youth and age are as it were intermingled, when the restless strife of acquisition and destruction ceases, when motion is paired with rest, so also in the physical and corporeal there is an analogous condition of maturity and relative rest, when the alternation of destruction and reformation is only carried on in the small vibrations of the interchange of material, maintaining vital motion and guarding against its being benumbed. In animals we see this condition commence when the organism has attained completion, is "grown-up" as it is called, when nothing more new is formed, but the actually existent enters upon its predestined function, into its service in the more elevated side of animal life. In Vegetable life we see the corresponding phenomenon in the fruit, which Aristotle already regarded as the aim of the formative activity of the Plant. With it is closed the series of structures, in the graduated production of which the plant runs through its metamorphoses; in it vegetable life comes to a peaceful conclusion, yet without the internal vital movement stopping at the same time with the cessation of external growth, for it is not so independent and permanent in any other part of the plant as in the ripening fruit. At this stage of development, therefore, in comparison with the preceding process, rest comes at the end, but at the same time, according to the relation to a higher sphere of life, the activity lying in the destination of the final form.

If we compare the structures of the earlier stages of life with the condition of the final forms, we see that in them also exists a pause, an effort at conclusion, which, however, has to be renounced before the development can advance towards its term. In opposition to such fixation at subordinate stages, which would become arrests of development, comes the active power of Rejuvenescence, spinning onward the threads of development with new lengths. Thus it is in every single creature which has a development at all, that is in every living thing. But we may give this reflection a wider expansion.

The term reached by the *individual*, is not the last term of development for the greater complex of the whole, nay the individual itself indicates this totality in its dependance. The individual existences of Nature are links in the development of that Kingdom of Nature to which they belong, and in the widest sense, links in the development of the totality of natural life. Hence the phenomena of Rejuvenescence present themselves not only in the individual existence, but connect themselves again on all hands with the term of the individual existence, going beyond this, constantly renewing living Nature in her individual members, and thus bearing up and carrying her onwards to her final purpose. To the *fruit* adjoins itself the *seed* as the commencement of a new individual course of development, just as the production of future generations is connected with the maturation of the animal organism.

Against this general relation, however, of the phenomena of Rejuvenescence to progressive development, may be raised the objection that the cases of Rejuvenescence last mentioned, on which depend propagation of natural bodies, are, in point of fact, very different in this respect from those first spoken of, those occurring within the cycle of the individual development; in the one case the aim of the Rejuvenescence would be a progress in the development, while in the other it would be a mere repetition of the like, as is distinctly demonstrated by the invariability of species in the Animal and Vegetable kingdoms. Yet this distinction vanishes when we test the gradations of the cases, on both sides, and particularly if we rise above the narrow field of vision of the present, in our examination of reproduction. The appearance of like alone being repeated in nature, is removed in looking back from our present stationary time into former epochs of the world. There we find really the first beginnings of the species, the genera, nay even of the orders and classes of the Vegetable and Animal kingdoms; we see at a glance how more or less profound transformations were connected with the appearance of the higher stages of the Organic Kingdoms, so that genera and species of the ancient world disappeared again, while new ones took their places. But through all this change are expressed not mere accidental revolutions of the earth, on the one hand of destroying, on the other laying the basis of new soil for the flourishing progress of organic life,—but far rather definite laws, penetrating into the very details of the development of organic life. Thus, for example, among the Vertebrate series the Fishes appear first, then the Amphibia, and, subsequent to both, Birds and Mammalia. The Fishes of the first periods, as fish the lowest of their class,* resemble in many respects the Amphibia, more indeed than the fish subsequently appearing, of higher orders, from the very circumstance

* Agassiz. *Poissons fossiles,* Introduction, xxx.

that the types of the individual classes were less distinct in the first representatives; the special character of the class, which is ever more distinctly impressed in the succeeding series of Fishes, not yet being fully developed. Equally remarkable is the relation of the first Mammals of the earth, the celebrated Marsupialia of Stonesfield,* to the class Mammalia generally. The Marsupialia (including the Monotremata) stand, as is well known, below all Mammalia, nearest to the oviparous animals of the preceding classes, the Birds and Fishes, and not merely in regard to the structure of the organs of generation, but also in that of the brain; while, on the other hand, they adjoin in their external form, in the structure of the extremities and the teeth, the higher orders either of the Herbivorous or the Carnivorous series, the Rodentia and the Feræ. We thus see again here the character of the class imperfectly represented in the beginning, and the subsequently diverging series of the class united even to indistinctness. In the geological occurrence of the separate sections of the Invertebrate animals, also, we find the developmental connexion many times confirmed, in that a determinate fundamental type appears first in a few simple forms, then in the course of epochs the number and multiformity of the representatives increase more and more, till finally, when the series of forms is developed to its extreme term, it often suddenly vanishes again from nature, or leaves but a few representatives behind. One of the most remarkable examples of this kind is presented by the family of the Ammonites.†

* *Phascolotherium Bucklandi*, and *Thylacotherium Prevostii*, Owen. Vide Buckland, 'Mineralogy and Geology,' i, 72.

† The transition period possesses the single genus of the family of Ammonites, the *Goniatites*, the trias period the genus *Ceratites*, the Jurassic age 11 sections of the genus *Ammonites*, the chalk period 14 sections of the same genus, 10 of which are peculiar, and besides these the genera *Crioceras*, *Ancyloceras*, *Scaphites*, *Hamites*, *Ptychoceras*, *Baculites*, *Turrilites*, and *Heticoceras*, all of which occur exclusively in the chalk formation, with the exception of *Ancyloceras*, of which genus the Jura formation already possessed species. Then the family of the Ammonites vanishes totally. See Leopold von Buch on *Ammonites*, and D'Orbigny, 'Palæontologie Française,' i, 433.

The Vegetable kingdom of the ancient world likewise exhibits a periodical progress corresponding to a gradation of structure still existing, since the oldest periods have exhibited scarcely anything but Flowerless plants (Cryptogamia), which are soon followed by the Gymnosperms (Cycadaceæ and Coniferæ), and in some degree by still doubtful Monocotyledons, while the Dicotyledonous plants appear distinctly latest. The results of geological research appear to confirm, more and more, that all this progress of organic nature, from the first onset to our own time, has an essential connexion, and, although disturbed in many ways by the catastrophes which the earth has suffered, has never been altogether interrupted; in a word, that it represents a single history of development, and not a series of separate and independent creations.

The ancient changes in the living garment of the earth, appear then as Rejuvenescences of organic nature in mass, and the individual genera and species of the organic kingdoms as subordinate links in its great chain of development. The fact that nature halted at determinate points, in the calm intervals, and during the epochs produced, essentially at least, only the like, does not remove the relation to the totality of the development. This is the same phenomenon, on a grand scale, as when we see the plant repeat itself in the same form, often hundreds of times, at particular stages of its growth, before the metamorphosis advances to a new stage, as for example, often hundreds, or even thousands, of the ordinary (euphyllary) leaves (*Erica*, *Calluna*, *Tamarix Abies*), bracts (hypsophyllary leaves) (*Dipsacus*, *Cnicus*, *Celosia*), petals (*Nymphæa*, *Mesembryanthemum*, *Illicium*), stamens (*Papaver*, *Dillenia*, *Helleborus*), or carpels (*Myosurus*, *Anemone*, *Anona*), are formed in unbroken succession on one and the same axis. But even in these times of halting, by no means the absolutely like is formed. No leaf, even when belonging to the same formation, exactly resembles another; and with every successive leaf, if the development advances as far as the terminal blossom, the plant approaches one step nearer the formation of the flower. Neither are the individuals of the same species exactly alike; and the capability of developing certain sets of varieties testifies the developmental power of the species, even within the restriction to the specific type.

We cannot, therefore, ignore a certain relation to the development of the great whole, even in those phenomena of Rejuvenescence which continue the series of individuals in what seems a mere repetition of the like. This relation speaks most meaningly in the highest region of the whole graduated series of Nature, where the development passes over from the physical into the spiritual. Who would deny the relation of the production of new generations to progressive development, in the field where it lies nearest to us, namely, in the *Human Race?* The condition of humanity in this respect falls within the sphere of our contemplation, for the aim to which the infinite Rejuvenescences throughout all Nature strive, through the attainment of which our period of creation is distinguished from all the ancient epochs, is the very existence of Man, towards whom Nature points, from step to step, ever more distinctly throughout her entire series; and Man again cannot be considered without that which itself constitutes his humanity, the development of *Mind.* The development of Mind cannot be separated from its substratum Nature, since although Mind itself is destined to rise victorious over all the obstructions of physical life, it must also penetrate backwards through all the stages of that life, and give them a spiritual signification. Only by starting from this standing point, fixing the aim of the entire development in Nature, can we find the true internal connection of all the gradations of natural life, and by the very conjunction with the course of development of Man, Natural History acquires its highest import. As Nature without Man presents externally only the image of labyrinth without a clue, scientific examination which denies the internal spiritual foundation of Nature, and its essential connection with Mind, leads only to a chaos of unknown matters and forces,* that is of matters and forces which are sealed books to the mind, or more properly of unknown causes which co-operate in a manner to us inexplicable. From this dark chaos no bright path leads up to the mind; nay, it is inconsequent to regard the mind from this point of view as anything but an inessential result of the co-operation of unknown causes. The study of development is pre-eminently calculated to defend us from such a miserable spoliation of Science, for the connection of the perceived phenomena of *Being* must necessarily lead us to the recognition of the *Becoming*, as an internal essence (specifically) the same through all changes.

The comprehension of the individual phenomenon as a member of a series of essential correlative representations, requires not merely the carrying back of the research to the earliest rudiment, from which alone the succeeding transformations can obtain their correct interpretation, but also a continuation of the observation up to the term of the development, whereby is first perceived, on the other hand, the true destination of the efforts in the formative processes. This is equally true of individual organs, whose physiological destination is first distinctly realised when the formation is complete, and of the individual whole, whose specific and generic character is chiefly expressed in the last stage of the metamorphosis, —for example, in the flower and fruit of the Plant. This is true, moreover, of the more comprehensive developmental series in Nature. The character of every genus, family, class, &c., should grasp its type, as it were its ideal object, for which purpose the lower members of the

* The sadness of such an *essence-less* view of nature, which of course must strive to eradicate from the ideas and language of science, all which from its own standing point appears anthropomorphic, does not strike us in its fulness, simply from the fact that the desired eradication cannot be so readily carried out, on account of the intimate and immemorial blending of the more profound ideas with human language. See Schleiden, 'Die Pflanze und ihr Leben,' 15. 'The Plant,' translated by A. Henfrey.

series are always less fit than the higher, in which it is stamped more plainly and completely. Thus in the *Ornithorynchus* the type of the Mammal is so imperfectly and aberrantly represented, that doubt could long exist whether it belonged to the series of the Mammalia at all, and the flowers of the Cycadeæ are so little like a flower, that it was only after much comparative study that the conviction was arrived at, that these plants actually belong to the commencement of the series of Flowering plants (Phanerogamia). If we apply this mode of examination to Nature as a whole, as the developmental series involving all the subordinate series, if we here also seek the solution of the problem, at the term of the development, we are most distinctly directed to the completion of the development of Mind as the destination of the whole process, becoming visible at the highest stage of natural life. The mind which becomes developed in Man, is not fitted together, with the physical organism, from without, for we behold its evolution indicated in the lower stages of natural life, especially in the Animal kingdom; the spiritual life is rather the purest and most refined representative of the fundamental life, which we meet as natural life in the preceding stages. We may say of *Mind*, that it is the *youngest*, and yet the *oldest*, existence in nature, destined to attain in its last age, its eternal youth, the freedom fitted to its essential nature. Rising from the groundwork of Nature bearing and supporting them, the spiritual Rejuvenescences in the history of Man strive towards this aim of internal vital emancipation, driving the mind out of every senility, every fetter of time, to soar upward in a new flight of life.

Thus is our own history connected with the history of Nature. The thought of Rejuvenescence in Science, Church and State, now again moves nations, and meets us in the most varied efforts, in ways crossing one another in manifold directions. As yet, alas, we have become acquainted almost solely with the negative side of these efforts, the Destructive; but in the eyes of the naturalist this dissolution would tend merely to indicate the proximity of the transition to a new, upgrowing time which will seize the Positive, in all fields, more profoundly, and give it a more perfect shape. Will this hope be fulfilled? Has not Old Europe rather arrived at a hoary age, and an approach to its dissolution? The answer to this must be written first of all in our own hearts; but if you would seek it externally, look with the eye of the naturalist into the hidden workshops of the future, and you will find an infinite abundance of germs and buds, which bear the promise of a rich future within them; you will above all find them in the domain of Science, as the highest region of mental development, from which alone the latest reformations of life can and ought to issue. But these are digressions leading us too widely from the purpose of the foregoing considerations. If however it be true that all the domains of life are parts of a great total development; if it be true that every department of science leads in its more profound establishment to the same eternal idea, which is the foundation of all reality and all truth,—each department must be mirrored in the others, and thus the naturalist may be permitted to contemplate each movement of the human life which surrounds him, in the mirror of Nature; to find in whose lawfully connected government, the key to calm judgment, is often his gain and payment.

In the preceding observations we have sought to regard the phenomenon of Rejuvenescence in its general, external mode of appearance, and to mark out the wide field in which it is repeated in such a multifold and yet essentially always the same way. A profound investigation into the nature of Rejuvenescence would pre-require somewhat minute research into the essence of age and youth. A few more remarks upon youth may be permitted here. According as we regard life as a mere result of *external causes*, or discover its basis in one original *internal endowment*, will youth appear to us, in the one case as poverty, want, and crudity, in the other as the yet undivided fulness and strength of the undeveloped existence, as superabundant wealth of energy, striving to unfold itself. These two modes of considering the question occur, for example, in application to the earliest, youthful stages of the Human Race; thus we find on the one side the doctrine of the originally animal condition of Man, according to which Man, scarcely distinguishable from apes, probably of black colour, perhaps even sought after his nourishment on all fours or climbing, devoid of art, language and thought; then gradually discovered speech through imitation of natural sounds, and as it were accidentally; and was only led through external necessity, not through internal impetus, through the combat with external nature which his extraordinary defencelessness and helplessness brought upon him, to each flight upward of life in art and civilization, upbuilding all progress from without, not unfolding from within. In opposition to this representation stands the doctrine of the paradisaical condition of the first Man, who at his first appearance stood face to face with obedient Nature, as Lord, as complete Man and likeness of God, urged by the fulness within to give outward shape in word and work to his inborn divine ideas. When we acknowledge both the internal and external, in their co-operation in life, we shall easily be able to unite these two views, that is if we disregard the exaggerations on the one side, and on the other the mythical imagery (which represents the inner potentiality as the external actuality.) The insufficiency of the first view, which logically carried out entirely disowns anything internal and essential in natural phenomena, may be shown us, if, as was referred to above, we do not find it in our own life, or are disinclined to draw conclusions from that as to life outside us, by the instinct of animals, in which is revealed so great an abundance of gifts, not given from without, but undoubtedly inborn, as the gift of song, the impulses to art, or to migration, &c. The phenomena of mental life in animals, which we ascribe to Instinct, have been correctly compared with what has been called, in the material sphere, the specific formative impulse, or typical force. Instinct is the continuation of the formative impulse in a higher sphere, as is particularly clearly manifest in the phenomena of the constructive impulse, in the formation of envelopes and clothing (*Serpula, Phyganea, Psyche*), nests and dwellings, as a kind of ulterior and more external material organisation. The specific formative impulse, however, is not an outwardly derived direction of the activity, but one inwardly contained, acting, from internal causes, as inner determination and force. This is shown by the fact, that under like external conditions of existence, the organism shapes itself in a peculiar, specific, nay even individual way, in each creature, whence the multiformity of the picture which every mingled wood, every meadow, every field, displays to us. Hence in the grove we see the woodruff and the herb Paris, later in the summer the willow-herb and the fox-glove, on the rock the oak-fern, the dragon's-mouth, and the stone-crop, side by side; they take up the same nourishment, and form their structures out of the same elements. What maintains them in the distinctness? It is the same force that enables different animals to elaborate the same food for such constantly varying bodily development, and, on the other hand, prevents a considerable change of food from effacing the specific type. This internally given force of life is pre-eminently expressed in youth, while in later age the formative forces are more and more fettered to the products of their own activity, and work only in a narrower circle, till at length their activity, everywhere more hampered in its own products, becomes extinguished.

For the definition of *Rejuvenescence*, we draw from the foregoing considerations, the conclusion, that the renouncement of forms already attained, and the retrogression to new rudiments, with which Rejuvenescence begins, only mark the external side of the process, while its inner and essential side is rather an inward *gathering-*

up, as it were a new draught from the proper source of life, a renewed recollection of the specific purpose, or a renovation of the conception of the typical ideal, which is to be represented in the outward organism. This gives to Rejuvenescence its definite relation to development, which can only bring into gradually perfected representation, that which lies in the *essence* of the creature, that which is inwardly its own.

This inner part of the process of Rejuvenescence may be rendered more clearly comprehensible by sleep, for this also is a phenomenon of periodical Rejuvenescence, the Rejuvenescence of the consciousness. In sleep the mind is relaxed from the tension in which it is held towards the outward world while awake. All images and shapes of thinking life vanish, or appear only as reflected pictures in dreams; the mind sinks back into a condition comparable to that in which it was before it first awoke to consciousness, therefore, externally regarded, to a lower condition of development, for sleep is older than waking in the history of development of human life. But the mind does not lose itself in sleep, it rather gathers itself up into new force, new comprehension of its purpose, and much that crossed the waking thoughts, scattered and entangled, becomes sifted and arranged through this recollection.

Sleep, a necessary recreation for the mind, is equally required by all the powers of the body immediately serving the mind. The inner formative processes, on the contrary, through which the body itself is preserved, do not rest during this time of retreat, they rather act the more undisturbedly and concentratedly. Hence the rejuvenising power of sleep also for the body, which appears so wonderful to us in many cases, as when sleep occurs at the crisis in severe diseases. But the most remarkable instance of the connexion of sleep with bodily Rejuvenescence, is seen in the pupa-sleep of insects. Here, where occur the most important metamorphoses we know in the Animal kingdom, that of the sluggish caterpillar into the light-winged butterfly, the footless or headless maggot into the deeply-segmented fly; — here, also, occurs the greatest retreat and gathering in of life, a deeper sleep of weeks, months, or even years' duration, which may be compared with the embryonal sleep in the earliest period of formation of the organism, the sleep in the egg. Without nourishment and without locomotion, as it were shrouded in its pupa-coats, the insect prepares the rejuvenised body for its future resurrection into a freer, more mobile existence.

The awakening of the butterfly from the pupa-sleep, recalls to us the awakening of Nature from its winter sleep in *Spring;* and this leads us to the proper subject of the present considerations,—the Rejuvenescence in Vegetable life. The Vegetable Kingdom is, indeed, the principal workshop of Spring: "the wonderful workshop where myriads of vegetable atoms, in brief space, spin the threads to clothe the trees and weave the verdant carpet of the earth. With all its sunshine over land and sea, with all its swelling streams and brooks, Spring would be barren and empty without leaves and flowers, as a sky without stars. Leaf and blossom alone give life and freshness to the active scene." *

First of all, however, we must here dispel the illusion that all the splendour of the new-born vegetable world, which appears so magically in spring, is merely the work of the few days in which it comes so suddenly into view. No, the labour of Rejuvenescence begins earlier in the workshops of vegetable life, and Spring merely brings the last steps before our eyes. The breath of Spring only urges to its unfolding that which was prepared long before in silence, that which was reserving and strengthening itself during the evil season of winter. For in the same proportion as the vegetable world advances in summer and autumn,—in shoot, leaf and flower, in wood and fruit, in obedience to the impulse to outward representation, to

* Elias Fries, "*der Fruhling*" (Spring). 'Archiv Scandinav. Beiträg,' i, pp. 182, 214.

expansion and firmer establishment, does it retreat simultaneously into itself in the formation of buds and seed, to prepare the germs of new life. Thus the greater part of that which unfolds itself in Spring, after winter has passed over it, was already formed in the preceding summer and autumn. Even now in August we find in the terminal and lateral buds of the *oak*, within numerous, five-ranked bud-scales, the rudiments of the leaves destined for next year; nay, in the mostly paired terminal buds of the *lilac* (*Syringa*), we find not only these, but the rich thyrse of blossom for the future year, with hundreds of closely crowded flowers, which at this time indeed appear only as inconspicuous green nodules, scarcely the twelfth part of a line in diameter. In the heart of the *tulip* bulb, shielded by three- to four-fold succulent leaf-scales (cataphyllous coats, *Niederblatt-hülle*), exists, in autumn, a little greenish-yellow bud; this is the tulip stem for the next year, with all the parts which it elevates from the earth nine months later, namely, two or three leaves, between which lies hidden the blossom, scarcely a third of a line high, the petals and stamens appearing as extremely small, uniform papillæ, scarcely distinguishable, and not yet closed in as in later shape of the flower-bud, while the pistil is visible in the middle as a little, three-lobed papilla. The spike of the *hyacynth* is somewhat more advanced, at the same period, in the interior of the many-scaled bulb, for the three outer petals of each flower already begin to close up. In *Ophioglossum*, a strange little plant of the alliance of the Ferns, which unfolds annually only one leaf and one spike, we find in May, in the bud still hidden under ground, enclosed in a cellular covering, (not formed of cataphyllary leaves or bud-scales, but thallus-like,) not only the leaf and spike for the next year, but also the rudiment of the leaf for the year after that.

A further penetration into hidden workshops of Rejuvenescence in plants, requires, first of all, a more minute investigation of the bud. The plant is bud, so long as its existing rudiments are kept, in relation to completion, in a stage of close connection of the organs. Those things which are subsequently removed and unfolded, are here still closely approximated, and, as it were, fitted one within another. The bud is, therefore, properly regarded as an entire young plant, and each new bud on an old stem as a new plant, as an *individual: "Gemmæ totidem herbæ"* was an axiom laid down even by Linnæus, and since his day has oftentimes been repeated.* Nevertheless, this conception of the bud has remained itself to a certain extent in the condition of a bud, since the surprising abundance of conclusions derivable from it, have never been properly developed up to the present time. In the first place, however, the idea of the bud as individual still requires an essential clearing up. Since the word *bud* merely expresses a certain stage of existence of the thing in question, we must here rather call this *sprout* (*Spross*), in the definite sense that we here understand by *sprout* all belonging to one axis of the plant, that we therefore regard as belonging to a *sprout* all which is produced directly from one centre of vegetation (*punctum vegetationis*), and belongs essentially to one line of development. *Eye* and *bud* are only the commencement and young condition of the *sprout;* and that which we call bud frequently comprehends only one part, and not the whole of the sprout, as when the lower portion of a sprout is already unfolded and the upper part of it alone remains in the condition of a bud. Thus every richly clothed, but gradually progressing and gradually unfolding leaf-bearing axis, as, for example, the sucker of the willow, the rosette of the lettuce before its flower-stalk has arisen, the crown of the palm or of the agave, has a bud (a "heart") hidden among the uppermost leaves, which bud, however, passes by almost imperceptible gradations into the unfolded part of the crown, rosette, or shoot. In other cases there is a sharper division between the earlier unfolded parts and those remaining long in the

* For instance, by Röper, ('Linnæa,' 1826, p. 434,) and quite recently by J. N. Carus, ('*Zur näheren Kenntniss des Generationswechsels*,' 30.)

bud state, in reference to the period of unfolding and the stage of formation; thus, for instance, in the oak, the beech, and other trees, where the leafy shoot terminates in a bud, the shoot does indeed begin again with cataphyllary leaves (bud-scales), and unfolds itself a year later than the preceding portion of the branch, but is, nevertheless, the direct continuation of the axis, and therefore belongs to the same sprout. So also when a flower-bud forms the termination of a sprout, on which the preceding formations were unfolded earlier than the terminal flower, as in the tulip, the ranunculus and the pæony. Hence it is not the separated bud which we must regard as an individual, but the entire shoot, which in these cases includes several superimposed buddings. A Rejuvenescence in the course of formation of the plant, is indeed expressed in each production of a bud; but we must not, therefore, attribute an equal individual importance to each, for some buddings belong to the individual completion of the particular branch (all terminal buds), while others form the commencement of the new individual line of development of a new sprout, as is the case in all lateral buds. If individual value be attributed to the terminal buds also, it will follow, in reference to the cases where the terminal bud unfolds gradually, and is renewed in like progression in the centre, that we must accord the rank of an individual at last to every single leaf with its supporting internode, since each is a specially rejuvenised link of the progressive development. And if we attribute an equal importance in this respect to each step of Rejuvenescence, we cannot stop here, for then every organ of the plant, as internode and leaf, is itself again formed by a series of Rejuvenescences, as we see in the cell-formation of the organs; and the single cell itself finally has its own periods of Rejuvenescence. Consequently, if we wish to review the various gradations of the phenomena of Rejuvenescence in vegetable life, we must consider separately: —1, the Formation of Sprouts; 2, the Formation of Leaves; and, 3, the Formation of Cells.

1.—THE FORMATION OF SPROUTS.

There cannot be any doubt that the formation of sprouts belongs to the class of the phenomena of Rejuvenescence, for with every sprout commences a new train of development, the relation of which to the entire developmental chain of the specific vegetable life, we have here especially to investigate. The principal sprout of the plant takes its origin from the seed, and is indeed merely the direct development of the seedling (embryo), thus grown up from the first point of vegetation of the plant, which, traced backwards, leads to the primary germinal vesicle. The lateral sprouts (branches), although their origin is unconnected with the co-operation of the sexes, agree with the main sprout in that they also are developed from special centres of formation, distinct, after their first origin, from the principal sprout. We shall return in the sequel to the origin of the principal sprout, with which every new vegetable "stock"* arises, when examining propagation from the point of view of cell-formation; here we must occupy ourselves with the lateral sprouts, which belong to the sphere of completion (*Ausbildung*) of the vegetable "stock" itself.

Unfortunately we are deficient in thoroughly worked-out researches on the origin of the lateral sprouts or branches; but so much is known, that the origin of the sprouts is subsequent to that of the leaves, that they derive their origin from the already more developed tissues of the stem, while the first rudiment of the leaf coincides with the earliest stage of formation of tissue underneath the point of vegetation.† While the leaf,

* The word "stock" is used here and elsewhere in the sense of what may be called a *phytidom* (like a *polypidom*), indicating the total organically connected structure composed of a number of partially independent links or members.—*Trans.*

† Vide Nägeli, 'Zeitschrift fur Wissenschaftl. Botanik,' Heft iii, iv, pp. 153, 177.

as essential part of the sprout, has its history of development intimately connected with that of the stem;* on the other hand the formation of the sprout does not seem to have any essential connection with the completion of the stem from which it proceeds. This is further confirmed by the circumstance that the sprouts are not always distributed, like the leaves, in definitely regulated order on the stem, but in many cases may arise without order at any points of herbaceous stems,† or of the older lignified trunk, nay even from the root‡ and the leaf, as the so-called *adventitious buds*.

It is a remarkable indication for the essential distinction in the origin of the leaf and sprout, that no adventitious leaves occur. The character of the new formation is expressed most distinctly in the formation of adventitious buds making its appearance in detached fragments of roots of woody plants, as has been described by Trécul in *Ailanthus*, *Paulownia*, *Tecoma*, and *Maclura*. Here, in a deep-seated layer of the cellular bark, a new focus of development is formed through a local thickening of the cellular tissue, and on this point again originates a much more delicate mass of cellular tissue, a new sphere of formation, which soon grows externally, although still enclosed in the tissue of the bark, into a leaf-producing point of vegetation, and on the inside strikes, stem-like, into the formative zone (the cambium-layer) of the root, there, by the formation of a proper system of vessels, which takes its origin on the limit between the stem of the adventitious bud and the wood-cylinder of the root, acquiring a firm connection

* The essential interconnection of the leaf and stem is expressed in the completed structure also, in the fact that there is no sharply defined limit between the leaf and the portion of stem bearing it. Remark, for instance, the pulvini gradually lost in the stem of *Larix*, *Picea*, *Cacteæ*, *Cacalia articulata*, &c., and stems winged by the decurrence of the borders of leaves.

† In *Euphorbia*, *Linaria*, and *Anagallis*, from the internode below the cotyledons.

‡ Frequently in woody, rarely in herbaceous plants, *e. g. Euporbia Cyparissias*, *Linaria*, *Rumex acetosella*, *Ajuga genevensis*, *Nasturtium pyrenaicum*, *Jurinea Pollichii*, and *Helichrysum arenarium*.

with the latter.* The bud breaks out subsequently through the bark in which it was previously concealed. In this instance there can be no doubt that the sprout is really a new, and in this case even an accidental product, a new commencement of life, which creates its own sphere of formation, its own point of vegetation, and through the development of this, its own axis, around which it arranges its organs. Hereby we are warranted in regarding the sprout as an *individual*, for, if we may ascribe individuality to the plant generally, in which we are certainly justified by the repetition of its mode of appearance in determinate cycles of development, we must, consequently, conceive the individual as a developmental series of unit power, and set up as its criterion the unity of the point of vegetation from which the series proceeds, or, in the developed condition, the unity of the axis. According to this, only the simple sprout can be regarded as a vegetable individual, and that this, far as the vegetable individual stands behind the animal individual in inner unity, is actually the analogue of the animal individual, is proved beyond all doubt by comparison with those animals in which "family stocks" are produced by the formation of sprouts.

The formation of the compound vegetable "stocks" (trunks or common stems) is thus a phenomenon of propagation, if we use this expression according to the meaning of the word and the custom of language, in general application to the production of new individuals for the increase and maintenance of the species of plant. Propagation by the formation of sprouts, on which not only depends the formation of compound stocks, but in which is also given the possibility of the formation of separate stocks, has indeed been distinguished as mere *multiplication* from the proper (sexual) propagation, or

* Trécul 'Recherches sur l'Origine des Bourgeons Adventifs.' 'Ann. des Sc. Nat.,' 3 sér. viii, 268, 1847. The cases there described as two different modes of origin, and represented in Plate vii, fig. 6 under *b* and *b'*, may probably be only stages of one and the same process.

called *propagation of the individual*, in contradistinction to the propagation of the species effected by the formation of seeds.* But, disregarding the contradictions which here exist even in the expression, these definitions by no means reach the true essence of the modes of propagation occurring in the formation of sprouts, for it is incorrect that the formation of the sprout is *merely* for the object of multiplication, as I shall endeavour to show in the sequel; in like manner it does not always apply, that the new stocks formed by separation of sprouts (cuttings, layers, &c.) constantly retain unaltered the individual (more accurately the *variety's*) character of the parent stock, for even without separation from the stock, particular shoots "sport," as it is called, out of the species. The well-known example of the occurrence of isolated blue bunches of grapes on stocks of white varieties, isolated bunches of red currants mingled with the white ones of the same stock, isolated pure sulphur-yellow roses among variegated flowers of the red and yellow Austrian briar-rose (*Rosa eglanteria*, var. *bicolor*) afford proofs of this. The remarkable phenomena relating to this point in the hybrid *Cytisus Adami*, which displays in particular sprouts the characters sometimes of one, sometimes of the other parent species, will have more particular attention paid to them in another place.

The true import of the formation of sprouts upon the vegetable stock is that of a subordinate propagation. The cycle of development given by the sexual propagation (formation of seed) divides again, in the majority of plants, in the most varied manner, into subordinate series of development, which proceed out of one another by the formation of sprouts, so that what in more highly individualised beings is completed in the simple individual, is distributed in the plant, through the inter-

* Link, 'Element. Philos. Bot.,' p. 208. "Gemmæ individuum continuant, cum semina speciem propagent." We have already shown above that the lateral sprout, morphologically considered, is no *continuation*, but a new beginning.

position of a subordinate process of propagation, among a society of individuals, a developmental series, and a family circle formed thereby. The subordinate nature of this mode of propagation represented by the formation of sprouts is expressed—1. In the connection of the formation of sprouts with the lower stages of development of the plant. 2. In the imperfection of the "sprout individual" in reference to the series of stages of development which specifically belong to the plant. 3. In the complementary relations in which the various sprouts of the same plant stand towards each other.

In the first respect, all sprouts agree, with the exception of the seed-sprouts (commonly called ovules), which as standing in the closest relation to sexual propagation, may be here left out of consideration. All other sprouts spring from the so-called vegetative region, while inside the flower, omitting monstrous occurrences in antholyses, no more formation of sprouts takes place. The cataphyllary (*Nieder-blatt*) region, the euphyllary (*Laub*) region, and the hypsophyllary (*Hoch-blatt*) region, have more abundant or more sparing formation of sprouts according to the peculiarity of the species of plant; nay the production of sprouts is not unknown, as already mentioned, in the descending portion of the plant, the root. How characteristic the formation of sprouts is of the vegetable "stock" is shown by the circumstance that there exists perhaps not one single plant wholly without the formation of sprouts.* If this assertion look at first strange, considering the number of plants which are diagnosed with "caule simplici" and "simplicissimo," more accurate examination of such plants as appear to want the formation of sprouts, will readily confirm it. A few instances may serve to bear this out. *Cicendia filiformis* is certainly one of the simplest plants in this respect. A delicate threadlike stem bears a few pairs of small euphyllary leaves and ends in a terminal blossom.

* The leafless plants of the lowest ranks of the vegetable kingdom are temporarily passed over in this assertion.

But the rudiments of the formation of sprouts exist in the axils of the lower leaves of this series, and quite as many specimens may be found with one or two branches, as perfectly simple. In a similar way, in many other plants which usually possess abundant ramification, we find specimens which, under the influence of unfavorable conditions, do not complete the branches which really exist in rudiment, and therefore appear quite simple. Such simple "arrests" (*Kümmerlinge*) occur, for example, in *Erythræa pulchella*, *Gentiana utriculosa*, *Saxifraga tridactylites*, *Silene conica*, *Gypsophila muralis*, *Papaver Rhœas*, *Myosurus minimus*, &c. In all these cases, therefore, the want of branches depends solely upon an accidental obstruction. Other plants appear simple because the formation of sprouts is hidden beneath, or is close down upon the earth, as in the tulip, which forms sprouts in the cataphyllary leaf region (bulbels), also *Trollius europæus*, *Papaver nudicaule*, *Gentiana verna*, which form sprouts in the axils of the ground leaves ("radical" leaves), whereby the originally simple "stock" passes into a cæspitose complexity, and acquires what is called a "radix multiceps." *Paris* is deceptive in another way, the simple and one-flowered erect stem being itself a lateral sprout from a subterranean cataphyllary-leaved stem (rhizome). Among the simplest plants altogether devoid of sprouts, apparently presenting solely a flower without a stem, is the celebrated *Rafflesia* and the parasites nearly allied to it; but it is most probable that the flowers of these plants arise as sprouts out of a thallus-like basis, creeping along under the bark of the nursing plant.* The *Melocacteæ* form an exception in the family to which they belong, ungrateful to the admirers of that family, in sending out no sprouts from their green, globular "stocks;" but here also the rudiments of the formation of sprouts are indicated, by headed-down "stocks," sometimes sending out sprouts from the lower

* See R. Brown 'On the Female Flower and Fruit of *Rafflesia Arnoldi*,' &c. 'Trans. Linn. Soc.,' xix, 3, p. 232 (note).

portion; moreover, *Melocactus* normally exhibits formation of sprouts in the terminal tuft of flowers, in which (as in all Cacteæ) the flowers stand laterally. The palms are also mentioned as plants which usually form no sprouts; but leaving out *Cucifera thebaica*, which acquires a multiple crown by the formation of leafy branches, the inflorescences originating in the axils of the leaves are lateral sprouts. *Corypha umbraculifera*, with terminal inflorescence, has, in the inflorescence itself, *i. e.* in the hypsophyllary leaf region, an extremely rich ramification, carried out to many degrees, and in addition to this, sends out sprouts from the root, at the time of the maturation of the fruit.* *Cycas* would have better right than the palms to be regarded as a plant devoid of sprouts, at all events if the cone- or Ananas-like male blossom is terminal, as Richard expressly states. But Rumph says of *Cycas circinalis*, that the stem at first grows very slowly, but afterwards more rapidly, particularly when it has borne the "ananas." Such a continuation of the growth of the stem can, however, only be conceived through the formation of a lateral sprout, if the male blossom is actually terminal, or, if a direct prolongation of the stem occurs, the male blossom must be a lateral sprout. The female tree of *Cycas circinalis* is stated by Rheede † to divide frequently into four or five tops when old, which again can only take place by the formation of sprouts. Lastly, in *Cycas revoluta*, formation of sprouts from the lower part of oldish stems, mostly close down to the ground, is quite a common phenomenon, and may be seen in every old trunk in our gardens; recurring moreover in the fossil stems of Cycadeæ.‡ Many Ferns, especially most tree-ferns, would appear as sproutless plants, in the strictest sense of the word, were not the entire Fern stem itself a

* Vide Mohl, in Martius's 'History of the Palms.' The palms are also very subject to subterraneous branching, and lateral sprouts sometimes break out from old leaf-axils on full-grown trunks.—A. H.

† Hist. Malabar., iii, t. 20, fig. 3.

‡ See plates in Buckland's 'Geology and Mineralogy,' t. 58, 60, 61.

second generation, *i.e.* a sprout produced from the thallus-like pro-embryo (*prothallium*). The circumstances are similar in *Isoëtes*. Thus, even after very extensive investigation, there probably does not remain to us one single plant which, through the whole course of its development, from the germinal vesicle to the fruit, is but a single, simple individual, uncomplicated by subordinate propagation.*

The subordinate condition of the propagation presenting itself under the form of the production of sprouts is expressed, secondly, in the fact that the particular sprouts, and indeed the main sprout as well as the lateral sprouts, do not, in the majority of cases, bring into existence all the stages of vegetable metamorphosis which belong to the "stock" as a whole. Consequently there exist, in reference to the share in the graduated structure of the entire plant, sprouts of different kinds, and the individual sprout on that account mostly represents only more or less imperfectly the history of life of the plant.

The deficiency of the sprout may relate either to its commencement or its conclusion. The formation with which a sprout commences mostly stands in relation to the region of the parent-shoot from which it takes origin. Thus we frequently see a series of sprouts, accurately graduated in this respect, arise from successive regions of the (absolute or relative) main-sprouts, *e.g.* sprouts beginning with cataphyllary structures from the cataphyllary region, with euphyllary leaves from the euphyllary region, with hypsophyllary structures from the hypsophyllary region. *Hypericum perforatum* and *Mentha aquatica* are well-known examples exhibiting this phenomenon. But a retrogression of the sprout to a lower formation, as well as an advance to a higher, is possible. The former

* See on this subject, Hofmeister, 'Frucht-bilding, &c. der höher. Kryptogamen," Leipsic, 1851. He however regards the fronds of ferns as branches, a view which does not appear admissible. The first product from the *prothallum* is the primary axis of a new individual, continued by a terminal growth, but forking of the rhizome may occur, and this must depend on the formation of secondary sprouts. In *Isoëtes* the stem appears simple.—A. H.

occurs especially when the sprout is destined to be subsequently developed into the central shoot. Thus many lilies exhibit in the axils of the euphyllary leaves cataphyllary buds, which finally fall off as bulbels, and continue their development in the following year; so also we see the buds formed in the axils of the euphyllary leaves of most trees, intended to overlast the winter and unfold in the next year, commence with cataphyllary structures. In many instances the plant first reaches the lowest stage of its metamorphoses by such a retrogression, the lateral sprout going down to a lower rudiment than the main or original sprout brought forth by the seed. This is a process through which the plant enters more closely into connexion with the earth in the second generation than in the first, and becomes more firmly established in it, preparing a more fixed, enduring and sheltered existence, to the vegetable life, though its cataphyllary formation and the adventitious roots mostly following this. The following remarks may serve to illustrate this case, which is especially important in reference to the biology of perennial herbaceous plants. It is self-evident that the cotyledons of Dicotyledonous plants, although mostly strikingly different * in shape from all the following leaves, do not belong to the lowest leaf-formation, but rather bear, essentially, the characters of the second leaf-formation, that of the euphyllary leaves; while, on the other hand, the sheath-like cotyledon of the Monocotyledons is mostly decidedly like a cataphyllary leaf. Now Dicotyledons continue the euphyllary formation directly from the cotyledons, without ever producing cataphyllary leaves either on the main or the lateral sprouts; perennial Dicotyledons, on the other hand, mostly descend from the original leafiness to cataphyllary formation, and this either on the main sprout itself, as in *Adoxa*, *Helleborus niger*, *Hepatica*, and *Anemone nemo-*

* The first leaves of the sprouts have been compared with the cotyledons of the main sprout, a ground for which is indeed to be found in their position, but only rarely in their forms.

rosa; or on the lateral sprouts arising from the axils of the cotyledons and the euphyllary leaves next succeeding these on the main sprout, in which case the main sprout dies down either entirely, or at least in the upper part, and this indeed mostly without having carried its development up to blossoming; while the lateral sprouts last through the winter in the form of basilar buds or runners penetrating into the soil, and in the second year bring forth a more vigorous generation, mostly advancing to the terminal point, blossom and fruit. This is the condition, for instance, of most of the perennial species of *Aster, Solidago, Achillea, Tanacetum, Mentha, Lysimachia, Hypericum, Epilobium, Lythrum,* &c.; *Oxalis stricta* and *Solanum tuberosum* also belong here, in which the parent stem dies entirely away, and only the ends of the runners live over the winter as the foundations of a new, more vigorous generation. It is well known that the potato raised from seed does not usually flower, or only exceptionally. Perhaps, however, *Physalis Alkekengi* affords one of the best examples of this kind. Between the stalked, broadly lanceolate cotyledons of this plant, spreading out above ground, rises in germination a stem about a span high, with twelve or thirteen (euphyllary) leaves, increasing in size upwards, and when winter approaches this stem dies down without having flowered. In the axils of the cotyledons and the succeeding leaves standing close down to the earth, in the course of the summer, while the sterile main sprout is being developed further upwards, arise buds, which, scarcely a line long, turn their points at once obliquely downwards, and subsequently, becoming more and more elongated, penetrate almost perpendicularly into the earth. They are clothed with distant, clasping, apiculated, cataphyllary leaves, bent inwards like a cap at the tips, and these are reddish above ground, whitish beneath. The uppermost of these sprouts penetrating into the earth and laying the foundation of the more vigorous and fertile generation of the second year, begin again with small, dwarfed, euphyllary leaflets, and descend gradually on the tips penetrating into the earth to cataphyllary leaf-formation.

The *anticipatory* condition of the sprout is no less frequent than the retrogressive. It occurs, for example, where we see flowers arise without bracts (*Vorblätter*), or with such leaves as belong to the hypsophyllary leaf-formation, from the axils of euphyllary leaves, as in *Linaria cymbalaria*, *Lysimachia Nummularia*, *Tropæolum*, &c.

More important for our purpose is the consideration of the deficiencies of the sprouts in the *upper part*, *i. e.* in reference to the formation with which they close. Not every sprout carries the developmental series, whether it take it up lower down or higher up, to its termination in the formation of flower and fruit; but certain determinate sprouts remain fixed at determinate subordinate stages, beyond which they have no power, or only in extraordinary cases, to advance; nay, there are even cases where instead of an advance to the final term in the building onwards of the sprout, a retrogression of the metamorphosis takes place, which is frequently followed by a periodical vibration up and down of the formations, connected with the changes of the seasons. So, for instance, in the oak, the beech, and the chesnut, the sprouts of which produce cataphyllary and euphyllary leaves in regular alternation from year to year.*

These limitations downwards and upwards, which determine the history of the individual sprout, in contradistinction to the history of the life of the entire plant, form the most essential causes of the infinite multiplicity we meet with in the formation of sprouts in vegetables. Far removed, therefore, from merely subserving to an asexual increase and a multiplication of identities, the plant rather developes its great multiplicity in this very formation of sprouts, and thereby becomes a "*vegetable*"

* The same is the case with *Adoxa*, which creeps along the ground and rises and descends in undulations with the alternation of euphyllary and cataphyllary formations.

(*Gewächs*), *i. e.* a whole composed of subordinate individuals.

Lastly, the subordinate import of the sprout is expressed, *thirdly*, most distinctly in their reciprocal compensations. For how were it otherwise possible in the frequently so one-sided endowment of the sprout, limited to a few, nay often to a single formation? A mere cataphyllary sprout necessarily requires the appearance of euphyllary formation in another series of sprouts, and when these again do not proceed as far as the formation of hypsophyllary leaves and flowers, further ranks of sprouts must be introduced. Thus in the pine we find on the main-shoot and the branches resembling it (in the earliest youth of the germinating seedling excepted), only scale-like cataphyllary leaves; the euphyllary formation so requisite to the tree is committed to a second order of sprouts, to the little branchlets which bear the two, three, or five-fold bunches of acieulate euphyllary leaves. These, however, produce neither flower nor fruit; it is a new rank of sprouts which produces the staminal leaves (stamens), and again, another which forms the foundation of the cone, on which, as the last formation of sprouts appear the fruit-scales, in the axils of the bracteal scales (hypsophyllary leaves) of the cone. Thus the pine has five qualitatively different orders of sprouts, or, if we count as a separate rank the main-sprout or trunk, differing in its earlier behaviour from the branches which form the crown of the tree, even six.

The most important and interesting point revealed by these investigations, is the *definite order* of *generation* in which the different ranks of sprouts proceed one out of another. Only a small proportion, namely, of (Phanerogamic) plants, reach the goal of the metamorphosis, blossom and fruit, in the first generation; the majority attain this term only in the second, third, fourth, or sometimes not until the fifth generation of sprouts.* Every

* If we include the seed-bud (ovule) as the last generation of sprouts, we have, for all plants which do not possess a "terminal" or "central" ovule, a

vegetable species has its specific law in this, and sometimes even nearly related species are distinguished by their character in this respect;* more frequently, however, the species of a genus, nay even the genera of a family, follow essentially the same order in the production of sprouts. Thus, for instance, the Grasses, Cyperaceæ, Orchideæ, Labiatæ, Scrophularineæ, Primulaceæ, Cruciferæ, Onagreæ, Malvaceæ, Dipsaceæ, and Compositæ, never attain the flower in the first, mostly in the second, but sometimes not until the third generation; the Plantagineæ, as well as the majority of the Seitamineæ, Amentaceæ, and Leguminosæ, mostly in the third; a few of the last, as *Phaseolus*, *Apios*, *Hedysarum coronarium*, and *Trifolium montanum* in the fourth. But this enumeration of the essential generations of sprouts, or, as they may be called, the system of axes of the plant, merely marks the most general outlines of conditions which include an infinite multiplicity of subordinate cases. The number of the axes being equal, they divide, in the first place, according to the distribution of the formations on the axes in question. Especially important in this respect is the behaviour of the last axis, which bears the flower. Whether the last axis sets the flower *immediately*,† or after the preceding formation of a *definite* number of leaves,‡ or, finally, an *indefinite* number of leaves precede the flower,§ are distinctions of importance even as characters of families. But also with like distribution of the formations, further distinctions occur in reference to the region from which the next system of the axes arises; as also, lastly, less essential ones, of great importance however in regard to the habit of the plant, in respect to

still further term in the series of generations, and the really uniaxial plants are then reduced almost to none.

* Note the genera *Echium*, *Arabis*, *Sagina*, *Silene*, *Potentilla*, *Viola*, *Lysimachia*, *Veronica*, &c. See the Ratisbon 'Flora,' 1842, 692.

† Cyperaceæ, Orchideæ, Cruciferæ, Balsamineæ, Primulaceæ.

‡ Gramineæ and Irideæ have one bract (*Vorblatt*); Labiatæ, Scrophularineæ, Lythrarieæ, and Leguminosæ, have two; Gesneriaceæ have three.

§ Polemoniaceæ, *Ligustrineæ*.

the number of the co-ordinate sprouts of each rank, the region and the abundance in which the said formations occur on the various axes, the relative dimensions of these axes, &c. A few examples placed side by side for the sake of comparison, may render these further distinctions more clear.

Paris quadrifolia and *Lysimachia Nummularia*, both have a two-membered chain of sprouts; but the endowment of the two axes is quite different. In *Paris*, i is a cataphyllary sprout creeping underground; ii, brings forth successively a basilar cataphyllary formation, the euphyllary formation, and the flower. In *Lysimachia Nummularia*, i is a creeping euphyllary sprout; ii, immediately produces the flower.

Convallaria majalis and *Convallaria multiflora* have both three-membered series of sprouts, both also have the same distribution of the formations, namely, on axis i, the cataphyllary and euphyllary formation; on ii, the hypsophyllary formation; while iii concludes with the flower. But they are distinguished in the relations of the emergence of the shoots; in *Convallaria majalis*, ii, arises from the cataphyllary region of i; in *Convallaria multiflora* from the euphyllary region. They differ, moreover, in reference to the number of the co-ordinate sprouts, since *Convallaria majalis* possesses only a single sprout of the second generation, thus only one inflorescence; *Convallaria multiflora* numerous inflorescences, but less numerous sprouts of the third generation, *i. e.* only a few flowers in each inflorescence. *Cyclamen* and *Centunculus* both have two-membered series of sprouts, both the same distribution of the formations and the same regions of origin of the sprouts: i, being a euphyllary sprout; ii, blossoms from the axils of the euphyllary leaves. Here the relative dimensions are the principal causes of the very different habit. In *Cyclamen*, i is a tuberous stock; ii, the blossom, on the other hand, has an elongated stalk; in *Centunculus*, on the contrary, i is a delicate little sprout, while the flower is almost sessile.

Plantago major and *Impatiens Balsamina* owe their very different habit, in like manner, principally to the different relative dimensions. In both, i is a euphyllary sprout; in both the ii, hypsophyllary leaf bearing sprouts (the axes of the inflorescences), arise from the axils of the euphyllary leaves; from the axils of the hypsophyllary leaves (bracts), finally, iii, the flowers; but i is a short stock in *Plantago*, forming a rosette upon the ground. In *Impatiens* it is a very much elongated sprout; ii, on the contrary, is a sprout in *Plantago*, especially elongated in the lowest part, and thereby forming the shaft, or rachis, as it is called. In *Impatiens*, on the contrary, it is an extremely short stalk, thus hidden in the axil of the leaf; iii, the flower, is sessile in *Plantago*, and furnished with a long stalk in *Impatiens*. In ii is to be added the distinction in reference to the abundance in which the formation occurs, for in *Plantago* a great number of hypsophyllary leaves exist, laying the foundation of a rich spike; while in *Impatiens* there are but few hypsophyllary leaves, which is the cause of the poverty of blossom in the small axillary cyme.

The complementary relations of the sprouts become still more manifold through the superaddition of a *division* of a *generation*, to the consecutive series of generations, which can start from any generation contained in the vegetable "stock," but in many cases appears even in the first generation, produced by sexual propagation, and then gives rise to the existence of two different complementary "stocks." The latter is the case in all diœcious plants, the former in the monœcious, unless the case occurs of the terminal structures distributed to the two kinds of flowers being attained by a simple series of generations. Cases of monœcia through division of generation, so that one part of the sprouts belonging to the same generation terminates (immediately, or even in the second or third line) with male flowers, another portion with female flowers, occur in *Pachysandra*, *Arum*, *Silphium*, *Calendula*, and *Eriocaulon*, in which the flowers belonging to the same spike or the same capitule, *i. e.* arising from the same parent axis and thus forming only one generation, are partly male (the lower or outer) and partly female. The Hornbeam (*Carpinus*) may furnish an example of a more complicated case. Male and female catkins arise as co-ordinate sprouts from the same parent axis, but the male flowers form the second generation on the male catkins, the female blossoms the third generation on the female inflorescences. The division of the generations occurs therefore here in the last generation but one for the males, in the last but two for the females; the two kinds of catkin are, to a certain extent, themselves again "stocks" upon the "stock," the male "stock" (catkin) with two-membered, the female with three-membered series of generations.* Examples of monœcious condition through mere succession of generations are furnished by many Euphorbiaceæ, for instance, *Euphorbia* and *Buxus*, where the male blossoms are produced as lateral sprouts from the sprouts terminating with female flowers.†

Besides the sprouts which present themselves as essential members of succession of generations and of division of generations, and consequently are necessary to the full carrying out of the series of formations up to blossom and fruit, most plants possess other sprouts, which are not necessarily connected here, and therefore may be distinguished from those hitherto examined, under the name of *inessential sprouts.* In plants which possess terminal flowers, *i. e.* in which the main-sprout terminates in a flower, all the lateral sprouts, however numerous and regular they may be, are to be regarded as inessential. The inessential sprouts *enrich* the "stock" within the annual period of vegetation, if they succeed the main sprout quickly in their development, as is the case, for example, among annual plants (summer plants) with all the sprouts; in herbaceous perennials with the

* It is similar in *Quercus*, only here both the female and the male flowers form the second generation within their inflorescences.

† *Sarcococca* exhibits the reverse.

upper sprouts. If the sprouts remain undeveloped, as buds, until the commencement of a new period of vegetation, they *maintain* and *renew* the plant, while the old "stock," in so far as it bears such buds capable of development, does not die away, as is seen in perennial herbs, half-shrubs, and true woody plants, in which less or greater, merely underground or also an above-ground portion of the "stock" is preserved. This gives the possibility for the plant to rise up in new generations from the same stock, year after year, and thus repeatedly to produce flower and fruit. Finally, if such inessential sprouts become detached, whether by dying away of the old "stock," as in the monk's-hood (*Aconitum Napellus*), the potato, and many bulbous plants; or, the old "stock" persisting, by a natural solution of the connection with it, as in the young plants springing from the runners of the strawberry,—the sprout becomes a new "stock," and appears as a *multiplying sprout*, as a natural *layer*. All these modifications may occur in one and the same plant. Thus the common spurge (*Euphorbia Cyparissias*), exhibits two kinds of *enrichment-sprouts* above ground, namely, in the euphyllary leaf region, the densely-leaved spreading, mostly barren euphyllary sprouts, which give the characteristic fulness to the euphyllary region of this plant; in the hysophyllary region, further, the branches of the umbels arising from the circle of hypsophyllary leaves beneath the small terminal capitules, with further bifurcated and scorpioid ramifications of their branches, forming the rich and finely compound infloresence of this plant. Below the ground, in the cataphyllary region, occur in summer numerous small, reddish-white, little buds; these are the *sustaining* and *renovating sprouts* of the plant, arising with a cataphyllary formation, advanced somewhat in development, and destined to shoot up in the next year and renew the "stock." Other little sprouts, finally, not unlike these, are met with here and there on the branches of the root approaching the surface of the earth, where however they assume an independent character, through forming roots of their own, and sooner or later become detached from the parent "stock," thus presenting themselves as *increase-sprouts* or *layers*.

All these modifications in which the inessential sprouts occur, agree in the circumstance that they represent, in greater or less extension, only repetitions of that which the plant possesses in its essential sprouts. They lie outside the straight line towards the flower and fruit, being interposed laterally, at various heights, as inessential lines of repetition. In many cases the presence or absence of such repetition-sprouts, appears, usually, as something accidental and indifferent to the plant, as for instance, when the tulip stem acquires a branch with a lateral flower. In general, however, these repetition-sprouts are of more importance, and are more necessary to the plant than might appear, so that they must be regarded as in certain respects essential, thus, namely, in reference to the *characterisation* and also to the *economy* of plants.

That the repetition-sprouts are characteristic, is expressed generally by their influence on the "habit" of plants, on the architectural design of the "stock," whether as a whole, or in its separate parts, as in the inflorescence especially. Entering more into particulars we find characteristic features in the arrangement and direction of the branches, in the frequently peculiar arrangements of the leaves and rudimentary traces of such arrangements on the branches, in the laws of curvature of the lines of arrangement of the leaves on rudimentary branches, especially in the laws of antidromy occurring on the branches placed symmetrically opposite to each other, in the relations of the subtending leaves to the branches, particularly the conditions of fusion of the two, &c. A multiplicity of good and important characters would be altogether lost if the inessential branches were removed; nay even the mere presence or absence of certain modifications of them, as of subterranean or above-ground bulbels,* stolons,†

* Thus in the genus *Saxifraga;* in *S. granulata*, and *S. bulbifera.*

† See the genera *Carex, Epilobium, Hieracium, Valeriana, Viola.*

above or below the earth, with or without tuberous structures, spine-branches,* &c., are characteristic of particular species of plants. Thus, in spite of the distinction between essential and inessential sprouts, we must acknowledge, that from a higher point of view all sprouts appear essential. As it is not merely in the last stages of the metamorphoses that the life reveals its peculiarities, since every one of the lower stages also turns outwards a special side of the living essence, not only are those sprouts which bear relation to the attainment of the goal of the metamorphosis to be called essential, but also, everything else in the collective circle of those structures which are destined to represent the plant on all sides, and cannot be removed from that circle without essential interference with the characterisation of the plant. A few examples may render more clear the importance of the inessential or repetition-sprouts in the characterisation of the plant.

The peculiar forms of the crowns of trees, for instance of the pyramidal poplar, of the cypress, depend upon the proportion of the vigour and abundance of the repetition-sprouts to the main sprout or trunk of the tree. The relation of arrangement shows itself more distinctly in many Conifers, where the repetition-sprouts over-leap certain tracts which remain without branches, and form tolerably regular whorls. In *Pinus* the tracts between the larger, whorled branches are occupied by the small (essential) leafy branchlets. Essential and inessential sprouts occur in extremely regular alternation in *Tropæolum minus*, when every third flower-sprout is followed by a euphyllary leaf sprout. When there is $\frac{2}{5}$ arrangement of the leaves on the main-shoot, the euphyllary leaf sprouts derive from this an arrangement according to $\frac{2}{5}$ in the reverse direction. Here also may be mentioned the peculiar cases where the leaves having a many-ranked direction, the branches are nevertheless in distichous arrangement, on account of only part of the leaves pro-

* See *Prunus, Pyrus, Cratægus, Rhamnus.*

ducing branches in their axils, as in the Arbor Vitæ (*Thuja*), and several of the branched Mosses, for instance, *Hypnum abietinum, delicatulum, tamariscinum*, &c. Hence arise pinnate forms of ramification, which frequently stop at a determinate degree of pinnation; as in the three species of *Hypnum* just named, the first is simply, the second doubly, the third triply, pinnate. In the Horse-tails we see a determinate degree of ramification kept to, even in a verticillate arrangement of the branches.* If we take the characteristic branches away from such a plant, it would lose its peculiar "habit." Imagine, for instance, a Tamarisk (*Tamarix*) robbed of its numerous minutely-leaved euphyllary leaf twigs, and the fine bushy, thousand-leaved, pyramidal shrub becomes a simple, meager, naked rod, on which the distant, minute leaves are scarcely visible. Even characters applicable to generic distinction may vanish through removal of inessential branches. All the lateral spikelets of *Lolium* and *Triticum* are inessential, insomuch that a terminal spikelet exists; but with their removal is wholly lost the distinction between the two genera, founded on the different commencement of the branches of these lateral spikelets. Thus also would one of the most important distinctions between the genera *Festuca* and *Bromus* become imperceptible through the disappearance of the panicle-branches, namely, the one-sided direction of the first secondary branch, which principally distinguishes *Festuca* from *Bromus*. But inflorescences above all show most distinctly what important and weighty characters of plants are expressed by mere repetition-shoots. All inflorescences having a terminal flower, evidently consist, with the exception of the main axis of the inflorescence terminating in that flower, of repetition-sprouts; and yet what distinction, what multiformity of structure, exists in these inflorescences! What a distinction, for instance, between the simple raceme of *Menyanthes* and *Berberis*, the umbel of the coriander,

* *Equisetum arvense* and *E. sylvaticum*.

the pyramidal panicle of the lilac (*Syringa*) or the phlox, and, finally, the *anthelæ* of *Luzula* and *Ulmaria*, rendered so remarkable by the strong development of the lower flower branches. But the essential lateral parts of the spiked or racemose inflorescence may be developed to most characteristic forms of the inflorescence, by inessential sprout-formation from the bracts (*Vorblätter*), *e.g.* to the *forked form*, by the equilibrium of a homodromous and antidromous sprout, to the *screwed form* by the predominance of the homodromous, to the *scorpioid form* by the prevalence of the antidromous sprout. All these characteristic forms are produced by mere succession of inessential generations, which proceed one out of the other according to determinate laws, and are frequently intimately chained together into apparently continuous axes (*sympodia*).

Another side, on which the sprouts which have been termed inessential in the foregoing, appear in a deep and essential connection with the course of existence of the plant, is their relation to the economy of vegetable life. Formation of sprouts, generally, especially however the formation of inessential sprouts retrograding to the lowest stages of the metamorphosis, gives the plant the means of attaching itself to the most varied conditions, of persisting through periods of continued cold and heat, damp or drought, according as the climate may produce, and guarding against death in all cases of frustrated seed-formation. Under the varied circumstances which may frustrate the fertilisation, under the readily possible prevention of the formation of seed after fertilisation has taken place, it is of importance, since the proper individual of the plant (the simple sprout) can only once flower and ripen seed, that the "stock" should have the capacity, by another kind of propagation, namely, the formation of sprouts, of repeating the blossoming and ripening, either in the same period of vegetation,—whereby, for example, in every many-flowered inflorescence, any temporary disturbance loses its effect upon the whole through successive opening of the flowers, which is especially important in the case of annuals,—or in a succeeding period of vegetation. The latter condition is particularly important for such plants, as, in consequence of the contrivance of the organs of fertilisation, rarely bear fertile seed, as is the case with most of the Orchideæ,—as also for such as through their situation are often prevented from flowering for a long time, as is the case with many water-plants, when the level of water remains long very high. Thus *Littorella lacustris*, which never flowers under water, maintains and increases itself by lateral runners, year after year, at the bottom of the lakes of the Black Forest, and only comes into flower when the water retreats, in the driest years, which scarcely recur oftener than once in ten. Similar conditions are exhibited by many nemoral plants, as for instance, the woodruff; when the shade of the wood is too dense, or even when too free an opening of the wood interferes with its flourishing above-ground, it maintains itself many years without flowering by subterranean runners, waiting from generation to generation the return of a season favorable to its success. The well-known phenomenon that annual plants almost entirely disappear in the extreme north and in the Alps, likewise deserves to be mentioned here, since it shows how, in proportion as the ripening of seed is endangered by cold, a formation of sprouts adapted to the persistence through the cold season takes place. Lastly, the formation of sprouts is of especial importance for hybrid plants, which as a rule can only be maintained and increased by naturally or artificially detached sprouts. The frequent experience that hybrids of annual or biennial plants, *e.g.* the hybrids of the genus *Verbascum*,* acquire a duration of many years through continued formation of sprouts from the old "stock," is a speaking testimony of the interposition of sprout-formation in cases where propagation by seed is difficult or impossible, since in this instance

* I have observed this phenomenon also in the hybrid between *Œnothera biennis* and *muricata*, not unfrequent in the district of Freiburg.

the longer maintenance of the hybrid form is effected by a sprout-formation, not merely inessential in the sense above denoted, but also quite extraordinary, and altogether absent in the parents of the hybrid.

To these indications respecting the connection of the inessential sprouts with the economy of vegetable life, we have to add also the consideration of certain cases, which completely remove the sharpness of the former distinction, since, as *cases of transition,* they may be taken in two ways. In contrast to the essential sprouts, which, as determinate series of subordinate generations in which the metamorphosis of the plant is carried to its term, represent, according to number, a firmly fixed system of axes, each successive one bringing something new—we have called the inessential sprouts, lying outside the series and indefinite in number, repetition-generations. But cases occur of real repetition-generations, which do not lie outside the line, but belong to the series of transition generations necessary to the attainment of the goal. Here refer the strengthening generations—already noticed above*—of many perennial plants, which in the first year are still too weakly to form flowers and fruit. The fortification to the point of fruitfulness may occur either in the next succeeding generation, otherwise essentially like the first, or deviating only in a retrogression to cataphyllary leaf-formation, and thus in the second year, if every generation is destined to a year's duration,—or, more or less numerous, and then mostly numerically indeterminate, in all essentials completely similar generations, may succeed one another, till at length that age of the "stock" is attained in which it advances to the formation of blossom. The latter condition occurs especially frequently in trees, and indeed most distinctly in those which have no terminal buds, and consequently, in the strictest sense, unfold each new year a generation composed of undoubtedly new individuals (evident lateral buds). Three

* See pp. 29, 30.

examples, very unlike, but agreeing in the conditions here referred to, the asparagus, the lime, and the vine, may be examined a little more minutely, to illustrate this point.

The common asparagus (*Asp. officinalis*) differs from other perennial herbs formerly mentioned which arrive at blossom only through strengthening generations, in the circumstance that it produces several strengthening generations in one and the same year, three or four in fact even in the first year, while in the succeeding years the number of generations sprouting out of one another, in one summer, amounts to eight or ten. The single shoots of asparagus are namely, really so many successive generations, and not as it might appear co-ordinate members of one and the same generation, since the horizontal root-stock is not a continuous axis, but a *sympodium* formed by the chaining together of the basilar portions of the individual shoots. Each succeeding shoot arising from the axil of the second, sub-basilar cataphyllary leaf of the foregoing, hidden in the ground, is related antidromously to the foregoing, like the successive flowers of a scorpioid inflorescence. From the first shoot, arising from the seed, which is the weakest of all, and sends out the second, already somewhat stronger, from the axil of the first leaf after the cotyledon, the shoots produced in scorpioid succession out of each other, in the above-described way, increase in strength till about the fourth or fifth year, when the asparagus has attained its perfect vigour, which remains pretty equal for about fifteen years, and then again gradually decrease with age. A subordinate reaction occurs during this, the last shoots of each year decreasing somewhat in strength. The shoots of the first, and often even of the second year, are infertile, for the asparagus does not usually flower until the third year. Since three or four shoots are produced in the first year, and five or six in the second, the asparagus requires a series of eight to ten generations to strengthen it up to the point of bearing. All generations, both the earlier infertile and the later fertile ones, are essentially alike in all other respects. The first shoot bears, after the cotyledon, a basilar, subterranean, amplexical sheathing leaf, then in the upraised stem distant smaller and narrower scale-like leaves, which might be taken for hypsophyllary leaves if they were not preferably to be regarded as cataphyllary formations, since it is their axils that the aciculate, leafless branchlets, arise, which here, as in *Ruscus*, take the place of the euphyllary leaves. The shoot thus exhibits two essential axes, the main axis with two gradations of the cataphyllary formation, and the leafless lateral branchlets, which represent the euphyllary formation, and are mostly enriched by others similar (inessential), whence arises the tufted arrangement of these last branchlets. These two essential axes are repeated in all the succeeding shoots, only progressively more vigorously and richly through the increased number of leaves on the main axis, and through the occurrence of inessential lateral branches, which repeat the upper part of the main axis, and, finally in the most vigorous shoots produce again lateral twigs of the second, third, or even of the fourth degree, whence arises the stately panicled growth of the asparagus. The essential axes are not multiplied by this enrichment until the flower, which arises on each side from the basis of the branches, appears as the third essential sprout-formation of the asparagus. The bearing shoot of the asparagus has thus three different and essential systems of axes or generations of sprouts, but appears, itself, as a whole, only after a series of generations resembling itself, but barren, which are indeed repetitions of the like, but nevertheless essential preparatory or transition links.

Like the root-stock of the asparagus, the stem of the lime is also a *sympodium;* for the lime, from the first annual shoot of the germinating tree onwards, never produces terminal buds, the stem being developed forth from year to year from the uppermost lateral shoot. The lime, when raised from seed, grows very slowly, and does not flower until it has attained an age of full thirty years; so that the number of necessary strengthening generations is considerable here. When the bearing age is attained, the flower appears in the blossoming generation as the third axial system, since it arises out of the axil of the winglike first leaf of the lateral buds.

The relations of the strengthening generations are much more complicated in the vine. The germinating vine produces first two small leaf-like cotyledons, and then a weak, upright shoot, scarcely a span high, with seven to ten, seldom more, euphyllary leaves, which are arranged spirally according to the $\frac{2}{5}$ or $\frac{3}{7}$ order. It is probable that a weak tendril-formation occurs at the summits of vigorous seedlings, and beyond this an apparently direct continuation from the uppermost euphyllary leaf, as we are enabled to make out more clearly on the shoots of the succeeding year; but the whole of this uppermost portion acquires, in any case, but a very slight development, and dies at the top as the winter comes on.* This first main-sprout of the seedling forms the basis of the so-called *head* (*ceps*, in French), from which arise the climbing shoots (*Reb-schosse*), following in the second year; but these are produced through a peculiar agency. In the axils of the euphyllary leaves, namely, (nay even of the cotyledons,) buds are formed, on which we find, first a cataphyllary leaf, then a euphyllary leaf, and the trace of a tendril, which latter organs, as well as those following further on, are mostly very stunted in their development, or even wither up before fully unfolded, while a new bud is formed in the axil of the cataphyllary leaf, which becomes more swollen than the chief bud, and is protected by its own two cataphyllary leaves (bud-scales). In this

* Unfortunately I have no seedlings of the vine at disposal at present. On those formerly observed I noticed no formation of tendrils, but have seen this in the radical sprouts (suckers), which behave just like the seedlings in the arrangement of the leaves and other respects. The statements as to the conditions of the lateral axes of the first and second year are also derived from the latter. (The supposition mentioned above was not confirmed by later observation. See author's preface, Trans.)

way, if the chief bud is not unfolded, there arises the appearance of two buds placed side by side, one drying up and the other fresh. The stuntedly developed chief-buds are no other than the first "*Geitzen*" of the vine, which are repeated in a more distinct manner in the following years; from the lateral buds, on the contrary, are developed in the next years the first "*Lotten*" of the vine, which at once grow out more vigorously and more slender than the head-shoot of the seedling, and, as the preceding statements indicate, arise from the base of the stunted "*Geitzen*," and not directly from the middle-shoot, thus representing properly a *secundane*, a ramification of the second degree. The "*Lotten*" differs from the head-shoot in many respects; they have never spiral, but always distichous arrangement of the euphyllary leaves; they bear numerous tendrils, or "forks," as they are called; and, what is most important here, a minute examination shows that they are never simple, but linked sprouts, forming a *sympodium*. It is well-known that the tendrils of the vine stand opposite to the euphyllary leaves; this is explained by the fact that the tendril, as the temporary apex of a sprout, becomes turned towards the side by the succeeding sprout, arising from the axil of the uppermost euphyllary leaf, while the new sprout is attached upon the euphyllary region, as an apparently direct prolongation. Another point especially worthy of remark in this is, the regular alternation in the character of the sprouts linked together to form a "*Lotte*," occurring after the first member of this series of sprouts. The first sprout with which the "Lotte" commences is different from all the succeeding, since it commences with a cataphyllary formation (with the two basilar bud-scales, visible even in the first year), and after this produces mostly more than two (3—5) euphyllary leaves, before it terminates with the formation of the tendril. The tendril, like all the succeeding tendrils, bears a hypsophyllary leaflet, from the axil of which arises a branch, which gives the tendril the well-known forked form. All the succeeding sprouts (members of the series of generations of the "Lotte") are added upon the foregoing without repetition of the cataphyllary formation, and possess alternately one and two euphyllary leaves before the transition to the formation of the tendrils. From this arises quite a peculiar arrangement of the tendrils, which are arranged distichously, but in such a manner that two successive tendrils always fall on the same side, since every third leaf of the "*Lotte*" is without an opposite tendril.* It is further to be remarked, that the imposition of the distichous arrangement of the leaves occurs with *prosenthesis* on the first or basal sprout of the "*Lotte*," while all the following commence without *prosenthesis*; hence arises the uninterrupted continuation of the distichous arrangement of the euphyllary leaves, through the whole chain of sprouts of the "*Lotte*," while at the origin of the "*Lotte*" occurs a crossing of the ranks with the subtending leaf (the basilar cataphyllary leaf of the "*Geitz*." In the axils of the euphyllary leaves of the "*Lotte*" new buds are formed, unfolded more or less perfectly during the course of the summer, and representing the branches of the "*Lotte*," which have a connection similar to the "*Lotte*" itself, *i. e.* are in like manner chains of sprouts. They are weaker than the "*Lotte*" from which they arise; very often only very poorly developed, especially on the lower parts of the "*Lotten*." These are the true "*Geitzen*" of the vine, which we met with in a yet almost irrecognisable condition of development on the principal shoot. They form the second annual series of generations, and are distinguished from the "*Lotten*" by their basal sprouts possessing constantly only one cataphyllary leaf and two euphyllary leaves. Although all "*Geitzen*" are of similar nature, they originate in two ways, part, namely, are primary axillary sprouts (those from the axil of the lower euphyllary leaf of the two-leaved joints of the "*Lotte*"); part secondary (accessory) axillary sprouts

* I have found this constant, not only in *Vitis vinifera* but also in several American vines.

(those from the axil of the upper leaf of the two-leaved and of the single leaf of the one-leaved joints of the "*Lotte*"). Therefore, on the two-leaved joints of the "*Lotte*" the secondary sprout from the upper leaf-axil behaves like the primary sprout from the lower, while it is essentially different from the primary sprout of the upper, since the primary sprout (which carries on the *Lotte*") is added on without a cataphyllary leaf and without *prosenthesis*, and the secondary sprout (which forms the "*Geitz*") begins with a cataphyllary leaf and with *prosenthesis*. The "*Lotten*" grow all through the summer, and often on until late in autumn, forming a chain, endless in its nature, which is only forcibly broken off by the commencement of winter. I have counted as many as twenty-six constituent joints (thus twenty-six tendrils and about forty leaves) in strong "*Lotten*." The "*Geitzen*" also die away at the point in winter; the weak and late developed often even down to the base, so that only the cataphyllary leaf with its axillary bud remains. This lowest part of the "*Geitz*" is of especial importance. In the axil of the basilar cataphyllary leaf of the basal-sprout of the "*Geitz*," is found a bud (as stated above, in describing the condition in the first year); this bud begins with two firmly-connected cataphyllary leaves, and endures through the winter in the closed condition. It is this resting-bud from which the series of generations of the "*Lotte*," and indirectly the formation of "*Geitzen*," is repeated in the next year. It is, therefore, first of all a "*Lotte*" bud, and, if the vine has attained the proper age, which is usually in the fifth or sixth year, at the same time a bearing bud, since the inflorescence appears at the lower parts of the "*Lotte*" in place of the previous tendril-formation. In this case numerous hypsophyllary leaves occur in place of the single hypsophyllary leaf of the tendril, and the axis ends in a terminal flower; by graduated ramification from the axils of the hypsophyllary leaves arises, then, the richly panicled blossom of the grape, which, in opposition to ordinary botanical language, is commonly called a "*traube*" (raceme).

When we seek to separate the essential and inessential sprouts, in this complicated biography of the vine, which could only be given in very rough outline here, we might be inclined to see in the repeated succession, not of mere simple generations, but even of whole chains of generations, as occurring in the "*Geitzen*" and "*Lotten*," clearly essential arrangements of sprouts, because the same are necessary transitional links to the attainment of flower and fruit; but if we take the essential succession of sprouts, in the sense explained in the preceding pages, as a series of partially endowed, reciprocally complementary sprouts, we must rather acknowledge that the vine is essentially only *uniaxial*, since it produces all the essential stages of metamorphosis on one axis, as we see them represented in the basilar sprout of the fertile "*Lotte*," which includes cataphyllary, euphyllary, hypsophyllary, and flower formations. All the rest of the members of the succession of sprouts are either preparatory representatives of the same series of formations not fully attaining the goal, or imperfect repetitions of these. But how characteristic is this varied rise and repetition, this linking into a complicated succession of sprouts, in the developmental history of the vine, and how essentially it lays down the conditions under which this plant can live and grow! It is true that if we compare the ordinary methods of cultivation, adapting the vine to our conditions by systematic crippling, we might wonder at the abundance of superfluity which the vine annually produces. The "*Geitzen*" are carefully broken off, and the long luxuriant "*Lotten*" cut back to a few joints! In the south, on the other hand, when the vine appears as a widow, when not supported by the lofty elm, we see how this superfluity essentially belongs to the economy of the vine; when left to its freedom, it twines itself over the highest trees.

Thus, then, we see that much as the law of superfluity prevails in the formation of sprouts in plants, as it does everywhere in nature, yet all formation of sprouts, the inessential no less than the essential, possesses a determinate relation to the maintenance and progressive development of the plant. From the consideration of the sprouts as individuals, the vegetable "stock" must appear to us as the living trunk of a family, rejuvenised and increased according to determinate laws of propagation, the differently gifted members of which family we have endeavoured in the foregoing, though only in mere indications, to represent, as arranged according to descent and collateral relation, in their either closer (direct) or looser (indirect) relation to the destination of the whole.* And thus may the import of sprout-formation become clear, as a subordinate propagation, subserving the individual destination in its wider sense. The undeniable interweaving of propagation and development within this circle, may at the same time form an acceptable guide to the destination of the individual in the larger circle of the species, as well as that of this again in the totality of the series of organic creation,† which has already been referred to in the Introduction.

II.—LEAF-FORMATION.

From the Rejuvenescences which the plant experiences through formation of sprouts, by which the subject (or theme) of the plant is many times repeated and variously distributed on the "stock," in subordinate individual

* The study of sprouts is the broadest and fairest field in Morphology, but as yet, unfortunately, the least cultivated. What C. Schimper long since accomplished in this department, but has not yet published, I have already mentioned in a public lecture on "the Vegetable Individual," which I shall print after this discourse. The phenomenon of the essential and necessary succession of sprouts long known in the vegetable kingdom, agrees completely with that occurring in the animal kingdom, the so-called alternation of generations, brought into its true position chiefly by Sars and Steenstrup. I have shown this by a detailed comparison in the above-mentioned lecture.

† Victor Carus has given important hints upon the analogy of the alternation of generations with the succession in the series of organic beings, in his before-mentioned Essay 'Zur Näheren Kenntniss des Generations wechsels,' p. 54.

structures, we pass to the examination of the phenomena of Rejuvenescence in the individual sprouts themselves. The single links of Rejuvenescence which we meet here, are the leaves built up successively one above another, separated and at the same time held together by stem-formation, forming, as it were, the persistent waves of the vegetable life, flowing towards its goal in alternating rise and fall, concentration and expansion. But before considering these separate Rejuvenescence-waves of the sprout, represented in the formation of leaves, we must examine the greater, upward-striving periods of the metamorphosis (which contain the smaller waves within them), as they manifest themselves in the conditions of the successive leaf-formations.

Previously, however, to tracing the great tide of the ascending metamorphosis and its subordinate waves, we will connect this entire section with the preceding, by a minute examination of certain cases of *descending* and *vibrating* metamorphosis. It has been remarked above, that not every sprout carries the metamorphosis towards the goal, that in fact not merely a normal persistence at particular formations occurs, but in certain sprouts even a retrogression.* By such a retrogression the sprout recurs, as it were, to the commencement of its theme, becoming renovated and rejuvenised in repetition of the impulse, but giving up as a prey to age the relinquished product of the earlier period of growth. In fact Rejuvenescence of the sprout itself bears great resemblance to the Rejuvenescence by the formation of new sprouts; indeed, in a physiological point of view, and in reference to the vital economy of the plant, these two kinds of Rejuvenescence are of equivalent import. Both stand related in the same way to the periodicity of the seasons, in both cases is seen the same independence of the new formation of the foregoing structures. As in the formation of lateral sprouts, the chief sprout from which

* See page 31.

they are sent out either dies (*Solanum tuberosum, Saxifraga granulata*), or becomes a mere supporting and subservient scaffold, to a certain extent a *soil* for the new generation, so in the Rejuvenescence in the sprout itself, we again find these two cases, since the fore-running part of the sprout sometimes dies away, sometimes becomes the support of the rejuvenised continuation. The first case is seen in all root-stocks dying away at the posterior end,* as also in bulbs† dying away externally and becoming rejuvenised in the centre; the latter we find especially in woody plants which possess terminal buds. On the other hand, there is the essential distinction, in morphological respects, between the two cases here compared, that in the one case the renovated vital movement is undertaken by really new individuals (lateral sprouts), while in the other cases the same individuals (the old sprouts), rise up to new vital activity, which distinction has already been remarked upon above, in the introductory consideration of the buds.‡ Moreover those sprouts which are incapable of advancing to the uppermost stage, do not in all plants possess the power of Rejuvenescence through retrogression to a lower stage of formation, *i. e.* the power of forming terminal buds destined for the succeeding period of vegetation; this is rather, indeed, a privilege of but a few perennial herbs with subterraneous perennial stocks, and of a portion of the woody plants.§ Among those which possess this power, again, two cases have to be distinguished: either

* *Anemone nemorosa, Epimedium alpinum.*

† *Narcissus,* for example. The terrestrial species of *Isoëtes,* particularly *I. hystrix* and *I. Duriæi,* afford an especially fine instance of this kind. See my description of them in the 'Exploration Scientifique d'Algerie.'

‡ Distinction of lateral and terminal buds, pp. 18-20.

§ Formation of terminal buds does not occur, for instance, on the middle leaf-bearing chief sprout of *Urtica urens* and *Mercurialis annua;* since these plants are also devoid of lateral buds, they die away altogether after the fruit is quite matured. *Urtica dioica* and *Mercurialis perennis* die down only to the cataphyllary region, from which arise the cataphyllary sprouts lasting over the winter. *Carpinus, Salix, Ulmus, Morus, Maclura, Tilia, Diospyros,* and *Calycanthus,* are examples of woody plants without terminal buds.

the sprout, after many years' vibration, runs through, as it were by a fresh impulse, to the goal, and thus concludes its growth, or it sinks back again to infinity, after each new flight upward. Both kinds of behaviour are represented not only among woody plants, but also among perennial herbs and bulbous plants. In *Quercus*, *Fagus*, *Populus*, *Xylosteum*, and *Camellia*, all the cuphyllary sprouts return at the tops to cataphyllary formation, continuing their growth in the following year from the terminal bud, with a new cuphyllary shoot. They acquire by this the power of infinite growth, which indeed finally finds obstacles in old trees, but is made good by taking off slips and grafts. If we compare with these, *Acer*, *Æsculus*, *Juglans*, *Rhododendron*, &c., we find the same condition during a more or less extensive series of years, but at last, when the growth has elevated the plants sufficiently above the earth, the shoot is sufficiently invigorated and limited by repeated periodical renovation. It does not return to the formation of cataphyllary leaves, but advances to the formation of the inflorescence (with or without a terminal flower), and then comes to the end of its growth. In *Juglans*, only, the female inflorescence is attained in this manner, while the male catkins appear as lateral branches. *Rhododendron* is remarkable, from the fact that the terminal shoot of the sprout, which appears (on branches of full-grown "stocks") mostly in the third year, consequently after two intermissions (*Absätze*) with cataphyllary and cuphyllary formations, overleaps the cuphyllary formation, and passes at once from the cataphyllary leaves (bud-scales of the last terminal bud) to hypsophyllary formations, the bracts from the axils of which the flowers arise. Side by side with the first-named examples (with infinite rising and sinking Rejuvenescence), we may place *Hepatica*, *Adoxa*, and *Oxalis Acetosella*, from among the perennial herbs. The *Hepatica* every spring produces a bud composed of eight scale-like cataphyllary leaves, followed by three cuphyllary leaves; after this, it recurs to the formation of a similar terminal bud. The flowers arise laterally from the axils of the cataphyllary leaves. The *Adoxa*, on the contrary, creeps along under ground with a slender stem, rising above the surface every spring to bring forth, after an indefinite number of small, tooth-like, cataphyllary leaves, one to three (mostly two) long-stalked euphyllary leaves, from the axils of which arise the flowering stems, with two smaller, sessile, euphyllary leaves, and the head of flowers. Between the two long-stalked euphyllary leaves the stem recommences its growth as a descending runner, repeating the same process in the following spring, and so on, *ad infinitum*. *Helleborus niger*, *Anemone nemorosa*, *Epimedium*, *Actæa*, and *Pyrola*, may be mentioned as examples of another kind of growth. I will describe the first two somewhat minutely, for comparison with *Hepatica* and *Adoxa;* the short ground-stem or root-stock of the black hellebore annually produces one single euphyllary leaf, which is succeeded by a terminal bud of two to four cataphyllary leaves. After alternating in this way for four or five years, the euphyllary formation is skipped over,* or only imperfectly indicated, and the plant attains the hypsophyllary and floral formations, and then rises up above the alternating euphyllary and cataphyllary leaf regions through the elongation of the flowering stem. In like manner, *Anemone nemorosa* prolongs its creeping, subterraneous growth, with alternations of euphyllary and cataphyllary formations, for several years before it arrives at flower terminating the shoot. The number of annual cataphyllary leaves on the horizontal rhizome increases from year to year, rising gradually to eight, and each of these preparatory sections terminates with a single long-stalked euphyllary leaf, till, finally, the last section, after producing its proper number of cataphyllary leaves, rises into an upright shaft, producing the three-leaved whorl of euphyllary leaves and the nodding flower. Among

* As in *Rhododendron* (see above) and *Pyrola*.

bulbous plants, the narcissus and its allies, the snowdrop, on the one hand, the tulip and onion (*Allium*) on the other, may furnish examples. *Narcissus poeticus*, when arrived at a flowering age, annually produces a sheath-like, closed, cataphyllary leaf, and four euphyllary leaves, the last of which, bearing the flower in its axil, is devoid of the embracing sheath of the preceding. As long as no axillary flower is produced, the innermost euphyllary leaf of the annual cycle possesses a sheath. *Leucojum vernum*, similar in other respects, has only three euphyllary leaves, the middle one being that which bears the flower, and is devoid of a sheath; the third, which has again a sheath, is thus already on the retreat back to the cataphyllary formation. In *Galanthus nivalis* the annual cycle is composed of one cataphyllary leaf and two euphyllary leaves, the upper of these two being without the sheath, and with a flower. While in the heart of the bulb of this plant one annual cycle succeeds another in an infinite series, the product of the earlier years dies away, *pari passu*, at the periphery of the bulb, since not only does one sheath after another dry up and moulder away, but also the base of the axis of the bulb throws off the superannuated part by exfoliation. The old circles of roots are also thrown off, and replaced by new. The tulip displays a different character. While in the narcissus the flower arises as a lateral sprout, in the tulip the heart of the bulb itself shoots up, after mostly three tubularly closed cataphyllary leaves, into a flower-stem with euphyllary leaves. But before this happens, the development alternates for several years with cataphyllary and euphyllary formations, annually sending above ground only one euphyllary leaf, and then returning to cataphyllary formation in the centre. With this frequently occurs the remarkable case, that, in buds not yet arrived at sufficient maturity to produce flowers, the central bud of the bulb sinks down into a descending spur, formed out of the inclosing base of one of the preceding leaves, in this way leaving the old bulb and descending deeper into the bosom of the earth.*

A retrogression from the hypsophyllary formation to the euphyllary, or even to the cataphyllary formation, is far more rare than the periodical sinking from euphyllary to cataphyllary formation. *Ananas* affords a normal and universally known example of this case, the summit of the inflorescence returning to the euphyllary formation, attaining complete Rejuvenescence in the "crown," as it is called, and when this is removed and planted producing new blossom and fruit in the third year. The same phenomenon is exhibited by the New Holland genera of *Myrtaceæ*, *Melaleuca*, *Callistemon*, *Beaufortia*, and *Calothamnus*, the brush-like spikes of which owe their strange "growing-through," or innovation, to a similar recurrence to the formation of an euphyllary shoot from the end of the hypsophyllary region. What are called the viviparous grasses, *e. g. Poa bulbosa* and *P. alpina*, which occur only in this condition in many places, and behave like *Ananas*, might appear as paradoxes, but here it is really the hypsophyllary region which is made into an euphyllary region by a retrogression;† and the tufts of euphyllary leaves arising in this way subsequently become detached, to recommence the ascending development as independent stocks. At the same time the behaviour of these grasses is not that natural to the species, but that of a monstrosity become a variety. Leafy shoots occur not unfrequently, as a mere accidental monstrosity, at the summits of inflorescences: I have seen them especially fine in *Plantago lanceolata*, where the leafy shoot at the end of the spike became developed into a new perfect stock. Even in flowers, retrogression of this kind occurs as a malformation; well-known garden examples are

* This is not the place for a minute description of this strange phenomenon. The description of it given by Henry, 'Nov. Act. Cur.,' vol. xxi, p. 1, leaves some questions still open, which I shall take up at another opportunity.

† The lowest glumes of the spikelets are mostly unaltered here, many of them even having flowers in their axils. Vide Mohl, 'Bot. Zeit.,' 1845, p. 33, t. i, fig. 2.

furnished by the roses, where the stem grows onward through the middle of the flower, and the *Digitalis purpurea monstrosa*,* in which the terminal flower is grown through in the same way. The female head or cone of *Cycas* may be regarded as a flower normally grown through, with a retrogression from the (certainly very imperfect) carpel-formation to the cataphyllary and euphyllary formations. In *Cycas*, before the age of blossoming, girdles of scale-like cataphyllary leaves alternate in regular order with girdles of pinnate euphyllary leaves, which latter at all times form the crown of the tree. This alternation has, in our botanical gardens at least, a biennial period, so that the crown of euphyllary leaves undergoes Rejuvenescence every two years. When the fruit-bearing age arrives, this alternation becomes more complicated, the order being as follows: 1, a zone of cataphyllary leaves (forming before the unfolding of the succeeding parts a large, shortly conical, terminal bud); 2, a zone of euphyllary leaves; 3, another zone of cataphyllary leaves; 4, a zone of spathulate seed-bearing leaves (carpels), originally packed together in a conical form, afterwards spread out. In the centre of this head or cone, representing the female blossom, is formed a new cataphyllary bud, with which begins anew the whole cycle of Rejuvenescence, and this is repeated as long as the tree exists.†

I will not close the examination of these points without remarking, that such periodical Rejuvenescence connected with the alternation of the seasons, is not always combined with so decided a retrogression of the metamorphosis as in the above-mentioned examples. The retrogression to cataphyllary formation, in particular, is very frequently absent (but not universally) in the trees of more southern regions, in which the place of transition from one yearling shoot to another is merely marked by

* Vide the 'Flora,' 1844, No. 1, t. i.

† Vide Rheede, 'Hort. Malabar,' iii, t. xiii, xx, especially t. xvii, where this growing-through of the female blossom is represented.

smaller euphyllary leaves, as for example in numerous New Holland *Myrtaceæ*, as also in the South European myrtle. While our firs and pines annually retrograde to cataphyllary budding, we find the limits of the yearling shoots of the more southern Conifers of the genera *Araucaria* and *Cunninghamia*, marked merely by smaller euphyllary leaves. Many evergreen plants, however, of our own climate, exhibit an exactly similar behaviour, as for instance, *Juniperis communis* and *Lycopodium annotinum*, in which the yearly lengths are only to be detected by contracted places on the closely-leaved shoots. Among herbaceous plants, *Lysimachia Nummularia** and *Isnardia palustris* belong here, these prolonging their creeping stem by a considerable piece every new year, while the lengths of the previous years die away. *Veronica Chamædrys* has the peculiarity herewith, that the euphyllary shoot, from which the inflorescences go out laterally as second axial systems, is erect until the time of flowering, and only bends down its elongating end to the earth after the plant has flowered, striking root then to ascend again in the following year and bear flowering branches.† In *Glechoma hederacea*, also, the shoots which are erect until the time of flowering, turn back, at least in part, towards the ground, not however to ascend again in the next spring, but to send only branches upward.‡

The simplest mode in which the periodical Rejuvenescence presents itself to us, is that in which the same sprout annually produces only *one* new leaf. Thus in the brake fern (*Pteris aquilina*), which annually sends forth from its subterraneous creeping rhizome only one of its distichously-arranged leaves, not unfolded until the third year, an euphyllary leaf, often of enormous size, and pinnatifid in beautiful gradation up to the fourth degree. So again in the *Ophioglossum*, already mentioned § above, and at all events in our greenhouses the

* Vide A. de St. Hilaire, 'Leçons de Botanique,' p. 103.
† Ibid., p. 105.
‡ Ibid., p. 105. § See ante, p. 18.

large-leaved *Coccoloba pubescens*. These cases lead to the individual leaf, as a link of Rejuvenescence, the investigation of which, however, must be preceded by the consideration of one point more.

The rejuvenising force and activity of vegetable life does not display itself merely in the particular cases of periodical, retrogressive, or alternately advancing and receding metamorphoses, such as we have just examined; it shows itself also in the *ascending metamorphosis*, in the advancing series of formations, such as occur as the universal types in the higher divisions of the vegetable kingdom. Here occurs, in the closest connection with the progress from stage to stage, an alternation of vigorous advance and checking retraction, an increase, a decrease, and a renewed rise of the energy of the outward representation, a Rejuvenescence in the truest sense of the word, since here with every new onward flight of the old being, the plant appears not in mere repetition of the old form, but by deeply grounded renovation, in a more perfect and more expressive shape. This it is which, since Goethe's time,* has been called the *metamorphosis* of plants, a term borrowed from the transformation of insects, which has however given rise to mistaken views,† but is capable of being made the basis of a more profound conception of the phenomenon. Goethe himself, although his theory of metamorphosis is mixed up with various obscure elements, pointed out many features of the more profound side of the question. He speaks of the metamorphosis of plants not merely as of a series of outward phenomena of transitions between the different structures, but as of an inward principle of the formative process advancing from one modification of form to another. In his eyes the metamorphosis was a force which might be observed ever acting with a graduated power

* 'Versuch die Metamorphose der Pflanze zu erklären,' Gotha; 1790.

† That Goethe was not even free from the erroneous notion that one organ of a plant might be actually transformed into another, *e. g.* stamens into petals, or ovaries into leaves, is evident from the very first paragraph of his Introduction.

from the first seed-leaves to the final maturation of the fruit, and, by the conversion of one form into another, leading up to the highest point of vegetable life, as it were, by an ideal flight of steps.* This ideal flight of steps which Goethe perceived in the metamorphosis of plants, is a speaking testimony of the profound conception of it entertained by him; for that which leads the formative process of the plant from one stage to another, which connects the steps of the series, which causes each succeeding step, although separated from the preceding, to appear as a stage of conversion of the latter, can in reality be only an inner and ideal bond. Only the inner identity of the nature of the plant, through all the change of outward manifestations, can justify us in regarding the gradually advancing Rejuvenescences as really a metamorphosis, that is, a series of transformations of an essentially identical element. In this sense Goethe speaks, too, of the mysterious affinity of the different external organs of plants, pointing out that the real identity of the organs corresponding to each other at the different stages can indeed only be deduced from that inward connection of the steps of the metamorphosis, and not from mere outward resemblance.

Goethe already directed attention to the great vibrations of the metamorphosis which we here first examine, since he speaks of an alternation of expansion and contraction in the successive leaf-formations.† This is one of the most important factors in his attempt to explain the metamorphosis of plants; for a minute discussion of which, however, it is necessary that we should cast a hasty glance over the series of the leaf-formations them-

* Vide Goethe, l. c. § 6.

† Goethe, l. c. "From the seed up to the highest development of the stem-leaf, we observed first an expansion, after which we saw the calyx arise from a contraction, the petals from an expansion, the reproductive organs by another contraction, and shall now soon make out the greatest expansion in the fruit and the greatest contraction in the seed. In these six steps Nature completes, without pausing, the eternal work of the propagation of vegetables."

selves. The metamorphosis of plants exhibits three principal divisions: 1, the "*stock*," or as it is termed in plants not forming wood, the *herb* (*kraut*); 2, the *flower;* 3, the *fruit*. The first two divisions are again divisible each into three stages, while the third principal division does not admit of further analysis. Thus we obtain from 3+3+1 the number 7 for the stages of form in plants. The character of these seven sections or regions is chiefly expressed in the graduated change of shape of the leaf, while the stem takes a less striking, though still considerable share in the transformation from step to step. We shall therefore consider the steps of the metamorphosis more particularly in regard to the behaviour of the leaf, as it presents itself at the different heights upon the plant, applying to the more essential gradations which are distinguishable the denominations of so many *leaf-formations*. As a general rule, as already stated, there are seven of these, which, however, do not exhibit perfect representatives in every plant, for their number may be lessened either by imperfect differentiation, or by falling short of or overleaping forms.

1. The *cataphyllary* formation (*Nieder-blatter*), to which belong the scales and sheathing leaves of subterraneous or aërial buds, bulbs, runners, and tuberous rhizomes. They are remarkable from their broad basis, small height, and most simple shape and nervation;* they have no laminæ, no stalks, no subdivision,† consequently never have stipules, and are constantly entire. Their consistence is often fleshy, cartilaginous or leathery, in

* In dicotyledonous plants even these are mostly parallel-nerved, and the parallel-nerved appearance of the euphyllary leaves of the monocotyledons is but a sign that the euphyllary leaf-formation is less characteristically developed in them, and hence is more like the cataphyllary formation than is the case in the dicotyledons.

† There are exceptions to this in the cataphyllary-leaves separating into two distinct scales, in the buds of certain trees, *e.g.*, *Betula*, *Carpinus*, *Corylus*, *Fagus*, and *Quercus*. This structure may be regarded as a transition towards the euphyllary-leaf formation, the leaf being here divided into two stipules and an abortive central leaf. In *Quercus* the first bud-scales are still undivided. These conditions are described by Doll,—'Zur Erklärung der Laubknospen der Amentaceen,' 1848.

rare instances they are delicately membranous, in which cases the axis which bears them is mostly fleshy; their colour is never a decided green, generally whitish, passing into yellow, flesh-colour, brownish, or even black. Their development goes on very slowly; they are tolerably enduring, and the chief part of their existence is passed in the winter season.

2. *Euphyllary* formation (*Laub-blatter*).—These are the organs, especially and ordinarily simply called "leaves," which give most character to the vegetative structure or *stock*. They are readily distinguished from the leaves of the preceding formation by the greater longitudinal development with a narrower base, in general more considerable dimensions, and the green colour, never absent although in many cases concealed. Their especial mark is the blade-structure, with which is ordinarily combined its contrary, the stalk or petiole structure. Through multifold alternations of the conditions of expansion and contraction arises the so frequent production of divided and compound euphyllary-leaves, to which also belongs, as a special case, the division into main-leaf and accessory leaves (stipules). The multiplicity of conditions of nervation within the body of the blade, corresponds to the multiformity in the outline of the leaf. The consistence is mostly stoutly membranous, frequently leathery, more rarely fleshy. The principal part of the life is passed in the summer; the duration is considerable, especially in those of fleshy or leathery consistence.

3. *Hypsophyllary* formation (*Hoch-blätter*), to which belong the involucral leaves and common calyces of inflorescences, bracts and bracteoles, glumes and paleæ, which accompany the flower. These again approach in character the cataphyllary leaves, as the stalk and blade-structures, as well as the green colour, vanish more or less or even quite completely.* They are distinguished from

* Stalked hypsophyllary-leaves are a rarity, *e. g.*, in *Podolepis;* the formation of a stalk occurs more frequently above the sheath-like part of the leaf, as for instance, in the formation of awns on the glumes of the grasses.

the cataphyllary-leaves chiefly by the narrowness of the base, more delicate structure, and more rapid formation and decay.

4. Formation of the *calicine-leaves* (*sepals*). These form the first proper envelope of the flower, and are again thicker, tougher, and greener than the upper-leaves, mostly have a broader base, little or no laminar expansion, no stalk-formation, and are either simple or but slightly divided.* They are mostly more enduring than the succeeding formations of the flower, they often outlive these, and frequently take part in the formation of the fruit.

5. Formation of the *coralline-leaves* (petals), strikingly characterised by delicacy of texture, beauty and variety of colour, with the exclusion, however, of green. As a rule, they are longer than the sepals, but have a narrower base; mostly exhibit an extensive laminar portion but no distinct stalk-structure, often radiant or forked, but very rarely pinnate, division.† Excrescent growths doubling the limb or laminar structure (*emergences*) sometimes occur upon the surface of the petal, as in *Narcissus*, *Nerium*, *Lychnis*, or longitudinal wing-like edges, as in *Saponaria*, *Agrostemma*, and the Hydrophyllaceæ.

6. Formation of the *pollen-leaves* (stamens), comprising the smallest and thickest leaves of the flower, characterised by distinct stalk-formation (*filament*) from the narrowest base, with a box-like expansion of the lateral halves of the little developed blade (*anther*). Folding over of the blade (*Ueberspreitung*), which occurs but rarely in the petals, is here almost an universal rule, whereby the chambers of the anther become doubled on each side. They are distinguished above all the other parts of the flower by the most rapid completion of the

* Sepals with pinnæ (*Rosa*), with stipules (*Peganum*), or with a ligule-structure (*Mesembryanthemum*), are rare exceptions.

† Ex. gr. *Schizopetalum*. *Drummondia*.

structure, and the greatest perishability after the opening of the blossom.

7. Formation of the *Fruit-leaves* (carpels). These are again larger, thicker, greener than preceding parts, but especially distinguished by the permanent folding together, passing into confluence. Springing from a narrow base, the lower part expands like a blade, forming the cavity of the fruit by closing together its own borders or coalescing with the neighbouring carpels, while the upper part is mostly drawn out (stalk-like) into the style. From the inside of these leaves arise the little seed-sprouts (ovules), so that they become the cases of the seeds, running through with these a process of development (maturation), prolonged far beyond the life-time of the flower, and often requiring even more than one year for its completion.*

To those who have studied Comparative Morphology in an unprejudiced manner, there can be no debate on the question as to whether all the structures of these seven formations are really leaves. On this side the theory of metamorphosis stands on a firm and unshakeable foundation.† But the structure which is to be erected on this foundation, the theory of the formations, giving the true representation of the vital history of the plant as it is displayed in the successive transformation of similar fundamental organs, is as yet unfortunately scarcely dimly shadowed forth. It is a problem which appears so much the more difficult the nearer we try to approach to its solution, for it then is not sufficient to mark the characters

* The ripening of the fruit and seeds occupies two seasons in many Conifers (*Juniperus communis*, *Pinus*,) and many oaks (*Quercus Cerris*, *Suber*, *rubra*, &c.)

† Wigand ('Kritik und Geschichte der Lehre von der Metamorphose der Pflanzen,' 1846, p. 118,) very correctly calls "the great law of the unity of all axial and of foliar organs," the nucleus of the doctrine of metamorphosis, remaining behind when we have subtracted the multifold and strange clothing with which it is ordinarily enveloped. On the other hand, the problem of giving to the discovered nucleus its true natural investments, does not appear to be sufficiently recognised. Multiplicity will not be wanting in the *true* clothing, and we shall certainly have to own to strangeness and oddity in nature.

of the formations by comparison of external forms, which, from the multiformity prevailing in the vegetable kingdom, is an endless task; for the true characteristic of the formations must be at the same time an inward one: it must comprehend the outward product in its relation to the inner vital tendencies, entering into conflict with the external world,—and thereby endeavour to represent to us the developmental history of vegetable life according to the inner causes leading through all the external complications. That the above short description of the leaf-formations can make no claim to such a character as this, need not be said; it is merely intended to bring forward a few peculiarities calculated to make evident the regular alternation of rise and fall in the course of metamorphosis, its successive "accessions" or "flights" (*Aufschwünge*), which we desire to examine here as phenomena of Rejuvenescence. The peculiarities which we have chiefly to keep in view here are,—the relative size of the leaf in general; then, in particular, the breadth of the base in proportion to the circumference of the stem; the height or length of the leaf; the development in breadth above the base (the lamination), and its opposite, the contraction into stalk-formation, on the contrasted proportions of which chiefly depend the further working out of the forms of leaves; finally, the solidity or delicacy, and the persistence or caducity. Even the most superficial examination reveals clearly that the path through the formations from "stock" to flower, and again from flower to fruit, does not ascend uniformly, that it does not exhibit either an uniform decrease in the perfection of the organs, or an uniformly increasing refinement of their structure. The assumption of a single rise and fall in the perfecting of the leaf-formations, the highest point of which should fall in the middle (the euphyllary formation), is equally opposed to experience, for even the flower, and still more the fruit, contradicts this view.* It is, indeed,

* Agardh goes so far on this false hypothesis, as to regard the higher

unmistakeable that the leaf-formations take three successive onward flights (*Aufschwünge*) in the course of the metamorphosis: one in the stock or body of the plant, one in the flower, and, finally, the last in the fruit. A close investigation of this phenomenon shows, that there are also subordinate risings and sinkings even within the first and second regions of elevation.

If we examine, in the first place, in reference to this point, the conditions of breadth of the base of the leaf, we find on the stock or stem of the plant, from the first to the last of its leaves, a decrease, sometimes gradual and sometimes taking place by starts, and this decrease is indeed so constant, that perhaps every exception might be traced to the phenomenon of retrogressive metamorphosis examined above, although it is not equally obvious in all.* But with the advent of the flower a new increase of the breadth of the base of the leaf frequently occurs, the sepals exhibiting a broader base than the highest

development of the fruit consequent on fertilisation as a pathological condition, a disease. (!) 'Essai de réduire la Physiologie végétale à des principes fondamentaux,' 1828, pp. 32, 38.)

* Among these exceptions is the condition of the cotyledons in the numerous dicotyledonous plants in which the opposite half-embracing cotyledons or seed-leaves are succeeded by alternate, more extensively embracing euphyllary-leaves, or wholly or almost wholly embracing cataphyllary-leaves, which latter is the case, for instance, in *Asarum*. In the monocotyledons, on the contrary, the seed-leaf is always completely amplexicaul. There appears, moreover, a strange case in *Convallaria majalis*, in which a number of cataphyllary-leaves forming closed sheaths, are followed by one which is only two thirds embracing, (the same which bears the inflorescence in its axil), and this is succeeded by two euphyllary-leaves, which are again completely amplexicaul. *Crocus luteus*, also, and other species of this genus, exhibit a strange aberrant condition to be mentioned in connection with the foregoing. A number of completely embracing cataphyllary-leaves, closed round into tubes, are succeeded by euphyllary-leaves, mostly arranged according to the ⅜ position, the sheath-like basilar portions of which are not closed into tubes, but are confluent together one with another in the direction of the longitudinal path of the line of arrangement of the leaves, (the spiral line cutting through the points of origin of the successive leaves), whence arises as it were a single connected spiral sheath common to all the euphyllary-leaves. The breadth of the base of a single leaf consequently amounts here to ⅜ of the circumference of the stem. These are followed by hypsophyllary leaves preceding the terminal flower, the first closed into a tube, like the cataphyllary-leaves, the second, on the contrary, open, and only imperfectly embracing the stem.

hypsophyllary-leaves. This may be observed especially in calices with right-handed overlapping reaching down as far as the base. That the breadth of this decreases again in the region of the petals and stamens, might even be deduced from the fact, that scarcely any right-handed (entopic) overlapping occur, since the overlappings do not proceed from the base, but only arise from the overlapping of the petals subsequently expanding above. The stamens, as a general rule, never overlap, and the great number of them which stand in a circle in many polyandrous flowers, shows the narrowness of their bases. The bases of the carpels are not expanded transversely or overlapping, it is true, but their smaller number, in the majority of cases, as well as their close approximation, nevertheless testifies to the greater thickness of their bases. The decreasing breadth of the base in the leaf-formations of the "stock" may be made clearer by the mention of a few more examples.

Tulipa.—The bulb exhibits 3—4, completely embracing, tubularly closed, cataphyllary leaves, followed by 3—4 euphyllary leaves on the stalk which shoots up, the lowest of the latter being still amplexicaul and closed round at the bottom, the succeeding embracing in a gradually decreasing extent $\frac{3}{4}$ to $\frac{1}{2}$.

Convallaria Polygonatum.—The cataphyllary leaves on the horizontal rhizome completely embracing, the margins even overlapping. The first of the euphyllary leaves occurring on the stem rising above ground embraces almost completely, about $\frac{9}{10}$ths; the second $\frac{3}{4}$ or $\frac{2}{3}$; all the following $\frac{1}{2}$.

Veratrum (*nigrum*).—The subterraneous cataphyllary leaves, which are best seen in autumn on the still undeveloped central buds of young "stocks," or in the lateral buds of older "stocks," are embracing, and form a cone or cup, closed completely, with the exception of a small, scarcely perceptible slit at the upper end, this cap being broken through above in the subsequent unfolding of the bud. The first six or seven euphyllary leaves have long closed sheaths, reaching down to the abbreviated subterraneous portion of the stem; these are followed mostly by two sheaths, also closed round, but shorter, which arise on the portion of the stem shooting up. The succeeding euphyllary leaves, further separated from each other, and becoming progressively narrower and shorter, are no longer embracing, and exhibit a gradual decrease of the breadth of the base, following something like the ratio $\frac{3}{4}$, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{2}{5}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{2}{9}$, $\frac{1}{5}$, and then remaining more equal, decreasing to $\frac{1}{6}$ as a minimum. The leaf embracing $\frac{1}{2}$ is the first which produces a branch, the lowest lateral spike of the large, compoundly spicate inflorescence arising on its axil. The small hypsophyllary leaves, from the axils of which the individual flowers arise, embrace $\frac{1}{6}$ or $\frac{1}{7}$.

Valeriana officinalis.—The subterraneous runners exhibit white, one-sidely apiculate, completely embracing, cataphyllary-leaves, closed into tubes by the blending of their borders. Of the alternating, two-ranked euphyllary-leaves succeeding them, the lowest have likewise a completely embracing sheathing base, while the last embrace only about $\frac{3}{4}$. The euphyllary-leaves found on the erect part of the stem are connected in pairs, and embrace $\frac{1}{2}$, or, on the triple whorls sometimes occurring, only $\frac{1}{3}$. The hypsophyllary leaves have an arrangement similar to that of the euphyllary leaves, but the two opposite leaves of each pair do not quite reach one another with their bases; they are less than $\frac{1}{2}$, finally only $\frac{1}{4}$ embracing.

Heracleum.—The lower and middle euphyllary leaves of the species of this genus have overlapping sheaths, therefore they reach somewhat more than completely round the stem; the upper, already smaller ones, having a less divided and scarcely stalked lamina, usually approximated together, and having the umbel-bearing branches in their axils, exhibit imperfectly embracing sheaths, rapidly decreasing in breadth, about in the proportion $\frac{2}{3}$, $\frac{1}{2}$, $\frac{2}{5}$, $\frac{1}{3}$, or falling still more quickly. Finally, the small linear, or almost bristle-like hypsophyllary leaves of the involucre and involucel exhibit scarcely $\frac{1}{10}$ — $\frac{1}{12}$ breadth of the base.

Mahonia Aquifolium.—The cataphyllary leaves (bud-scales) are about $\frac{3}{4}$ embracing; the euphyllary leaves falling to $\frac{2}{3}$ or $\frac{1}{2}$; the hypsophyllary leaves on the axis of the panicle $\frac{1}{4}$; the little bracteoles (*vorblätter*) occurring on the stalk of the flower itself, which, however, rarely come to evident development, are still narrower than the bracts (*deck-blätter*) of the inflorescence.

Thus the plant, as a general rule, exhibits the phenomenon of decrease in regard to the breadth of the base of the leaf, yet with two retrogressions (inconsiderable, however), namely, at the commencement of the flower, and again at the close of series, in the formation of the fruit. The following remarks will show that this decrease in the breadth of the base of the leaf does not in itself indicate any decrease in the energy of the leaf-formation, but that, on the contrary, the expansion of the base stands in an antagonistic relation to the development of the middle of the leaf.

The development of the leaf in *length* or *height*, which is the most influential factor in reference to the size of the leaf generally, and the vigour which declares itself in its formation, exhibits, in the progressive metamorphosis of the plant, a totally different course from that of the breadth of the base. Both in the first and second regions, on the "stock" and in the flower, the longitudinal development of the leaf shows, first an increase and then a decrease; the commencement of the last region, the fruit, is connected with another increase. Thus after a double rise and fall the terminal formation is attained in a third ascent. Reviewing first of all the first region, we find that the first cataphyllary-leaves of a sprout are always the shortest and smallest; this rule prevails, in like manner, in the first euphyllary-leaves of plants, or in individual sprouts of plants where the cataphyllary leaf-formation is wanting. The cotyledonary commencement often forms an exception in this respect, as in reference to the conditions of breadth, for the cotyledons of many plants are longer and larger than the succeeding leaves of the principal sprout, as, for example, in *Quercus*, *Vicia*, *Casuarina*, *Opuntia*, &c. The increasing length in the succession of cataphyllary-leaves, may be seen in beautiful gradation almost everywhere on the subterraneous buds of perennial herbs, and on the buds of trees; see, for instance, *Pæonia*, where the 6 — 7 lower leaves show graduated increase from 3 lines to 1½ inch,* *Mahonia Aquifolium*, where they increase from 1 to 6 lines, *Æsculus*,† *Rosa*,‡ *Rhododendron*,§ &c. The increasing length and magnitude of stem-leaves in germinating plants is especially well seen in *Acer*, *Corylus*, *Vitis*, *Phaseolus*, &c. The increasing length of the leaves is mostly continued, more distinctly in the euphyllary than in the cataphyllary formation, till it reaches its maximum in a determinate median region, from which an equally graduated decrease commences, mostly prolonged even into the hypsophyllary region. It depends on the conditions of extension of the stem whether the maximum of the longitudinal development of the euphyllary leaves lies in the lower abbreviated part of the stem, so that all the euphyllary leaves situated on the developed internodes belong to the decreasing series; or, when no such rosette-like crowding of the lower euphyllary leaves exists, at a determinate height on the shoot itself.‖ Examples of the first kind are seen in *Nigritella angustifolia*, *Chrysanthemum Leucanthemum*,

* Decandolle, 'Organographie,' t. xxi, figs. 1, 3.

† Ibid., t. 20.

‡ Malpighi, 'Anat. Plant., t. xii, fig. 59.

§ Henry, 'Knospenbilder,' Nova. Acta. Nat. Cur., xxii, 1, t. xxii.

‖ Both conditions are found combined, consequently a double maximum in the euphyllary formation, a lower in the abbreviated part of the stem (in a rosette of what are termed radical leaves), and an upper, on the shoot, mostly, it is true, distributed through two seasons, in many biennial plants, *e. g.*, *Pedicularis palustris*, *Anarrhinum bellidifolium*, *Œnothera muricata*, as also in perennials with biennial sprouts, *e. g.*, *Jasione perennis* and *Pulmonaria officinalis*. This phenomenon, however, does not properly belong here, but to the case mentioned above at page 59 of retrogressive metamorphosis within the euphyllary formation.

Hieracium vulgatum, *Scabiosa Columbaria*, *Swertia perennis*, *Aconitum Lycoctonum*, &c.; examples of the second in *Orchis globosa* and *maculata*, *Canna*, *Hieracium subaudum*, *Gentiana germanica*, *Bocconia cordata*, *Aconitum Napellus*, *Helleborus fœtidus*, and *Ruta graveolens*. Under these circumstances, when the number of leaves is great, the increase and decrease are often very gradual, as for instance, in most species of *Linaria*, *Linum*, *Phlox*, &c. Thus in *Phlox paniculata*, where the sprout begins with pairs of half-embracing subterraneous cataphyllary leaves, 1 — 3 lines long, and rounded off at the top, we see above ground about thirty pairs of broadly lanceolate, acuminated euphyllary leaves, which are only about $\frac{3}{8}$ embracing, and attain their greatest length, of about 3 inches, somewhere near half-way up the stem, from which point they decrease, at first almost imperceptibly, more rapidly in the inflorescence, and finally pass into the hypsophyllary formation. The last finely-pointed hypsophyllary leaves are only about 3 lines long and scarcely $\frac{1}{4}$ embracing. In other cases the leaf-formation ascends to its maximum by a few large steps, sinking down again as quickly, as for instance, in *Hydrophyllum canadense*. This plant bears upon its condensed lower-stem (rhizome) which creeps on the surface of the ground, distichously arranged, thick, fleshy, persistent, cataphyllary scales from $\frac{1}{4}$ to $\frac{1}{2}$ an inch long; the last two scales of the sprout* usually pass at their points into a petiole- and blade-formation, and therefore are already the first euphyllary leaves, distinguished however from the following by their persistent fleshy scale-base. These first two euphyllary leaves are already developed in autumn before the sprout shoots up; the first is often only rudimentary, the second longer and stronger, attaining a height of 3 to 6 inches. These are followed

* That is to say, in case it has sufficient force to blossom. Young plants, and the weaker lateral shoots of older ones, alternate for several years between euphyllary and cataphyllary formation, like the examples mentioned at pp. 54-55.

mostly by three more euphyllary leaves (unfolded in the next spring), the first of which is seated either on the creeping portion of the stem, or raised but a little above the ground on the lowest part of the erect euphyllary-leaved stem, and it is by far the largest of all, for it equals or even exceeds in height the entire shoot, attaining a length of a foot to a foot and a half. The two following, situated high up on the stem, are, the first 9 to 6 inches, the second 4 to 3 inches long. The hypsophyllary leaves succeeding upon the inflorescence are totally suppressed in this plant. The exaltation of the leaf-formation expressed in the euphyllary formation appears most strikingly in the cases where this is represented by a single euphyllary leaf, which is then mostly of remarkably large size. Thus in *Epimedium alpinum*,* where the tolerably numerous subterraneous cataphyllary leaves, from 1 to 5 lines long, are ordinarily followed by a single twice or thrice divided euphyllary leaf about a foot long, after which the metamorphosis springs over suddenly to the small and numerous hypsophyllary leaves, the length of which amounts at most to 1 line, and sinks to ⅓d of a line. There is somewhat of a deviation from the usual position of the maximum of development in length of the leaves, in the rare cases where this occurs at the end or the beginning of the euphyllary formation, instead of in the middle. We see the first case in *Heliconia cannoidea*,† in which the decrease of length commences in the hypsophyllary formation; the last in *Pæonia* and *Actæa*. The bane-berry (*Actæa spicata*) presents on the subterraneous stock several short-sheathed cataphyllary leaves, increasing in length from 1 to 3 lines; to these succeed, upon the erect stem, mostly three euphyllary leaves; the lowest, largest, very decomposed, is about 1 foot long, while the third,

* Other examples of one-leaved euphyllary formation are furnished by *Malaxis monophylla*, and very many exotic Orchidaceæ; also by many Aroideæ, *e.g.*, *Arum echinatum*, (Wall. pl. as. rar. t. cxxxvi); by Gesneriaceæ, as in *Platystemma violoides*, (Wall. l. c., t. cli); by *Sanguinaria;* and lastly by many Cyperaceæ, as for example, *Scirpus mucronatus*.

† Richard, 'Comment. de Musac.,' t. ix.

uppermost and smallest, mostly only simply trifid, is from 1 to 2 inches long. The hyposophyllary leaves, following the last, and from whose axils arise the flowers of the terminal spike, are from $1\frac{1}{2}$ to 1 line long.

In conclusion, I will describe the phenomenon of increase and decrease in the length and size of the leaves upon the "stocks" of plants, in one more example, where it presents itself in an uncommon grandeur, namely, in the plantain (*Musa*).* I have not had an opportunity to examine the subterraneous portion of the stem of this plant, rising upward from a horizontal commencement; when this comes above ground, as a young shoot, we at first see a few cataphyllary leaves, which are probably preceded by a considerable number underground. In *M. sapientum* they are acuminated, triangular, shining, dark-brown leaf-sheaths, which manifest the commencement of the euphyllary formation by the commencement of petiole- and blade-formation at the summits. Not only the sheath but also the stalk and lamina now grow longer, from leaf to leaf, until the well-known splendour and magnitude of the plantain leaf are attained. The complete development of the sprout of a plantain requires with us several years, in its tropical home at most two years; the outer leaves die away as the inner unfold. All the leaves of a shoot which has not yet shot forth into blossom, arise close to the ground on an abbreviated stem, and, simply by the rolling of their sheaths round one another, form a tall pseudo-stem, whence Richard called *Musa* a bulbous plant. Consequently the length of the leaves here determines the height of the entire

* The following statements are derived from two species in the botanic garden of this town (Freiburg), one large, with overhanging inflorescence and numerous flowers in the axils of bracts, which appears to be *Musa sapientum*, and a smaller, with erect inflorescence and beautiful rosy bracts with only three flowers in each axil. In our garden this bears the name of *M. rubra*. On this especially have I been able to investigate minutely the distribution of the leaves upon the stem in reference to height. The arrangement of the middle-leaves is $\frac{3}{7}$ in both, of the bracts $\frac{4}{11}$. In the statements of the conditions of length of the two species I shall distinguish them as *M. sapientum* and *M. rubra*.

plant. Under these circumstances the innermost leaves are the longest; in *M. sapientum* I have found them as much as 25 feet long, of which the sheath made about 13 feet, the petiole 2 feet, and the blade 10 feet. In *M. rubra* they are only about 15 feet long, the petiole being longer in proportion than in *M. sapientum.* From the point where the stem shoots up into the slender flower-shaft, breaking through the stem-like convolution of sheaths, commences the decrease of length of the leaves. In *M. rubra* I found as many as five euphyllary leaves on the elongated portion of the stem, the upper three of which, especially, exhibited a considerable decrease, not merely in the length of the sheath, but also in that of the blade; the last of them was only about 4 feet long, namely, the sheath $1\frac{1}{2}$, the stalk 1, and the blade $1\frac{1}{2}$ feet. The internodes bearing these last five euphyllary leaves measured respectively about $1\frac{1}{2}$, 1, 2, 3, 3 feet in length. Not quite 2 feet distant from the point of origin of the last euphyllary leaf, followed a transitional leaf, about $1\frac{1}{2}$ feet long, and of broadly-linear, gradually acuminated form, leading to the hypsophyllary formation; at no more than 2 inches above this, began the long succession of approximated, ovate, rosy bracts, the first of which are about 5 inches long, the following sinking down gradually to 3—2 inches. The lowest six bracts of the inflorescence of *M. rubra* which I examined, bore female flowers in the axils, all the succeeding bore male flowers.* *Musa* also exhibits a beautiful graduation of the breadth of the base of the leaves. All the leaves of the lower part, up to the flowering-shoot, are completely embracing. I found, in *M. rubra,* the uppermost three euphyllary leaves embracing $\frac{15}{16}$, $\frac{10}{11}$, and $\frac{6}{7}$ of the circumference; the transitional leaf $\frac{3}{5}$, the bracts of the female flowers $\frac{1}{2}$ to $\frac{2}{5}$, those of the male $\frac{1}{3}$. In the plantain, therefore, we see the leaf-formation ascend by gradual

* According to Rumph, in *Musa paradisiaca* 12 to 20 bracts have female flowers, and 12 to 20 of them in each axil; so that a single inflorescence bears 100 to 200 fruits.

stages, from a few inches often to the enormous length of 25 feet, and sink down again, with more rapid steps, to about the same brevity; to which it must be added, that on minute examination of the earliest subterraneous leaves of the sprout, and of the cotyledons of the germinating plant, the point of departure would doubtless be found smaller, as, on the other hand, we may conclude, from the file-like rows in which the flowers stand in the axil of a bract, that the (in proportion to the flower) large bracts are not the last members of the hypsophyllary formation, but that undistinguishable hypsophyllary-leaves (bracteoles) exist at the base of the individual flowers, forming the true termination of the leaf-formation of the "stock."

A similar rise and fall in the length of the leaves is repeated in the region of the *flower*. The *sepals* are sometimes immediately connected with the last hypsophyllary-leaves by their length, often by their whole form, excepting the usually greater breadth; this is the case in *Helleborus fœtidus*, *Ruta graveolens*, and *Phlox paniculata*, in which the sepals agree almost perfectly, in size and shape, with the last hypsophyllary-leaves. But more frequently the calyx exhibits a new increase of length in relation to the last hypsophyllary-leaves. To confirm this I need only refer to the numerous plants which possess bracteoles (*Vorblätter*) on the peduncles of lateral flowers, these bracteoles being almost always very small and slender, and even frequently almost indistinguishably small; see, for instance, *Aconitum*, *Delphinium*, *Viola*, *Polygala*, *Colutea* and other Leguminosæ, *Molucella*, *Calamintha*, *Gratiola*, *Convolvulus*, &c. We can also detect this in terminal flowers, *e. g.* in *Dianthus*, where the sepals, blended below into a long tube, are preceded by several pairs of shorter scales;*

* The two to three pairs of scale-like leaves beneath the calyx of the pinks increase in length in the ascending order, and therefore belong properly to the new advance of the leaf-formation commencing in the flower, forming an epicalyx, as occurs also in the mallow.

also in *Hypericum calycinum*, in which the sepals of the solitary terminal flowers are twice or four times as long, and three to four times as broad as the preceding hypsophyllary-leaves; finally, most distinctly in *Chelidonium majus*, in which the sepals are about three lines long, while the two to three pairs of preceding hypsophyllary-leaves, from the axils of which the lateral flowers of the corymb arise, attain scarcely half a line. In the calyx itself the metamorphosis usually keeps at the same stage, so that at least no remarkable difference occurs among the sepals; yet the cases are not rare in which an evident gradation occurs within the calyx itself, an increase of length corresponding to the succession of the sepals; as, for instance, in the quinate calyx of *Hypericum calycinum*, imbricated in the $\frac{2}{5}$ arrangement, the inner two sepals of which are almost twice as long as the outer two, the third being of intermediate length. The conditions are similar in *Polygala*, where the innermost two sepals are not merely many times longer than the outer three, but already exhibit the petaloid colour, forming what are called the wings of the flower.* In *Oxyria* and the female flowers of *Urtica* we find a four-leaved calyx, the outer two sepals of which are shorter than the inner two; in *Rumex* a six-leaved, with three outer shorter, and three inner longer. *Berberis* has a double ternate, *Mahonia* and *Podophyllum* a triple ternate, and *Epimedium*, a triple binate calyx; in all these the inner whorls are formed of longer sepals than the outer. Lastly, in the Cacteæ, as also in *Calycanthus*, the gradual increase of length is exhibited most remarkably with an acyclic structure of the calyx.

The length of the leaf within the flower attains its maximum in the *corolla*. It is scarcely necessary to illustrate, by examples, the proportionate lengths of the corolla and calyx; and the assertion that the petals are longer than the sepals in the majority of plants possessing

* The same occurs in *Dipterocarpus*.

corollas, will not be contested although we omit to demonstrate it by a numerical comparison, which of course would have to be based on a determinate and perfectly known flora. Splendid and conspicuous examples of it are furnished by the genera *Datura* (*e. g. D. arborea*), *Convolvulus*, *Gentiana* (*e. g. G. acaulis*), *Campanula*, *Cucurbita*, *Pæonia*, *Dillenia*, *Hibiscus*, &c. This relation holds good also in small-flowered plants, as, for instance, in *Vitis*, in the Umbelliferæ and the Compositæ. Even in the Monocotyledons, where generally speaking the abrupt differentiation of calyx and corolla does not exist, the inner three segments of the perianth are frequently distinctly longer that the outer three, as, for instance, in *Lachenalia* and *Uropetalum*, of the Lily family, in all the Bromeliaceæ, Commelyneæ, Cannaceæ, and Alismaceæ. The rarer occurrence of petals shorter than the calyx, is explained, in many cases, by an introversion of one formation into the other, whereby the maximum of longitudinal development becomes displaced. Thus, in many Ranunculaceæ (*e. g. Trollius*, *Nigella*) the petaloid calyx is succeeded by shorter and more contracted petals approximating to the stamens. In other families also occur isolated genera, with a petaloid calyx, the leaves of which are longer than the true petals; *e. g.* in *Fuchsia* (calyx mostly bright-red, rarely white, petals mostly violet), *Ribes* (*Chrysobotrya*), *Commarum*, and *Chimonanthus*. The last-named genus has about eight delicate yellow sepals, followed by an equal number of dark purple-red petals, only half as long. In other cases the small size of the petals is connected with a tendency, prevailing in many families, to suppression of the corolla (*Sibbaldia*, *Saginæ* sp., *Paronychia*, *Gnidia*, *Santalum*, &c.), to which we shall return hereafter.

No farther increase of length takes place within the corolla itself, at least I am unacquainted with any instances of it; on the other hand, the decrease which succeeds to the maximum of longitudinal development in the second member of the flower, not unfrequently commences even within the formation of the corolla. Thus in most cases of double or multiple corollas we see the inner circles formed of shorter and smaller petals. In *Fumaria* the inner two petals are only inconsiderably, but in *Hypecoum* considerably shorter than the outer two. *Jacquinia* and *Achras* exhibit the same thing in pentamerous and hexamerous circles. *Asimina triloba* has a trimerous calyx, the sepals of which are four lines long. This is followed by three trimerous circles of petals: those of the first circle are 7—8 lines long, those of the second about 5 lines, and those of the third scarcely more than 2 lines long. The stamens are 1 line long; the three-lobed fruit (formed of three carpels) attains a length of 4—5 inches when ripe! The decrease of length of the inner petals is further shown in all flowers with very numerous petals, whether they stand in a complex cyclic or in an acyclic arrangement, as, for instance, in *Illicium*, *Nymphæa*,* and *Mesembryanthemum*.† Finally, the graduated decrease in length in successive petals is very beautifully exhibited by all "double" flowers, as they are called, and most distinctly of all, in those where the doubling arises merely from formation of petals in the place of stamens (and often of carpels also), without the superaddition of axillary sprouts.‡ The best examples of this kind are found in the Ranunculaceæ, especially in *Ranunculus*, *Clematis*,

* *Nymphæa alba* has about twenty-four petals, the inmost and shortest of which exhibit a gradual transition into the staminal formation.

† Many species have more than one hundred petals.

‡ In the majority of double flowers the "doubling" is complicated by the formation of sprouts in the axils of the petals. The sprouts thus appearing are again imperfect flowers, with undeveloped axes, and mostly formed of few petals and occasionally several stamens. Hence arises an apparently irregular accumulation of large and small petals, interposed in various directions, and often intermixed, with isolated stamens, of which it cannot be accurately determined which organs belong to the parent flower and which to the progeny. This occurs frequently, for instance, in double May flowers, Pinks, Cruciferæ, Mallows, and Roses. However, doubling sometimes occurs with and without axillary increase in the same plant. Sometimes the axillary products of double flowers acquire greater completeness, as is shown most beautifully in the case not unfrequently occurring in gardens of *Althæa rosea*, first observed by G. Engelmann. Vide Engelmann, 'De Antholysi,' t. i, fig. 6.

Hepatica, *Caltha*, and *Aquilegia*. The *Camellieæ*, the Campanulaceæ and *Narcisseæ* also exhibit this kind of "doubling," and the decreasing length of the petals connected with it.

With the transition from corolla to *stamen-formation* commences a new decrease in length. Far the majority of plants possessing a highly developed corolla, agree in having the stamens, notwithstanding their considerable development of stalk, shorter than the petals. Cases of the opposite kind, in which the stamens exceed the corolla in length, are rather rare.* Where two or more successive circles of stamens exist, there is often a further degradation in length, the inner stamens being shorter than the outer. This is the case in *Narcissus*, *Muscari*, *Daphne*, *Myricaria*, *Boronia* and other Rutaceæ, many Malpighiaceæ and Melastomaceæ, *Lythrum*, *Cratægus*, &c. An opposite relation of length in successive circles of stamens does however occur, to which we shall return in the subsequent examination of the subordinate rises and falls of the metamorphosis.

The third and last increase in length presents itself in the *fruit*, often expressed even at the flowering epoch, by the projection of the points of the carpels (styles and stigmas) beyond the stamens, as universally in the Campanulaceæ, Compositæ, and Cactaceæ, but often first becoming distinct with the ripening of the fruit.†

Thus the leaf-formations exhibit altogether three maxima in reference to length and magnitude, the first falling in the euphyllary formation, the second in the corolla, the third in the fructification. These maxima become somewhat displaced if we regard the leaf in reference to its *inner differentiation*, to the more or less distinct development of the contrast between stalk- and blade-formation, and the completeness of the working out of form con-

* For example: *Ribes stamineum*, *Fuchsia*, *Cynoglossum stamineum*, *Hydrophyllum magellanicum*, *Hyssopus*, *Vaccinium stamineum*, *Erica staminea*, *carnea*, *multiflora*, &c.

† Leguminosæ, Cruciferæ, (especially the *Siliquosæ*), Geraniaceæ, Palmæ, &c. See also *Asimina triloba*, above, page 79.

nected therewith. In the first region, indeed, the euphyllary formation exhibits the maximum in this respect also; in the flower, on the contrary, it is not the corolline but the staminal formation which represents the maximum in relation to internal subdivision, since we detect in the latter the most distinct separation of petiolar and laminar formations. Even vaginal and stipuloid expansions and appendages now and then occur at the base of the stamens, still further confirming the analogy with the euphyllary formation. The same position also denotes the physiological importance of the staminal leaves; for euphyllary leaves, staminal leaves, and carpellary leaves, are evidently the three most essential leaf-formations, to which the most important physiological functions are distributed, and without which a perfect and complete plant is inconceivable,* while there is a possibility of all the rest being omitted. At the same time I have hitherto searched in vain through the Vegetable kingdom for a plant devoid of all the inessential formations at once, possessing, that is, really only leaf, stamen, and fructification.

The maxima of the leaf-formation are again differently distributed when we take the *consistence* and *persistence* of the leaves for a standard. In the first region the euphyllary leaves claim the highest place in this respect also, for although succulent and fleshy cataphyllary leaves are not rare, the majority of them are soon killed by the growing warmth of spring, while the euphyllary leaves of very many plants, fleshily succulent as well as leathery, are of several years' duration.† In the flower, the calyx has the greatest durability, thereby showing a relation on the one hand to the euphyllary formation,

* Only such plants as do not elaborate their own nutriment, parasites on living plants and parasite-like vegetables which are nourished like Fungi on decaying remains, can dispense with the leaf-formation.

† *Ex. gr.* in the Cycadeæ, Coniferæ, Palmæ, *Aloe*, and *Agave*, Crassulaceæ, *Aizoideæ*, *Buxus*, *Ilex*, *Citrus*, *Laurus*, and the endless host of evergreen trees of the tropical zones. In the silver fir the duration of the acicular leaves extends to seven or eight years.

and on the other to the fruit, which relationship is also particularly confirmed by many abnormal phenomena. In monstrous affections of the flower, namely, the calyx on the one side passes very readily into a leafy structure, and, on the other, often acquires a fruit-like development, not only normally, but also in abnormal ways,* while in return the fruit may become calicoid, or even strike into leafy structure in antholytic flowers. In the point of view just examined, therefore, the euphyllary formation, calyx, and fruit, form the analogous sections of the three regions.

The preceding indications may suffice to show that the leaf-formation by no means exhibits merely a simple decrease or increase, but, in all respects, a swaying up and down, a series of vibrations, in the last of which only is the goal actually attained. These vibrations are not of equal magnitude or equal force in all plants; on the contrary, there occurs, without affecting the general law, a great multiformity in their conditions. Sometimes the wave expressed in the vigour of the leaf-formation, rises and sinks slowly and gradually, as we have seen in the vegetative region of *Phlox;* sometimes it gathers itself up abruptly and suddenly, as in *Epimedium* and *Mayanthemum;* sometimes it ascends suddenly and sinks down more gradually, as in *Pæonia;* sometimes it ascends contrariwise, gradually, and sinks down again more suddenly, as in *Heliconia.* The transition from one region of ascent to another is marked sometimes by a slight, sometimes by a strong depression. This difference is especially manifested in the transition into the flower, since on the one hand there is not unfrequently a direct passage from the euphyllary formation into calicine formation, (almost devoid of any retrogression in the leaf-formation, and with total omission of the hypsophyllary formation especially representing the descending

* I have observed this in especial beauty in a malformation of *Citrus medica,* where the calyx formed as it were an open citron surrounding the inner natural fruit.

side of the first region,) as in *Gentiana;** while, on the other hand, the leaf-formation often sinks down before the transition into flower, to complete disappearance of the leaf, which as it were emerges anew in the flower. Within the general lines of rise and fall, even, occur other subordinate lines of undulation, corresponding to the individual formations, which will be briefly touched upon hereafter. Every plant has its proper vital lines for these vibrations of the metamorphosis, the constructive representation of which lines will make clearly conceivable, characters which botanists have hitherto only seized in the most fragmentary manner, or have felt obscurely as something indescribable in the habit.

A particularly important phenomenon belonging to this series is the occurrence, at determinate points of transition of the metamorphosis, of the above-mentioned *disappearance* or non-appearance of leaves which exist in rudiment, but either do not come to full development, or are suppressed in the earliest stages of formation.† This dipping down of the leaf-formation, occurring so frequently, and connected with determinate regions,‡ is the best evidence of the undulating course of the metamorphosis, and the best criterion for the separate sections. Disappearance of this kind occurs at four different places in the process of the metamorphosis, namely, first at the two points of depression, already considered above, at the points of transition of the three chief regions one into another, from stock to flower and from flower to fruit; and at two

* See especially *G. campestris*, in which the first two sepals are completely foliaceous.

† This phenomenon belongs to what botanists call *abortus*, against the multifold groundless and superficial assumptions of which Schleiden very justly inveighs repeatedly, ('Grundzüge,' ii, 188.) The correct application of the comparative method will guard us from such idle speculation, and indicate to us with certainty suppression of leaf-formation, even in cases where observation of the course of development is perhaps never capable of affording a demonstration.

‡ Another series of abortions, here left entirely out of view, is connected with the zygomorphic and antagonistic structure of what are called irregular flowers.

other, subordinate points of descent which have still to be examined more narrowly, at the transition of the euphyllary formation unto the hypsophyllary formation and of the corolla (or calyx) into the staminal formation. In order to represent the occurrence of regions of vanishing in their relation to the entire graduated series, we will once more review the series, in the order of the transition of the metamorphosis from formation to formation.

Within the cataphyllary formation we have observed an increase of strength in the leaf-formation, which is continued without any preparatory decrease into the euphyllary formation. The leaf-formation runs progressively from the cataphyllary formation to the euphyllary formation either without any, or with imperceptible descent at the point of transition, consequently no vanishing ever occurs between these two formations. I shall not venture to decide whether this transition takes place really without any descent, or sometimes, perhaps, has connected with it a slight decrease in the leaf-formation. The latter hypothesis seems to be borne out by *Adonis vernalis*. I found the 7 or 8 cataphyllary leaves of this plant of gradually increasing length, growing from 1 to 8 lines; a transitionary leaf following them, and exhibiting the first trace of blade-structure at its apex, was somewhat shorter than the last true cataphyllary leaf, namely, only about 7 lines long.

In the euphyllary formation we see the attainment of the maximum of vegetative leaf-formation followed by a decrease, which is frequently continued into the hypsophyllary formation without any new accession of strength. But the case is not always such; the transition of the euphyllary formation into the hypsophyllary formation is often effected through the medium of a strongish retrogression, which may go as far as disappearance, whereby then the hypsophyllary formation is cut off as a distinct wave, since it then possesses its own special rise and fall. The hypsophyllary region, cut off in this way, thus forms within the vegetative sphere a prototype of the flower, which affords a certain justification of the old application of the name "compound flower," to the capitule of the Compositæ and the spikelet of the Grasses. If we examine the order of capitulous-flowered plants (Compositæ) in reference to this point, we find hypsophyllary formation but seldom exhibiting a mere decreasing condition of the leaf-formation, for the involucres or "common calices" are mostly formed of hypsophyllary leaves larger than those immediately preceding them on the stalk,* and within the involucre itself there mostly occurs a further increase of size of the successive involucral-leaves, as is shown in the so-familiar "involucra calyculata" and "imbricata."† This phenomenon is truly splendidly exhibited in the coloured, radiantly expanded involucres of *Carlina*, *Xeranthemum*, and *Helichrysum*. In the last-named genus (*e.g.* in *H. proliferum*), we even find the rare case of hypsophyllary formation far exceeding in its ascent the size of the euphyllary leaves. After the maximum is attained the hypsophyllary formation sinks down again, upon the main axis, to the form of little paleæ or teeth, often passing into a fibrous dissolution, frequently at last vanishing altogether, (*receptaculum paleaceum*, *denticulatum*, *fibrillosum*, *nudum*.) I will describe somewhat minutely in this respect *Calliopsis bicolor*, an ornamental plant generally diffused in gardens, as an example. Cataphyllary leaves are absent. We find the leaf-formation advancing, on the abbreviated base of the stock, from simple to simply pinnatifid and bipinnatifid euphyllary leaves. On the ascending part of the stem follows a decreasing series of small-lobed bipinnatifid, simply pinnatifid, and at last simple euphyllary leaves, which form the transition to a few very small linear, brownish-coloured hypsophyllary leaves scattered on the stalk of the capitule. The 8 outer leaves of the involucre are already somewhat larger, especially broader,

* See, for instance, *Hieracium subaudum* and allied species, *Leontodon squamosus*, *Catananche cærulea*.

† *Ex. gr. Chrysanthemum Leucanthemum*, *Taraxacum*, *Scorzonera*, *Cynara*.

than the preceding scattered hypsophyllary leaves; the 8 inner involucral leaves, in the axils of which are seated the 8 florets of the ray, are 5—6 times as long and broad as the outer, lighter coloured, and more scarious. This constitutes the maximum of the hypsophyllary formation; the succeeding bracts (palcæ) are shorter, almost filiform, and transparent, with a thin brown central streak. Another example, which exhibits not only a sinking and reascent, but an actual disappearance, at the transition from the cuphyllary to the hypsophyllary formation, is afforded by *Emilia sagittata* (*Cacalia sonchifolia* of gardens.) The large cuphyllary leaves embracing the stem with their arrow- or heart-shaped bases, are followed by a narrow linear transitional leaf, from the axil of which arises the first branch of the corymbose inflorescence. From 2 to 4 leaves are thus wholly suppressed, their existence being merely detected by the branches of inflorescence being apparently devoid of subtending leaves. The leaf-formation rises up again in the involucre of the terminal capitule, composed of 13 equally long, linear hypsophyllary leaves, and generally vanishes again on the "*receptaculum nudum.*" A similar disappearance and re-advance of the hypsophyllary formation, only distributed on distinct axes, is seen in those Umbelliferæ which are devoid of an involucre, but have an involucel, as for instance in *Angelica sylvestris*, *Seseli montanum* and *Hippomarathrum*, and *Bupleurum rotundifolium*. The leaves of the involucels are at the same time the bracts (subtending leaves) of the outermost flowers of the umbellule, while the subsequent, more internally situated flowers, arise from the axils of suppressed leaves. Thus, the *Bupleurum* mentioned has only five involucellar leaves, but eight to thirteen flowers in each umbellule, the central flower not included; therefore three to eight flowers must spring from the axils of invisible leaves. A third large order, in which the hypsophyllary formation occurs in similar conditions, is that of the Grasses. Here it is universal for the cuphyllary formation to be followed immediately by a suppression of the leaf-formation, which persists through the whole main superstructure of the inflorescence, and only ceases in the spikelets. The leaves often disappear entirely in this region, or they present themselves as more or less evident thickenings, sometimes completely embracing the stem as rings,* and then often curved up and down in wavy lines, sometimes only partially embracing, and then mostly with decurrent borders,† rarely ascending on the axis.‡ In *Elymus europæus* the lowest annular abortive leaf is often elongated into a sharp tooth; in *Nardus* all the subtending leaves of the spikelets are tooth-like. Only few grasses exhibit a considerable development of the lower leaves on the axis of the inflorescence, such as occurs in *Sesleria.* In *Sesleria cærulea* they present themselves as tubular, ochraceously-truncated, or irregularly excised, membranous sheaths.§ A similar development of the first leaf of the inflorescence occurs not unfrequently as an accident and exceptionally, in other grasses. I have observed a strange form of this phenomenon, and this frequently, in *Glyceria aquatica.* The transitional leaf occurring here, in the axil of which stands the first so-called semi-verticil of the panicle, has an undeveloped

* Thus, for instance, the lowest abortive leaf of *Triticum*, *Secale*, *Oryza*, &c., while the succeeding do not embrace; in *Glyceria fluitans* and *aquatica* several of the lower abortive leaves are annular.

† Especially fine in *Melica altissima* and *Phalaris arundinacea.* Very beautifully so in the lower abortive leaves of *Lolium*, *Poa compressa*, *Cynosurus*, and *Dactylis.* The obliquely descending borders are even confluent on the lowermost. The overlooking of these abortive leaves led to the error of regarding the glume of the spikelet of *Lolium* as its subtending leaf. This mistake might be pardoned in a superficial examination, but it is incomprehensible how any one could see the true condition clearly, and even draw it, and yet retain the false explanation, as Turpin has done. See his plate of *Lolium perenne* in the 'Dict. des Sc. Nat.,' and the explanation given of the figures.

‡ Thus, for example, the lowest and not always distinguishable abortive leaf of *Alopecurus agrestis.*

§ These ochraceous leaves are followed by one or the other unilaterally developed bract; at the base of the uppermost lateral spikelet, on the contrary, they vanish entirely, as in other grasses. In *Oreochloa* they are not so strongly developed, and only the lowest are one-sided. See on this point also Röper, 'Zur Flora Meklenburgs,' ii, 12.

middle, simply a protuberance, while the lateral portions growing together on the side opposite to the middle, acquire very considerable development. Hence arises an appearance as though the subtending leaf stood opposite to the branch. It often attains a considerable size and a more or less foliaceous expansion, exhibiting a distinction into stalk and blade. The sheath usually reaches a length of 1½ to 2 inches; the blade seated upon this, about of equal length, is double, on account of the absence of the middle, the two halves diverging at an obtuse angle. Among the grasses in which the disappearance of the leaves in the inflorescence is most complete, so that even the lowermost often does not even leave a protuberant process, are *Catapodium*, many species of *Eragrostis*, *Eleusine*, *Digitaria*, and *Sorghum*. In the spikelets, finally, the leaf-formation comes to light again, frequently gradually, as in *Oryza*,* and all other grasses in which the first glume is very small (*Vulpia*, *Airochloa*, *Anthoxanthum*); frequently suddenly, as in all grasses with two large glumes (*Holcus*, *Phalaris*). Most of the many-flowered grasses exhibit, further, a distinct increase and falling off in the successive hypsophyllary leaves of the spikelet, since the first sterile paleæ are shorter than the succeeding fertile ones, which themselves again decrease in size towards the point of the spikelet.† It is rarer for the first paleæ to be the largest, so that a simply decreasing condition exists.‡ The reverse, a merely ascending condition of the paleæ of the spikelet, is exhibited by many one-flowered grasses, in particular the already cited Rice, and most of the genera allied to *Panicum*.§

* In *Oryza* the spikelet begins with four sterile paleæ, followed by only one fertile. The first two or three sterile paleæ appear only as small teeth. *Leersia* is distinguished from *Oryza* merely through the still more imperfect development of the first four paleæ of the spikelet.

† Thus, for instance, in *Bromus*, *Festuca*, *Poa*, *Dactylis*, *Secale*, *Melica*, *Molinia*, *Phragmites*, *Chloris*.

‡ Thus in *Triodia*, *Agrostis*, *Calamagrostis*.

§ A decrease may take place in these in an abnormal manner, when, namely, the axis or rachis of the spikelet develops additional paleæ (and flowers in their axils). An interesting case of this kind occurs almost

From the vanishing region at the entrance of the hypsophyllary formation, where this separates as independent, we come to the consideration of that transition in which the disappearance of the leaf-formation is commonest, to the transition from the *hypsophyllary formation to the flower*. Here where the most important revolution occurs in the metamorphosis, where the leaf-formation is to return in new arrangement and altered attire, there is most frequently a preparatory total contraction, so that the region of transition into the flower must be designated as the principal break in the metamorphosis. The disappearance of the leaf-formation occurring here may extend simply to a last organ, or over the entire hypsophyllary formation; in fact, it may even invade the outer formations of the flower. Of the first case, in which only a final section of the hypsophyllary formation undergoes suppression, we have already seen above a fine example in the Compositæ with naked receptacles succeeding a fully-developed involucre; and in the Umbelliferæ with umbellules, the outer rays of which arise in the axils of involucellar leaves, while the inner possess no visible bracts. Such cases are more uncommon on racemose or spicate inflorescences with elongated axes, but *Castanea* and *Acalypha* may be mentioned, the spikes of which have perfectly developed hypsophyllary leaves at the lower part, bearing the female flowers in their axils, while the male flowers succeeding upward arise from the axils of abortive leaves. Here refer also the Aroideæ, which possess a large, often petaloid, coloured hypsophyllary leaf at the base of the spadix, while no further visibly developed leaves occur upon the spadix. Suppression of the last hypsophyllary leaves is more commonly found when these are situated on a second axial system, than

normally in a *Panicum* cultivated in gardens, which I have named *P.* (*Echinochloa*) *mirabile*. This species, allied to *P. stagninum*, very frequently presents, besides the three ordinary glumes and the normal palea (*deck-spelze*) enclosing the flower, a second smaller palea, which, like the first, conceals a perfect flower in its axil.

when on the same axis. Thus it is a very common phenomenon for the axis of racemose inflorescences to have developed hypsophyllary leaves (bracts), while those on the flower-stalks (*vorblätter*, bracteoles) are suppressed. Numerous examples of this are furnished by the Scrophularineæ,* Verbenaceæ,† Labiatæ,‡ Leguminosæ,§ and also *Fumaria* and *Corydalis*, *Hedera Helix*, *Mahonia*, *Thesium ebracteatum* and *rostratum*.‖ The other case, in which the entire hypsophyllary formation is composed of abortive leaves, is likewise very common, we find it in almost the whole family of Cruciferæ, in *Convallaria multiflora*, of which, besides, there is a variety with developed and even foliaceous bracts; in many Leguminosæ, *e. g. Trifolium*, in the Umbelliferæ without involucre and involucel, *e. g. Anethum* and *Fœniculum*. Great numbers of examples might be cited of plants with terminal flowers, where consequently the leaf-formation reappears again on the same axis, in the flower, after the suppression of several leaves, *e. g. Solanum*, *Gilia tricolor*, *capitata*, many

* *Ex. gr. Digitalis*, *Antirrhinum*, many species of *Linaria*, *Verbascum Blattaria*, while in *Verbascum Thapsus*, and the allied species, as also in *Scrophularia*, *Gratiola*, &c., the bracteoles are developed.

† *Verbena*, *Aloysia*, while *Vitex* exhibits developed bracteoles.

‡ *Teucrium*, *Prunella*; in many other genera of the family the bracteoles are visible. *Scutellaria* exhibits a beautiful transition to the suppression of the bracteoles, for in many species, for instance *S. alpina*, they exist only as scarcely perceptible papillæ. *Salvia* presents a series very instructive in this respect. *S. patens* and *dulcis* have solitary flowers standing in the axils of bracts, without visible bracteoles; *S. coccinea*, *splendens*, and *involucrata*, have three-flowered, *S. farinosa* (*trichostyla*, Bischoff), and *confertiflora* many-flowered cymes without visible bracteoles; *S. Horminum* three-flowered cymes with developed bracteoles of the middle flowers, but not of the lateral flowers; *S. glutinosa*, lastly, has three-flowered cymes with developed bracteoles of both the middle flowers and the lateral flowers.

§ *Pisum*, *Galega*, *Podalyria australis*; in *Colutea* and *Lupinus* the extremely small bracteoles at the base of the calyx are often scarcely visible; in other genera, *Phaseolus* in particular, they are more considerably developed.

‖ I have purposely chosen only such examples as at once show the existence of the supposed bracteoles, either by the visible presence of these in other genera of the same family, or even other species of the same genus, leaving out of the question other grounds for the assumption. In the family of the Fumariaceæ they are visible in *Dielytra*; in the Berberideæ in *Berberis* itself; in the genus *Hedera* in *H. capitata*; in the genus *Thesium* in all the other indigenous species except the two mentioned above.

Boragineæ (*Myosotis, Omphalodes linifolia*), most of the Hydrophylleæ (*Phacelia, Hydrophyllum canadense*), *Cistus salviæfolius* and *monspeliensis, Ulmaria palustris*, &c.

The suppression of the leaf-formation at the transition into the flower may affect, as above remarked, not merely the last section of the leaves preceding the flower, but even the commencing formations of the flower itself. Thus we see the calyx, at least its free portion, undeveloped or appearing as a crown of hairs in the Compositæ, many Umbelliferæ, Rubiaceæ, and Valerianeæ, while the corolla is developed fully in these families. Calyx and corolla are suppressed together in *Fraxinus*, while the nearly related genus *Ornus* exhibits both; the same occurs in many Amentaceæ, especially of the group of Betulaceæ.* The perigone of the Monocotyledons is suppressed in many Aroideæ, *e.g.* in *Calla*, while it is visible in *Pothos* and *Acorus;* in the Cyperaceæ, also, where it frequently presents itself in the form of bristles, which may be compared to the pappus in the Compositæ;† and, finally, in the Grasses, in which, however, the inner circle of the perigone, analogous to the corolla, comes to light, wholly or partly, in the form of little scales (*lodiculæ*).‡

* In *Alnus* and *Betula* the calyx is indistinguishable in the female flower, but visible in the male; in *Carpinus* and *Corylus*, on the other hand, the male flower is devoid of a visible calyx while the female possesses one.

† The three scales in the flower of *Fuirena* do not belong to the perigone, but correspond, as Nees correctly assumes, to the inner circle of stamens. They stand decidedly inside and not outside the three fully-developed stamens. See, for other points, the in other respects accurate description of the flower of the *Fuirenæ*, by Schlechtendal, ('Bot. Zeit.,' 1845, p. 849.)

‡ The inner perigonial circle is perfect, composed of three little scales, in *Stipa* and the *Bambuseæ;* in most of the other grasses it is imperfect, the leaf falling posteriorly being suppressed. Sometimes the abortion extends to the inner circle of the perigone, as in *Crypsis, Alopecurus*. As regards the foundation for the assumption of an outer, constantly abortive perigonial circle, it can only be observed here that it is derived from the comparative study of the rudiments of the branches of the monocotyledons and the rules of insertion of lateral flowers dependent thereon. Under the hypothesis that it possesses a double perigone, the flower of the Grasses stands in the axil of its bract exactly like the bracteolate flower of the Irideæ. The same attachment of the flower is probably to be assumed of the Cyperaceæ also, only in this family the bracteole (the inner palea) is constantly suppressed, while in the Grasses it is fully developed, except in a few cases (*Trichodium, Alopecurus*).

We now come to the transitions within the flower itself. The transition from the *calyx to the corolla* corresponds to that from the cataphyllary to the euphyllary formation, and takes place like this, without any, or with an insignificant retrogression of the leaf-formation, on which account no suppression occurs between these two formations. We have above seen, in many cases, an increase of the leaf-formation within the calyx, and recognised in this the expression of the renewed impulse received in the first half of the flower; the contrary case, a decrease of size following the order of succession of the sepals, expressing an indentation in the line of impulse ascending to the corolla, is a rare phenomenon, and is only represented by faint indications. Thus in the *Gentianæ*, *Gerania*, *Nicotiana*, even in the *Roses* and *Brambles*, the inner sepals are somewhat shorter than the outer. Of all cases of this kind, the calyx of *Acanthus* exhibits the most striking character, which, however, from the irregularity of the whole flower, cannot be explained simply in this way. It is composed of four pieces, an upper, broadest and longest (the second sepal); a lower, somewhat narrower and shorter, which has two points (it is formed from the confluence of the first and third sepals); finally, two lateral, which stand further inwards, and are much shorter than the upper and lower pieces.* These little lateral sepals are the fourth and fifth, consequently the last two leaves of the calyx. The calyx is preceded by two very narrow linear bracteoles, which are about half as long as the calyx; a broader and longer bract, having sharply-toothed borders, bears the flower in its axil. Here, therefore, we see a descent from the bract to the bracteoles, an ascent from the two bracteoles to the outer sepals, and another descent from these to the two inner, and finally, from these to the corolla a fresh ascent of the leaf-formation.

That which is found only in rare and faint indications

* The two lateral pieces are $1\frac{1}{2}$ to 2 lines long, the lower about 15 lines, the upper 17 lines.

in the transition from calyx to corolla, is a very frequent phenomenon in the transition from the *corolla to the stamen-formation.* As the hypsophyllary formation is not unfrequently cut off from the euphyllary region by sinking down even to the suppression of the leaf-formation, so we see the stamen-formation frequently cut off similarly by a region of suppression, from the preceding formation. It is often difficult to decide here whether the parts subject to abortion, which may occupy one or more circles, are to be regarded as suppressed inner petals or suppressed stamens. As imperfectly developed leaves, they are, looked at by themselves, neither one nor the other; but comparative examination shows that the abortive circles are certainly to be attributed sometimes to one and sometimes to the other side, and in this sense are to be regarded sometimes as inner circles of the corolla, and sometimes as outer circles of stamens. Thus in the Primulaceæ for example, we have reason to consider the abortive circle as an inner corolline circle, since the corresponding circle of the flower is developed in some of the genera of the allied family of the Myrsineæ (*e.g.*, *Jacquinia*), as also in many of the genera of the likewise related Sapoteæ, actually in the form of an inner corolla, never in the form of a circle of stamens. The same holds of the Ericaceæ, in which I have seen the abortive circle developed abnormally, in *Erica baccans,* as an inner corolla. The same occurs in the Jasmineæ, for some of the species of jasmine exhibit an inner corolla almost normally. In the Oxalideæ and Geraniaceæ we must also assume an abortive inner corolla, the traces of which exist in the form of glands or little scales. In abnormal flowers of *Pelargonium,* I have often found some of the organs actually developed into the form of petals. That the abortive circle of the Geraniaceæ is to be regarded as an inner corolla, is still more distinctly proved by the mode of arrangement of the parts of the flower in the genus *Monsonia,* belonging to this order. *Monsonia* possesses not merely two, but three quinate circles of stamens, which though $\frac{1}{3}$ prosenthesis are placed in a ternary relation of alternation, while the abortive circle still belongs to the binary condition of alternation (though $\frac{1}{2}$ prosenthesis). In the Crassulaceæ likewise, the abortive circle may be regarded as an inner corolla, although the arguments for this are less direct. On the contrary, the abortive circle is in some cases decidedly an outer circle of stamens, for instance, among the Monocotyledons, in the Burmanniaceæ and Pontederaceæ, among the Dicotyledons, in many Malvaceæ and Tiliaceæ, *e.g.*, *Helicteres*, *Hermannia*, moreover in the Ampelideæ and Rhamneæ. Both united, *i. e.*, two abortive circles, a suppressed inner corolla and a suppressed outer circle of stamens, at the same time, occur in the Crassulaceæ which have only one circle of stamens properly developed, as for instance *Crassula* and *Tillæa;* likewise in *Erodium*, of the family of the Geraniaceæ, and the allied *Linum;* in *Blæria* and *Azalea*, of the heath family.* As we have seen in the conditions of the transition to the flower, examined above, that the whole of the preceding hypsophyllary formation frequently vanishes, so this is repeated here. Not merely particular segments, but even the entire corolla may vanish. We have already seen an approximation to this in the exceptional cases, in which the maximum of the leaf-formation within the flower is not attained in the corolla, but already in the calyx, while the petals appear small and imperfect.† The apetalous flowers produced in this way occur in very many families,‡ and allow their true nature to be readily decided when we

* In this and similar cases no circle seems to be absent, since when two succeeding circles are suppressed, the alternation of the properly developed circle is restored.

† See pages 78, 79.

‡ To prevent misunderstandings, I must remark that the condition of abortion is not the explanation of all apetalous flowers. There are families in which the metamorphosis actually progresses directly from the calyx-formation to the stamen-formation, without any suppressed intermediate formation corresponding to the corolla; thus, for instance, in the Polygoneæ and Laurineæ.

accurately make out the conditions of relationship. Thus, for example, the genus *Glaux* agrees so closely with the type of the very sharply-defined Primulaceæ, that we have no hesitation in ascribing the apetalous condition of this genus to the suppression of two circles of petals. The Chenopodiaceæ, Amarantaceæ, and Scleranthеæ, are connected so unmistakeably with the petaliferous families of the order of the Caryophyllaceæ, particularly with the *Alsineæ*, that we at once regard them as Apetalæ produced by the suppression of the corolla, especially when we take into consideration how such a suppression occurs in particular cases among the *Sileneæ* and *Alsineæ*, and may even be demonstrated in one and the same species, sometimes in all gradations, as for instance, in *Stellaria media*, which is found with very different sizes of the petals down to complete abortion of them (var. *apetala*). The conditions are similar in the apetalous state of *Peplis* among the Lythrarieæ, *Isnardia* among the Onagreæ, *Chrysosplenium* among the Saxifrageæ, *Sterculia* among the Tiliaceæ, and *Pistacia* among the Terebinthaceæ. In *Phytolacca decandra*, the quinate corolla vanishes together with a ten-membered outer circle of stamens, which latter exists perfectly developed in *Ph. icosandra*.

I will only add, to these already too widely extended remarks on the subordinate retrogression of the leaf-formation which is frequently interposed at the transition to the stamen-formation, and which causes an independent separation and uplifting of this most important section of the flower, that the ascending condition in the succession of stamens or of circles of stamens, mentioned above as an apparent exception,* is explained by this, corresponding exactly to the rise in the magnitude of the hypsophyllary leaves, which we have already examined.† This phenomenon is met with, for example, in *Aloe*, *Anthericum*, *Ornithogalum*, in which the three

* See page 80.

† See page 85.

inner stamens are longer than the three outer, also in the Cruciferæ, in the well-known tetradynamous condition; in *Asarum*, with six outer shorter, and six inner longer stamens; in *Rheum*, with six outer shorter, and three inner longer; in *Oxalis* and *Limnanthes*, with five outer shorter, and five inner longer; in *Monsonia*, with ten outer shorter, and five inner longer; lastly, most beautifully in *Hibiscus* and other Malvaceæ, in which numerous quinate circles of stamens are piled up into a more or less abundantly clothed column. Most of the Ranunculaceæ, in particular *Anemone* decidedly, exhibit a gradual increase of length of the stamens, together with an acyclical, spiral arrangement of them; and many of them a decrease again at the close of the formation, as in *Pæonia Montan*, the innermost, shortened, and abortive staminal leaves of which, form by their confluence the well-known crimson crown round the germen, which Decandolle considered as one of the principal supports of his theory of the torus.*

The structure of the chinese Peony just noticed, leads us to the examination of the transition from the stamen-formation to the fruit, the last chasm which the plant has to pass over in its path to the goal. In this transition to the last stage of the metamorphosis, a complete suppression of the leaf-formation occurs far more frequently than at the transition from the corolla to the stamen-formation, a circumstance of especial importance for a correct insight into the structure of most flowers. In the Monocotyledons only, in which in general the formations are less sharply separated, a direct transition, uninterrupted by intermediate abortive circles, is the more frequent condition, while in the Dicotyledons this occurs as the rule only in few families, particularly such as exhibit affinity to the Monocotyledons in other respects; in many others not at all, or only in isolated genera. This also furnishes the explanation of the rarity of

* Decandolle, 'Organographie,' i, 184.

abnormal transitions between these two formations, a transformation * of stamens into carpels, or, retrogressively, of carpels into stamens,† while the transitions between calyx and corolla, as well as between petal- and stamen-formation are comparatively far more frequent. The abortive circles must here be accounted partly to one and partly to the other of the formations adjoining, the altered conditions of arrangement and number so frequently occurring in the fruit affording a distinct support for this in many cases. The abortion of an inner circle of stamens is exhibited most convincingly by many species of *Juncus*, which occur sometimes hexandrous and

* I use this term in the sense explained above, pp. 60, 61.

† The occurrence of such transitions is in most cases a certain indication that no abortive circle exists, but the cases must be closely examined, in order that a mere multiplication of the organs of one or other formation, such as may happen through an alteration of relative position or through axillary formations, may not be taken for a substitutive aberration of structure. Consulting the sections on the transformation of pistils into stamens, (218), and stamens into pistils, (220), in Moquin Tandons 'Teratologie,' we find that after separating the doubtful from the trustworthy and accurately known cases, the examples mentioned belong to three families of the Monocotyledons, (the Liliaceæ, Colchicaceæ, and Palmæ), and eight families of Dicotyledons, (the Ranunculaceæ, Magnoliaceæ, Papaveraceæ, Cruciferæ, Crassulaceæ, Ericaceæ, and Primulaceæ). I have myself observed most of these, as well as many other less known cases. To the latter belong, for instance, the transformation of the carpels into stamens in *Allium Schœnoprasum*, which seems to occur as commonly in the chives cultivated in gardens, as the opposite case of the inner stamens turning into carpels in the cultivated *Sempervivum tectorum*. This transformation is exhibited in the chive in the most varied degrees; it is further remarkable from the fact that the stamens appearing in the place of the three carpels, have extrorse anthers, while the anthers of the six normal stamens are introrse, a condition which reminds us of the similar double character of the anthers in the Laurineæ and Polygoneæ. Strange too, is the occurrence of three more shorter stamens, which are confluent with the three replacing the carpels, and which I can only regard as axillary structures like those occurring in double flowers, (see note, p. 79.) In this case we find inside the decomposed germen, which has passed over into a staminal formation, a new more or less perfectly developed whorl, the organs of which alternate with those of the preceding whorl. Another case, apparently also little known, but equally frequent, occurs in the cultivated horse-radish (*Armoracia rusticana*). The two carpels are here transformed more or less completely into stamens, while two other organs, absent in normal flowers, make their appearance as carpels. The reverse case, the transformation of all the stamens into carpels, is shown by *Cheiranthus Cheiri gynantherus*, Dec., a monster which has become a variety in the Paris garden, and for which I am indebted to M. Gay.

sometimes triandrous,* also by the Irideæ, Graminaceæ and Cyperaceæ,† *Alisma* and *Actinocarpus*,‡ *Cerastium semidecandrum*, and *tetrandrum*, *Mœnchia quaternella*, the tetrandrous species of *Sagina*, the pentagynous Campanulaceæ, *e. g.*, *Campanula Medium*,§ *Drosera*,‖ *Tamarix*,¶ *Viola*, &c. On the other hand, an outer circle of stamens is abortive in *Triglochin palustre*, while in *Tr. maritimum* both circles are fully developed; in most of the digynous Solanaceæ (*i. e.*, with two carpels), in like manner, while in *Nicotiana quadrivalvis* the fruit becomes four-chambered, by the development of both circles; moreover, in most of the Gentianeæ and Apocyneæ, the Scrophularineæ and Labiatæ, the genera of Rutaceæ with a double circle of stamens, the digynous and trigynous *Alsineæ* and *Sileneæ*, as well as the pentagynous genera *Malachium* and *Agrostemma*.**

An inner circle of stamens vanishes, together with an outer circle of carpels, for instance, in *Stellaria media* (*pentandra*), in most of the Diosmeæ, *Cneorum*, Celastrineæ, *Ludwigia*, and *Isnardia*, *Circæa* (?),†† Hederaceæ, Umbelliferæ, &c. It is probable that in the Polygoneæ there is a suppression of 1½ to 2 circles of stamens, and one circle of carpels. In Rosaceæ, Pomaceæ, Amygdalineæ, Myrtaceæ, and *Philadelphus*, there is certainly a suppression of several circles of stamens at the transition to the fruit; probably also we ought to assume two abortive circles between the stamen-formation and the fruit in the flowers of the Papilionaceæ. A glance back over

* *Juncus supinus* is ordinarily triandrous, the variety which is held as *J. nigritellus*, Don, is hexandrous.

† At least in the *Cyperinæ*, the *Caricinæ* may be different; see below.

‡ *Alisma* and *Actinocarpus* are rudimentarily enneandrous, like *Butomus*.

§ The suppressed circle of stamens appears developed in the *double Campanula Medium* of gardens. In this case the first circle of stamens becomes the inner corolla, the abortive circle the circle of stamens. The form and arrangement of the carpels remain unchanged.

‖ Both circles are developed in *Drosophyllum*.

¶ In *Myricaria* (*Tamarix germanica*, L.) both circles are developed.

** See the 'Flora,' 1843, No. XXII, et seq.

†† See the 'Flora,' 1835, I, 179.

the examples previously mentioned of the occurrence of abortive circles at the passage from calyx and corolla to stamen-formation, taken in comparison with the instances just brought forward, of abortion of leaf-formations at the transition to the fruit, leads to our remarking that they are almost throughout derived from different natural families, which gives rise the observation, that a suppression at both the said points of transition at once is among the less frequent cases. Thus abortion occurs merely at the first point in the Primulaceæ, Geraniaceæ, and Malvaceæ, solely at the second place in the Rutaceæ, Onagreæ, Solanaceæ, &c. Cases where it is met with in both regions are furnished by the apetalous Caryophyllaceæ, *e. g. Stellaria media apetala*, *Scleranthus;* also by the apetalous Leguminosæ and Rosaceæ, but most convincingly in *Limnanthes.* This genus exhibits five sepals, and five perfect petals alternating with these; next, also alternating, five glandular scales, the traces of an abortive inner corolla; these are succeeded by two pentamerous circles of stamens, the outer of which, lying opposite the petals, are shorter, the inner, opposite the sepals, larger; finally, five carpels, which are opposite the inner stamens, and therefore lead to the supposition of the abortion of one circle.

In many plants, intermediate structures occur in the position of the abortive circles, between flower and fruit, softening the abruptness of the passage from the acute and transitory stamen-formation to the calm and enduring structure of the carpel. In many cases these transitional structures are but stunted, as, for example, in the circle of glands which succeeds the three circles of stamens in the flower of the cinnamon tree; very often they are more developed, as in the two circles of lanceolate, sinuate-bordered leaflets inside the staminal circles of *Aquilegia*, and the above-mentioned structure of *Pæonia Moutan.* It is remarkable that these transitional structures sometimes assume completely the shape of an inner corolla. We have already noted above the affinity of the calyx to the fruit; so, just as in the ascent from calyx- to stamen-formation, the corolla lies between the two, we again find the petal formation, as a *perigynium*, in the descent from the stamen-formation to the fruit-formation. In many Limes the similarity between the *perigynium* and the corolla is perfect, while in other species of the same genus normally developed stamens occupy its place. The resemblance to petals is less marked in the *perigynium* of the Byttneriaceæ and Dombeyaceæ; in the Malvaceæ, especially distinctly in *Hibiscus*, it forms the inside of the tube, from the outside of which the circles of stamens pass off at various heights.

Lastly, we have still to consider the cases in which, at the last stage of transition of the metamorphosis, the suppression acquires such extent, that the entire stamen-formation becomes involved, or, on the reverse, this exists, and the fruit-formation is suppressed. The necessity of these two formations to propagation, makes it a condition that, in such cases, the plant bears two kinds of flowers,—staminate (male) and pistillate (female) flowers, united on the same "stock," or distributed on distinct "stocks." Examples of this kind occur not merely scattered singly in the most diverse families, but there are even entire families in which this condition appears as the rule. To the former belong diœcious species of the genera *Lychnis*, *Silene*, *Rhamnus*, *Rumex*, the genus *Rhodiola* of the family of Crassulaceæ, the genera *Smilax* and *Ruscus*, of the alliance of Lilieæ, and *Zea* and *Coix* among the Grasses; to the latter belong the Palmæ and Cucurbitaceæ. In all these the male and female flowers have the same type, but differ in the completion, since the plant is incapable of combining the contrast of stamen- and fruit-formation within the ideally limited space of *one* flower. In the male flower the leaf-formation sinks down after bringing forth the stamens, without acquiring power to rise again to fruit-formation; in the female flower the latter is attained by an earlier retrogression of the leaf-formation, suppressing the stamens, whereby space is gained for its new uprising in the fruit-formation.*

Let us now turn from the examination of the undulation which the metamorphosis of the plant follows in its greater soarings and subsidings, to the consideration of the individual steps in which it completes its course, the single leaves. The leaves present themselves to us as the single waves in the great stream of vegetable development, a stream flowing and ebbing with a periodicity regulated by law. As we have regarded the sprout as the first subordinate Rejuvenescence of the plant, as we have further considered the regions and formations on the sprout as circles of Rejuvenescence of the metamorphosis, so have we now to examine the individual leaves (with the internodes bearing them,) as links of Rejuvenescence within these larger circles. In this sphere, the theory of Rejuvenescence already presents itself to us in a declared form and developed into a system in recent scientific literature,† but truly, in spite of much that is to the point

* At the same time, all diclinous flowers do not behave in the same way; on the contrary, there exist great and essential differences in the structure of flowers with separated sexes, which, however, are often difficult to make out. While in the cases above considered the unisexual flower presents itself merely as a one-sided development of an hermaphrodite flower, its origin depends in other cases, like the sex in animals, on the different mode of development of parts, which, according to their position in the flower, are *like*, as is the case, for example, in the Willows, in which the *same* leaves appear in the male as stamens and in the female as carpels. The observations which I have made on the so-called hermaphrodite flowers of *Carex*, in particular of *Carex stricta*, seem to testify the same for this genus. In *Hydrocharis* we meet with a case which stands mid-way between the two mentioned modes of origin of unisexual flowers. In this plant the flower is composed of six alternating trimerous whorls. The first and second (calyx and corolla) behave alike in the male and female flowers. The third, fourth, and fifth, appear as perfectly developed stamens in the male flower, while the sixth consists of blunt processes which sometimes have been called staminodia, sometimes abortive pistils. In the female flower, on the contrary, the third and fourth whorls appear as blunt processes, (staminodia and nectaries of authors) while the fifth and sixth become fully developed in the form of carpels.

† C. H. Schultz, 'Die Lehre von der Anaphytose oder Verjüngung der Pflanzen, ein Schlüssel zur Erklarung des Wachsens, Blühens und Fruchtragens der Pflanzen,' 1843; and 'Neues System der Morphologie der Pflanzen nach den Organischen Bildungsgesetzen,' 1847.

and suggestive, on the whole in a manner of little use, because deficient in firm morphological foundations.*

Schultz's theory of *Rejuvenescence* makes strikingly prominent the difference between animal and vegetable Rejuvenescence: animals repeat, as Schultz expresses it,† the contrast of living and dying, the unity of which forms the Rejuvenescence, in all their internal organs, and there thereby undergo continuous dissolution and reformation, the effete parts being at the same time cast off like a husk. Plants, on the contrary, never rejuvenise an internal organ once completed, but repeat the contrast of living and dying only in their outer members, advancing constantly beyond the completed structures to new productions. This peculiarity lies in the nature of vegetable growth, which goes on solely by repetition of the same parts, by *Anaphytosis*. For Schultz to combat the theory of metamorphosis, as he does, by this doctrine of the *anaphytosis* of plants, is an inconceivable contradiction, cutting off all purpose or aim from the doctrine itself. The doctrine of *anaphytosis*, which is characterised as the theory of the constant self-rejuvenescence of plants through living repetition of the same parts, aiming at the object of demonstrating the laws of this repetition characterising the whole growth of plants, cannot really stand in contradiction with the theory of metamorphosis of plants, which, in like manner, leads back to the original likeness of the vegetable parts or organs repeating themselves in various forms.‡ Since the links or members of the Rejuvenescence of the plant (*Anaphyta*) are not exactly of similar character as they succeed one another,

* This is not the place to carry this out further by demonstration of the morphological errors in the said works; the botanist accustomed to morphological researches finds proof of the above assertion in every paragraph, *e. g.*, in § 34, where leaves in leaf-axils, and buds in branch-axils of forked stems, are spoken of. See also the critique of Mohl, in the 'Botanische Zeitung,' 1843, p. 667.

† Die Lehre von der Anaphytose, 89.

‡ "The plant represents the most varied shapes by modifications of a single organ." Goethe, 'Metamorph.,' § 3.

but present themselves in a series of modifications, the theory of metamorphosis is necessary to the completion of the doctrine of *anaphytosis,* since its object is to demonstrate the laws ruling over the various modes of appearance of essentially similar parts, the definite course of transformation of the *anaphyta* progressing through a series of stages. As the animal combines a metamorphosis with its *internal* process of Rejuvenescence, so does the plant also with its *external,* only the metamorphosis of the plant, in correspondence with the peculiarity of its *anaphytosis,* does not present itself as an internal recasting of the organism, as in the animal, but as an externally projected, many-stepped process of development. A doctrine of *anaphytosis* without recognition of metamorphosis, robs the plant of its inmost principle of life,—the principle of development, the graduated revelation of the internal foundation of its existence; it denies progress and aim in the processes of vegetable construction, and is compelled to ascribe the difference of the links of the Rejuvenescence to the accident of external influences, while this is rather the expression of the gradual triumph of the specific inward essence over external nature.

If it be true that the plant runs through its metamorphoses in a process of Rejuvenescence characterised by a series of stages and links; that, to use Schultz's expression, it possesses a *phytodom,* progressing by *anaphytoses,* our first object must be to define the links of the Rejuvenescence accurately. But this fundamental condition of a correct theory of Rejuvenescence, is exactly that in which Schultz's exposition is deficient. The "anaphyton," or simple link of Rejuvenescence, by the continued repetition and manifold combination of which the whole structure of vegetables is explained, is indeed theoretically characterised as a totality fitted out with all essential vital apparatus, and as an independent vegetable individual; in what, however, we really discover how the *anaphyta* proceed one out of the other, and how they combine, is nowhere clearly shown; it is termed a universal morphological or phytodomic element, the primitive link or element of all external organs of plants, from the varied combinations of which are formed the root, stem, and leaf, which have been incorrectly regarded as essentially different organs of the plant;—but where the limits of the single *anaphyton* are to be found in these structures, how it is to be recognised in its combinations and separated as an independent constituent part, remains, in most cases, altogether obscure. Much of what Schultz ascribes to the *anaphyton* is applicable to the cell; but Schultz's *anaphyton* is not the cell, for Schultz imagines therein a morphological unity, in which it is essential to embrace the various principal modifications of the tissue, as organs of the individual life. Such a morphological unity, the varied combinations of which would explain the variety of the external parts of plants, has, in reality, no existence whatever, as unprejudiced examination readily shows. When we trace the *anaphyton* in Schultz's "construction" of vegetable structure, we find the most diverse things thrown together without the slightest morphological tact.* We meet with the *anaphyton* at one time as an internode bounded by nodes, or as an articulated piece of the petiole of a compound leaf; at another time, however, as any given piece of an inarticulated trunk bearing a bud, or capable of producing one; or even as a totally arbitrary piece of a root (as such without articulations), which is said to be composed of as many *anaphyta* as pieces it can be cut into capable of producing adventitious buds; further, the *anaphyton* appears as a longitudinal strip of a flat leaf;† lastly, actually as a circular Rejuvenescence-layer in the interior

* Schultz's doctrine is in this respect certainly much more variegated than the "chaotic hash of the theory of metamorphosis." 'Neues System,' p. xvii.

† Broad flat leaves are said to originate by lateral (*sympleuric*) fusion (*symphytosis*) of normal stalk-shaped *anaphyta*. 'Neues Syst. der Morph.,' page 2.

of the perennial trunk.* The parts of the flower again are regarded partly as simple *anaphyta*, partly again as composed of a number of *anaphyta*.†

When we gather all this together, we cannot wonder that even an admirer of Schultz's doctrine of the *Anaphyton* says, that it is a Proteus, which we cannot grasp, and which everywhere slips away from us, yet lies at the base of all actual shapes.‡ To those who test the new system for themselves, in the living plant, it will certainly be clear from Schultz's explanation, that this Proteus is a mere thing of the imagination, existing neither by itself nor in its combinations, which are forged out of actualities found in the most diverse sections of the vegetable organism: sections partly existing as such, partly purely imaginary. The correct perception that there exist in the plant multifold phenomena of Rejuvenescence, repeated in diverse morphological regions, and subdivisions (*Gliederungen*) conditioned thereby, is completely reversed by Schultz's system, in that all these perceptible subdivisions (not to consider the merely hypothetical) are regarded as essentially like members of the plant, and

* 'Anaphytose,' § 41.

† The flower is to be conceived only physiologically, and not morphologically ('Anaphyt.,' p. xi), and yet its formation is explained from morphological elements, *i. e.* *anaphyta* (ibid., p. 62). Although composed like the individual parts of the plant, that is, the parts of the vegetable "stock," of *anaphyta*, the parts of the flower are said to possess only an apparent and no real similarity to these, and to be essentially different from them (p. 67). Since the parts of the flower, as *anaphyta*, are explained, at the same time, like the individual parts of the plant, as independent individuals (p. 92), and since the whole plant is said to repeat itself, with all its essential functions, in each *anaphyton*, it is impossible to see, from Schultz's doctrine, whence comes the asserted *essential* difference of the *anaphyta* of the same plant. Schultz's own distinction, namely, the *anaphyta* of the vegetable "stock," as mere individual (!) (asexual) individuals, and the *anaphyta* of the flower (*enanaphyta*) as sexual individuals, cannot be regarded as essential, and removing all real similarity, since, on the one hand, the parts of the flower must still have an individual existence, and, on the other hand, the *anaphyta* of the vegetable "stock" must have ascribed to them, from the production of new *anaphyta*, not merely individual existence, but power of propagation. Hence Schultz's opposition to Metamorphosis appears wholly groundless on this side.

‡ Vide 'Botanische Zeitung,' 1843, p. 741

misused for an atomic theory of *anaphyta* (*anaphyten-atomistik*), which can far less attain to the comprehension of the living course of the shaping-out of the plant, developing the parts out of the whole, than even the atomic theory of cells, since its atom is not a real, like the cell, but an imaginary unity.

The repeated attempts to represent the plant as a series of leaves growing one out of another forwards, and firmly intergrowing with one another backward, appear to rest more definitely upon the real and essential subdivisions of the structure of the plant, and it is no great step from here to the idea that the plant is to be regarded as a series of generations, the individuals of which are represented by the leaves, and the metamorphosis of the plant as an alternation of generations, through which, after numerous preparatory and asexual individuals, the generation finally arrives in the flower at the formation of the sexual individuals closing the series.* This attempt to trace back the whole plant to the leaf-formation, has been carried out most ingeniously by Ernest Meyer,† and recently supported through anatomical researches by Hanstein.‡

Here also we refer Gaudichaud's§ accounts of the morphological construction of the plant through repetition and combination of individually independent vegetable elements (*Phyta*,) each of which is regarded as composed of three regions; leaf above, internode in the middle, and root below,—as also the building up of the plant of stages (or storeys) as explained in the essays of Hoch-

* See the explanation, according to this theory, by Steenstrup, in his 'Alternation of Generations in the Lower Classes of Animals,' p. 128. (Ray Society's Publications, 1843.)

† E. Meyer 'Die Metamorphose der Pflanze und ihre Widersacher,' Linnæa, vi (1832), p. 401.

‡ Hanstein, "*plantarum vascularum folia, caulis, radix utrum organa sint origine distincta, an ejusdem organi diversæ tantum partes?*" Linnæa, xxxi (1848), p. 65.

§ Gaudichaud 'Recherches sur l'Organographie, la Physiologie, et l'Organogénie des Vegetaux,' 1841.

stetter on the structure of the grass-plant.* All these attempts to compose the plant of leaves are wrecked upon the fact of the existence of the stem as an original, independent and connected structure, the more or less distinct articulation of which certainly depends upon the leaf-formation, but the first formation of which precedes that of the leaves. The graduated metamorphosis of the plant requires the stem as a bridge between the steps; the theory of the arrangement of leaves requires it as the basis upon which the leaves form their regulated ranks; the comparative morphology of the lower plants demonstrates the independence of the stem, since it never shows leaves without stem, although certainly stem-formation without leaves;† finally the history of development brings the stem before our eyes, in its earliest period of formation, as the visible foundation, out of which the leaves are developed.‡

* 'Jahreshefte des Vereins fur Vaterländische Naturkunde in Wurtemburg,' 1847, p. 1; and 1848, p. 144. The leaf and the segment of the halm beneath it form, according to Hochstetter, a whole, which he calls a stage or storey (*Stockwerk*), and which consists of three parts, the *foot* (internode of the halm), the *trunk* (the leaf-sheath), and the *head* (the blade of the leaf). Each new stage is produced from its predecessor by a branch being given off at the node between the foot and the trunk. In this way each leaf is regarded as the terminal prolongation of the internode of the stem, which original relation is supposed to be clearly preserved in *Juncus,* on the round stalk-like and erect highest leaf (according to Hochstetter, homologous with the point of the sterile halm), from which we see the inflorescence escape laterally through a slit. Hanstein also regards the leaf as terminal, since he asserts that each new leaf originates through uplifting of the centre of the point of vegetation: "*Puncti vegetationis centrum in novum extenditur folium,*" l. c., p. 83.

† In the higher classes of plants even we meet with cases of the development of the stem without leaves, as well-known in tendrils and thorn-structures. The sterile halm of the Rushes (*Juncus conglomeratus,* &c.) affords an equally familiar, though less noticed case.

‡ The recent researches on the commencement of leaf-formation leave no doubt on this point. See the works of Schleiden, especially on the origin of the cotyledons in the embryo and the coats on the nucleus (' Wiegmann's Archiv,' 1837, and elsewhere); Von Mercklin ('Zur Entwicklungsgeschichte der Blatt-gestalten,' 1846:—on the development of the forms of Leaves, trans. in 'Ann. des Sc. nat., 2d ser. Botanique,' tom. vi, p. 215, 1846); Adr. de Jussieu, on the formation of the embryo of Monocotyledons ('Ann. des Sc. nat.' Juin, 1839); Duchartre, on the organogeny of the parts of the flower of the Onagraceæ, Primulaceæ, Malvaceæ, Nyctagineæ ('Ann. des Sc. nat.,' 1842-4-5-8.) Even in the Ferns, in which the leaf-nature of the frond, as

A more detailed examination of the stem from these four points of view, would lead us too far from our subject; but it may be permitted to discuss somewhat more closely the first point, the import of the stem in reference to a theory of metamorphosis assuming a vital continuity and not an atomic composition of the stages. We have above characterised the leaves as those parts, in the repeated formation of which is especially expressed the Self-rejuvenescence in vegetable life, and through the successive emergence of which the metamorphosis acquires its graduated structure. That this graduated structure requires a connecting organ, different from the leaves, and not formed from them, an organ which is not lost in the individual stages, but rather carries up the process of development beyond the one-sided development of the stage,—this it is which we would here briefly put forth, so that we may acquire a basis, out of and upon which the undulation of the metamorphosis flows. A general characterisation of the fundamental organs, distinguished by essential differences in the direction of development, such as the general contemplation of vegetable structure and vegetable life in its relations to external nature impresses them upon us, may hence not be misplaced here as a preliminary settlement of our position (*Orientirung*). The difficulty of comprising the phenomena in such a general view will serve as an excuse for the imperfection of its execution.

it is called, has been often questioned and disputed, I have satisfied myself beyond the possibility of doubt of the excentrical origin of the leaves around a central apex of the stem. The often ell-long creeping subterraneous stolons of *Struthiopteris germanica* are clothed with scale-like cataphyllary leaves, which on the points of the runners coming up above ground, pass gradually into the ordinary euphyllary leaves of the erect stem. They are arranged according to the $\frac{3}{8}$ type, about an inch distant from each other, 1 inch long, but decurrent for a length of about 2 inches; the undeveloped leaves situated on the nascent points are closely crowded. Taking away all the leaves already more than 1 line long, there remain still about 8 rudiments, the outermost of which are about $\frac{2}{3}$, $\frac{1}{3}$, $\frac{1}{6}$ of a line high, the rest scarcely measurable. The four innermost appear as slightly-vaulted papillæ, gradually diminishing in size around a central papilla, which is the largest, and therefore cannot possibly be mistaken for one of them.

The Vegetable kingdom, like every kingdom of nature, each of its divisions, each genus, and each species, has, in virtue of its peculiar internal essence, its special destination. With this special purpose it enters into the circle of the multifold life of nature, which meets it partly as a friend, partly as a foe, partly favouring and bearing it up towards its object, partly limiting and interrupting the carrying out of it. Hence, every created thing which, in realising itself, enters into the totality of natural life, has to overcome the detracting influence of the lower kingdoms, above which it has to elevate itself. The vegetable kingdom is preceded by the kingdom of the shaped and shapeless elements, the kingdom of inorganic nature. We behold in this, the kingdom of universal combination in rest and motion, the kingdom of gravity and cohesion, of universal mechanical antagonism; in detail the kingdom of the homogeneous and unchangeable, in which every change of matter is at the same time a destruction; and, where it attains to shape, the kingdom of fixed and motionless form. Throughout all this region there is indeed a development of the whole through detached shaping out of the individual parts, but the individual parts have no progressive vital development, no transformation as such, and no Self-rejuvenescence of being. But above this kingdom of bondage the plant rises in more emancipated development of life. It acquires shape, not through a mere act of formation, but through a process of development running through different periods, in which it overcomes more and more inorganic nature and its bondage, subordinates it as a means, bringing the peculiar, more highly gifted nature, in it and through it, to ever freer and more perfect unfolding. We see the gradual solution of this problem realised in the metamorphoses of the plant. The elevation above the earthly, merely passively physical, is expressed even in the ascending growth,* which is constantly combined with the progres-

* Stems growing downwards or creeping horizontally only occur in the retrogressive or in persistent low stages of metamorphosis.

sive metamorphosis. The single organs of this graduated elevation, the links of the ascending growth, in which the internal impulse towards an increasingly purer and more victorious representation of its true nature finds its graduated accomplishment, are the *leaves*. It is a peculiarity of vegetable life that it fixes itself at each stage, bringing each to its own permanent and strictly limited development. Hence each leaf is a thing limited and unalterably fixed at a determinate stage of the metamorphosis.

Since, then, the plant does not exhaust its life in the single representation, this being rather only a stage beyond which the metamorphosis advances to new representations, some organ must exist serving as the means for this advance, in which the life is not expended in the establishment of the stage, is not terminated in a partial realisation, but which, retaining its independence, secures a future development, rises beyond each representation until the last, as a more active central point, constantly renewed and sending out new radii, and only loses its import as an individual centre of formation when the last and most perfect representation, the aim and concluding structure of the metamorphosis, is attained. This organ of the plant is the *stem* or axis. The stem is not ordinarily continued beyond the last radii, coinciding with the limited or terminal stage. Its terminal prolongation is lost, without any final structure belonging peculiarly to itself, among the last leaves of the sprout, whether this concludes with a flower or not, in the former case, therefore, among the carpels.* But this must not be supposed to mean

* Among the exceptional cases in which the stem acquires a development rising beyond the last leaf, or, if it is a lateral sprout, appears in an independent structure devoid of any leaf-formation, becoming itself developed in a radiating manner, are: 1, the free central placenta; 2, emergence into tendril-formation; 3, emergence into thorn-formation; 4, emergence into bristle-formation (*Setaria, Chenopodium aristatum*); 5, the soft needle-like ramification of *Asparagus;* 6, the leaf-like summits of the stems and branches of *Ruscus, Medeola asparagoides;* and 7, the above-mentioned sterile halm of

that the stem takes no part in the metamorphosis; for it is rather in the terminal prolongation of this, that the gradual changes of purpose lying at the foundation of the metamorphoses are prepared, to pass over from it to the developing radii, so that the stem shows, more or less strikingly according to the structure of the leaves, the characters and functions of those leaf-formations of which it constitutes the support. Thus we see the lower stem colourless and devoid of stomates, like the cataphyllary leaves; the middle stem green, and furnished with stomates, like the euphyllary leaves; that part of the floral axis which bears the carpels often developed even into a fruit-structure (*Fragaria*). Thus stem and leaves together form one whole, the ascending vegetation, in which the metamorphosis is revealed, throwing out its halting points in the leaves, and advancing, through the medium of the stem, to further stages.

Opposed to the ascending vegetation (*Pflanzenwuchs*), as a whole, stands the *root*, without which the former would be baseless. In the universal bond of nature all the higher must rest upon the lower, grow forth within and out of this, find its basis and seek the material for its realisation in the lower realm, and thus as it were, descend into and absorb the lower, which it is to overcome. This necessary vital direction, first of all acting in opposition to the true purpose, but in the sequel becoming again subservient to it, finds its representation in the root. The root, as a downward growth, is produced in contrast not merely to the stem, but to the whole ascending growth of the plant; it originally follows simply the attraction of gravitation in its growth, penetrating perpendicularly downwards, and is diverted into

Juncus, which presents itself alone, in place of the euphyllary formation, bearing only cataphyllary leaves at its base. The development of these enormous leafless stem-summits deserves a closer investigation; so far as I could trace it, I found nothing which could warrant the idea that these green halms were leaves, in particular no sheath at their base. The smallest and youngest that I could dissect out always appeared as elongated conical points, and no other *punctum vegetationis* could be distinguished.

deviating directions only in its branches. Thus it gives the plant its basis and connection with the inorganic soil, and especially supplies that material, by the assimilation and subordination of which the entire plant becomes realised. In correspondence with its direction of growth, it forms a contrast to the total ascending development of the plant; it therefore has no metamorphosis. For the same reason it is devoid of leaves, these being the steps in the course of the metamorphosis.

Thus, then, *stem*, *leaf*, and *root* present themselves as essentially different parts of the vegetable organism, as its fundamental organs depending on the difference of the directions of development of vegetable life. The sure and exact distinction of these forms the basis of Morphology. That the study of the lower plants leads us to structures in which the different directions of vegetable life do not appear clearly distinguished, is no reason why we should deny their essential and inconvertable difference when they present themselves really separated, as is almost everywhere the case throughout the higher classes of the Vegetable kingdom.

Leaves and stem form together, as above remarked, one whole, opposed to the root; if we regard the leaves as rays, the stem forms the centre, necessary to the idea of the rays; if we regard them as waves, the stem represents the level on which the undulations originate, forming the troughs between the waves: a mode of viewing the phenomena suggested by the theory of the arrangement of leaves. Not only in the fully-developed leaf, do we see that it is not sharply cut off from the stem, but runs gradually into it, as shown in the formation of the *pulvinus*, in decurrent margins, &c.: this is indicated even in the earliest appearance of the leaf, primarily a scarcely distinguishable papilla, extending laterally into a little ridge (running back as it were into the stem), the papilla sinking down outside (below) quite gradually into the stem. How the leaf is really formed, how it takes its first origin in the stem, and by growth emerges from this, is a problem which the research, recently so industriously devoted to the history of development, has not yet been able fully to solve. The idea of Schleiden, that the leaf is pushed out, as it were, from the stem, the apex first emerging, and the lower parts being gradually extricated by development at the base,* is devoid of exact demonstration, which can only be given by a complete history of the development, accurately illustrating the succession of the individual cells, of the apex of the stem, and the rudiments of the leaves arising from it, which certainly exist before they are elevated as papillæ. The assertion of Schleiden, that the leaf is formed by a process of cell-formation advancing from the apex to the base, has been contested by Nägeli,† who, resting on complete observations on the formation of the leaf in the Florideæ, Characeæ, and Mosses,‡ sets up the contrary doctrine, that the original growth of the leaf advances by cell-formation at the apex and at the circumference, that is, from the base upwards and outwards, and that only the later growth, connected with final completion of the structure of the leaf by expansion of the cells, begins at the point and circumference, and progresses towards the base. How far these results, derived principally from the Cryptogamic plants, are applicable to the leaf-formation of the Phanerogamia, can scarcely be safely determined, from the deficiency of researches on the latter. That *supplementary* cell-formation, presenting itself in all or only isolated parts of the first cellular structure, following the original cell-formation (doubtless progressing according to accurately defined rules in the higher no less than the lower plants), that *supplementary* development which Nägeli calls abnormal or accidental, appears to be of great importance to the ulterior development of

* Schleiden, 'Grundzüge du Wiss. Botanik,' ii, 113, (2d Ausg.) 'Principles of Scientific Botany' (London, 1849), p. 261.

† 'Ueber das Wachsthum und den Begriff des Blattes,' Zeitschr. f. wiss. Botanik, 1847, 153; 'Wachsthums-geschichte der Blätter der Laubmoose,' Ibid, 1845, p. 175.

‡ With regard to the two last-named families, I can fully confirm Nägeli's observations through my own.

the leaf of the Phanerogamia; but that Schleiden's theory of leaf-formation is only partly warranted, even in this second stage of growth, is shown by Grisebach's discovery, that several points of vegetation or foci of development frequently present themselves within the leaf, and an intercalary cell-formation occurs not only at the base, but at various points.* Even the last stage of growth of the leaf, depending on the mere expansion of the cells, does not always, or in all parts of the leaf, progress in the descending (centripetal) direction, as followed indisputably, even before Grisebach's researches, from the observations of Steinheil (especially on the leaf of the *Magnolias*) and Munter (on pinnate leaves†), although the difference between the growth by cell-development and cell-formation was not actually distinguished in them.‡

The general and partial gradual unrolling, advancing toward the apices, and the final expansion of the Fern-leaf connected with this, is a well-known phenomenon, which has been incorrectly regarded as an evidence against the foliar nature of this organ.§

* Grisebach, 'Beobachtungen über das Wachsthum der Vegetations organe in Bezug auf Systematik.' (Weigmann's Archiv, 1844, 134.)

† 'Observationes sur la mode d'accroissement des feuilles.' (Ann. des Sc. nat. 1837.)

‡ 'Beitrag zur Lehre vom Wachsthum der Pflanzen,' Bot. Zeit., 1843, p. 785.

§ Especially remarkable, in this respect, are certain Ferns, in which the points of the leaves are never totally unrolled, as in the narrow, simply pinnate *Platyzoma microphyllum*, and the *Jamesoniæ* resembling them in habit (*e. g. J. imbricata*, Hook. et Grev., t. 178, *scalaris*, *cinnamomea*, *verticalis* Kunze, 'Die Farrnkräuter in Colorirten Abbildungen,' t. 71 and 82). Still more remarkable are many species of *Gleichenia* and *Mertensia*, in which the development of the leaf is arrested above the first pair of pinnules (and in multipinnate rudiments often repeated in several degrees of the ramification), so that the point, seeming to form a bud in the bifurcation, either remains permanently undeveloped, or is only unfolded in the succeeding season, and then again in like manner only imperfectly. This sectional development of the leaf, in which we behold one of the most remarkable phenomena of Rejuvenescence within the leaf itself, appears capable of lasting through many years, on which head it would be very desirable to obtain more accurate information from observers in the native countries of these Ferns (see Kaulfuss, 'Das Wesen du Farrnkräuter'), 1827, p. 36). That the leaves of these Ferns do not possess, however, as might seem, an unlimited growth, is proved by the leaves of the young *Mertensiæ* with a

The tendrils of the Cucurbitaceæ, certainly belonging to the leaf-formation, behave, leaving out of view the suppression of the blade-formation, exactly in like manner, and the pinnate leaves of the Dicotyledons have not only a centrifugal expansion-growth of the petiolar apparatus; but the lateral leaflets unfold distinctly in ascending order, while at the same time each individual leaflet completes its own growth by a centripetal expansion.*

In spite of the imperfection of our insight into the laws regulating the formation of the leaf, we may at least regard it as certain, that the leaves are developed forth from an axis formed before them, and that this axis, whenever leaf-formation occurs, is developed into a stem after the rudiments of the leaves have come into existence; it may be further regarded as certain, that the formation of the leaves is not simultaneous but successive;† so that between two following leaves there always exists at the outset, a separating structure, the axis, permanent as such, whether it may be developed as an internode or not. If we conceive the leaf in relation

similar apiculated terminal structure, of which Martius ('Icones plant. crypt.,' t. 60, ii) has represented an interesting series, but erroneously referred to a distinct species (*M. pumila*). The *Hymenophyllum interruptum* figured by Kunze ('Anal. pteridograph., t. 30), likewise deserves mention here.

* The phenomenon may be seen especially well in the *Mahoniæ* with pinnate leaves, the lower pinnules of which are already expanded, green, and coriaceously hardened, while the upper are still scarcely half as large, half folded together, reddish, and soft.

(Vide also 'Proceedings of the Linnean Society of London,' May 6th, 1852, in a paper by Dr. Alexander on the leaf of *Guarea grandifolia*, Dcnc. In this the upper leaflets are developed after the lower have fallen off, periodical growth at the apex of the petiole going on for several years.—A. H.)

† This holds good even of the leaves of whorls, as transitions and substitutions of verticillate and spiral arrangements sufficiently testify. Although recent observations on the development of the parts of the flower describe the circles of papillæ, forming the earliest representatives of the circles of the flower, as coming to light simultaneously in all the segments, we must remember that these papillæ are by no means the earliest rudiments of the leaf-formation, but that to solve this question by means of the history of development, it would be necessary to go back to the origin of the cells, or groups of cells, which subsequently rise up as papillæ.

to the axis, as a ray, or in relation to the spiral series to which it belongs, as a wave, we recognise in any case, in the intimately connected origin of the stem and leaf, an alternation of emerging and retiring formation, of rising and sinking, radiation and concentration ; and this it is which we have characterised above as a course of development advancing in repeated acts of Rejuvenescence, as it were in an undulating flow of the metamorphosis. This would be the place to examine the definite proportions which the leaf-formation adheres to in its spiral undulation, and the conditions of arrangement of the leaves arising from these ; to trace them from the simple rudimentary plans ($\frac{1}{1}$, $\frac{1}{2}$,) with which the plant, as a whole, commences and which are mostly repeated at the beginning of a new branch, through all the complications which come in during the progress of the metamorphoses, and mostly attain their maximum in the hypsophyllary region ;* then, further, to show how the simpler plans ($\frac{2}{3}$, $\frac{2}{4}$, $\frac{3}{5}$,) recur, but in cyclic combination, in the flower, how here a new series of complications is established in the harmonious combination of the cycles, and how finally in the fruit, the arrangement frequently returns to the simplest condition. But to carry this out would demand an exposition of the theory of Phyllotaxy, which would far exceed the limits allowable in the present treatise.

Note.—The more recent researches on the Phyllotaxy of Plants will be found compared in Schleiden's 'Grundzüge,' 2te Ausg. ii, p. 177 ('Principles of Botany,' pp. 263-6), to which are to be added, a later treatise by the brothers Bravais ('Essai sur la disposition générale des feuilles rectiseriées,' 1840), an essay by the Swede Silverstrahle (translated in Hornschuch's 'Archv. scandinavischen Beiträge,' i, p. 382), agreeing in its conclusions with the first treatises of the brothers Bravais ; and the works of

* Vide Compositæ, Dipsaceæ, Plantagineæ, Proteaceæ, Piperaceæ, Zingiberaceæ, Cyperaceæ, Aroideæ.

Naumann, which, originally scattered through Leonhard and Bronn's 'Jahrbuch der Mineralogie' (1842), and Poggendorff's 'Annalen' (1842-43), were subsequently collected by the author into an independent treatise (Ueber den Quincunx als Grundgesetz der Blattstellung,' 1845). Since I have indicated the occurrence of simpler and more complicated conditions of the arrangement of leaves, and a determinate cycle in which these appear in the plant, I may be permitted to introduce here incidentally an observation on the actual existence of series of *different* conditions of arrangement, as asserted in Schimper's, and my own works, but questioned in the essays of the brothers Bravais. I feel the greater inclination thereto from a remark of Schleiden ('Grundz.,' p. 176; 'Principles,' p. 265), who characterises the theory of the Bravais, who sought to trace back to a single, irrational angle of divergence, alike for all, the modes of arrangement regarded by us as different and expressed by a series of rational divergences, as far preferable, since it indicates a simplicity of the law, and under like possibilities that explanation is always to be preferred which embraces the greatest number of cases under one point of view. But the theory of rational divergences which first recognised as such the multiformity of the cases which observation reveals, and then strove to subordinate them to a general law, should have been upheld on this very ground, in opposition to a theory which, in contradiction to itself, first denies the multiformity of the cases, to insinuate under them an abstract unity, and subsequently (in the second part) cannot avoid admitting that the rational and in reality dissimilar cases do occur in plants. To deny the multiformity of nature without sufficient proof is certainly not the right way to introduce unity of law into phenomena. The assertion of the Bravais that all supposable arrangements of leaves of the main chain are formed on a plan of equal irrational divergence, is just as contrary to nature as a system of crystallography would be that denied the existence of all the forms of a regular system bounded by a definite number of surfaces, on the ground that they all belonged to a single series terminating in the sphere, a surface without any boundaries. I am far from intending by this to take away all value from the labours of the brothers Bravais; the more complicated modes of arrangement are often so difficult to distinguish that the doubt as to their existence, as actually different, is often readily explicable, but, on the other hand, in the simple conditions, there cannot be the slightest doubt that they exist in the greatest mathematical accuracy, which indeed is admitted by the Bravais themselves. Hence arises with the Bravais a diversity of explanation of phenomena which evidently belong to the same series, a circumstance which by no means harmonises with the formulary praise which Schleiden gives to the theory of Bravais. Schleiden would certainly not have arrived at such a judgment had the subject of phyllotoxy been more experimentally familiar to him. At the same time, the question here is not so much of the preference as regards method of a theoretical exposition, as the establishment of a series of facts. I cite in support of my own convictions, gained by many years' study of the modes of arrangement of leaves, an observer whose trustworthiness is declared by most important labours in an analogous field. Naumann has not the least doubt of the actual and distinguishable occurrence of most complicated conditions of arrangement ($\frac{55}{144}$, $\frac{89}{233}$, $\frac{144}{377}$,) and refers the incredulous to the investigation of the Cactaceæ and Compositæ, remarking that in the sun-flower, a blind person will be able to distinguish the above-named allied plans of arrangement with the fingers, although they depend upon immeasurably small differences in the angle of divergence (Poggend. 'Annal.' 1843, p. 554—55). According to my own and Naumann's (*Ueber den Quincunx*, pp. 70—71) observations, not only $\frac{2}{5}$ and $\frac{3}{8}$ occur in the Cacteæ but also $\frac{5}{13}$ $\frac{8}{21}$ $\frac{13}{34}$, in a manner which even Bravais could not help acknowledging as not merely apparently but actually rectilinear and rational.

These most clear and decisive cases belong chiefly to the genus *Echinocactus*, in which, in combination with a most crowded arrangement of the leaves, the pulvini of the leaves are blended in vertical lines, so that these present themselves more clearly than all oblique lines. If, then, in another genus of the Cactaceæ (*Mamillaria*), the usually still more complicated modes of arrangement are less easily and surely distinguishable, because the leaves are not so closely crowded and the pulvini are separately developed, we certainly must not conclude from this that we have here a different irrational mode of arrangement, essentially distinct from the rational arrangement of the *Echinocacti*. As regards Naumann's method, of examining, measuring, and naming the arrangement of the leaves from the point of view of the vertical lines, it may be added that within a certain domain this has the same practical applicability as the mode of definition and denomination founded on the fundamental spiral; but if we go back to the genetic succession of the leaves, which is indubitably represented in the fundamental spiral, Naumann's method appears contrary to nature. While on the one hand it appears to afford a simpler explanation of the verticillate arrangement, on the other hand it is incapable of expressing, even in the formula of nomenclature, the actual and essential connection of the verticillate and spiral arrangements as the transitions in the plant demonstrate them, whence it must appear especially useless in the department of anthonomy or construction of diagrams of flowers. Schleiden further makes the objection to the whole study hitherto of the phenomena of the arrangement of leaves, that it has kept solely to fully-developed plants, instead of tracing the subject in the history of development, whence all theories are devoid of safe foundation (l. c., p. 175, Transl., p. 264); in this he is partly right and partly wrong, for everything has its time. What is requisite in the first place is an actual review of the conditions of arrangement of leaves occurring in the vegetable kingdom, the mode of their occurrence, their distribution in plants, their transitions and alternations, and all this can only be afforded by a more or less perfectly-developed condition of the plant. A sufficiently large number of leaves must have been formed before we can safely judge of their arrangement, since a measurement of the divergence of the earliest rudiments of the leaves is as impracticable as every later direct measurement. Hence the investigation of the earliest rudiments in reference to this point will be of little use until the condition of arrangement of the full-grown plant is known. Even those conditions frequently coming with the completion of the development, disturbing the original arrangement, as for example, the unilateral pushing together of the leaves when there is unequal thickening of the sides of the stem, the moving back of leaves by unequal adhesion of the base, the apparent change of the arrangement of the leaves from revolution of the stem, &c., require no great research into the rudimentary structure to set them aside. Thus the method of determination may be perfected, without directly tracing the first origin of the leaves, to such a degree that the modes of arrangement are almost everywhere to be arrived at, and a comparative investigation, carried out properly by means of the method we possess, is capable of bringing Phyllotaxy to such results, that it makes each individual case comprehensible in orderly connection with the entire system of the arrangements of leaves. The true side of Schleiden's objection is, that this is not the final result, the final establishment of Phyllotaxy, since for its completion we necessarily require the elucidation of the connection of the external arrangement of the leaves with the internal arrangement of the cells in the apex of the stem, from which the leaves emerge, and in which, simultaneously with their origin, is laid the foundation of their arrangement,—a problem toward the difficult solution of which, the study of development has not yet made the slightest step, at least in the realm of the Phanerogamia; moreover this also includes the explanation of the organic processes in the cells themselves, through which their arrangement is determined, as well as the forces with which the organism works; in a word it includes at its final point the Physics of Organization, of which botanical science has at present scarcely a foreshadowing. Therefore, everything at its proper time!

III.—CELL-FORMATION.

In proceeding to the subject of Cell-formation, we pass over a series of phenomena of Rejuvenescence which should be intercalated between the second and third sections, namely, the processes of Rejuvenescence which frequently occur in the development of the leaf itself, and through which the leaf acquires its subdivision and compound nature,—as well as the Rejuvenescence of growth also occurring in the ulterior completion of the parts of the leaf, of which we have spoken already in examining the leaf;* we farther pass over the phenomena of Rejuvenescence in the later completion of the stem, which occur both in the longitudinal growth and the increase of thickness, the former especially as intercalary growth of the internodes,† the lateral as periodically renewed growth of the cambium zone of the stem, between the wood-mass and the bark, whereby originate the annual rings in the trunks of the Coniferous and Dicotyledonous trees. All these, as well as the already examined phenomena of Rejuvenescence, necessarily lead finally to the consideration of the cell, as the simplest sphere of formation in the course of the life and growth of the plant, from which all development starts, which in infinitely varied repetition and modification accompanies the entire development, and to the independent representation of which the conclusion of the development once

* See page 113.

† See Grisebach, 'Ueber das Wachsthum der Vegetationsorgane,' Wiegmann's 'Archiv,' 1843, i, 267.

more returns. The investigation of each link, of each organ of the plant, leads back to the simple cell: the formation of the stem advances by division of a simple apical cell;* the formation of the leaf starts from a single lateral cell in the vicinity of the apex of the stem;† every lateral sprout is originally a cell, which, instead of remaining as a mere part of the tissue of the parent sprout, becomes the primary cell of a new developmental series.‡ To penetrate everywhere to these first rudiments of structure, to follow out from them the course of development of the tissues of all parts, and to make out the laws according to which the cell-formation progresses to produce the various arrangements on which the structure of the plant essentially depends, is one of the most difficult, but, at the same time, most profitable tasks, to the accomplishment of which Nägeli, in particular, has quite recently opened the path by accurate and methodical description of the history of the cell-formation and growth of numerous plants belonging to the lower orders of the Vegetable kingdom, from which alone the way can gradually be levelled up to the higher.§

The investigation of cell-formation is no less necessary

* Definitely demonstrated in the Florideæ, *e. g.*, in *Polysiphonia* and *Herposiphonia* (Nägeli, 'Zeitschrift,' heft 3 and 4, p. 207, t. 6-8); *Delesseria hypoglossum* (idem, heft 2, p. 121, t. i); *Laurencia* (Nägeli, 'Die neueren Algensysteme,' t. 8, f. 4); Characeæ, Musci (Nägeli, 'Zeitschrift,' heft 2, p. 138, t. 4); Equisetaceæ (idem, heft 3 and 4, p. 167). If the apical cell divides vertically into two equivalent cells, consequently into two apical cells, dichotomy results (see *Dictyota*, in Nägeli's 'Algensysteme,' t. 5, figs. 12-16), and by rapid repetition a fan-like expansion. Probably the fasciation, as it is termed, of the Phanerogmia, originates in this way.

† So at least in the Florideæ, Characeæ, and Mosses. (See Nägeli in the already mentioned places.)

‡ See the formation of branches of *Echinomitrion furcatum*, in Nägeli's 'Zeitschr.,' heft 2, p. 138, t. ii, figs. 1-6. Among the cases of which we have an exact description, is also the origin of the seed-sprout or ovule of *Orchis*, which, according to Hofmeister, ('Enstehung des Embryo der Phanerogamen,' 1849, p. 1, t. 1) is developed from a single cell of the placenta, which is first divided into two superposed cells, the upper of which by subsequent division forms the cellular coat, the lower the axial row of cells.

§ See the treatises relating to this in Nägeli's 'Zeitschrift fur wiss. Botanik.' (1845-47), as also his 'Kritik d. neuer. Algensysteme u. Versuch eines eigenen Systems d. Algen und Florideen,' 1847.

in physiological than in morphological respects; for to the cell is committed all the vital activity of the plant; the material and form of the plant are produced in and through it. In the cell resides the wonderful power of preparing the organic substances, which no other chemical laboratory has the means of forming; in it the force of endosmotic absorption and excretion, and that admirable circulation, not yet physically explained, by which the contents are, in the most varied manners, either imperceptibly diffused, or driven in active currents; in it the force of organic production of form and of growth, and, finally, the force of transformation and reconstruction, on which depend the multiplication and propagation of plants. The cell is, therefore, the immediate focus of Rejuvenescence, the point from whence come all the phenomena of Rejuvenescence in the building up of the articulated (or complex) organism of the plant. Hence, if we wish to become intimately acquainted with the phenomenon of Rejuvenescence, we must search it out in the cell itself. In the outset we distinguished two periods in the process of Rejuvenescence, the period of retrogression, of solution and removal of the old, and the movement of renewed progress, the repeated construction and reformation; accordingly, after a preliminary consideration of the *formation* of the cell in general, we shall examine the phenomena of Rejuvenescence in the life of cells in detail,—in the *Destruction* (*Entbildung*), and *Reconstruction* (*Neubildung*) of cells.

I.—FORMATION OF THE CELL.

Cell-formation is one of the most essential peculiarities, one of the most constant characters of the plant. In cell-formation, especially, the vegetable organism shows itself to be determined in its formation from within; through this the plant cuts off its structure, as a whole, as in the smallest subordinate sphere of life, from without, interposing a boundary structure, the cell-membrane, as a medium for the intercourse with the external world, and a protection from direct attack. Although the plant be developed almost infinitely through the unlimited nature of the process of sprouting, its life appears in every cell (with a few exceptions) as in a circumscribed and in a peculiarly inwardly determined sphere of formation, so that the cell also is, in a certain sense, an individual, and, in fact, has been pre-eminently regarded as the individual of the plant by many authors.*

As the single plant begins with a simple cell, so does the Vegetable kingdom. In the lowest stage of this the plant presents itself as a simple cell, and the first repetition of cell-formation is, at the same time, propagation. The farther we trace up the stages of the Vegetable kingdom from this point, the greater is the multiplicity of the division of the originally simple sphere of life into subordinate spheres, and the more frequently is the cell-formation repeated: the vegetable organism becomes multi-cellular. While the cell constitutes actually the sole individual of the plant in Uni-cellular plants, in the higher plants it becomes a sphere of formation subordinate to the more developed individual organism. With the less perfect organisation of the plant, as compared with that of the animal, with its peculiar deficiency in a permanent and thoroughly pervading central relation of the parts, the vegetable cell, as a subordinate part of the organism, possesses a far greater individual independence than the cell of the animal tissue, manifoldly changed in its structure, and more insolubly connected to the whole.

Unicellular plants, in the strictest sense, are represented properly only by those in which the whole cycle of life is completely shut up in one cell, the first reconstruction or division being at once the commencement of

* Schleiden, 'Grundriss der Bot.,' p. 28, and 'Grundzüge,' 11, p. 4. ('Principles of Sc. Botany,' London, 1849, p. 126.)

a new cycle; in which, consequently, the whole vegetative life is run through in the same cell where the propagation also finally appears. But in a wider sense, there are other Unicellular plants, if, namely, we regard those as one-celled, in which the conclusion and renovation of the cycle by the formation of a germ does not occur until after several generations of cells, yet the vegetative life is passed through, not in a rigidly combined series of cells, but in separate cells.* These cases are of two kinds. In cases of one kind the vegetative life is really completely shut up in one cell, but the formation of germ-cells in this cell is attained, not directly, but through the mediation of one or more transitory generations of cells.† Such plants are truly Unicellular, as far as regards vegetation,‡ since the transitory cells neither possess a special and peculiar vegetative development, nor contribute to the formation of a uniform vegetative tissue, but appear only as a rapidly over-passed, transitional stage previous to the formation of germ-cells,—as germ-cells, as it were, which divide once or more times before they arrive at the point from whence a new vegetative cycle can begin again with germination.§ In the other cases the multipli-

* Unicellular plants occur in the series of Fungi and Algæ, which have very varied correspondence in morphological respects. In regard to the latter I refer to Nägeli's most recent work ('Gattungen einzelliger Algen,' 1849), in which is laid a new and solid foundation for the knowledge of these plants, so interesting in this respect, but hitherto (with the exception of the Diatomaceæ and Desmidiaceæ), from want of observation on the development, only most superficially known, and heaped together in the most chaotic manner in the Systems of Algæ.

† Vide Nägeli, 'Einzelliger Algen,' p. 28.

‡ In systematic respects, also, the unicellular genera are most closely connected, since many genera with transitory cell-formation in the passage to spore-formation exhibit great agreement with those without this (excepting in this one character). Thus *Cystococcus*, Näg. (l. c., p. 84, t. 3, E), with transitory cell-formation, corresponds with the genus *Protococcus* (as limited by Nägeli), with immediate or simultaneous spore-formation; *Characium*, A. Br. (Näg., l. c., p. 86, t. 3, D), perfectly corresponds to the genus *Ascidium*, A. Br.; *Pediastrum*, Meyen, in many respects to the genus *Hydrodictyon*, Roth.

§ This case is repeated in multicellular Algæ, *Ulothrix*, *Ulva*, *Porphyra*, (Näg. 'Algensyst.,' t. 1, f. 61, 62), *Ectocarpus*, (ibid., t. 2, figs. 3, 4, 5); similar cases occur even among the Fucoideæ, since, according to Decaisne cation of the cell happens in the vegetative sphere, the cells increase in number by a succession of divisions before the vegetative cycle closes with fructification; but the plant is incapable of keeping intimately connected the generations of cells thus produced, of building forth the organism as a whole, in these divisions; it breaks up more or less completely into the individual cells, which thus, although members of a definite cycle of vegetation, lead a separate individual life. We see that which is completed by the higher plants in an organically connected series of cells, represented here by an alternation of generations of unicellular vegetable individuals.* It is therefore impossible to draw a strict line between Unicellular and Multicellular plants in this respect, since there exist numerous intermediate stages leading from the most intimate union to total separation.

The completion of the contrast of growth and differentiation of the organs does not always keep pace with the simplicity or complexity of the tissue. Even among the Unicellular Algæ, most strictly so called, we find the general opposition of growth of the plant expressed more or less distinctly in the unicellular individual; in fact we find that the very fundamental organs of the plant, stem, leaf, and root may be represented with more or less evident distinctness by parts of one and the same cell. The graduated succession which we detect, in this respect, among the Unicellular Algæ, is so well adapted to enlarge the ordinary conception of the cell, that we cannot omit a brief examination of it here.

The simplest condition of the unicellular plant would

and Thuret, the originally simple spore of *Fucus canaliculatus* breaks up into two, that of *F. nodosus* into four, of *F. serratus* and *vesiculosus* (doubtless by repetition of division) into eight spores. (Vide Decaisne and Thuret, 'Sur les Anthéridies et les Spores de quelques *Fucus*,' 'Ann. des Sc. nat.,' 1845.

* Here refer the Diatomaceæ, Desmidiaceæ, and most of the Palmellaceæ. For the course of the generations of the first, see Thwaites 'Further Observations on the Diatomaceæ,' ('Ann. and Mag. of Nat. Hist.,' 1848, sec. ser. i, 161.)

be, when the cell exhibited no other difference of its sides and parts beyond the contrast of contents and membrane, therefore was completely uniform over its whole periphery. According to the description Nägeli gives of his family Protococcaceæ, *Protococcus** may be regarded as the representative of this stage, being a genus of which the individuals are globular cells, producing free, likewise globular germ-cells, in their contents, after their vegetative growth is completed. But it appears to me doubtful whether, strictly speaking, such a condition of the cell, completely equal in its relations to all sides, ever occurs. If *Protococcus*, as is probable, possesses moving (swarming) germ-cells, these cells will doubtless be found to exhibit, in the moving stage, an elongation, so as to have a principal axis, and two different extremities, one of which bears the cilia, while the coloured contents of the cell are crowded into the other. In *Hydrodictyon*, which genus must likewise be included in the family of Protococcaceæ, the cells, connected into a net-like colony, have also a distinct longitudinal extension in their ulterior development, without, however, any difference in the two ends, since the extremities are both joined in a similar manner to the ends of the adjacent sister-individuals to form the network. But a distinct contrast between the upper and lower end of the cell presents itself in the same family, in the genus *Ascidium*, the free cells of which attach themselves to foreign objects by one end (that elongated and bearing the cilia at the period of swarming), whilst the free extremity (originally the more obtuse) becomes prolonged into a short point. In the tubular cavity of the cell, the contents form a coating over the inside of the wall, by a simultaneous division of which, after the vegetative development is completed, numerous germ-cells are formed, finally swarming out of the expanding mother tube,

* According to Nägeli's limitation of this chaotic genus. (Vide Nägeli, 'Die neueren Algensysteme,' p. 153.)

which becomes torn at the side or bottom.* The contrast in the development of the upper and lower ends of the cell presents itself still more strikingly in *Botrydium*. The young plant is a globular cell, which might be readily mistaken for a *Protococcus*, but, with further development, a hyaline prolongation is produced below, penetrating into the earth and branching like a root, while the upper part of the cell swells up more and more into a large obovate vesicle. The mucilaginous contents form a lining to the walls, containing numerous chlorophyll vesicles. After the growth is complete, numerous germ-cells are formed out of the lining coat of the wall, and these do not appear to swarm, but are set free by the membrane of the parent-cell becoming gelatinously softened, collapsing, and finally dissolving. In *Vaucheria* the lower part of the cell grows out in like manner into a branched pale-coloured root, and the upper part is elongated in a still more considerable degree into a stem-like filament, which grows on and on by apical development until its growth is finally arrested by fructification. From the ascending filament arise lateral prolapsing branches, endowed with special faculty of apical growth, some of these being large and erect like the main stem, others small and divergent. A single moving germ-cell is produced in the point of each erect branch;

* *Ascidium acuminatum*, A. Br., occurs near Freiburg, in waterbuts or troughs, or on stones or confervæ in rills flowing from springs. It resembles in aspect *Characium Sieboldii*, A. Br., occurring in similar situations, from which it is easily distinguished by the more bulging form of the cell, more apiculated at the apex, and never containing more than one starch-vesicle. The swarming germ-cells are $\frac{1}{200}$th — $\frac{1}{150}$th of a millim. long, longish, and furnished with two cilia at the narrower end, $1\frac{1}{2}$ to 2 times as long as the germ-cell. After the germ-cell has settled down by the ciliated end, the plant grows rapidly, is at first slender and attenuated upwards and downwards; subsequently it becomes bellied out, almost ovate, running out suddenly into a sharp point above. The full-grown cell is about $\frac{1}{20}$ millim. long. While young, the cell is filled up uniformly with green contents, later they form a rather thick coat over the wall, uneven on the inner free surface. When the formation of germ-cells commences the starch-vesicle disappears, and the coat lining the wall becomes subdivided into 50 — 60 gonidia.

in the horizontal branchlets are formed, in each case, one thick-coated, resting spore.* *Bryopsis* goes still further than *Vaucheria* in the development of different parts from one and the same cell; for in this the cell produces roots on one side, and, on the other, erect stems, with apical growth, multiplying themselves by ramification. On these stems are formed distichous, or spiral series of shorter branchlets, with limited apical growth, these clothing the stem like leaves, and finally, when the canal of communication with the stem has become closed up, falling off like leaves. The numerous moving germ-cells of *Bryopsis*† are formed in these branchlets. The genus *Caulerpa*‡ forms the last link in this series of remarkable shapings of the simple cell. In this the undivided cell forms in its development a creeping stem, growing on *ad infinitum* at its apex, from which (besides inessential branches, repeating the main stem, and, like it, unlimited,) proceed two kinds of branches with limited growth, different from each other and from the main stem, namely, to the under side divided roots, to the upper leaf-like branches which, originally cylindrical, expand into laminæ in subsequent growth, and present different forms according to the species; in *Caulerpa prolifera*, for example, lingulate and obtuse, in *C. denticulata*§ broadly lanceolate, deeply toothed, and somewhat acute, in *C. plumaris* pinnatifid or cut like a comb. Much as these structures remind us, by their form, of the stem-leaves of the higher plants, they are merely hollow prolongations of the one cell,

* *Vaucheria*, moreover, passes into a many-celled condition in the preparation for spore-formation, for the points of the branches on which spore-formation occurs, become shut off into distinct cells. Vide Unger, 'Die Pflanze in momente der Thierwerdung,' (1843), and Thuret, 'Sur les Organes locomoteurs des Spores des Algues,' ('Ann. des Sc. nat.,' 1843.)

† Vide the section on *Bryopsis*, in Nägeli, ('Algensysteme,' p. 171;) 'On the Formation of Spores,' J. Agardh, ('Ann. des Sc. nat.,' 1836.)

‡ Vide Nägeli's important researches in *Caulerpa prolifera*, ('Zeitschr. fur Wiss. Bot.') heft 1, (1844,) p. 134.

§ Decaisne, 'Plantes de l'Arabie heureuse,' 'Arch. du Mus.' ii, (1839,) t. vi, B.

which developes itself into the form of stem, root, and leaf. The origin of organs of distinct kinds, which is connected in the higher plants with a very complicated multiplicity in the cell-formation, appears here to be attained simply by development of one and the same cell, separating itself into different directions of growth.

The simplest plants with a *many-celled cycle of vegetation*, whether this be connected or broken up into constituent members, stand far behind the plants with a unicellular cycle last considered, in regard to organic differentiation. In this series again, nature ascends by a scale of different types, from a minimum of contrast in growth, to a progressively more distinct realization of the various directions of formation. That which was attained in the former cases through the differentiation of the individual cell, without isolation of its parts one from another, is here reached in the most manifold gradations through the formation of cells differing among themselves, this happening either merely by a difference in the generations of cells, or by a different character of the cells of the same generation. The distinctions occurring here may relate either to the mode of origin of the cells (combined or free formation), to the generative capability (permanent cells and mother-cells), or to the mode of final development (predominant growth in one or other direction, the different shaping of the contents and of the walls). Thus arises an infinite variety in the genealogy, arrangement and final development of cells, which becomes the more difficult to trace the higher we ascend in the vegetable kingdom. I confine myself to a few indications from the lower groups of the vegetable kingdom, especially from the Algæ, the deep study of which appears the more important the more fully the science becomes conscious of its object—to penetrate into the regulated course of development of vegetable structures in all their infinite complications.

The simplest conditions are exhibited by those plants in which all the generations of cells, except the transition-generation leading from one generation-cycle to another, are alike. As long as mere vegetative multiplication lasts, similar generations are formed; with the commencement of fructification is formed a last generation of cells, different from the preceding, constituting at the same time the first generation of the new cycle, and as such, although originally different, exhibiting in its final development the same characters as the succeeding vegetative generations. The last generation (that of the germ-cells or spores,) is either imperceptibly or perceptibly different from the foregoing, which circumstance gives room for a series of subordinate gradations. Among the instances of the former condition are the Chroococcaceæ,* to which are allied (with more intimate connection of the vegetative generations of cells) the Oscillarieæ, and a part of the Palmellaceæ,† to which are related the *Hormidia*,‡ with *Prasiola*. In all these the propagative cells agree with the vegetative in their origin, and are only distinguished from them by the circumstance of becoming free at last, while the vegetative cells of all or at least of several immediately succeeding generations remain combined

* Vide Nägeli, 'Einzellige Algen,' p. 44, t. 1. In *Synechococcus*, *Glœothece* and *Aphanothece* the cells of all the generations become elongated and divided in the same direction, and would, if they did not separate from each other, form filaments, like *Oscillaria;* in *Merismopœdia* the generations are divided alternately in two directions of a plane, whence flat, single-layered plates are formed; in *Chroococcus*, *Glœocapsa*, and *Aphanocapsa* the division takes place alternately in three directions of space, whence arise globular or finally shapeless families. Directing our attention to the difference in the position of the axes and the planes of section of the cells, in the last-named cases, we may distinguish in the succession of the otherwise similar generations, subordinate cycles, in one case with two members, in the others with three. There is also another respect in which the succeeding generations are not always exactly alike, the last generations frequently remaining smaller than the earlier, as, for example, is ordinarily the case in *Glœocapsa*, where the size of the cells diminishes with the increasing magnitude of the family-stock (*phytodom*).

† *Ex. gr. Stichococcus*, (Näg., l. c., t. iii, G); *Hormospora*, (Näg., t. iii, B); *Pleurococcus*, (Näg., t. iv, E); *Glœocystis*, (Näg., t. iv, F); *Palmella*, (Näg., t. iv, D); *Porphyridium* (Näg., t. iv, H); the first two forming rows of cells, the last four solid groups of cells.

‡ In the genuine *Hormidia*, not living in water, I have found no other propagation but a breaking up of the filaments into single cells. Hence *Hormidium* seems to me most closely allied to *Stichococcus* and *Hormospora*.

in families, either loosely (by thin or gelatinous enveloping membranes), or more firmly (by tougher cell-coats). The second case, in which the reproductive cells show important differences from the vegetative generations, is represented by a few Palmellaceæ with swarming transitional generations, and by the Diatomaceæ. In the former the reproductive cells originate, like their predecessors, by division, but they soon assume a peculiar form and, furnished with cilia, break through the enveloping membrane of the old family to commence the vegetative cycle anew, after a short period of motion;* in the latter, the Diatomaceæ, the transitional generation is formed in a way essentially different from the preceding division-generations, for two cells become connected by simple or double conjugation, and, form one or two reproductive cells by the combination of their contents at the point of connection; these reproductive cells are originally globular and altogether unlike the very peculiarly shaped vegetative cells of this family, but, by an uninterrupted growth, soon acquire the shape of the parent-cells, from which the first generation of the new cycle originating in this way is distinguished merely by greater size.†

* Vide the genera *Tetraspora*, (Näg., t. ii, C); *Dictyosphærium*, (Näg., t. ii, E); *Apiocystis*, (Näg., t. ii, A); the first of which forms a cellular plate, the second a free solid group of cells, the third a solid group attached by an attenuated base like a stalk. Besides the alternation in the direction of the divisions, there occurs in these genera a further slight distinction in the generation of cells, in that one or two generations of cells are alternately transitory, that is, they divide anew before they have attained the usual size of the vegetative cells.

† Vide Thwaite's 'Observations on the Diatomaceæ,' 'Ann. and Mag. of Nat. Hist.,' vol. xx, (1847,) t. iv; (*Eunotia turgida*), t. xxii; (*Cocconema lanceolatum*, *Gomphonema minutissimum Himantidium pectinale*), series 2, vol. i, (1848,) t. xi, (*Melosira* and *Cyclotella*.) The denomination of the reproduction cells produced through conjugation as sporangia (sporangial frustules) by Thwaites, depends on a too widely stretched comparison with those of the Desmidiaceæ. According to Thwaites's own description, the reproductive cells of the Diatomaceæ pass directly into vegetative cells, which is not the case in the Desmidiaceæ. The strange phenomenon that the primary generation formed through the conjugation attains about double the size of the parent cells, is simply explained by a gradual decrease of size in the series of vegetative generations formed by division, a phenomenon to which I have already called attention above in the case of *Glœocapsa*.

In the cases hitherto examined we could observe, in the series of successive generations of cells, only *one* different from the rest, the transitional generation, which is at once the last of the old and the first of the new cycle of generations. In the Desmidiaceæ, the Zygnemaceæ, and in *Palmoglæa*, the transitional generation is divided into a double one, since the last generation does not pass directly into the first, but the first generation of the succeeding cycle is produced, as a new structure, in the germination; so that we have here to distinguish three kinds of generation of cells,—the commencing generation, the concluding generation, and the intermediate vegetative generations. In the Desmidiaceæ, after a long series of vegetative generations of cells, which sometimes remain connected in rows (*Desmidium*, *Didymoprium*, *Hyalotheca*), sometimes vegetate as completely separate cells (*Micrasterias*, *Euastrum*, *Closterium*, &c.), there occurs a conjugation of two cells and union of their contents in the point of connection, whence is formed one,* or, more rarely (by double conjugation), two † reproductive cells, wholly different from the preceding vegetative generations in the form and aspect of the cells. They are always globular and thick-coated, sometimes smooth,‡ sometimes rough, like the ancient spiked mace-heads, with simple or many-pointed, forked or hooked spines; § and they do not pass, like the swarming-cells of the Palmellaceæ and the reproductive cells of the Diatomaceæ, directly and by uninterrupted growth into the primary generation of the new vegetative series, but persist for a long time in a condition of rest, during which, excepting as regards

* Vide the illustrations in Ralfs' excellent Monograph of the British Desmidiaceæ, (London, 1848), for instance, t. iii, (*Didymoprium*); t. xvi, (*Cosmarium*); t. xxiv, (*Tetmemorus*); t. xxv, (*Penium*); t. xxvi, (*Doeidium*); t. xxvii, xxviii, (*Closterium*); also Nägeli, 'Einzell. Algen.,' t. vii, f. 6, (*Cosmarium rupestre*).

† Ralfs, l. c., t. xxx, (*Closterium lineatum*).

‡ Ralfs, l. c., t. iv, (*Desmidium*); t. xxv, (*Penium*); t. xxix, (*Closterium*), &c.

§ Ralfs, l. c., t. vii, (*Micrasterias*); t. xii, (*Euastrum*); t. xvi, (*Cosmarium*); t. xxii, (*Phycastrum*), &c.

imperceptible internal processes, they remain wholly unchanged.

To distinguish these from the direct *germ-cells* (*gonidia*), I shall call them *seed-cells* (*spores*).* The development of these spores has not yet been observed, but it may be assumed as certain that they do not pass, as such, into the primary generation, but produce this at the period of germination by an internal transformation of their contents, and bring these to light as a new generation, with a dehiscence of the old envelope. Certain early conditions observed in *Closterium* and *Euastrum*, namely, families of unusually small individuals, enclosed in transparent, colourless vesicles,† render it even probable that in certain genera of this family, a number of individuals are produced from one spore, by a formation of transitory generations occurring already within the spore. The enclosing vesicle is probably the dissolved and swollen-up internal cell-coat of the spore, which holds the young individuals combined for some time after the outer coat of the spore has been thrown off. The behaviour of the spores of the family of the Zygnemaceæ, which appears to be closely allied to that of the Desmidiaceæ, confirms the conjecture as to the development of the spores of the latter. The filaments of the Zygnemaceæ are composed, like those of the Desmidiaceæ with connected cell-generations, merely of one kind of vegetative cells, which increase by repeated halving.‡ The last

* Many authors call these cells *sporangia;* but if we compare their behaviour with that of the spores of the higher orders of Cryptogamia, in which, in like manner, only the internal substance is developed into the germ-plant, the coat being thrown aside, we must regard them as true spores, while, on the other hand, those spores of the Algæ passing directly into germination, to which belong in particular all swarming-spores, differ importantly from ordinary spores, and would be better termed *Gonidia.*

† Vide Ralfs, l. c. t. xxvii, and Focke, 'Physiologische Studien,' (1847,) t. iii, fig. 27.

‡ So far as my observations extend, the filaments of the Zygnemaceæ appear, like those of *Desmidium*, to be formed merely by repeated division into equivalent cells, thus to possess neither apical growth nor distinction into an upper and lower end. I have never found the radical structure by which they are often attached otherwise than lateral. Unfortunately I

cells originating in this way are ordinarily shorter than those of the earlier generations, and enter into conjugation* in the well-known way, subject to many modifications. Through the union of the contents of the two conjugated cells, is formed, either in one of the two cells, or in the link connecting them, a globular or longish smooth spore, clothed with a multiple coat, from which the young plant is developed after a long stage of rest. In *Spirogyra* the coats of the seed-cell (spore) are thus torn,—first the outer, thinner, water-clear coat, next the inner, thicker, yellowish spore-coat is stripped off, and the contents, transformed into the germ-cell and clothed with a new coat, emerge in the form of a spindle-shaped body, having both ends of like character,† which bears great resemblance to the solitarily living cells of the Desmidiaceous genus *Spirotænia*.‡ But the observations of Thwaites, who saw the contents of the ripe spore separate into four portions in certain Zygnemaceæ, particularly *Mesocarpus* and *Staurocarpus*,§ testify that a formation of several germ-cells or young plants in one spore may occur in this family.

Essentially different from the conditions of the Desmidiaceæ and Zygnemaceæ is the propagation of *Palmoglœa*, a genus which has hitherto been reckoned among the Palmellaceæ, to which, although the occurrence of a conjugation of the cells might incline one to the opposite view, it is certainly more intimately related

have not been able to follow the observation of the germinating plant as far as the commencement of root-formation. (See Pringsheim, on *Spirogyra*, 'Flora,' 1852; Transl. in 'Annals of Nat. Hist.,' 2d ser., vol. xi, 210.—A. H.)

* Vide Hassall, 'British Fresh-water Algæ,' (1845) t. xviii—xlix.

† The germination of the *Spirogyræ* was observed by Vaucher ('Hist. des Conferves d'eau douce,' 1803). I have seen it take place in the above-described way in July of the present year, in *Spirogyra retiformis*, which had been collected with ripe spores eleven months previously. I shall mention hereafter some of the remarkable changes in the contents of the spores occurring as preparatory to germination. (See Pringsheim, l. c.—A. H.)

‡ Vide Ralfs, l. c., t. xxxiv, f. 1, 2.

§ I am only acquainted with these observations from the report in the 'Botanische Zeitung,' 1846, p. 498. ('Ann. Nat. Hist.,' xvii, 262. See on this subject also Pringsheim on *Spirogyra*, l. c., p. 296.—A. H.)

than to the Desmidiaceæ. While, in the Desmidiaceæ and Zygnemaceæ, the last generation of vegetative cells produces the seed-cells (spores) as a new generation, since the latter shape themselves out free in the interior of the conjugated parent-cells, through the loosening of the contents of the latter from the walls,—in *Palmoglæa* the last vegetative generation passes directly into the formation of seed-cells (spores), since the cells combining in pairs by conjugation, enter into perfect union, *i. e.*, not merely mix their contents in a new structure, but merge or flow one into another entirely (coat and contents) like two drops of water. The large seed-cells (spores) originating in this way gradually acquire a thick coat and oily contents, passing into a summer-sleep, overlasting the hot and dry season, till, with the recurrence of the cold damp season, the contents become metamorphosed and divided, while the coat of the seed-cell swells up and dissolves into jelly. Thus the primary vegetative generation is produced as a new generation out of the seed-cell, the contents first formed by blending, dividing again, and becoming freed from the coat of the mother-cell.*

So far as we have hitherto examined the differentiation connected with the succession of generations of the cells, we have found solely like cells within each generation; we have seen, moreover, all the terminal links of the multiplied series attain the conclusion of the cycle (as fructification-cells) in the same way, accidental exceptions being of course excluded. The further complications arise not only from a greater difference presenting itself in the successive generations, but from the cells of the same generation also exhibiting different characters. The latter, again, may happen in two ways: either two daughter-cells originating in one and the same mother-cell (therefore two sister-cells) are unlike each other, or the daughter-cells of distinct mother-cells belonging to

* Vide the figures in Pl. 1, and the more minute description of *Palmoglæa* in the Appendix.

the same generation (that is the first-cousin-cells) differ from each other. The first condition is of especial importance in regard to the development of the organic differences in vegetative structure, since on it depends the apical growth and the ramification of many-celled plants; on the latter depends, among other things, a duplicity of fructification, occurring even in the lowest groups of the Vegetable kingdom, and which we shall here, in the first place, briefly examine. Numerous Algæ produce two (or sometimes even three) kinds of reproductive cells, either two kinds of moving or motionless gonidia, or gonidia and spores, or, lastly, two kinds of spores, which last can also occur in the higher groups of the Cryptogamia. Probably this phenomenon is more generally diffused among the Algæ than can be accurately demonstrated at present; therefore when I mention many doubtful cases here, it is with the express purpose of directing attention to an object deserving of further investigation.

Among the examples of plants with two kinds of moving germ-cells, large (*macrogonidia*) and small (*microgonidia*) the Water-net (*Hydrodictyon*) already mentioned above, is especially worthy of mention. The unicellular individuals of this Alga, hitherto incorrectly arranged with the Zygnemaceæ,* are united in their earliest stages into a colony, forming a bag-shaped net. All the cells of such a net are sister-cells, for they all originate in one and the same mother-cell, but they do not all behave alike when fructification commences. In certain cells are formed somewhat larger and less numerous gonidia (according to the size of the mother-cell, 7000 to 20,000), in other cells of the same net somewhat smaller and more numerous gonidia (30,000 to 100,000). Only the former (the macrogonidia) form a new net, which they do after a short tremulous movement (lasting about half an hour), without leaving the mother-cell, by uniting together into a daughter-net, which is gradually set free by the solution of

* Kützing, 'Species Algarum' (1849), p. 448.

the coat of the mother-cell. The microgonidia, on the other hand, distinguished not only by their smaller size but by a longer shape, a small parietal red vesicle and four long cilia (which appear to be very short in the net forming macrogonidia), swarm out from the bursting mother-cells, move about very actively, often for the space of three hours, and after coming to rest, become green *Protococcus*-like globules, which vegetate for some time and at length die away without any further propagation. Thus we see here formed in previously indistinguishable sister-cells of the same net, brood-cells of two kinds, which are both direct germ-cells or gonidia, but are developed one into a fertile generation, the other into a sterile generation fated to destruction; both active, but in different degrees, one, moving for a short time, forming a net, the others, "swarmers," never reunited into a colony.* Two kinds of active germ-cells, (macrogonidia and microgonidia, occur also in *Chlamidococcus pluvialis* (*Hæmatococcus pluvialis*, Flotow†) a plant allied to *Chlamidomonas* and the Volvocineæ, into the complicated history of which, however, I cannot enter further here, lest I should be led away too far into the debateable ground between the Animal and Vegetable kingdoms. Another example, belonging to the group of the filiform and branched fresh-water Algæ, is furnished by *Draparnaldia*, from which *Stigeoclonium* is scarcely generically distinct. *Draparnaldia mutabilis*, the numerous species of *Stigeoclonium*, as well as the very nearly related *Chætophoræ*, are among those plants in which the formation and birth of active germ-cells may be most easily observed, and indeed have very frequently been

* I must reserve the history of this remarkable plant, to which I shall return several times, for another opportunity. My own observations were chiefly made in the summer of 1846, and the results made known at the meeting of the Swiss "Naturforschende Gesellschaft," at Schaffhausen, in August, 1847.

† 'Nova Act. Nat. Cur.,' vol. xx, ii, 1844. (Also Cohn, 'Nova Acta,' xxii, p. 397, an abstract of which paper is included in this volume. Also Schacht, 'Die Pflanzenzelle,' Berlin, 1852, p. 124.—A. H.)

examined.* In the three genera named there is formed, in each cell of the branches, after their last vegetative division, an active germ-cell, which, furnished with four cilia and a parietal red vesicle, breaks through the side of the cell-wall in swarming out. In *Stigeoclonium protensum*, K. (?), however, I have found, towards the end of the period in which this plant appears, a modification of the mode of formation of the active gonidia, in which each cell gave birth not to one, but (by perpendicular division of the contents) two to four smaller, more roundish swarmers; as to the germinative powers of which, however, I have no experience. In *Draparnaldia mutabilis*, also, I observed an analogous formation of microgonidia, not produced by perpendicular, but by further continued horizontal division of the cells. Nägeli† mentions an observation on *Melosira varians*, according to which the parietal colour-vesicles of this Diatomacean sometimes become detached, and move in the manner of swarm-cells, which might indicate an occurrence of active microgonidia, together with the above-described formation of larger, motionless germ-cells. Many examples may be cited of the conjoined occurrence of gonidia and true spores; many of these, however, still require more accurate investigation. In the family just named, the Diatomaceæ, certain genera seem to exhibit, as a second mode of reproduction, a formation of seed-cells with numerous young individuals, such as we have assumed above of *Closterium;* so also *Schizonema* and *Micromega*.‡ In the Desmidiaceæ, on the contrary, a

* Vide Treviranus, 'Verm. Schriften,' ii, 1, p. 73 (1817—*Draparnaldia*); Kützing 'über die Verwandlung der Infusorien in niedere Algen-formen' (1844—*Stigeoclonium stellare*); Fresenius, 'Zur Controverse über die Verwandlung von Infusorien in Algen' (1847—*Chætophora*). I have myself observed the active germ-cells of *Draparnaldia mutabilis, Stigeoclonium thermale* (June 1847), *subspinosum* (May 1847), *protensum*? (May 1848), *tenue* (July 1849), *Chætophora tuberculata* (Aug. 1847), and *elegans* (Sept. 1847).

† Vide Nägeli, 'Gatt. einzelliger Algen,' p. 10.

‡ Vide Kützing, 'die Kieselschaligen Bacillarien oder Diatomaceen' (1844), t. xxv, f. 8; t. xxvii, f. 11; t. xxviii, f. 1.

formation of gonidia seems to occur sometimes together with the spore-formation, and this in a double way. The formation of numerous small swarmers in unconjugated cells is mentioned by Ralfs as a not uncommon phenomenon, but in so indistinct a way, that we cannot form a satisfactory idea of it.*

The active corpuscles found by Ehrenberg in a *Closterium*, which he described as monad-like Infusorial animalcules, under the name of *Bodo viridis*,† might be referred here.

According to Morren,‡ there is a totally different process in *Closterium Lunula*, where, through conjugation of two individuals, a single large active germ-cell is formed, which commences a revolving movement in the connecting canal of the parent-cell, already inside the coats, then leaves the torn coats, and, after swarming from ten to twenty minutes, sinks down and immediately germinates, *i. e.*, becomes elongated and returns to the form of the old *Closterium*.

If these statements of Morren are correct, there occurs in the *Closteria* a double character of the reproductive cells formed through conjugation, these sometimes appearing as direct germ-cells (gonidia), and sometimes as true seed-cells, it being uncertain whether the two cases occur in one and the same species, or separately in different species.§ The two-fold fructification of *Vaucheria* has been spoken of already above (p. 128); it follows also, from the observations of J. Agardh,‖ that large spores are formed in addition to the small gonidia in *Bryopsis*. Moreover, the simultaneous occurrence of gonidia and spores is beyond doubt, in the large genus *Œdogonium*

* Ralfs, 'the British Desmidieæ, p. 9.

† Ehrenberg, 'Infusionsthierchen,' t. ii, f. 15.

‡ Morren, 'Mémoire sur les Closteries.' ('Ann. des Sc. nat.,' v, 1836.) (See also Smith, 'Ann. Nat. Hist.,' 2d ser., vol. v, 1.—A. H.)

§ It is remarkable that Ralfs, who has seen the formation of spores in so many Desmidiaceæ, says nothing about it in reference to this very *Closterium Lunula*, and the allied species *Cl. Ehrenbergii* and *moniliferum*.

‖ J. Agardh, 'Algæ maris mediterranei' (1842), p. 4.

and the allied genus *Bulbochæte*, in which particular cells, in *Œdogonium* those of the unbranched filament, in *Bulbochæte* those of the branches, swell up and produce within a motionless seed-cell, acquiring a special membrane, often quite removed from the membrane of the mother-cell, and destined to a long stage of sleep, while the contents of the rest of the cells, when otherwise sufficiently abundant in quantity, become converted into an active germ-cell, bearing a crown of numerous cilia. In *Œdogonium* the birth of the swarming-cell takes place through a transverse dehiscence of the parent-cell at the anterior end; in *Bulbochæte* by disarticulation of the small cell bearing the bristle, and rupture of the wall separating it from that of the large cell.* Certain species of *Œdogonium* (*Œ. echinospermum* and *apophysatum*) are especially remarkable, since they produce, in addition, two kinds of swarming cells, macrogonidia and microgonidia, the latter of which originate in special, very short cells, arranged mostly in groups between the larger cells. The macrogonidia germinate as soon as they come to rest, and grow up into normal filaments; but the microgonidia, although they germinate, produce only two-celled dwarfs, which die away without developing any further. The genus *Coleochæte*† affords another example of the united occurrence of gonidia and spores. Individual terminal cells of this genus are developed into

* In *Œdogonium fonticola* A. Br. ('Kg. Sp. Alg.,' p. 368), a species which occurs almost everywhere in the pools formed by running springs, the formation of the "swarmers" may be observed throughout the whole year, while the formation of the resting spores occurs but rarely. In *Œ. capillare*, the commonest species of the genus, I have hitherto met with "swarmers" alone. I have observed both kinds of fructification in *Œ. Landsboroughii* (Hass.), *vesicatum* (Vauch.), *fasciatum* (Hass.), *Braunii*, Kg., *echinospermum*, A. Br. (Kg. l. c. 366), *apophysatum*, A. Br. (ibid.), *Bulbochæte setigera*, Ag., and *minor*, A. Br. (Kg. l. c. 422). *Cymatonema confervaceum*, Kg. (Sp. Alg. 375), behaves exactly like *Œdogonium* in the bursting of the cells, but I have not yet succeeded in observing the swarming out. (See also Thuret, 'Zoospores des Algues,' Ann. des Sc. nat., 3d ser., xiv, p. 17, pl. 19.—A.H.)

† Vide Nägeli, 'Algensysteme,' p. 166, v, f. 22—31. I have observed the formation of spores, as well as of gonidia, in both species of this genus, *C. scutata*, Brib., and *pulvinata*, A. Br. (Kg. 'Sp. Alg.,' 424).

sporangia, in which several resting spores are formed by division of the coat lining the wall, while the contents of the rest of the cells are frequently converted into a *gonidium*, which in *C. scutata* breaks through the upper wall of the cell, and in *C. pulvinata* emerges laterally, to swarm. The gonidia of this genus appear to possess only two cilia. In the marine Algæ of the genera *Mesoglœa** and *Myrionema*, a double, in *Ectocarpus*† a triple, fructification has been observed; but it is very doubtful whether large resting spores occur in these genera, besides active gonidia, since Nägeli has pointed out that in *Ectocarpus* the contents divide into numerous small germ-cells, not only in the roundish apical cells of the branches, but in the longish, many-celled points of the branches, and in the expanding articulation cells of the stem. On the other hand, in the Fucoideæ, (in the strictest sense,) the occurrence of large resting-cells, together with very small swarming-cells, regarded by Decaisne and Thuret‡ as spermatozoids, is beyond doubt. Both kinds of fructification are formed, in the Fucoideæ, in the terminal cells of the jointed filaments which clothe the interior of the fructification cavities. The extremely small gonidia are of pale colour, and have a parietal red point. According to the authors cited, they exhibit two extremely delicate filaments, one in front vibratile, the other, behind, said to be passively swayed about.§ The

* Kützing, 'Phyc. generalis,' t. xxvii, 1.

† Vide Crouan ('Ann. des Sc. nat.,' 1839, p. 248, t. v); and Nägeli, 'Algensysteme,' p. 145, t. ii, f. 1—6. (Also Thuret, 'Ann. des Sc. nat.,' 3 ser., xiv, p. 25, pl. 24.—A. H.)

‡ Decaisne et Thuret, 'Recherches sur les Antheridies et spores des Fucus,' ('Ann. des Sc. nat. i, iii, 1845,) t. i—ii.

§ The position of the cilia is thus importantly different from that usual in the active gonidia of the fresh-water Algæ; on the other hand, the swarming-cells of the Fucoideæ do not agree at all in form with the spermatozoids such as we are acquainted with in the Characeæ, Mosses, and Ferns. Whether, like the spermatozoids, they are formed in special, minute cellules, or originate by simple division of the contents of the large parent cells, is unfortunately unknown. The character of the contents of the "swarmers" of the Fucoideæ renders it unlikely that they possess the power of germinating, but it cannot be deduced from this that they have a fertilising action.

larger spores, on the contrary, exhibit a strong membrane and dark olive-brown contents. After they are sown the membrane swells up, and the contents become divided, at least in some genera of the Fucoideæ, into two, four, or eight parts, which pass at once into germination, a process which reminds us of the above-described behaviour of the spores of the *Closteria* and certain Zygnemaceæ. As a last example of the occurrence of double fructification in the group of Algæ, I mention *Chantransia*. The ordinary, long-known fructification of this genus consists of globular, very thin coated germ-cells, having a central rose-coloured vesicle in the light verdigris green contents, which germ-cells are formed separately in the terminal cells of the tufted lateral branchlets, and are set free by the rupture of the parent-cells. They have no independent motion, but probably germinate directly after they are discharged; on this point, however, we have no certain observations. In the same plant, and indeed on the same "stocks" and branches, there occurs more rarely a second kind of fructification,* in which the cells forming the links of the branches swell strongly at the side, and form a large thick-coated spore in the protruberance, which becomes shut off as a distinct cell.

Chantransia therefore exhibits two kinds of motionless reproductive cells, the smaller of which are probably immediately-germinating gonidia, the larger resting

The decision of their true import therefore requires, on the one hand, further observations completing the history of their formation and life; and, on the other, the discussion of the question, whether the formation of active, and, as we have seen, in many cases sterile gonidia, is not to be regarded as a precursor of the formation of spermatozoids, just as in a higher group, the formation of two kinds of spores, the former of which are likewise, in many cases, sterile, must be regarded as an anticipation of the contrast of pollen and embryo-sac. (See Thuret, 'Comptes Rendus,' April 25, 1853; Transl. in 'Annals of Nat. History,' 2d ser., vol. xii, p. 64, who shows that the antherozoids do fecundate the spores of Fucoideæ.—A. H.)

* I observed this in October of last year in a form of *Chantransia chalybea*, Fries, very frequent at Freiburg, which Kützing ('Sp. Alg.,' 430) mentions as *Ch. chalybea*, var. *radians*.

spores. Two kinds of thick-coated and resting spores, macrospores and microspores, which are both found in the same way, in fours in mother-cells, occur, lastly, in many Lycopodiaceæ,* in the allied genus *Isoëtes*,† and in the genera of the Rhizocarpeæ, *Marsilia*, *Pilularia*, and *Salvinia*. In the examples last named we have advanced very far beyond the original simplicity of the vegetable structure which we had before us in the first examples; they only admit of citation here, in so far that they likewise exhibit essentially similar generative series of mother-cells, and finally go out into distinction of fructification cells.‡

In the higher groups of the Vegetable kingdom, the difference of the fructification-cells is preceded by a still more important difference of the vegetative generations of cells. The distinctly qualitatively differenced reproductive cells (fertilizing-cells and germ-cells) form the conclusion not of similar, but of unlike series of generations of cells, and, moreover, not of all, but only of certain series of generations, while a still greater number of series attain their purpose and destination within the vegetative organism, without arriving at fructification in the last generation. While in the lowest plants, all vegetative cells, as mere repetitions of the same thing, belong to one rank, in the higher the cells divide, in the course of the generations, into different ranks, by which the organism is completed on a different side, and through which is caused a more necessary coherence and more intimate combination than

* Göppert concludes that both the small and large spores are capable of germination, from observation of two different forms of the young plants in *Selaginella denticulata*. ('Uebersicht der Arbeiten der Schles. Ges. fur Vaterl. Cultur.,' 1845, p. 129.) (Proved incorrect.—A. H.)

† According to a recent note in a letter from Dr. Mettenius (Nov. 1844), spermatozoids are developed in the small spores during the germination of the large spores, which confirms the analogous observation of Nägeli on *Pilularia*. ('Zeitschr.,' 1846, 188.)

‡ (On this subject, much developed since the above was written, consult the Report on the Higher Cryptogamia, by A. Henfrey, in the 'Annals of Nat. History,' 2d ser., ix, 441, which also gives most of the new literature of this subject.—A. H.)

we have seen in the lower stages, where each cell strives to vegetate for itself alone. The development of different ranks of cells, with which is connected the realisation of the organic differences in the vegetative sphere, in the higher plants, is chiefly attained by the above-mentioned production of daughter-cells of different kinds in one and the same mother-cell, therefore by *differing sister-cells*. We will examine this condition in a few examples of the simplest kind, so as to indicate the path by which nature advances in the production of the multiplicity of cell-formation of one and the same plant.

We meet with the first separation of vegetative permanent cells from series of generations terminating in reproductive cells, in the Nostoc-like Algæ. The necklace-like filaments of *Nostoc*, composed of a row of cells, exhibit at one or both ends, as also here and there in the course of the filament, particular cells distinguished from the rest by size, regular rounding, thick membrane, and pale, homogeneous contents; while the remaining, smaller, thin-coated cells, filled with darker and often granular contents, continue to multiply in rapid succession by division, until they finally, in the last generation, fall apart as germ-cells, exhibiting no perceptible difference from the preceding generations. The large terminal and interstitial cells just named remain almost unchanged, neither undergoing further vegetative division, nor taking part in the propagation.*

The origin of these peculiar boundary-cells can only take place by certain of the cells dividing into two unlike daughter-cells, one of which becomes a vegetative permanent cell, the other a mother-cell of a series of uniform generations of cells, terminating in fructification. It is probable that the very first cell (the germ-cell) divides in this way into two unlike cells,† and then, when a filament

* These cells have been hitherto incorrectly regarded as seed-cells, (*spermatia*, Kg.).

† Very young plants of *Nostoc* (or *Hormosiphon ?*), exhibited a short filament enclosed by a gelatinous vesicle, having a boundary-cell only on *one* side, and this lying outside the gelatinous vesicle.

has been formed, this must be repeated, but in the reverse direction, by the cell at the opposite end, as well as by certain others lying in the midst of the filament. This first division into two unlike cells may be regarded as the rudiment of an apical growth, which, however, is arrested at the first step, since, after the production of a single cell of the second order, the further division of the cell of the first order of the second degree (the apical cell), produces merely cells of the first order. *Anabaina* (to which may be added *Sphærozyga* and *Spermosira**) and *Cylindrospermum* are distinguished from *Nostoc* by the occurrence not merely of two, but of three modifications of cells, since the cells multiplying by continued division (the cells of the first order) do not all behave alike in the last generation, but partly expand into larger, thick-coated seed-cells, doubtless destined to a long period of rest, and partly remain small and thin-coated, and then perhaps perform the function of a second kind of reproductive cells, corresponding to the more gonidium-like germ-cells of *Nostoc*, but, perhaps, at least in many cases, die away as sterile cells, when the filament breaks up. In *Anabaina* several of the intermediate cells of each section are developed into the larger seed-cells; in *Cylindrospermum* the lateral cells immediately bounding the terminal or interstitial cells.

The filaments of the Nostochineæ exhibit, otherwise, no perceptible contrast at the two extremities, and their intertwined and irregular position admits of no distinction into an upper and lower end.† In the group of the Scytonemeæ and Rivularieæ (excluding the Masticho-tricheæ) a contrast of this kind is distinctly present, but still without any root-like formation of the lower end,

* These three genera are so loosely defined by Kützing, that we cannot form any clear idea of his distinctions. *Anabaina* seems to me to be only sterile *Spherozyga*, and *Spermosira* to differ merely by shorter and more discoid cells, and *Nodularia* may be a sterile condition of the last form.

† I found indications of such a contrast in *Cylindrospermum humicola*, Kg., and other species, in which one end decidedly comes to its full development later than the other.

which is formed by a vegetative permanent-cell, like the boundary cell of *Nostoc*. In *Tolpothrix* and *Schizosiphon* several such vegetative permanent-cells frequently occur at the base of the filament, and in these very genera, as in *Scytonema* and *Euactis*, the formation of them is repeated at intervals in the course of the filament, where they appear as interstitial cells, which by subsequent parting of the filament, and the lower part overgrowing the upper, become basilar-cells of seeming branches. In the Scytonemeæ, the filaments are of pretty uniform structure throughout the whole length, but in the Rivularieæ they run out above into a more slender capillary point or flagellum. It is not yet made out whether the distinction of the upper and lower end of the filament of the Algæ of this group is caused by an apical growth continued on beyond the formation of the first basilar cells, but this much is certain, that the cells of the filaments multiply, in their further growth, as in the Nostochineæ, by repeated halving, which, however, does not terminate simultaneously in all parts of the filament, but continues longer in some parts than in others. In the Scytonemeæ it is carried on farther in the points (not merely of the entire filaments, but also in the individual sections).* In the Rivulariaceous genera *Mastichothrix*, *Mastichonema*, *Rivularia*, &c., in the lower; in *Euactis*, in the intermediate parts. With this is associated a distinction of the cells belonging to the different parts of the filament, becoming continually more evident with the progress of the division, and especially marked in the last generation. In the Scytonemeæ the cells pass into germ-cells, in the last generation, mostly only at the upper part of the filament; in *Euactis* only in the intermediate; in *Mastichothrix* and *Mastichonema* only in the lower, and thicker, not in the upper capillary portions; in Rivularia, lastly, the cells of the lower thicker part exhibit another difference, for the

* In many species of *Scytonema* and *Tolpothrix* the lower end of the sections may grow out in this way into new points.

lowermost (adjoining the basilar permanent-cell) becomes a large cylindrical, thick-coated seed-cell, as in *Cylindrospermum*, while the following shorter cells, richer in contents, are perhaps to be regarded as a second kind of germ-cell.*

From these examples of less decided and often still unsettled contrast of growth in the rows of cells chained together into filaments, let us direct our attention to certain others, in which the contrast of ascending and descending growth becomes more evident, on the one side by distinct root-formation, on the other by undoubted terminal development of the row of cells (cell-forming apical growth). This condition is exhibited in the simplest way, namely, by a filament-stem always single, in *Ulothrix* and *Œdogonium*, two genera, otherwise very different, which recent Algology has extracted from the earlier chaos of Confervæ. *Ulothrix zonata* † has active germ-cells, of which 8—16, or in weaker parts of the filament sometimes only four are formed in one mother-cell. These are of longish-ovate form, having four very fine cilia at the anterior pale extremity, and a red vesicle elongated in the transverse direction in the interior, lying at the side, about the middle. After swarming for at most two hours, these germ-cells come to rest, and immediately germinate. The cell then becomes elongated in two opposite directions, growing out in one, into a slender, hyaline, simple (or bifurcated at the point) fixing-root; at the other, extending cylindrically, and forming the commencement of a green filament-stem. Usually on the second day the first cell divides into two, about in the middle of the upper green end, and thus are produced a lower root-bearing end, dividing no farther, and an upper end which, after growing to not quite twice its

* It sometimes appeared to me as though the seed-cell, or the so-called *manubrium* of *Rivularia* originated by re-fusion of several previously separate cells, analogous to what occurs in *Palmoglœa;* but I could not attain a complete conviction of the truth of this.

† Vide Kützing, 'Phyc. generalis' (1843), t. lxxx. (Also Schacht, die Pflanzenzelle,' 1842, p. 120.—A. H.)

original length, separates again into a posterior longer, and an anterior shorter, cell; which latter repeats the same process, and so on. Thus, by a continually repeated division of the apical cell into two unlike cells, is formed a series of cells of a second order, the link-cells of the filament, the first of which is at the same time the root-cell. The filaments of *Ulothrix zonata*, once formed, grow no more in thickness, but gradually increase in diameter, from the base to the summit, in such a manner that the anterior parts often appear thrice or four times the diameter of the posterior, lying nearer the root.* The root-cell, as well as those next succeeding it, remain unaltered and are infertile; the following link-cells, on the contrary, after they have attained a length about twice their diameter, divide into two equivalent cells, consequently into cells of the second generation of the second order, whereby, since no further elongation takes place, cells are produced of about equal length and breadth. Still farther forward, therefore in the thicker part of the filament, this division is repeated once or twice more, so as to give rise to cells of the third or fourth generation of the second order, the length of which is only $\frac{1}{2}$ or $\frac{1}{4}$ their diameter. Finally, in the cells of the last generation of the second order, the germ-cells are produced by division of the contents alternately in the three directions of space.† The filaments of *Œdogonium*, in their earlier development, follow the same course as those of *Ulothrix zonata*, but differ in the subsequent subordinate division of the original link-cells, since these do not divide into equivalent cells, but into unlike cells, forming series of link-cells of the second degree, which is moreover accompanied by a longitudinal extension of the subordinate link-cells. The lowest link-cell, which expands at the base into a discoid, often elongately lobed root-foot, and is always of

* Hence the great variability in the diameter of the filament, which varies from $\frac{1}{100}$ to $\frac{4}{100}$, or sometimes $\frac{6}{100}$ millim.

† Vide Nägeli, 'Algensysteme,' p. 137, t. i, f. 53, 54.

greater diameter, and more bellied out than the succeeding, is the only one which divides no more, and constantly remains sterile. The resting spores of this genus are formed in the swollen end-cells of the subordinate rows of links.*

The *Ramification*, like the apical growth, of the many-celled Algæ, depends upon a division of the cell into two unlike parts, one of which retains the character of the mother-cell, and the other deviates; while, however, in apical growth the differing cell belongs to a higher order of cells, in ramification the differing cell returns, on the contrary, to a lower order, since it becomes a cell of the first degree of the first order, that is, the primary cell of a new series of generations.

Ramification is exhibited in its simplest form in *Sirosiphon* (*Hassallia*) and *Haplosiphon*.† Particular cells of the rows which form the filament-stem of these Algæ, divide in the perpendicular direction into two unlike cells, one of which, mostly larger, remains as a link-cell of the principal filament, while the other, elongating in the horizontal direction, emerges from the stem as a new axis, and then divides again, at right angles to the new axes, into two unlike cells,—a new apical cell, and a first link-cell of the branch. The further development of the branch takes place, as in the principal axis, by repeated division of the apical cell, which is followed subsequently by a division of the link-cells. The ramification proceeds in a different way in the *Cladophoræ* (the *branched Confervæ* of the older authors), in which the branches, solitary, or sometimes opposed in pairs, sprout forth from the upper margin of the link-cell, where a bagging out, as it were a new laterally projecting apex of the cell, is first formed, which, by division of the thus enlarged cell into the old and new parts, becomes the first cell of the branch.

* I am not acquainted with any genus of Alga with simple filaments formed solely by cell-forming apical growth without subordinate division of the link-cells. Among the ramified Algæ, *Batrachospermum* forms its stem in this way.

† Kützing, 'Spec. Alg.,' p. 894.

The ramification in *Chantransia*, *Bulbochæte*, *Chætophora*, and *Coleochæte pulvinata*, exhibits similar characters. In the last two examples there occurs, in addition, a descending ramification from the *lower* margin of the link-cells; so that, in many cases, an ascending branch springs from the upper border, and a descending branch from the lower border of the same cell. With the exception of the reverse direction, the mode of origin of these descending root-, or rather stolon-like branches, is the same as that of the ascending.

A further series of very varied organic differences next arises in the relations of the cell-formation of the branches to the cell-formation of the stem. If the cell-formation in the branches is limited, and the branches fall short considerably in size of the stem, they admit of comparison with leaves. Thus, for example, in *Draparnaldia*, in which the branches mostly arising in pairs from one cell of the stem, as well as the branchlets of the second order springing from these, are formed of much smaller cells than the stem, the upper, larger, forming the hyaline capillary points of the branches, while the lower and shorter, abundantly furnished with green contents, produce within them the germ-cells. The large cells of the stem of *Draparnaldia* are sterile vegetative-cells; only the apex of the long stem behaves in the same way as the branches, and is, like them, fertile, and terminated by a capillary point. In *Batrachospermum*, on the contrary, the stem is unlimited in its growth, formed of a series of link-cells, which originate through the repeated division of a dome-shaped apical cell, and undergo no further transverse division. From the upper border of the young, still very short link-cells arise 5—6 radiately-arranged projections, which are very early cut off, in the shape of special cells, from the central cavity, which remains as a link-cell, and these new cells then grow out, by limited link-formation, into the small, again much ramified branches, forming the peculiar globular whorls stem, starting from uniform* or dissimilar† division in the link-cells; how, moreover, the vessels are formed in the parenchyma of the stem in the vascular plants, *i. e.*, how their origin is connected with the generative succession of the rest of the cells.‡ It must likewise be demonstrated how the cell-formation in the leaf, progressing according to fixed laws, produces the simple cellular plate, such as is exhibited by most Mosses, and the many-layered plate, with varied arrangement and direction of the cells in the different layers, of the higher plants; how here again the formation of the vascular bundles enters into the tissue in the most diverse distribution, and how these vascular bundles are connected in their origin with those of the stem. Finally, it must be demonstrated how, beyond all the generations of cells arriving at vegetative permanence and at their final term in the graduated construction of the organism and the contrast of its organs, certain series of generations, withdrawing themselves from the vegetative termination, finally attain their destination prepared, protected, and supported by all the other series, in the formation of reproductive cells.

We have here stated a problem, the solution of which

* Vide *Styptocaulon*, in Kützing's 'Phycol. generalis,' t. xviii; in *Lemania* also, the formation of the compound tissue starts from a simple row of link-cells originating by horizontal division of an apical cell, which link-cells divide first by a cross-wise perpendicular segmentation into four, then by recurring horizontal division into eight equal cells. In what way the separation in the peripherical and central cells next takes place, and how the division proceeds in the interior, it is not easy to determine; but the result shows that the division occurring in the interior is far outstripped by that in the peripherical cells, since a rind is formed outside composed of two layers of very small cells, while the interior is occupied by many-times larger cells, separating from one another in the centre, and forming a medullary cavity.

† Vide *Ptilota* (Kütz. 'Phyc. general.,' t. 46, vi); *Naccaria* (ibid., t. 44, iv); *Alsidium Helminthochorton* (ibid., t. 45, xi); *Laurencia* (Nägeli, 'Algensyst.,' t. 8).

‡ Unger's treatise on the 'Genesis of Spiral Vessels' (Linnæa, 1841, 385, t. 5) shows that the so-called vessels of plants are only rows of cells of peculiar kind. (Transl. in 'Ann. des Sc. nat.,' 2d ser., t. xvii, p. 226. See also Mohl, 'Verm. Schriften,' 281; Schacht, 'Pflanzenzelle,' 185.—A. H.)

still lies far away from us; yet these observations may serve to make clear the importance of the cell as the organ of the graduated self-determination and isolation of life in all its formative movements, as the constantly renewed point of separation in growth advancing by successive links, and to indicate how the subordinate sphere of life of the cell is the more intimately interwoven in the totality of the organism, the more the specific vital purpose separates into its factors.

Examining the individual cell more closely, we must, in the first place, observe that the term *cell* does not correspond exactly to that to which we especially apply it, for we understand as cells not merely the membranous vesicles or utricles which form the tissue, but also their contents; we apply the name cell not alone to the little chamber formed by the completely closed-in wall, within which the vegetable life conceals itself, but also to its living inhabitant, the more or less fluid and inwardly mobile body, which is bounded, within the chamber, by its own more delicate coat (the primordial utricle). The cell is thus a little organism, which forms its covering outside, as the muscle, the snail, or the crab does its shell. The contents enclosed by these envelopes form the essential and original part of cell, in fact must be regarded as a cell, before the covering is acquired. From the contents issues all the physiological activity of the cell, while the membrane is a product deposited outside, a secreted structure, which only passively shares the life, forming the medium of intercourse between the interior and the external world, at once separating and combining the neighbouring cells, affording protection and solidity to the individual cell in connection with the entire tissue. Hence the development of the cell-coat, as a product of cellular activity, always stands in inverse proportion to the physiological activity of the cell. In youth, thin, soft, and extensible, the cell-coat allows abundant nutrition and advancing growth; subsequently thickened and therewith hardened by the deposit of lamellæ, it compresses the contents within continually narrower boundaries, more and more excludes intercourse with the external world, and puts a term to growth. Thus the life of the plant builds its tomb in the very cell—dies away at last in its own work.

That the origin of the cell precedes its enclosure by a cell-membrane, is shown most distinctly in those cases in which the cell originates free, that is, without contact with the mother-cell, or where it becomes free by being expelled immediately after its production. The last condition occurs in the swarm-cells, or active gonidia of the Algæ, which so long as the motion lasts, possess no cell-membrane separable from the contents, and must be regarded as bounded merely by the primordial utricle, which is intimately connected with the contents. It is well known that by the action of dilute acids or spirits of wine, the contents of the cell are contracted and wholly or partially removed from the cell-membrane, which thus appears as a structure clearly separated from the contents. The active gonidia of *Œdogonium*, *Bulbochæte*, *Ulothrix*, *Draparnaldia*, *Stigeoclonium*, *Chætophora*, *Hydrodictyon*, and other genera which I have repeatedly examined in reference to this point, contract, when so treated, *entirely*, without leaving a colourless membrane at the boundary of the original dimensions, which does always occur after germination has commenced. Thus the gonidia of *Ulothrix* and *Hydrodictyon* exhibited a hyaline vesicle, the contents of which were contracted on the application of tincture of iodine, a few hours after they had come to rest, on the same day that they were born. That these gonidia possess another membrane, intimately connected with the contents (the primordial utricle), is testified by their smooth and exact outline, and further by the phenomena which present themselves in the solution frequently taking place soon after birth in weak gonidia. In such cases the cell is seen to acquire a globular form and swell up; through absorption of water, large hyaline cavities originate, displacing the contents, except at a few points. The soon succeeding collapse and dissolution of the cell is distinctly opposed for some time by a membranous bounding-structure. In very large gonidia, especially those of *Vaucheria clavata*, this membrane exhibits considerable thickness, so as to be clearly distinguishable as such, but in this very case it shows that it possesses totally different properties from those of the cell-membrane subsequently enveloping it: while the cell-membrane, be it ever so delicate, appears tough and extensible, the primordial utricle is found soft and brittle, so that the slightest injury destroys its continuity, which, however, takes place so as to seem rather a separation or flowing apart of the substance than a tearing through.* It is this primordial utricle which bears the numerous vibratile cilia clothing the whole surface of the cell in *Vaucheria*, these appearing to be formed out of the substance of the coat itself and mere processes of it. Iodine causes these cilia to contract to a certain extent, and acquire a brownish-yellow colour, which colour presents itself the more distinctly, the more abundantly and closely the cilia are collected together, as, after *Vaucheria*, is the case especially in *Œdogonium* and *Bulbochæte*, where they form a dense crown of cilia. The body of the germ-cell acquires a deep brown colour with tincture of iodine; the hyaline apex mostly existing in the stage of motion, as well as the primordial utricle, indistinguishable from the contents in small swarming-cells, have this colour, sometimes appearing a little lighter. This colouring agrees with the well-known behaviour of the primordial utricle of the cells of the Phanerogamia.† The cilia disappear with the commencement of the rest, and before the formation of the proper cell-membrane, not only in *Vaucheria*, but in all Algæ where the germ-cells have a ciliary motion of short

* So says Unger, 'die Pflanze im Momente der Thierwerdung,' 1845, p. 36.

† Vide H. von Mohl, 'Botanische Zeitung,' 1844, p. 276. (Transl. in 'Scientific Memoirs,' vol. iv, p. 93.—A. H.)

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duration. The primordial utricle seems to retract its processes into itself, before it secretes the cellulose upon its surface. Different, and especially instructive in reference to the relation of the cilia to the internal body of the cell, is the behaviour in a series of Algoid plants, in which the ciliary motion is of lengthened duration, and which on this account have been hitherto included among the Infusorial animalcules, namely, the Chlamidomonada and the Volvocineæ.* In *Chlamidococcus pluvialis*, already mentioned above (p. 138), the active cells, bearing cilia at the acute extremity, are born naked, like the swarming cells of other Algæ; but within a few hours the periphery of the body exhibits a delicate, hyaline coat, which, by subsequent fluid secretion during the about three-days-long duration of life and growth of these "swarmers," becomes removed farther and farther from the body of the cell, forming a separate membrane, as it were, a loose coat around it. The ciliary motion persists throughout this formation, only it gradually becomes weaker and less active, since the cell-membrane becoming gradually pushed up further from the base of the two long cilia, more and more hampers their vibratile motion. We have here, therefore, indubitable evidence that the cilia belong to the proper body of the cell and the primordial utricle bounding it, and not to the surrounding cell-membrane.† Another Alga belonging to the same group, which I have called *Glœococcus*, produces, instead of the more solid cell-membrane, a semifluid gelatinous envelope, around its green body, which bears two very long cilia at its acute extremity, and these become en-

* Von Siebold ('de finibus inter regnum animale et vegetabile,' 1844, p. 12) was the first who distinctly claimed the Volvocineæ for the vegetable kingdom. (See Williamson, 'Proc. Manchester Phil. Soc.,' vol. ix; 'Trans. Mic. Soc. of London,' 1853; also Busk, 'Microscop. Trans.,' 1853, p. 31. —A. H.)

† Vide Von Flotow, 'Act. Acad. Nat. Cur.,' xx, p. 2, 1844, t. 25, f. 58—70; in reference to which figures, however, I must observe, that I have never found the cilia retracted completely within the membrane. (Compare Cohn, 'Nova. Act.,' xxii, and Abstract in this vol.; also Schacht, 'Die Pflanzenzelle,' p. 124.—A. H.)

tirely absorbed into the gelatinous envelope.* In *Gonium*, *Volvox*, *Pandorina*, and a plant similarly formed of eight closely connected cells, which perhaps is Kützing's *Botryocystis Morum*, each cell likewise possesses two cilia, which, issuing from the internal body of the cell, project through the gelatinous envelope, and set the whole family in motion by their vibrations.

The absence of a proper cell-membrane in the new-born gonidia of the Algæ is placed still further beyond doubt, when their origin and birth is closely observed. We will examine both somewhat more closely in *Ulothrix* and *Œdogonium*. In *Ulothrix*, as above mentioned (p. 149), the cells of the filament undergo many divisions, but always in the same direction, at right angles to the longitudinal axis of the filament (horizontal division). As soon as the division is completed, the contents may be separated from the newly-formed wall by acids or tincture of iodine, which proves that such a separation is

* The genus *Glœococcus* exhibits the following characters: ovate, green cells, with a colourless point, from which a reversed funnel-shaped, lighter space extends inwards, together with a largish vesicle at the posterior extremity. Multiplication by simple or double, in the last case decussating halving, after which the cells remain loosely connected together by secretion of soft gelatinous confluent coats, forming globular, and, finally, amorphous families. The cells of all the generations succeeding each other during the formation of these families (excepting the transitory cells in the case of double halving), are provided with two very long persistent cilia, which only disappear when division commences. The cells exhibit a feeble motion inside the enveloping and connecting jelly, the anterior end jerking in and out, or suddenly retracting a little. The last generation of the family leave the gelatinous mass and swarm out, to settle down quickly in some other place. It is probable that the formation of a new family is preceded by a longish stage of rest,—perhaps there are several resting generations,—but we have no observation on this point. In *Gl. mucosus* the full-grown cells are $\frac{1}{60}$th to $\frac{1}{30}$th of a millimeter long, the "phytodoms," or family stocks forming at the bottom of little ponds, attain the size of an apple, and are of compressed globular, often lobed shape, till they at length break up, and come to the surface of the water in irregular fragments. The gelatinous mass has a peculiar greenish spotted aspect, which depends upon subordinate groups of generations being more closely packed together. Another form, perhaps specifically distinct (*Gl. minor*), appears in the springs at Freiburg, in the spring, in the form of light yellowish-green, often pear-shaped "stocks," at most as large as a hazel-nut, attached to the sides of the gutters of the springs, finally becoming detached, swimming, and shapeless. The cells are somewhat smaller. $\frac{1}{100}$th to $\frac{1}{75}$th of a millim. long.

possible, when a cell-membrane is very young and delicate. With the commencement of fructification a new law of division displays itself, namely, a successive division of the contents in the three directions of space, beginning with two perpendicular divisions crossing at right angles, which are followed by the horizontal division, and sometimes by another perpendicular division. These divisions succeed one another so rapidly, that it is seldom possible to see the first divisions without the last. Even this circumstance renders it improbable that a formation of cell-membrane takes place at once after every division, enclosing the segments; and the phenomena occurring at the birth of the germ-cells, which I shall subsequently describe, show completely the inadmissibility of such a supposition. By progressive division, first two, then four, then eight, and finally sixteen cells originate, in the way described, in the individual link-cell. If each division were immediately followed by a secretion of cell-membrane, the originally simple chamber of the mother-cell must become divided, successively, into two, four, eight, and sixteen chambers, the soft plates of cell-membrane of the newly-formed walls, since they would immediately touch, must grow together, and the last parts (the germ-cells) produced by the process of division would thus be placed in a framework formed of a four-fold enclosure, and solidified by the cohesion of the vesicles packed one inside another. Not the slightest trace of such an apparatus of chambers can be seen at the birth of the germ-cells. If, then, the separate divisions of the contents are, nevertheless, followed by formation of cell-membrane, the entire series of special parent-cells must, in the few hours in which division and birth takes place, not only be formed, but also immediately re-absorbed, an assumption which here, as in other cases of transitory cell-formation,* would appear altogether arbitrary, and

* The absence of formation of cell-membrane from many generations of cells may be ascertained with especial clearness in many Palmellaceæ, in which, instead of a thin, firm, cell-membrane, a thick, soft, gelatinous

unsupported by any observations. The birth of the germ-cells of *Ulothrix zonata* takes place in the following way:—The mother-cell opens laterally by the tearing of the cell-membrane; the innermost delicate layer of the membrane of the mother-cell does not share in this rent, but, swelling and expanding by absorbing water, and loosened by this expansion from the outer membranes of the mother-cell, it protrudes in the form of a sac. Only rarely does this sac tear during its protrusion, and let out the germ-cells singly: in most cases it by degrees emerges entire, and, as a globular vesicle, still holds the germ-cells, already actively moving, imprisoned for some time in its interior. Finally the sac bursts, and the germ-cells separate rapidly in all directions. Even after the emptying it may be still detected as a delicate water-clear vesicle, without the slightest trace of secondary mother-cell membranes in the interior. Sometimes miscarriages occur, demonstrating the absence of the latter still more absolutely. It happens, namely, sometimes, that the germ-cells do not become detached from the mother-cell vesicle, but remain coherent with it. Such vesicles are born like the others; the included germ-cells become separated from one another by the expansion of the vesicle, without being able to leave its walls. In these cases, again, no trace of interposed membranes can be seen. I have observed a very similar process, without, however, a tearing of the vesicle, in which indeed the active germ-cells combine into a regularly-arranged colony, in *Pediastrum*.*

In *Œdogonium*† only a single germ-cell is formed in

envelope is formed, often alternating with more delicate membranous lamellæ, in which, therefore, the omission of the formation of these envelopes is very striking. See, as an example, the figure of *Glœocystis vesiculosa* in Nägeli's 'Einzelliger Algen,' t. iv, F. The multiplication takes place through simple or double halving, i. e. vegetative development and formation commences sometimes directly after the first division into two, sometimes after the second; the two transitory cells first formed producing no membrane. The first case is represented in fig. *n*, the last in figs. *o* and *f* of the plate cited.

* Vide plates iii and iv, and the detailed description in the Appendix.

† (See Thuret, 'Ann. des Sc. nat.,' 3 ser., xiv, 17, pl. xix.—A. H.)

each cell of the filament. The birth of these is effected by an extremely regular bursting of the parent-cell in the direction of a transverse annular fold, occurring near the anterior end of the cell, so that the cell opens as it were by a lid, the detached upper portion often remaining fixed at one side, and opening only laterally, the result of which is of course a knee-like bending, when the opening cell lies in the middle of the filament. The cell-contents previously lying closely applied upon the cell-wall, and merely betraying the impending birth by their darker colour, are then very gradually extruded through the opening of the box-like cell, exhibiting, even during the movement, at the posterior end lifted up from the bottom of the cell, a brighter spot, which after the birth becomes more distinctly developed as the nipple-shaped, hyaline apex, bearing the wreath of cilia. During the birth the germ-cell is here also preceded by an extremely delicate vesicle, which gradually expands into a large sac, the posterior end of which, however, never leaves the mother-cell. This sac is often not torn through for several minutes, but then it sets free the swarm-cell, already revolving while inside, which darts away from it like an arrow. The vesicle is here neither more nor less than the innermost layer of the mother-cell, still soft, taking no share in the dehiscence of the mother-cell, and expanding by the absorption of water. It is coloured distinctly blue by the application of tincture of iodine, even without previous treatment with sulphuric acid. That the germ-cell set free from its prison in the manner described, does not yet possess a cell-membrane, but represents merely the mass of contents of the mother-cell, is testified, as in *Vaucheria*, by its want of cohesion. I once saw, in *Œdogonium apophysatum* a small torn-off piece of the cell-contents left behind and assume the shape of a separate globule, which did not arrive at birth and movement, but remained in the cell. Probably the original cause of the tearing in this case was a slight adhesion of the cell-contents to the cell-walls, at a small point in the hinder part of the cell. In *Vaucheria clavata* I have often seen a separation of the germ-cell into two about equal portions, through a constriction* occurring during the birth between the anterior, already born, and the posterior portion still jammed in the elastically contracting mother-cell (the *club*). I observed a similar case in *Stigeoclonium subspinosum.* A germ-cell half born, *i. e.*, protruded through the lateral opening of the mother-cell, became constricted by the contraction of the small orifice of the elastic mother-cell, in such a way that the posterior portion could no longer penetrate. The part which had emerged, bearing the cilia, acquired a tremulous motion, which became the stronger the more the constriction cut it off from the posterior imprisoned portion, till at length it hung only by a fine thread. Finally, the born portion broke loose and hurried away, while the unborn piece remained behind in the mother-cell. The entire process lasted some minutes.†

That the formation of the cell-membrane does not take place until after the cell is separately constituted, is further shown by all those cases in which the formation of new cells takes place freely and without contact with the membrane of the mother-cell. In the formation of the resting seed-cells of *Œdogonium* we see the thickish cell-contents, composed of greenish coloured mucilage, mixed

* See the vivid description which Unger gives of this process (l. c., pp. 23-27). But where the author of this interesting treatise asserts that the escape of the germ-cell of *Vaucheria* is passive, and not a really independent act, I cannot agree with him. The swelling up of the club before it tears, together with the hemispherical vaulting of the lower cross-wall pressed downward in the filament, show clearly that the contents of the club undergoing conversion into the germ-cell, acquire a development which the firm membrane of the parent-cell cannot follow, so that this is brought into a condition of violent stretching, which results at length in a rupture, and, in consequence of the contraction of the walls, the gradual squeezing out of the germ-cell.

† (I have observed in a species of *Chlamidomonas*, while four active gonidia were being set free by the solution of the cellular membrane connecting them as produced from a resting vegetative cell, one of them divided into two, so that five were produced. I saw the entire process, which occupied about an hour.—A. H.)

with chlorophyll and starch vesicles, which, in the earlier vegetative period of the cell, form a lining of the wall, retreat from this membrane, and present themselves as a new, everywhere free cell destined for reproduction. The cell-body thus detached from the walls, appearing in a new form, with a new vital direction, presents itself with regular form and boundaries, before a trace of the cell-membrane subsequently clothing it is visible. It mostly assumes a perfectly globular form, even when the mother-cell is longish;* in this first period of formation its surface appears somewhat uneven from the projection of chlorophyll-vesicles; the whole internal cavity is filled up, and of deep green colour. Very slowly and gradually there appears, first a simple, afterward a double, and sometimes even a triple-layered membrane upon the surface, while the chlorophyll and starch formations in the contents progressively vanish, and give place to reddish oil-drops, which at length occupy nearly the whole cavity, and give the seed-cell a brownish-red, sometimes even a red-lead coloured appearance. The seed-cells of the *Zygnemaceæ* originate in the same way as those of *Œdogonium*, with the single distinction that in the former the contents of two chambers become united to form one seed-cell.† The formation of the cell-membrane, succeeding the shaping out and limitation of the cell, as a secondary phenomenon, may be well observed also in *Sphæroplea*.‡ The links of this Conferva are of unusual length, 10—20 times as long as broad. The distribution of the contents is extremely elegant, and allows, in some measure, of a comparison with that in *Spirogyra*, with this difference, however, that the chlorophyll forms, not spiral, but annular bands, 20 or 30

* Thus especially in *Œdogonium Landsboroughii*, Hassall.

† Vide Nägeli, 'Ueber freie Zell-bildung.' 'Zeitschrift,' 1847, p. 27. (Transl. in Ray Society's publications, 1849, p. 98.)

‡ My observations on this remarkable genus of Algæ were made in the autumn of 1847, on *Sphæroplea Braunii*, Kz., ('Sp. Alg.,' 462.) (Vide also Fresenius, '*Sphær. annulina*,' 'Bot. Zeitung.,' 1851, vol. ix, 241. —A. H.)

of which girdle the internal cavity as green zones, in each cell. In the median line of these zones are found, as in the spiral bands of *Spirogyra*, starch-vesicles, from five to seven in each ring; the surface of the rings, moreover, appears spotted with very fine granules, and the margins irregularly denticulated. The outer surface of the zones lies flat upon the cell-wall, the inner surface projects with a strong "keel" into the cavity. The whole series of zones are connected together by a delicate, colourless, mucilaginous layer or primordial membrane, which lines the whole of the internal surface of the cell-membrane, and which is traversed by extremely delicate lines and branched and anastomosing green longitudinal streaks issuing from the teeth of the zones. But the strangest peculiarity of the conformation of the cell-contents of *Sphæroplea* lies in the chambering which occurs in them. Each zone supports a delicate, colourless diaphragm, arising from the annular keel or ridge, and stretched across the cavity of the cell. These septa, which convert the cavity of the cell into a many-chambered tube, have no association at all with the external cell-membrane, they are merely connected with the mucilaginous layer, and formed of the same substance as this. I have had no opportunity of tracing the origin of these chambers, as I have never been able to find *Sphæroplea* in a sufficiently young state; but it can scarcely be doubted that their presence and arrangement is to be explained by the production of a row of water-bubbles in the originally homogeneous contents (protoplasm) of the cell, which idea is borne out by the not unfrequent occurrence of larger and smaller intermediate vesicles lying in the zones themselves. The whole of this artfully arranged structure of cell-contents collapses as soon as the fructification commences. First the zones become somewhat detached from the cell-membrane, so that the internal tube appears constricted by bands and articulated; then the primordial utricle, with the septa, vanishes altogether, the green zones become broken up irregularly; we see them fall in, tear up, and separate into little amorphous masses. From this solution the contents soon gather up into a new structure; the irregular green pieces become rounded, and take the shape of regular, accurately defined globules, of which two or three times as many are produced in each parent-cell, as there were previously chlorophyll zones present in it. In the first period after their origin, these balls, developing into seed-cells, exhibit a weak vibratory or revolving motion, but they soon come to rest, and become enclosed in a smooth, colourless cell-membrane, which, however, is shortly afterwards peeled off again, and replaced by a second, rough and papillose cell-membrane of considerable thickness.* The originally green colour of the contents is gradually changed into a brownish, brownish-violet or, in other species, bright red-lead colour.

Nägeli has observed in *Bryopsis Balbisiana* and other Algæ,† an *abnormal* formation of free cells out of the broken-up cell-contents of old cells, not unlike the normal formation of the seed-cells of *Sphæroplea;* these observations also confirm the secondary formation of the cell-membrane on the surface of portions of contents already individualised, *i. e.* shaped out into cells. With the last-named phenomena may be associated the processes of reorganisation, also observed by Nägeli, in injured and partially decaying cells,‡ which show that the surface of contents retracted from the cell-membrane by partial disturbance, clothes itself anew with membrane by continuous secretion of cellulose, and indeed that the healthy portion of the cell-contents has the power of cutting itself

* Kützing ascribes to the spores of a *Sphæroplea* an outer coat formed of a filiform structure wound spirally round the inner membrane, which doubtless depends on a misconception.

† Vide Nägeli, 'Ueber freie Zellbildung,' l. c., 24-26, t. iii, f. 1-3. (Transl. in Ray Society's publications, 1849, pp. 96-98, t. ii, f. 1-3.)

‡ Vide Nägeli, 'Wandständ. Zellbildung,' &c. 'Zeitschr.,' 1844, p. 91-95, t. i, fig. 8, 11, 12. (Transl. in Ray Society's publications, 1845, pp. 268-71, pl. vii, figs. 8, 11, 12.)

off from the decay commencing in another part, by a sharp line of demarcation, and of coating this boundary with cell-membrane.

The constitution and defined material isolation of the cell before the formation of the cell-membrane, has been observed in the free formation of the germ-cells of the Phanerogamia, as well as in the germ- and seed-cells of many Algæ. According to Wilhelm Hofmeister's researches on the Origin of the embryo of Phanerogamia,* researches widely extended and carried out with admirable acuteness,—after the formation of a few nuclei the protoplasm accumulated in the end of the mother-cell of the germ-cells (the embryo-sac) next the micropyle, divides into two or three longish, rounded balls, each of which encloses one of the nuclei. These balls display no trace of a cell-membrane in their earliest condition, and when they lie long in water, fall away into an amorphous semi-fluid mass; but they very soon become coated with a cellular membrane, and then are no longer liable to destruction, even from a long-continued action of water. These cells formed free in the contents of the embryo-sac, are the first rudiments of new plants, the germinal vesicles, as they are termed, only one of which is usually developed, through fertilisation taking place subsequently to their formation.

That which does not admit of doubt, in the cases just considered, where it is possible to observe the processes on the free surface of newly formed cells, namely, the secondary production of the cell-membrane around the already existing and defined body of contents of the cell, must certainly hold good also of those cases where the division of a mother-cell into two daughter-cells is apparently effected through the formation of a membranous septum. If it be once certain that the cell-membrane is formed by secretion on the surface of the

* Vide Hofmeister, 'Der Enstehung des Embryos der Phanerogamen,' (1849), p. 4 et seq.

cell, in this case also the formation of the separating membrane must be secondary, that is to say, the division and opposite limitation of the contents of the two new cells must take place before the septum can be formed between them by a secretion derived from the two sides and uniting at the surface of contact. Whether in this kind of cell-formation, which is most simply distinguished by the term *cell-formation by division*,* the separation of the two cells takes place simultaneously over the whole surface of contact, as Nägeli seeks to demonstrate, or advances gradually, as it were by an annular constriction, from the periphery to the centre, as Mohl represents in some examples, and Unger assumes as the universal law of vegetative cell-formation, is one of the most difficult problems in the study of cells. In a subsequent passage I shall endeavour to establish the existence of both conditions. If, in the latter case, namely the division of the contents by a gradually advancing incision and shutting off, the secretion of cellulose kept pace with the division, it would naturally result that the division would seem to be effected by an annular process of the cell-membrane growing inward from the wall.

If we have recognised that the secondary formation of the cell-membrane is the general rule, there can only exist one more difference of opinion, namely, as to *when* the secretion of the cellulose or allied substance on the surface of the contained mass commences. In most cases the commencement of this secretion would certainly coincide with the conclusion of the external limitation of the cell-mass, as the moment in which the creation of the cell, as an individualised sphere of formation, appears completed, and the outward development of the cell begins; and the very young cell may therefore frequently possess a delicate cell-membrane in such cases, where it

* Unger, 'Ueb. merismatische Zellbildung bei der Entwicklung des Pollens,' denominates this process *merismatic cell-formation;* (Nägeli, 'Zeitschr.,' 1844, p. 73,) calls it *parietal cell-formation around the whole contents.* (Ray Society Trans., 1845, p. 252.)

appears to be still devoid of a coat. Only transitory cell-formations, as I have endeavoured to show in certain examples above, remain without a coat of cell-membrane, and in the active gonidia of the Algæ (with the exception of the permanently moving cells of the Volvocineæ), the commencement of the formation of the cell-membrane, in all probability, does not commence until after the stage of ciliary motion, the endurance of which is, however, mostly very short, never extending beyond a few hours.

We have already ascribed, in the foregoing, the accurate limitation of the cells not yet clothed with a cell-membrane, to a coat belonging to the very body of the cell, not to be confounded with the cellulose envelopes; and we have sought especially to characterise as an example of this, the ciliated coat of the gonidium of *Vaucheria*, which may fully claim the title proposed by Mohl—"*primordial utricle.*" Whether, however, the occurrence of such a coat, distinguishable from the remaining mucilaginous contents or protoplasm of the cell, as we see it in *Vaucheria*, is an universal phenomenon, or whether the primordial utricle described by Mohl* is not rather a mere coat of protoplasm, a layer of mucilage lining the inside of the cell-wall,† produced through the protoplasm, originally wholly filling the cell, becoming excavated by a cavity filled with watery fluid, is a question which requires for its settlement more exact and extensive researches than we at present possess. Isolated, easily observed cases do indeed indicate that the mucilaginous layer of full-grown cells is not a simple protoplasmic investment, but is composed of two or three differently organised layers, the outermost of which, representing the proper coat of the cell-contents, is very probably formed in the earliest period, as the original

* Vide H. von Mohl, 'Bemerk üb. den Bau des veg. Zelle.,' Bot. Zeit., 1844, p. 275. ('Trans. Taylor's Scient. Memoirs,' vol. iv, pp. 91-92); and 'Ueb. die Saftbew im Innern der Zellen,' 'Bot. Zeit.,' 1846, p. 74. ('Transl. Annals of Nat. Hist.,' vol. xviii, p. 1, 1845.)

† This is Nägeli's view, ('Zeitschr.,' 1844, p. 91,—1847, p. 38). Transl. in Ray Society's publications, 1845, p. 268,—1849, p. 110.

boundary structure of the cell-mass (the portion of contents becoming individualised into a cell), and in this case, just like the coat of the gonidium of *Vaucheria*, claim may be made to the title of *primordial utricle*. Thus, in the Characeæ we find a mucilaginous layer, thicker or thinner in proportion to the age of the cell, in circulating motion; but outside the circulating mucilage exists a motionless soft coat, to which are attached the regularly arranged chlorophyll vesicles. In the earliest stage of formation of the cell, before the commencement of the circulating motion, the mucilaginous contents, surrounding a nucleus, fill up the whole cavity of the cell. The flowing movement, which carries along with it the nucleus still visible for some time, first commences after a hollow space filled with water has been formed in the cell; but the separate formation of the primordial membrane taking no share in this motion, must have been completed before the commencement of the circulation. In *Œdogonium*, in the contraction of the contents connected with the death of the cell, we frequently see the mucilaginous layer divide into a double utricle, an outer, lighter coloured, and an inner, darker coloured, and never contracted. The compound nature of the mucilaginous layer of *Œdogonium* may be detected even in the living cell, by the different arrangement of the chlorophyll in the two layers. In the outer layer the chlorophyll forms delicate longitudinal streaks, anastomosing here and there, and thus forming a network with narrow meshes; the chlorophyll vesicles, which are ultimately arranged in rows, are formed in these originally amorphous streaks. Inside this light-green, long-streaked net, we see, especially clearly in *Œ. fonticola* and *Œ. capillare,* a coarser, darker green net, forming a few irregular meshes, extending more in a cross direction, in which net are imbedded large starch vesicles (in the former species one or two, in the latter a greater number). In this inner layer is found also the parietal nucleus, remaining visible for a very long time. Finally, in

Hydrodictyon, I have most clearly observed a composition of the mucilaginous layer of three distinct lamellæ. When the cells of the full-grown Water-net are treated with dilute hydrochloric acid, the entire contents are ordinarily contracted from the cell-membrane as a closed utricle or tube, smooth on the surface, and no laminar separation can be detected in it. Sometimes, however, and as it appeared to me, in diseased cells, previously near their dissolution, there occurred, as in *Œdogonium,* a separation into an outer paler, and an inner, dark-green utricle, the former exhibiting a smooth, the latter a rough surface, and remaining connected here and there with the outer utricle by thick mucilaginous threads or *trabeculæ,* which originated through the inner, more strongly contracting utricle, drawing out the mucilaginous substance of the outer in the form of filaments, at these points, where it does not become completely detached from it. This phenomenon would not speak in favour of a membranous structure and consistence of the outer utricle; but further investigation shows that this outer utricle is not simple, but formed of two distinctly different layers, an extremely delicate pellicle, accurately defined inside and out, and a less sharply defined, somewhat thicker layer of mucilage, —which two layers separate from one another at various places, so that they may be very clearly distinguished. The entire contents of the cell of *Hydrodictyon* exhibit, proceeding from without inwards, the following sections:

1. *The primordial membrane.* It is of scarcely measurable thickness, colourless, opakish, and very finely and uniformly punctated, which depends on its being composed of closely conjoined, extremely minute globules, which, according to my estimate, can be at most between $\frac{1}{4000}$th and $\frac{1}{3000}$th of a millim. in diameter. This extremely delicate structure has a totally different character from the inmost layers of the cell-membrane, for it is diminished in diameter, and retracted from the cell-membrane by the action of acids, while the inmost layers of the cellulose remain connected with entire cell-membrane,

and indeed swell up more strongly than the outer layers, thus often falling into wave-like folds. The layers of the cell-membrane do not exhibit the slightest trace of punctation, or of a composition from globules; they are always homogeneous and hyaline.

2. *The outer mucilaginous layer.* This is thicker than the primordial membrane, but far thinner than the inner mucilaginous layer. When separated from the primordial membrane, its outer surface appears rough and wavy, as also its inner surface, which is connected here and there with the inner mucilaginous layer by stretched mucilaginous threads, and hence often appears torn on the inside. It is also opakish, of a yellowish colour, and exhibits largish, irregular, and indistinctly defined mucilage-granules.

3. *The inner mucilaginous layer.* This is the thickest of the three layers, rough on the outside, wavy, and exhibiting large, strong projections on the inside, depending on the starch-vesicles occurring in it. Only this layer is green, and, indeed, in vigorous and healthy cells, of a continuous green colour, strewn over besides with innumerable, mostly rather largish, dark-green granules, about $\frac{1}{1200}$th of a millimet. long, which sometimes form interrupted, curved, and much intertwined rows, but more frequently appear uniformly scattered. These granules are not yet distinguishable in young cells. This layer also contains the starch vesicles, which appear as bright globules, of at most $\frac{1}{150}$th of a millim. thickness. Their number increases with the age of the cell; while the young cell, in the first day of the formation of the net, possesses only a single starch vesicle, on the second at most 2, on the third 3—5, on the fourth 5—10, vesicles, the full-grown cell, about three weeks old, displays several thousands of them, which give the Water-net a beautifully punctated appearance,* and were wrongly

* Vaucher, 'Histoire des Conferves d'Eau douce,' 1803, described the starch vesicles as *grains brillans*, and considered them the male organs of *Hydrodictyon*.

imagined by Areschoug* to be the rudiments of the active germ-cells. When the cells are less perfectly developed, the internal mucilaginous layer exhibits a reticulated appearance, forming very irregular green meshes on a yellow ground. Whether, in this case, these are real reticulated perforations, or the chlorophyll merely is contracted within a continuous mucilaginous layer, I shall leave undecided. I mention this reticulated structure in order to observe, that although it vanishes subsequently on the more vigorous development of the cells, it is a normal occurrence in the young cells, and commences even on the first day of existence, by the green contents, originally uniformly filling up the cell, contracting into a broad green zone, which divides more and more in the succeeding days, and so gradually passes into the formation of a many-meshed net, a phenomenon which at the same time indicates that the separation of the contents into the various layers occurs in the very earliest youth of the cell.

4. *The fluid*, which fills up the interior of the three-fold sac. It is of watery consistence, and no further organic parts can be distinguished in it.

Thus, then, it is shown that the cell-contents form a far more perfectly organised body than is ordinarily imagined; that they exhibit a multiplicity of differences of organisation, which are no less important than the differences of the cell-membrane, to which vegetable anatomists have hitherto almost exclusively paid attention, and which after all may themselves be merely results of special peculiarities of the contents. As the modifications of the structure of the cell-wall have been used, not only for the distinction of the different kinds of tissue, but even for the characterisation of the great divisions of the Vegetable kingdom, so must the differences of the organisation of the cell-contents, which have hitherto found

* Areschoug, 'De Hydrodictyo Utriculato,' 'Dissert. Bot.,' Lundæ, 1839, Linnæa, 1842, and Hassall's 'Fresh-water Algæ,' 225.

some application only in systematic Algology, as generic characters,* be taken more and more into account.

Among the essential parts of the organisation of the cell, is also the cell-nucleus or cytoblast, as it were a cell in the cell, mostly containing in its interior again a nucleolus (nuclear corpuscle, *kernkörperchen*). Nägeli's extensive researches† have demonstrated its occurrence in all divisions of the Vegetable kingdom; only in particular families of the Algæ, as, for example, in the Palmellaceæ,‡ Chroococcaceæ, Oscillatorineæ, and Nostochineæ, as also in the large-celled *Cladophoræ*, and the unicellular Algæ, with unlimited growth of the cell (*Vaucheria*, *Codium*, *Caulerpa*), no trace of a nucleus has yet been discovered. Schleiden§ was the first to direct attention to the importance of the nucleus and its relation to the original formation of the cell. It undoubtedly originates before the cell is outwardly defined; it is thus, in the truest sense, a central organ, around which the vital circle of the new cell is drawn.‖ Originally it is always situated more or less in the centre of the protoplasm;¶ by the subsequent development of a cavity in the interior of the cell, it mostly becomes parietal, *i. e.*, imbedded in the layer of mucilage forming the internal

* See especially the family of the Zygnemaceæ, as also the Desmidiaceæ, in which latter Nägeli has founded the more accurate diagnosis of the genera in part upon the condition of organisation of the cell-contents, ('Einzell. Algen.,' p. 100, t. vi-viii).

† 'Zeitschrift. fur Wiss. Botanik,' 1844, pp. 34-68. Transl. in Ray Society's publications, 1845, pp. 215-246.

‡ In the genus *Chlamidococcus*, at least allied to the Palmellaceæ, (see above, pp. 138 and 158), I have found in the centre of the cell a vesicle filled with fluid, doubtless corresponding to the nucleus, surrounded and consequently hidden by the oily (?) red colouring matter of this plant. In most of the true Palmellaceæ there is a chlorophyll-vesicle in the centre of the cell.

§ 'Beiträge zur Phytogenesis,' 'Muller's Archiv,' 1838. Transl. in Scientific Memoirs, vol. i, p. 281.

‖ Vide, in reference to this especially, Nägeli, 'Ueber Entwicklung des Pollens,' (1842), and Hofmeister, 'Enstehung des Embryo der Phanerogamen,' (1849).

¶ H. von Mohl, 'Bot. Zeit.,' 1846, p. 76. ('Ann. Nat. Hist.,' xviii, 3. —A H.)

investment of the cell; thus in the filaments of the genera *Œdogonium* and *Ulothrix*. It then often appears surrounded by radiating streaks of mucilage, *e. g.*, in the embryo-sac of the Phanerogamia,* frequently becomes the starting point and centre of the circulation occurring in such threads of mucilage, as is seen most beautifully in the hairs of the stamens of *Tradescantia;*† or, finally, it is itself carried along by the current, as is the case in the Characeæ (where, however, it soon vanishes) and *Vallisneria.*‡ More rarely the nucleus retains its central position in the hollow cell also, when it appears as if suspended in the centre of the cell by an apparatus of radiating mucilaginous threads, as may be seen most beautifully in *Spirogyra.*§ In *Zygnema* it is held in the centre of the cell by a strip of mucilage, which connects two large starch-vesicles, these being again connected with the wall of the cell by radiating mucilaginous filaments, rich in chlorophyll. The Fucoideæ|| also exhibit a central nucleus, occupying the middle of a delicate circulation-network. In *Closterium*¶ the nucleus, with its colourless mucilaginous envelope, is maintained in the centre of the spindle-shaped cell by the green lamellæ of contents, arranged radiantly around the long axis of cell, which lamellæ are interrupted by it in the middle of the cell. In many cases it seemed to me to be surrounded, as by a band, by a cavity containing water. In the cells of the delicate links of the antheridium of the Characeæ, lastly, the nuclei are so large that they occupy the greater part of the cell, sometimes occupying the centre, sometimes pushed a little to one side.

* Vide Hofmeister, l. c., t. ii, f. 18-26.

† Meyen, 'Pflanzen Physiologie,' ii, t. viii, f. 6-10.

‡ Ibid., f. 2, and Schleiden, 'Grundzüge,' p. 293, f. 91, 'Principles of Sc. Botany,' p. 93, f. 95.

§ Schleiden, 'Grundz.,' ii, t. i, f. 7; 'Principles,' t. i, f. 7.

|| Nägeli, 'Zeitschrift,' 1844, p. 43, t. ii, f. 1-3. (*Sphacelaria scoparia* and *Zonaria Pavonia.*) Transl. in Ray Soc. public., 1845, p. 222, pl. vii, fig. 1-3.

¶ Vide Focke, 'Phys. Studien.,' t. iii, f. 11 and 26; Nägeli, 'Einz. Algen.,' t. vi, c, d, e.

I have prefaced with these few indications of the structure of the cell, in order to give a preliminary characterisation of the essential parts, the behaviour of which will be of importance to us in the phenomena of Rejuvenescence of the cell.

II. DESTRUCTION (*Entbildung*) OF THE CELL.

"The question of the multiplication of cells includes," says Schleiden,* "the origin and the life of the entire plant." With better right may we say that the examination of the Rejuvenescence of the cell includes that of the whole life of the plant; for there are plants which run through their entire vegetative vital development in one single cell, consequently without multiplication, but not without partial Rejuvenescence of the cell. The multiplication of cells itself is nothing else than a phenomenon of Rejuvenescence of the cell. All Rejuvenescences in cell-life, however, are connected with a more or less deeply invading destruction of the already consolidated parts of the cell standing in opposition to a progressive development. These phenomena of undoing and stripping off the proper earlier structures of the cell, are what we have here to examine first of all, and this, first in reference to the coats, then in reference to the contents of the cell.

The *cell-membrane*, by its hardening and lamellar thickening, sooner or later becomes an obstacle to the growth and the vital development of the cell or its successors, the daughter-cells forming within the mother-cell membrane. Numerous cells attain the aim of their life with the complete formation of the cell-wall, as, for example, all liber- and wood-cells, the spiral vessels, &c. In other cells, on the contrary, we see the living process overcome the straitening case, sometimes through mechanical

* 'Grundzüge,' i, 304 (2te Aufg.) 'Principles,' p. 102.

bursting, and sometimes through chemical softening and solution. The cases of forcible tearing of the cell-membrane are themselves of varied kinds ; we distinguish:—1, *tearing* of the cell-membrane, without its being wholly peeled off; 2, complete peeling of the cell-membrane, *skinning* of the cell ; and, 3, *slipping-out* of the rejuvenised cell-structure from the old membrane.

1. One of the most beautiful examples of the *tearing* of an outer cell-membrane, from its not keeping pace with the growth of the inner cell, has been described by Schimper* in the paraphyses of *Diphyscium foliosum*. These paraphyses are composed of a simple row of cells, which become very considerably elongated during the completion of their development. As soon as they have attained about half their length, the outer cell-membrane splits annularly in the middle of the cell, like a circumscissile capsule ; the two halves separate and remain attached upon the links as bell-shaped or bowl-shaped collars, while the cells continue their longitudinal growth, sometimes opening and retracting their walls in the same manner a second time. I have observed in certain Confervæ, especially *Ulothrix Braunii*,† and *Zygogonium ericetorum*, conditions comparable with the process in *Diphyscium*. The delicate filament of the first-named plant is composed of a row of cells, which divide by double horizontal division, each into four cells. The membrane of the mother-cell of this group of four cells tears crossways, during this process of division, into two equal halves, which remain as short, abrupt sheaths on the upper and lower ends of each four-celled group. *Zygogonium ericetorum* exhibits the same phenomenon in manifold repetitions, and even in cells which have ceased to divide, and are only undergoing elongation ; but the

* W. P. Schimper, 'Recherches sur les Mousses,' (1848,) p. 52, pl. vi, f. 42-46.

† Kützing, 'Spec. Alg.,' p. 346. The above-mentioned species can scarcely be included in the same genus with *Ulothrix zonata*, since it forms only two germ-cells in a mother-cell, which, moreover, possess not four, but only two cilia, as in the aquatic *Hormidia*.

persistent, double or triple, firmly connected sheaths are not so clearly distinguishable as in *Ulothrix Braunii*. The escape from the mother envelope is exhibited in a different way in the Scytonemeæ (especially finely in *Arthrosiphon*) and Rivularieæ (especially in *Schizosiphon* and *Euactis*). Here it is not the individual cell, but a whole series of cells, which breaks through the enveloping membrane. In these genera a common coat of either leathery or gelatinous consistence is formed around the whole row of cells, through the cells separating only by their side-walls (not at the joints of the link-cells.) With the progress of longitudinal growth, this production is repeated, so that numerous layers are formed, the outer of which, however, are successively broken through at the upper end, remaining as open funnel-shaped sheaths, one fitted inside another, no longer shutting up the upper end of the filament. In *Arthrosiphon* these funnels are short, pale-coloured, and transparent, whence this elegant genus is especially fitted to exhibit the true structure of the compound sheaths in the said group of Algæ. In *Scytonema* the sheathing funnels are longer, thinner, and very firmly connected, so that the entire sheath assumes merely the appearance of one many-layered sheath, clearly streaked with oblique lines, however, in the longitudinal section. In *Euactis*, lastly, the delicate and soft funnels separate into loose lamellæ, whence the lateral view which is obtained by the microscope exhibits the appearance of a fibrous breaking-up of the outer surface of the sheath. The phenomenon of unilateral rupture of the coats is exhibited again in another way by the remarkable genus *Urococcus*,* of the family of the Palmellaceæ.

The large, globular, brownish-red or blood-red cells of this genus, throw off colourless layers of cell-membrane,

* Vide Hassall, 'British Fresh-water Algæ,' (1845,) t. lxxx, especially figs. 4 and 6. A form belonging to this genus, apparently standing between *U. Hookerianus* and *U. insignis*, occurs on the elevated moors of the Black Forest.

which, as in *Glœocapsa,* appear to be separated by intermediate layers of softer jelly, whence arises a distinctly concentric structure of the envelope. But the enveloping layers of *Urococcus* do not retain their original form and integrity; not increasing themselves in size, they are pushed off on the upper side by constantly succeeding inner coats, being at first merely attenuated at one side, but subsequently, as it seemed to me, actually broken through. Since this emergence from the old coats is always repeated on the same side, a membranous-gelatinous peduncle is produced, formed of cups fitted one into another, so as to give an annularly streaked, apparently shortly articulated aspect. The red cell, which occupies the summit of this peduncle, sometimes divides, and this of course produces a subsequent dichotomy of the peduncle. If the periods of the formation of the separate enveloping layers were known, the age of the little plant, whose history is preserved in the gelatinous peduncle, might be determined by the number of rings. As a last example to be included here, I may mention the formation of the so-called *veil* of *Zonaria Pavonia.** The fan-shaped thallus of this Alga possesses two unlike surfaces, one of which, the outer or back surface, in reference to the early unrolling of the thallus, is clothed with a layer of smallish cortical-cells, these becoming coated with a thickish membranous layer, comparable to the cuticle of higher plants, by more active development of membrane on the side next the surface. From these cortical-cells are developed the fructification-cells and paraphyses, in alternating zone-like collections (*sori*). The former originate from a division of the cortical-cells, parallel to the surface of the thallus, into two unlike daughter-cells, the lower of which retains the character of a cortical-cell, while the upper emerging from the surface of the thallus, becomes the mother-cell of the spore;† the latter (the

* Vide Kützing, 'Phyc. Gen.,' t. xxii, 1, and Nägeli, 'Algensyst.,' p. 180, t. v, f. 2, 3, 7.

† Kützing and Nägeli regard this as the seed-cell itself, ("*Spermatium*,"

paraphyses) originate by similar elevation and division of the cortical cells, which, however, is repeated several times. The cuticle, at the same time, is incapable of sharing in this development of the cortical cells; it is separated from the sorus as a connected pellicle, pushed upward, torn up at one side and thrown over, so that it looks not unlike the indusium of an *Asplenium*.

2. The complete *skinning* of the cell, the real peeling off of an outer cell-membrane, while the inner follows the new development of the contents, is displayed in the germination of the Mosses* and Ferns;† it doubtless occurs also in the germination of all the thick-coated spores of Algæ, when they awaken from the stage of rest. It was seen by Vaucher in the Zygnemaceæ,‡ and according to my own researches (already mentioned above, p. 135) it is double in *Spirogyra*,§ for two membranes are stripped off in succession. The strange skinning of the newly-formed spores of *Sphæroplea* has also been mentioned (p. 166). And the peculiar manner in which the spore of *Equisetum* frees itself from its mother-cell membrane, splitting into two right-wound spiral bands,‖ may be called a skinning. But we find skinning of the cells connected not unfrequently with the vegetative development and multiplication of the cells by division, among the Unicellular Algæ. The stripping off of the mother-cell membrane connected with the multiplying division of many Desmidiaceæ, was described and figured by Focke¶ in *Closterium Trabecula*. The cell-membrane

Kz., "*germ-cell*," (*keim-zelle*,) Näg.); but Decaisne, ('Classif. des Algues,' p. 26,) states distinctly that the spores escape from it by rupture, while it remains behind upon the thallus as an empty perispore.

* W. P. Schimper, 'Recherches sur les Mousses,' t. i.

† Leszczyc-Suminski, 'Zur Entwicklungsges. der Farrenkräuter,' (1848,) t. i.

‡ Vaucher, 'Hist. des Conferves d'Eau douce,' t. iv, f. 5; t. vi, f. 4.

§ (See Pringsheim, Transl. from the 'Flora,' in 'Annals of Nat. Hist.,' 2d ser., vol. xi, p. 210.—A. H.)

‖ Mohl, ('Flora,' 1833, p. 45, and 'Verm. Schrift.,' p. 72, t. ii, figs. 6, 7), represents these bands as left-wound, an error which probably arose from neglecting the use of the mirror in the first lithographing.

¶ Focke, 'Phys. Studien.,' p. 75, t. iii, f. xvii. According to Ralfs, tears at both ends, and the two stick-shaped young ones strip it off, slipping out from the two opposite sides of the old coat, like a finger from a glove. I have observed a similar skinning in *Euastrum* (*Cosmarium*) *margaritiferum*.* In *Closterium* (*Penium*) *curtum*,† on the other hand, I saw the mother-cell membrane tear cross ways, in the middle, during the division, so that its two halves separated and were stripped off by the two new individuals on opposite sides. I have observed a very peculiar mode of the phenomenon of skinning in a new genus of Palmellaceæ, which I have called *Schizochlamys*.‡ The globular cells of this little Alga produce a hyaline cell-membrane, which becomes removed to some distance from the green body of the cell by subsequent secretion of fluidish jelly; soon, however, (probably from endosmose,) becoming unable to withstand the expansion of the jelly, it splits in the direction of an equatorial circle, by a clean line, into two similar halves, or, if the dehiscence takes place by two circular lines cutting at right angles, into four similar pieces. This splitting and peeling of the membrane, either coincides with a division of the internal cell-mass, or it occurs without any such division. By frequent repetition of this process the cell gradually becomes surrounded by an accumulation of old fragments of the membranous shell, which are held together by the extremely transparent jelly set free. The division of the cell may be either a simple halving, in which case each part is immediately clothed again with a hyaline cell-membrane, or double, through the cells produced by the first division separating immediately into two cells, without previously acquiring a coat of cell-membrane, and therefore

Closterium Trabecula belongs to the genus *Docidium;* according to Nägeli, to the genus *Pleurotænium*. Focke, moreover, confounds at least two distinct species of this genus under his *Closterium Trabecula*.

* Focke, l. c., t. ii, fig 17, represented in division, but without notice of the skinning.

† Ralfs, 'Brit. Desmidieæ,' t. xxxii, f. 9.

‡ Kützing, 'Sp. Alg.,' p. 891. Perhaps Hassall's *Sorospora virescens*, (Hass., t. lxxviii, f. 8, *a*,) may belong to my *Schizochlamys gelatinosa*.

without skinning.* I have also seen a skinning of the cell by irregular tearing and exfoliation of the outer lamellæ of very much laminated cell-membranes, exhibited very beautifully in *Chroococcus decorticans*,† a species very closely allied to *Ch. rufescens* (Näg. 'Einz. Alg.,' t. i, A) and *Ch. turgidus* (Kütz. 'tab. phyc.,' 6). I have also met with irregular bursting and peeling off of the outer coats of multicellular families, or sometimes also of isolated cells surrounded by manifold coats, in a *Glæocapsa*, with dark purplish-brown coats, standing near to *Gl. Magma* (Kütz. 'tab. phyc.,' 22); also in *Glæocystis vesiculosa*, Näg., and *Gl. ampla* (*Glæocapsa*, Kz.). Nägeli also figures a skinning in *Pleurococcus miniatus* (l. c., t. iv, E. 6).

3. The *slipping-out*, or better, the *expulsion* from their old membranes of rejuvenised cells, intimately transformed, and passing into a renovated development, is distinguished from the skinning of the cells just examined, in that the cell-membrane is not stripped off the resting body of the cell, but, *vice versâ*, the coat, remaining in its place, drives out the contents separating from it, after the latter have burst the envelope. This occurs particularly in the cases where the cell discharging its contents is fixed, either by an independent attachment, or belonging to tissue, by connection with its fellows. In free cells no accurate limit can be drawn between *skinnning* and *slipping-out* of the contents. Slipping-out is the ordinary process by which the reproductive cells of many Algæ, Lichens, and Fungi, emerge from their mother-cell chambers; if they are active, it is at the same

* Vide plate ii, and the explanation.

† The cells of this new species are smaller than in its two allies, from $\frac{1}{150}$ to $\frac{1}{80}$ millim. in diameter, and verdigris green; the colourless membranous layers tougher, more clearly distinguishable. When the divisions of the cell succeed rapidly, the thin coat exhibits but four layers; when the division is intermitted, numerous (8—10) layers of membrane are found, often appearing thickened on one side, and finally exfoliating irregularly. Tincture of iodine colours the contents reddish or yellowish-brown, the coats golden yellow. It occurs on the walls of the tufa caves near St. Aubin on the Neunburger Sea.

time a "swarming-out," in which the peculiar motion begins sometimes during the birth, or even before the birth, inside the parent envelope. The orifice in the mother-cell membrane, as in "skinning," may be either an irregular rupture or a regular dehiscence. The contents left in the old coat are either undivided, entering upon their altered destination as a whole, or divided, *i. e.* separating into several cells in the transition to a new course of life; the cells coming to light are sometimes naked gonidia, sometimes spores already clothed with a new cell-membrane. We have already had cause to examine, in detail, many of the examples to be cited here, so that it suffices merely to recall them to recollection. A single active germ-cell frees itself from its chamber by dehiscence of the latter at the apex in *Vaucheria* (*vide supra*, p. 163); in *Gongrosira Sclerococcus** by tearing at the apex or the side, according as the mother-cell is an apical-cell or a link-cell; by bursting of the back-wall of the cells of the circular thallus adherent by its lower surface, in *Coleochæte scutata* (*vide supra*, p. 141); by a lateral splitting of the cells of a shrubbily-branched thallus in *Coleochæte pulvinata* (p. 142), *Chætophora*, *Stigeoclonium*, and *Draparnaldia* (p. 138); by annular dehiscence at the upper end of the cells in *Œdogonium* (pp. 141 and 162); by disarticulation of the laterally attached bristle-cells and breaking-open of the septa separating them from the link-cell of the filament in *Bulbochæte* (p. 141). A single resting cell is set free from its coat (the *perispore*), and this by dehiscence at the apex, in *Chantransia* (p. 143), *Chroolepus* (?), and the Fucoideæ in the extended sense.† Two active germ-cells slip out from a mother-cell, breaking through it laterally, in *Ulothrix Braunii*

* Observed in July, 1847. The almost globular gonidia possess four cilia, like the allied genera *Chætophora*, *Stigeoclonium*, &c.

† *Algæ pycnospermeæ* et *angiospermeæ*, Kützing. In regard to the existence of a perispore, *vide* the observations on *Zonaria*, p. 179. Decaisne and Thuret also figure perispores visible even after the slipping out of the spores in *Fucus nodosus* and *serratus*, ('Ann. des Sc. nat.,' 1845, t. i, c, f. 21, and t. ii, f. 32).

(see p. 177); by breaking through the back-wall of the cell of a creeping filament in *Aphanochæte repens*.* I have observed four active germ-cells expelled through a breaking across of the mother-cell exactly in the middle in *Conferva bombycina*;† J. Agardh likewise saw four active gonidia emerge from the cells of *Enteromorpha clathrata*;‡ 4, 8, or 16 break out laterally, in the way described above (pp. 148, 161), from the parent-cell of *Ulothrix zonata*. *Chlamidococcus pluvialis* (pp. 138, 158) may be mentioned again here. Four (rarely two or eight) active cells emerge from the thick-coated, resting (seed-) cells by irregular dehiscence of the cell-membrane, during which operation the innermost extremely delicate layer of the mother-cell membrane becomes detached, partially emerging as a vesicle, and tearing subsequently to the outer thick cell-membrane. The gonidium-like cells gradually produce an extremely delicate membrane over themselves in the way above described, inside which they finally divide again into 4 (rarely 2 or 8) parts, or, when the formation of microgonidia takes place, into 32 parts, which begin to move about inside the roomy coat even before they swarm out. In *Pediastrum* (p. 161) 4, 8, 16, 32, or 64 active gonidia, enclosed by the vesicular inner layer of the mother-cell, break out by a tear in the old cell. A larger number of active gonidia,

* *Aphanochæte* is a new genus of Algæ, which perhaps will have to be united with *Herposteiron*, (Kz., 'Sp. Alg.,' p. 424,) from which it differs through the absence of the vertical torulose branches. The bristles, which frequently spring from the back of the cells, are not sheathed, as in *Coleochæte*, yet articulated in the upper part, but at the same time so delicate that the upper portion is difficult to make out. The formation of the pairs of germ-cells takes place by division parallel to the septa. The germ-cells are nearly globular, possessing two cilia. *A. repens* occurs not unfrequently near Freiburg, particularly on *Œdogonia*, *Vaucheriæ*, *Mongeotia*, *Sirogonium*, *Conferva*, &c. I observed the swarming of the germ-cells in August, 1847.

† Observed in October, 1847. It is remarkable that the formation of the germ cells of this very common Conferva has been but seldom observed.

‡ 'Ann. des Sc. nat.,' 1846, p. 199, t. xii, f. 6. According to Thuret, ('Ann. des Sc. nat.,' 1845, p. 274), the gonidia of *Ulva* and *Enteromorpha* possess four cilia.

formed in like manner by repeated division of the cell-contents, break through the mother-cell of *Cystococcus*,* *Characium*,† and *Ectocarpus*.‡ Very numerous swarming-cells, not formed by successive division of the green contents, but by simultaneous division of the mucilagenous layer alone, issue through irregular lateral bursting of the parent tube in *Ascidium* (p. 128), *Hydrodictyon*,§ *Chætomorpha ærea*,‖ *Bryopsis*;¶ through tearing open of the apex of the tube in the genus *Derbesia*,** separated by Solier from *Bryopsis*, as also in *Saprolegnia ferax*, K. (*Achlya prolifera*,†† Nees.); by a hole formed regularly at the upper margin of the cell in *Cladophora*;‡‡ by a most elegant, lid-like dehiscence in certain species of the genus *Chytridium*§§ parasitical on

* Nägeli, 'Einzell. Algen,' p. 84, t. iii, E.

† Ibid., p. 86, t. iii, D.

‡ Crouan, ('Ann. des Sc. nat.,' 1839, p. 248, t. v). According to Thuret, ('Ann. des Sc. nat.,' 1845, p. 274), the gonidia of this genus have two cilia.

§ In particular from these cells in which no new net is formed, (see above, page 137.

‖ According to J. Agardh. ('Ann. des Sc. nat.,' 1836, p. 194, t. xii, f. 1.)

¶ Ibid., l. c., p. 200, t. xii, f. 9.

** 'Ann. des Sc. nat.,' 1847, t. vii. The genus *Derbesia* includes *Bryopsis tenuissima* and *Lamourouxii* of authors, the fertile branchlets are shorter and more inflated than in *Bryopsis*, they let the mass of the germ-cells escape at once by bursting at the apex, while in *Bryopsis*, according to Agardh, the germ-cells escape singly by a small, lateral, nipple-like and outwardly projecting orifice. The germ-cell of *Derbesia* possesses a wreath of cilia, like those of *Œdogonium*.

†† Vide Unger, 'Einiges zur Lebensgeschichte der Achyla prolifera,' ('Linnæa,' 1843, p. 129, t. iv.) I have repeatedly observed the mode of origin of the gonidia from the mucilaginous layer of the fructifying end-cell; I could only detect a single, short cilium, while Thuret describes two.

‡‡ According to observations on *Cladophora glomerata*, (June 1847), and *fracta*, (August 1847). Meyen observed the birth of the active spores in the former species, ('Nov. Acta.,' t. xiv, ii, p. 445, t. xxvii, f. 5, 6.) In regard to the number of cilia my observations agree with Thuret's; I found two in *C. glomerata*.

§§ The *Chytridia* form a new genus of unicellular, parasitical Algæ, or, if it be preferred, of aquatic Fungi, related to *Saprolegnia* about as much as *Ascidium* is to *Bryopsis*. The entire plant is composed of a single, balloon-shaped cell, which penetrates into the Algæ upon which it grows by a more or less developed root-like base. The inflated portion of the cell is filled with colourless mucilage, from which are formed, not through successive other Algæ. In several of the last-named genera, an active whirling motion of the gonidia occurs, even inside the mother-cell, as especially in *Ascidium*, *Hydrodictyon*, *Chætomorpha ærea*, *Bryopsis*, and *Cladophora;* in *Derbesia*, *Saprolegnia*, and *Chytridium*, on the contrary, the motion does not become evident until after the birth of the previously crowded germ-cells. In *Phormidium*, *Lyngbya*, *Scytonema*, *Tolpothrix*, *Calothrix*, *Mastichonema* (see p. 147), and other allied genera, longer or shorter filiform pieces of connected, motionless gonidia are seen to emerge gradually from the sheaths common to the whole rows of cells, and open above, breaking-up into the separate joints after they are set free. Here, as in all the preceding cases, it is doubtless the elasticity of the walls which effects the expulsion of the germ-cells; the bursting of the mother-cell coats is caused either by the turgidity of the germ-cells, or if these do not wholly fill the cavity (as in *Ascidium*, *Hydrodictyon*, and *Cladophora*), by increased absorption of water after previous softening of the cell-membrane. We see the effect of elasticity most clearly in the well-known smoke- or cloud-like explosion of the spores in certain families of Fungi, especially in *Helvella** and *Peziza*,† in which the rows of eight spores are cast out with great force from the clavate or fusiform parent-tubes, forming the thecal membrane (*hymenium*) of these Fungi.

division but by a simultaneous process, very numerous small globular germ-cells, which exhibit a sharply-defined darker nucleus in the interior, and possess a single very long cilium. From their want of colour, and the activity of their motion, these gonidia resemble the most minute monads. Their extrusion occurs either through the casting off of a lid, or through mere tearing of a nipple-shaped point. Of fifteen different species which I have observed in the vicinity of Freiburg, *Ch. olla* is the largest, and at the same time exhibits the lid-like dehiscence most beautifully; it grows on the anterior wrinkled end of the bulging parent-cells of the spores of *Œdogonium Landsboroughii*, the root penetrating into the folds and attaching itself to the spore. The free inflated portion of the cell is ovate, with the lid somewhat thrown up at the edges and apiculated like a short nipple in the middle. The germ-cells are about $\frac{1}{300}$ millim. in diameter.

* Vide Bulliard, 'Champignons de la France,' ii, t. 242.

† Ibid., t. 154, and Corda, 'Icones Fungorum,' iii, t. vi, 95. (Also Tulasne, 'Ann. des Sc. nat.,' 3e sér., xvii, 72.)

I will add to these examples of the setting-free of the cells destined for the Rejuvenescence from their "super-annuated" envelopes, a few very strange examples of normally imperfect release of the germ-cells. I have applied the name *Sciadium** to a minute Unicellular Alga, which displays an originally obovate tube, gradually becoming elongated into a cylindrical form, obtuse above, and prolonged into a slender attached pedicle below. The contents consist of uniformly green mucilage, in which a small vesicle may sometimes be distinguished, but only in the earliest stage of growth. The pedicle is transparent and colourless, and secretes at its base an originally yellowish-brown, afterwards dark-brown mass, which gradually expands into a disk-shaped foot. When the growth is completed, the green contents become divided into several masses, developing into a series of 5—8 germ-cells; the cell-membrane dehisces, throwing off its summit as a finger-stall shaped cover, but the germ-cells instead of leaving the opened tube, all collect at the point of exit with their inferior, narrower, and somewhat pedicellately elongated ends sticking in the tube. Thus is produced a capitule, and by the advancing growth of the young family, an umbel formed of individuals exactly resembling the parent individual from which they originated. The emptied mother-cell tube remains as the stem and support of the umbellate family, and gradually becomes filled from above downwards with the same yellow and reddish-brown secreted substance, which it exhibits at its own base. The imperfect birth of the germ-cells just described, is repeated at the transition to the third, and mostly even to the fourth generation, so that little arborescent groups are produced,

* Vide Kützing, 'Sp. Alg.,' p. 490, who places this little plant in the neighbourhood of *Bryopsis*. To me, *Ophiocytium*, Näg., ('Einz. Alg.,' t. IV, A), seem the nearest allied genus; young specimens completely resemble *Characium* and *Ascidium*. The only species, *Sc. Arbuscula*, occurs near Freiburg on various filiform Algæ, especially on *Œdogonium Landsboroughii* and *Vaucheria racemosa*, in the water reservoirs of the Botanic garden.

with twice or thrice repeated umbellate ramification, till at length the cells which form the outermost umbellules, scatter out their germ-cells, which, after a short swarming,* fix themselves again to be developed into ramified stocks of new families. Nägeli has described another case of ramification through imperfect birth of germ-cells, in the genus *Valonia*.† I have observed a still more wonderful mode of imperfect birth in *Saprolegnia capitulifera*.‡ The formation of the fruit-clubs and germ-cells takes place as in *S. ferax*, only the formation of the fruit-clubs is never repeated by the elevation of the bottom and growing-through of the fruit-club, but by the formation of opposite, divergent lateral branches, close beneath it. The fruit-club, as it is called, *i. e.* the cell cut off from the remainder of the stem, from the contents of which the germ-cells are produced, finally opens at the apex, and the germ-cells (40 or 50 in number) move actively towards the mouth, in front of which they make a halt, and, crowding up closely together, form a globular capitulum. I could not clearly make out what really kept them back here. But the duration of this capitule is very short, for within only a few hours the germ-cells leave this, their first station, slipping out of a membranous coat, probably formed during their period of rest, and swarming again for a short time after this skinning. All that remains of the capitules is a collection of empty vesicles, unless a few germ-cells accidentally remain sticking in them, when these immediately begin to germinate, sending out an acute tubular process.

It scarcely requires to be mentioned, that the phenomena of mechanical release from "superannuated"

* The swarming germ-cells of the last generation appear to possess two cilia.

† Nägeli. 'Algensyst.,' p. 156, t. ii, f. 12-14.

‡ Kützing, 'Spec. Alg.,' p. 160. The observations were made in August and September, 1847, on specimens from the Tili Sea in the Black Forest; which vegetated luxuriantly on decaying pieces of *Nuphar pumilum* (*Spennerianum*), but which also rapidly attached themselves upon flies falling into the water.

envelopes obstructing the further development or rejuvenised formative action, such as we have here examined in the life of the cell, are repeated in the compound organism of the plant. Thus we see that the first leaves and roots of *Marsilia* and *Pilularia* break through the tissue of the proembryo, the first roots of most of the Monocotyledons, as well as all the subsequently appearing adventitious roots, through the cortical tissue of the stem. The leaves of *Ophioglossum* break through the cellular cover under which they are formed; the young sporange of the Hepaticæ breaks through its outer coat above, leaving it behind as a sheath at the base; the sporange of the Mosses tears it in two at the base, and lifts it up as the calyptra. In like manner many Agarics tear open the veil which encloses them in their young stage. The bark of many trees exhibits a process of peeling off. We find a periodical exfoliation of the periderm in *Rubus odoratus*, *Spiræa opulifolia*, and particularly distinct in the Birch and the Strawberry-tree (*Arbutus Andrachne*); a peeling of the outer liber-layers in the Vine and Clematis; a scaling-off of the bark in the Plane, the Apple, the Fir, &c. The tuberous stem of *Isoëtes* scales off at its circumference. Finally, the emergence of the embryo from the seed-coats in the germination of Flowering plants, presents itself as a complete "slipping out."

We now pass to another mode, in which cell-structure advancing to a rejuvenised vital activity frees itself from the envelopes previously formed by itself, namely, to the phenomena of *chemical softening* and *solution* of the cell-membrane, which take place sometimes as a swelling-up, terminating in dissolution, and sometimes as an imperceptible resorption. The change of the cell-membrane into a more or less fluid jelly which is at length wholly dissipated, at the advent of the series of generations, is a very frequent phenomenon among the lowest groups of the Algæ, as, for instance, in the families of the Palmellaceæ,* Chroococcaceæ,† Nostochineæ, &c., only unfortunately we are very deficient in satisfactory investigations into these gelatinous structures, both in morphological and chemical respects. While they were formerly mostly regarded as excretions through the cell-walls (extra-cellular substance), Nägeli,‡ if I do not misunderstand the passage, explains them as outer layers of the cell-wall itself, under the name of enveloping-membrane (*Hüll-membran*).

In *Glæocapsa*, *Glæocystis*, and the other examples mentioned above, this explanation seems to me undoubtedly correct, while in other cases the gelatinous mass appears to be a real secretion on the surface of the cell-membrane; as, for instance, in the gelatinous envelope, which, according to Thwaites, surrounds the conjugated individuals of the Diatomaceæ, or the amorphous, very fluid jelly in which many of the Desmidiaceæ live, as, for instance, *Penium curtum*, the individuals of which undergo the "skinning" above described, in their division,§ inside this jelly. In many cases these gelatinous envelopes appear not so much like altered and swollen layers of cell-membrane, as coats originally secreted in a fluid-gelatinous form. At the same time undoubted cases show that a gelatinous softening, swelling-up, and final solution of cell-membrane, formed of cellulose of normal character, does really occur. My observations on the frequently mentioned Water-net (*Hydrodictyon*), afford an opportunity for a minute description of such a process. The cells of this plant exhibit, in their full-grown condition, a tough and firm cell-membrane, about $\frac{1}{400}$th millim. in thickness. By close examination, we may distinguish three layers in this, the outermost of which is the thin-

* Vide, for instance, *Palmella*, (Nägeli, 'Einz. Algen.,' t. iv, D.)

† *Ex. gr.*, *Glæocapsa*, (ibid., t. i, F,) *Aphanocapsa*, (t. i, B,) *Glæothece*, (t. i, G), *Aphanothece*, (t. i, H.)

‡ 'Einzell. Alg.,' p. 13.

§ Vide supra, p. 181.

nest, the middle the thickest; both the inner layers are colourless, the outermost is of a pale yellow tint. When treated with dilute sulphuric and tincture of iodine, they exhibit different behaviour. The external layer, which I shall call the cuticle, neither swells up evidently, nor becomes coloured; the inner two, on the contrary, acquire a violet colour, more or less intense according to the circumstances, and swell up, so that the membrane as a whole appears twice or thrice as thick as at first. The innermost layer here becomes thicker than the middle one, which was previously the thickest, at the same time becoming folded in waves on its surface, and allowing us to make out clearly a composition out of two subordinate layers. If strong sulphuric acid is applied, the circumference of the entire cell is perceptibly contracted; the cuticle, however, does not share in this diminution of size, but gradually separates, forming numerous wavy or vesicular elevations, from the inner layers of the cell-membrane, under which circumstances it can be readily ascertained that it extends over the surfaces of articulation of the cells, and therefore completely encloses the individual cells, like the inner layers. A long-continued action of strong sulphuric acid dissolves the cell-wall, the cuticle however appearing to withstand this longer. A swelling-up of the cell-membrane, exactly similar to that produced artificially by acids, takes place in the natural course of life of the Water-net, at the period of propagation. As soon as the germ-cells are formed in the interior, the cell-membrane appears thickened, and its internal surface somewhat wavy. While the spores are commencing their originally very slight movements, the cuticle tears. From this time those cells in which large gonidia, destined to form new nets, have been produced, are distinguished from those which contain small gonidia destined to swarm out.* In the former, namely, the entire cell-membrane expands very perceptibly and uniformly in the course of a few minutes, the cuticle,

* Vide supra, p. 137.

now too small, being peeled off in little strips By this expansion the cell-membrane is removed to a little distance from the layer of macrogonidia previously lying close upon it, and these, now gaining space, commence a more active tremulous motion, soon uniting together into a new net inside the mother-cell membrane, and in this combination settling to rest. The young net enclosed by the membrane of the mother-cell now grows rapidly, the mother-cell membrane continues to expand for a short time longer, becoming at the same time continually less distinct, and by the second day it has entirely vanished. In those cells, on the other hand, containing microgonidia, the cell-membrane does not expand uniformly, but forms a bulging enlargement, at one or other part where the cuticle is torn, which bursts and lets out the microgonidia in a dense swarm, moving most actively. Emptied by the swarming out, it remains unchanged, and is for a long time distinguishable as an empty coat, a proof that the more rapid solution of the net-forming mother-cell is produced by internal causes. Other cells which do not arrive at fructification, never exhibit the process of softening. While, under favorable circumstances, the entire process of vegetation of the *Hydrodictyon* net is completed in 3—4 weeks, in which time the individual cell is enlarged (longitudinally) more than a hundred-fold (sometimes even 4—5 hundred-fold),—other nets, in unfavorable conditions, exhibit a slower development, vegetating for four or five months without attaining the normal dimensions. In the cells of such retarded nets, never attaining to fructification, we observe a proportionately thicker and very firm cell-membrane, which exhibits in the sectional view a delicate transverse striation (pore canals ?) which I never could detect in normally developed cells.*

* (This striation seems analogous to that sometimes occurring in liber-cells of certain Phanerogamia, as first described by Schacht. See a notice on this point (by the present translator) in the 'Journ. of Microsc. Science,' vol. i, p. 233, (1853.)—A. H.)

The contents of these cells mostly exhibit an abundant formation of oil, of which scarcely any perceptible trace otherwise occurs, and they decay finally with various phenomena of dissolution; but the cell-membrane is still firm and uninjured after the death of the contents. All this proves beyond doubt the relation of the softening and solution of the membrane to the processes of Rejuvenescence in the contents of the cell. A similar softening and solution of the cell-membrane occurs in *Botrydium** at the period of formation of the germ-cells. The vesicle, of a leek-green colour at the time of the vegetative completion, assumes a sea-green colour at the period of ripening, which results from the thickening and clouding of the cell-membrane which occurs at this time; the previously indistinguishable laminated structure of the membrane becomes clearly visible about this time, and the cell-membrane, become limp by softening, collapses, finally melting away, and leaving the germ-cells behind upon the ground. The *solution* and *resorption* of the parent-cell membranes, so frequently occurring in the tissues of plants, which have been most accurately observed in the formation of the spores of the Ferns and Mosses,† as also in the formation of the pollen of the Phanerogamia, undoubtedly depend upon similar processes. The gelatinous thickening of the membrane of the mother-cell mentioned both by Nägeli‡ and Unger,§ is probably intimately connected with the quickly succeeding resorption.

We may also again call attention here to analogous occurrences in the compound structure of the plant. As the old envelope of the individual cell becomes softened and dissolved, and vanishes imperceptibly, in the trans-

* Vide supra, p. 128. My observations were made on the smaller species of this genus, *B. Wallrothii*, Kütz.

† For the latest reseaches on this head, see Hofmeister, 'Fruchtbildung, &c., der höher. Kryptogamen,' 1850.

‡ 'Zur Entwicklungs-geschichte des Pollens der Phanerogamen,' 1842.

§ 'Ueber Merismatische Zellbildung bei der Entwicklung des Pollens,' 1844.

formation advancing to a new individualisation, so are the compound masses of cellular tissue, which do not themselves become rejuvenised, but enclose parts in process of Rejuvenescence, dissolved and destroyed. Thus, in the development of the seed of the Phanerogamia, the enveloping tissue of the nucleus (the axis of the ovule or seed-bud) is first resorbed in mass, as the embryo-sac increases in size; soon afterwards, the tissue formed in the embryo-sac, the albumen or endosperm surrounding the embryo, is again either wholly or partially consumed, while the embryo enclosed by it advances in its development inside the seed. A similar process takes place again in germination, for in albuminous seeds a softening and solution of the albumen takes place at this period. We find examples of a gelatinous swelling up of very thick-coated albumen-cells, at the period of germination, especially in many Palms (*Phœnix*, *Manicaria*, *Phytelephas*), and many Leguminosæ (*Cercis*, *Cathartocarpus*, *Ceratonia*, *Gleditschia*, *Tamarindus*, *Bauhinia*, *Parkinsonia*, *Dialium*, *Mimosa*, &c.) A similar gelatinous unfolding of the cells occurs also in the internal layer of cells of the testa (the epithelium of the seed), as, for instance, in the quince and many Cruciferæ. The remarkable expansion of certain layers of cells of the spore-fruit of *Marsilia*, producing at the dehiscence of the fruit the gelatinous mass issuing in the form of a long worm, on which are attached the likewise gelatinous indusia enclosing the individual sori, also deserves mention here.*

While the phenomena of putting off the old clothing of the cells, examined up to this point, have displayed to us only the external side of the process of Rejuvenescence, the consideration of the phenomena of solution, through which the newly-shaped products are prepared in the contents of the cells, must necessarily carry us deeper into the essence of Rejuvenescence. The *process* of *solution* and *transformation in the contents of the cell*, invades more or

* 'Explor. Scientifique d'Algérie,' Bot., t. xxxviii, f. 24-26; Schnizlein, 'Iconographia.' Marsileaceæ, f. 4.

less all parts of these; we see it most clearly in the behaviour of *starch* or of *amylon*, of the fixed oils, as also of the *nucleus*. There are certain products of cell-life which furnish a measure of the age of the cell. While the formation of chlorophyll is especially proper to the more vigorous youth of the cell, we see in the formation of starch and oil, in the interior of the cell, just as in the formation of cellulose-layers upon its surface, the commencement of a limitation and quieting of the vital activity, which marks the more advanced age, with the distinction, however, that the preponderating formation of cell-membrane (the process of lignification) usually results in the permanent death of the cell, while the filling of the cell with starch or oil brings with it a condition of sleep, from which it may awake, under certain circumstances, even after thousands of years, as is proved by the well-known experiments on the germination of grains of wheat from the tombs of the Egyptian kings. This is more particularly true of the condition of rest produced by formation of starch, while the formation of oil, although frequently, is not always accompanied by a condition of the cell in which it is capable of Rejuvenescence.

The formation of chlorophyll stands in inverse proportion to that of starch and the fixed oils, in the cells; while starch and oil appear in greatest abundance in the old age of the cell, and are again either wholly or partially destroyed in its Rejuvenescence, the green colouring matter, on the direct reverse, vanishes in the old age of the cells, reappearing in their Rejuvenescence. Thus the leaves of the ivy are coloured more or less with brownish red in winter, and grow green again in spring. The embryos of many seeds are green in the earliest period of formation, but as the seed ripens, passing into the stage of sleep, they become white, from the chlorophyll disappearing and the cell becoming filled with starch or oil, till finally, in germination, awakening to new life, they again acquire a green colour. The contents of the spores of many Cryptogamia also include chlorophyll before they are mature, but lose the chlorophyll, and become yellow, brown or red,* through formation of oil, or white,† through formation of starch, in ripening; till at length the chlorophyll reappears in the germination. Chlorophyll, however, this green colouring matter of plants, so characteristic of the Vegetable kingdom in its total manifestation, so intimately connected with the independent‡ vegetative process, is one of the vegetable substances which has hitherto been least subjected to accurate investigation, in reference to its chemical conditions, its genetic connection with other substances of the cell-contents, and its transformations; nay even in reference to the shapes in which it occurs, either alone or combined with other substances, in the cell,—so that we are compelled to rest satisfied with these brief indications.§

We will trace more in detail the play of formation, solution, and reformation in the contents of the cell, in the phenomena exhibited by *starch*. Schleiden calls starch the most widely diffused substance in the Vegetable kingdom, saying that he is not acquainted with a single plant which does not contain more or less starch at some season or other, at all events at the period of the rest of vegetation.‖ This particular occurrence of starch at the period of *resting* vegetation, in the organs in which the plant preserves its life for a future season of vegetation,

* Vide the spores of *Vaucheria*, *Spirogyra*, *Œdogonium*, *Bulbochæte*, &c. According to Mohl, the spores of *Jungermannia* contain chlorophyll in youth (correct, A. H.). In *Chlamidococcus pluvialis*, the green colour vanishes entirely in the resting generation (the seed-cells, spores) which become reddish-brown or bright red; the active generations (*gonidia*), on the contrary, gradually become green again; (see farther on.)

† Thus in the spores of Characeæ.

‡ It is absent, as is well known, from most parasitical plants, Cryptogamia as well as Phanerogamia.

§ (On the complex chemical conditions of chlorophyll; See Morot, 'Ann. des Sc. nat.,' 3me ser., Bot., tom. xiii, p. 160.—A. H.)

‖ 'Grundzüge,' 2te Aufg. 1, p. 180, ('Principles,' p. 18.) Schleiden here forgets to mention the *Fungi*, in which, as in the fungoid Phanerogamic parasites, starch-formation appears to be absent. In the Phycochromiferous during the period of rest (the winter or summer sleep), points to the destination of starch in the economy of vegetable life. Thus we find starch deposited in especial abundance in tuberously thickened roots (*e. g.*, *Curcuma leucorhiza*), in the subterraneous stolons forming propagation-tubers (potato), in perennial rhizomes (*Iris*, *Arum*, *Isoëtes**), in subterranean buds and bulbs (Liliaceæ), in the seeds of the Phanerogamia, either in the albumen (Graminaceæ, Polygoneæ, Chenopodiaceæ), or the embryo (Leguminosæ, *Castanea*, *Æsculus*), and also in the spores of many Cryptogamia (*e. g.*, Characeæ and Rhizocarpeæ). We find some starch deposited even in the bark and alburnun of trees in the winter. At the re-awakening of vegetation a new formative activity sometimes presents itself in these same organs and the same cells, as in the embryo and spores awakening from the seed-sleep; sometimes the tissue filled with starch is merely subservient, preparing nourishment for other organs in course of development, by the process of solution taking place in it, dying away itself after fulfilling this destination, as is the case in the albumen of seeds, the tubers of the potato, the thick cotyledon of the chesnut. But the occurrence of solution of starch is not confined merely to such Rejuvenescence connected with the changes of the seasons : I have observed it oftentimes in the Algæ in the midst of summer, and without a preceding period of rest, in progress of transition to propagation, in particular in the preparatory stages of the formation of gonidia. *Hydrodictyon* exhibits the following phenomena in this respect. The grains of starch† forming gradually in the course of the period of growth of the net, make their first appearance as minute globules (or vesicles?) from $\frac{1}{800}$th to $\frac{1}{500}$th of a millim. diameter, of

Algæ, (Chroococcaceæ, Oscillatorineæ, Nostochineæ, &c.), both starch and chlorophyll are deficient. (Nägeli, 'Einz. Alg.,' p. 5.)

* In the cake-shaped rhizome of *Isoëtes lacustris* there is an abundant quantity of starch, but only slight traces of oil, while in the rhizomes of the terrestrial species there exists a preponderance of fixed oil; (see p. 200.)

† See above, pp. 172, 192.

higher colour than the surrounding green mass, which exhibits the deepest colour immediately around them. I could not observe how these first globules, or vesicles, originated in the green mass; the first of them displayed itself immediately after the gonidia uniting to form a net had passed into a condition of rest, before the cavity of the cell had become excavated, and with each succeeding day appeared new ones, which did not seem to have been formed by division of the first, but to have an independent origin. Even by the second day these vesicles were found surrounded by a more or less evident border, originally green, and with a somewhat sinuous or denticulated outline, but soon assuming the shape of an accurately defined, exactly circular envelope. The larger globule originating in this way was from $\frac{1}{200}$th to $\frac{1}{150}$th millim. in diameter, and did not subsequently increase in size; it exhibited a yellowish or light yellowish-green colour, the nucleus (the globule first formed) always appearing somewhat lighter than the envelope. On applying tincture of iodine, these globules assumed a violet colour, the nucleus seeming to me lighter, more of a wine-red; after a previous bleaching, by keeping a longish time in alcohol, the envelope was coloured darker, the nucleus paler blue-gray; by a stronger action of iodine, so dark that the colour was no longer distinguishable. On the application of solution of caustic potash, the envelopes swelled up to about three or four times the diameter, and finally vanished entirely, while the nucleus remained unaltered.* No lamination could be seen in the swelling coats. Thus it cannot be doubted that the envelope, originally infiltrated with chlorophyll, was composed, in its fully-developed condition, of starch, while the starchy-nature of the nucleus remains very doubtful. The described mode of formation of the starch-granules of *Hydrodictyon* appears to tally better with the theory of Fritsche and Schleiden, that the concentrically striped

* Whether or not the nucleus would dissolve by longer action of potash requires a repetition of the investigation.

starch-granules originate by external formation of layers around a nucleus, than with that set up by Münter and Nägeli, of an inner (centripetal) formation of layers.* Examining the behaviour of these starch-grains at the commencement of propagation, we find them disappear in the inverse order of the origin of their parts, the envelope first dissolving, the nucleus remaining distinguishable for some time, till at length this likewise vanishes without leaving a trace. This entire process of solution is ordinarily completed in one night; the formation of the gonidia and the above-described softening of the cell-membrane follows at its heels. I have observed an exactly similar disappearance of the starch-granules shortly before the commencement of the formation of the gonidia in *Cladophora glomerata*, the cells of which, as in *Hydrodictyon*, contain a great abundance of starch-

* Schleiden ('Grundzüge,' 3te Auft., p. 187, Transl., pp. 11, 567); Münter ('Uber das Amylum der Gloriosa superba,' &c.; 'Bot. Zeit.,' 1845, p. 198); Nägeli ('Zeitschrift,' 1847, p. 117). In spite of the many researches upon starch we possess, the origin and development of the starch grain requires a new and careful investigation, since none of the views hitherto put forth are sufficiently supported by direct observations. The theory of centripetal lamination is apparently borne out by the greater softness of the inner layers, but I would suggest that the cavity of the concentric starch grains is always so small that, taking into account the enormous enlargement which the starch grain undergoes during the formation of the layers, an expansion of the outer layers after their formation must be assumed, such as is scarcely conceivable. The small starch-granules which so frequently occur among the layers, seem to possess no cavity at all; in the sometimes single, sometimes associated starch granules found so frequently in the interior of chlorophyll vesicles, (I found 10—12 of them in one chlorophyll-vesicle of the uppermost foliar joints of *Chara hispida*), no trace of a cavity can be distinguished. Hence the conjecture may be admissible that the cavity in the larger granules is not an original but a secondary phenomenon, resulting from the disappearance of the nucleus. If the starch grains are not cells themselves, but bodies secreted by the cell-contents, like the cell-membrane, with which they are so closely allied chemically, thin concentrical formations from the outside is by far the more probable. I would compare their origin with that of pearls in the oyster shell, disregarding of course the accidental character of the latter. As many pearls, when in contact with their shell, become covered up by the later lamellæ of the shell, structures resembling starch grains occur in *Hydrodictyon*, as abnormal formations, enclosed between the lamellæ of the cell-membrane. I shall describe these more minutely at another opportunity, together with other strange structures occurring in the cell-membrane of *Hydrodictyon*.

granules; also in *Ulothrix*, where the cells contain about six, and in *Ascidium* and *Pediastrum*, where the cells have only a single starch-grain. In *Chlamidococcus* the starch-grains vanish at the commencement of the division of the active cells (to be described hereafter).

The formation of fixed oil is intimately connected with that of starch in the economy of cell-life; its appearance, in like manner, announces the repose of age in cell-life, its disappearance the beginning of Rejuvenescence. We meet with fixed oil in the cells, either mixed with starch, substituted for it, or gradually displacing it; its occurrence is perhaps still more general than that of starch, since it exists even in the Fungi and Phycochromiferous Algæ. Like starch, it is met with in greatest abundance in those parts in which vegetation is destined to rest and to await a future re-awakening, for instance, in tuberous stolons (*Cyperus esculentus*) and rhizomes (*Isoëtes*,* *Aspidium Filix mas.*); in the seeds of the Phanerogamia, either in the albumen (*Euphorbia*, Umbelliferæ, *Vitis*), or in the embryo (Cruciferæ, Compositæ, Cucurbitaceæ, Amygdaleæ, Juglandeæ); in the resting spores of Ferns, Lycopodiaceæ, Mosses,† Hepaticæ,‡ Lichens,§ and many

* Especially in the terrestrial species: *I. hystrix*, Durieu; and *I. duriæi*, Bory, ('Explor. Scient. d'Algérie,' Bot., t. xxxvi), as also those which grow on spots only overflowed in winter, as *I. setacea*, Bosc., *I. adspersa*, A. Braun, *I. velata*, A. Br., (ibid., t. xxxvii). All these contain only a little starch but a great abundance of fixed oil, in the short tuberous stem, while our always aquatic *I. lacustris* exhibits but little oil with abundance of starch. The oleaginous *Isoëtes* all have the power of surviving a long time in a perfectly dry condition. *I. hystrix* and *Duriæi* grow upon the dryest hills of Algeria, in loose sand, close to the surface of the ground, where they are exposed during eight or nine months to the greatest drought and the most burning heat of the sun. According to the experience of Durieu, the tubers of these species still remain alive, after having been kept dried for five or six years; I myself have seen a specimen of *Isoëtes setacea* revive and vegetate after it had lain almost two years in an herbarium.

† According to W. Schimper, ('Recherch. sur les Mousses,' p. 77), the contents of the spores of Mosses are oily, without a trace of starch.

‡ According to Mohl, ('Verm. Schrift.,' pp. 87, 90), the developing spores of *Anthoceros* contain starch-grains, while the ripe spores contain only a mucilaginous fluid in which oil-drops are intermixed.

§ The spores of the Lichens (Mohl, 'Verm. Schrift,' p. 75) often contain an oil-drop.

Algæ (*e. g. Vaucheria, Spirogyra, Sphæroplea, Œdogonium, Bulbochæte, Cylindrospermum, Rivularia, Palmoglæa*). In the spores of Characeæ we find a small quantity of an often dark-yellow oil among the numerous starch-grains; the large spores of *Marsilea* also contain a dirty-yellow fixed oil, besides starch. That the collections of fixed oil, so frequent in tubers and seeds, are at least partially used up as nutriment, *i. e.* become transformed in such a manner that they may subserve the vegetative processes over again, is a fact not admitting of doubt, although not yet sufficiently explained in its chemical relations. Certain experiences of the Algæ referring here, not only confirm this transformation of the fixed oil, but also indicate that the necessity of a condition of rest for most seeds, as well as for most tuberous and bulbous plants, is connected, at least in part, with this transformation of the fixed oils.*

In *Spirogyra* the green spiral bands undergo a remarkable change in those cells destined for conjugation; their regular course becomes interrupted by curvatures of different kinds; the beautifully toothed margins vanish; among and beside the simple or compound starch-grains previously present, lying in the median line of the bands, numerous oil-drops are found, at first very small, but some becoming as large as the starch-grains, which are distinguished from the latter even by their brilliancy, but still more certainly on the application of iodine. Through the union of the contents of the con-

* Schleiden ('Grundz.,' 2te Auft. ii, p. 432; 'Principles,' p. 462, in the chapter on Germination) proposes the question, "Whence does it arise that the conditions which can and must introduce a determinate process into the embryo, are capable of remaining a long period without action?" and he connects with this the conjecture that the cause of this phenomenon may depend upon unknown slow chemical processes. The observations which follow indicate that one of these processes must be sought for in the gradual transformation of the fixed oil through contact with atmospheric air, which contact is brought about or else increased by drying. The well-known phenomenon that many oily seeds, for instance those of the Cucurbitaceæ, germinate more certainly and readily after having been kept dried for a number of years, than in the first year, is certainly explained by this.

jugated cells, the continuity of the spiral bands is finally wholly loosened, the originally green contents of the spores become sometimes lighter, sometimes darker brown, and appear densely filled with oil-drops of different sizes. I have neglected to examine whether or not the few starch-grains present at the formation of the spore are still retained when it is ripe; at all events, the drops of oil form the most important part of the contents. The contents of the spore appear totally changed when it is about to germinate; the multitude of large and small oil-drops has vanished, and the opake mucilage, now become green, again exhibits, but indistinctly, a few small drops or vesicles. Newly-formed spiral bands become visible, as dark, very closely approximated, frequently somewhat flexuous, oblique streaks, even before the germinating internal cell has broken through its double envelope.* (See pp. 135 and 180.)

The strange formation of the spore in *Palmoglœa*, by complete union of two vegetative cells into one single seed-cell, has been already examined (p. 136). During the gradual growing together and fusion of the two combining cells, we may trace the formation of fixed oil step by step. Before the beginning of the combination, the cells are filled with finely granular green contents, in which we see arise, during the progress of the union, shining drops, at first very small and distant, gradually growing larger, coming in contact and coalescing, so that the intermediate contents almost entirely disappear, and the complete spore appears filled merely with a mixture of oil-drops of the most varied size. During this process the colour of the cells changes from green to a light yellowish-brown. Vegetative cells, with homogeneous green contents, originate subsequently through transformation and division of the contents of these oleaginous seed-cells. The process of the new-formation which I

* Vide Pringsheim, translated from the 'Flora,' 1852, in 'Ann. of Nat. Hist.,' 2d ser., vol. xi, p. 210.—A. H.

have not succeeded in seeing in its stage of transition, must doubtless depend upon a complete internal dissolution of the contents of the seed-cell by transformation of the fixed oil, preceding the division and external assumption of new shape. Since *Palmoglœa* does not grow in water, but on damp rocks and moss, and in its formation of seed coincides with the commencement of the warm and dry season of the year, it is probable that the gradual transformation of the oil begins even in the period of dryness, even requires the drying up as a condition of this process. That which I can only express as a conjecture in regard to *Palmoglœa*, is a certainty in the following examples. *Penium curtum** is a small Desmidiaceous plant allied to *Closterium*, growing in rain pools, which are alternately quickly filled and dried up in the changes of weather. In late autumn and in spring many pools in the neighbourhood of Freiburg appear filled with bright green clouds, which are formed by the social growth, and the very fluid, widely extended gelatinous investment of the cells. The gradual ascent of these delicate green clouds from the muddy bottom, when the little basins of water fill again after a dry period, presents a

* See above, p. 181. Ralfs ('British Desmid.,' p. 109) included this little plant, discovered by Brébisson, first placed under *Closterium* and then separated from it in the genus *Penium*, among the *Euastra*, and in the genus *Cosmarium*, a mistake from which a more thorough regard to the arrangement of the cell-contents would have saved him. According to Nägeli, *Penium curtum* should be referred to the genus *Dysphinctium*, subgenus *Actinotænium*; it is very like the *D. Regelianum* figured by him, ('Einz. Alg.,' 109, t. vi, E), but differs in the more numerous green longitudinal bands. The plant here named is also remarkable for exhibiting the peculiar movement of the Desmidiaceæ more regularly and more actively than the other members of the family, a motion very different from that of the Diatomaceæ. It is a remarkable sight to behold all the individuals in a dish of water in a short time turn their long axes toward the light, and thus arrange themselves in beautiful streaks in the gelatinous mass. Observation with the microscope shows that it is the younger half of the cell, distinguishable as such for a long time after division, which here turns toward the light. For those who believe in the animal nature of the Desmidiaceæ, I will add, that the cell-membrane of *Penium* is totally destroyed by a red heat, so that it is not a siliceous lorica; on the other hand, it remains uninjured when boiled in solution of potash.

beautiful and peculiar aspect. The formation and subsequent solution of the oil, as I have observed it in these little plants, is not connected, as in the preceding examples, with formation of spores, but occurs in the vegetative cells; the formation of seed, in *Penium curtum*, doubtless taking place through conjugation, has not yet been observed. In fresh vegetating individuals the contents of the longest cell, somewhat constricted in the middle, exhibit the following character: in the middle of the cell exists a rarely clearly distinguishable nucleus; in the middle of each half a large globe, which Nägeli calls a chlorophyll-vesicle, but which I found completely filled with starch, at least certainly in older cells. The rest of the light-green general mass of the contents is traversed in each half by ten to twelve darker green, somewhat granulated longitudinal bands, which, seen from the apex of the cell, appear like thickish plates, arranged radiantly around the long axis, and united in the middle. If *Penium curtum* is cultivated for a length of time in a dish of water, all the individuals undergo a peculiar alteration, some sooner, some later. The dark-green longitudinal streaks become indistinct and irregular, till at length they disappear, while a quantity of lighter and more brilliant globules appear, which, increasing in size, wholly displace the green contents of the cell, so that the previously bright green cell at last assumes a pale, dirty yellow aspect. Accurate examination shows that the brilliant globules now filling the cells are not the spores, as might perhaps be conjectured, nor starch-grains,* but really drops of oil. Tincture of iodine scarcely perceptibly alters their colour, while the two large globules of starch still existing in the two halves of the cell acquire a dark violet tint. If oil of turpentine is applied to a specimen not quite dried up, the globules of oil coalesce into larger irregular drops; when more completely dried

* Meyen observed the cell of *Closterium Lunula* densely filled with starch grains, ('Pflanzenph.,' iii, 437.)

up they all clearly run together, and fill the cell in an uniform mass, by which the two starch-grains previously hidden among the crowd of oil-drops, become very distinctly evident. With this condition of formation of oil commences a stage of rest in the life of this little organism; the cells no longer increase by division; the stimulus of light no longer produces any movement; the gelatinous envelope vanishes without any new formation of jelly. Unless peculiar circumstances arise, the individuals gradually die away, entirely losing their colour. But if the water is allowed to dry up (as happens from time to time in the natural habitations of this plant), and the dried remains are again immersed in water, after a shorter or longer period,* new gelatinous clouds rise up afresh on the following day, in which are found a multitude of new, again freshly vegetating individuals, containing, instead of the former oil vesicles, homogeneous green contents, in which the green longitudinal bands are again soon to be distinguished. The multiplication by division also soon commences again. That these rejuvenised, revived individuals are not a brood originating from spores, is shown by their size, which agrees with that of the dried-up individuals.†

I have observed still more completely the Rejuvenescence, caused through drying up, in the probably oleiferous cells of the *Chlamidococcus pluvialis*, already many times referred to.‡

* I have not yet made out how long the life can be retained in the dried condition, in *Penium curtum*.

† I have not unfrequently seen a filling of the old cells with drops of oil, similar to that in *Penium curtum*, in other Desmidiaceæ, in Diatomaceæ, *Pediastrum*, *Conferva bombycina*, and exceptionally, as above mentioned, in *Hydrodictyon*. In most cases this formation may end with the death of the cell; this is tolerably certain in *Pediastrum* particularly.

‡ See above, pp. 138, 158, 184, 200. I can only indicate here the most essential elements of the strange history of this creature, embracing a complicated alternation of generations; to trace it completely through all its normal and abnormal complications, would require a separate essay and numerous pictorial illustrations. As the observation of the many interesting phenomena afforded by this plant is by no means difficult, and as it is desirable that these observations should be repeated by many

Normal fully-developed cells of this multiform creature, sometimes like a plant, sometimes like an animal, present the appearance of globules, from $\frac{1}{50}$th to $\frac{1}{25}$th millim. in diameter, with a thick tough cell-membrane, and granular-punctate, opaque contents, sometimes of brown, sometimes (at other periods or in other localities) bright red colour. In the mass of the dark contents lie hidden several other structures, which at this period are completely concealed, namely 4—6 starch-globules, of $\frac{1}{300}$th, or at most $\frac{1}{200}$th millim. in diameter, in which, as in those of *Hydrodictyon*, a nucleus and an envelope may be distinguished, acquiring a dirty violet colour with iodine, the nucleus becoming rather redder. Sulphuric acid causes a considerable swelling up of the coat. There also appears to exist in the centre of the cell a large, very delicate nuclear vesicle, which, however, is so covered up by the rest of the cell-contents, that it can only be very indistinctly perceived, and cannot even be clearly displayed when the contents are squeezed out. When these resting globular cells are placed in water, they give birth, in the way already described (p. 184), to four gonidium-like swarming cells. Even before the

persons, I venture to draw attention to the very wide diffusion of this species. Von Flotow, the discoverer of *Chlamidococcus pluvialis*, found it, in the year 1841, in a shallow hollow in a granite slab forming the foot-bridge across the Frosch-graben, near Hirschberg; subsequently (1846) also in excavations in the granite rocks of Opitzberg, near Hirschberg, where the rain-water collected. Dr. Mettenius found it recently, also, in cavites of granite rocks, at Harlass, near Heidelberg. I found it for the first time in shallow hollows of horizontal sandstone slabs, on the walls of several bridges near Freiburg, in February, 1848, accompanied everywhere by a beautiful Rotifer (*Philodina rosea*), and in one shady spot associated with *Mastichonema pluviale*. The pastor Brunner found it last winter in the district of Donaueschingen, in several churchyards, in the basins cut to hold holy water of the (sandstone) gravestones, and also in the iron vessels fixed on the tombs for the same purpose. I found it at Neuenberg, in Switzerland, in the years 1844 and 1848, in the hollows formed by ancient denudations of the calcareous rocks bordering the lake, and in this place of especially bright red colour. Kützing indicates it also from Bohemia (according to Corda), France (Brébisson), and Scotland (Greville), as he regards *Hæmatococcus Cordæ*, *Meneghini*, and *Protococcus nivalis*, Grev., (Scott, 'Crypt. Flora,' t. 231,) as the same plant as *Hæmatococcus pluvialis*, V. Flotow, on which point I do not yet venture an opinion.

commencement of the division of the contents by which the latter are formed, a change begins in the colour of the parent-cell, the red colour retreating to some extent from the periphery, and a yellow (sometimes rather greenish) border forming round the deep red inner mass. The young swarmers also, for a short time after they issue out, have only a narrow yellow rim round a dark red middle. During the two to three days' period of movement and growth of these swarming-cells,—in which they grow to about four times the original size, changing their obtusely ovate form, at the same time, to a reversed pear-shaped, apiculated shape, and forming a delicate enclosing membrane (p. 158),—important new changes take place in the contents of the cells. The red colour becomes more and more concentrated into the middle of the cell, so that a sharply defined bright red nucleus is formed, in the interior of which a lighter space is often clearly perceptible, corresponding to the nuclear vesicle above mentioned, around which the red colouring matter forms a covering, mostly complete, but sometimes imperfect and interrupted. The rest of the cell-contents have become a brilliant green, and in them may be clearly distinguished the above-mentioned starch-globules, as well as many more smaller green granules. The ciliated point of the cell, often drawn out like a beak, is colourless. This first moving generation is succeeded by a not yet accurately determined number of similar active generations, populating the water for some weeks, and often giving it a bright green colour, till at length universal rest recommences, and the cells sink to the bottom or attach themselves to the sides. The transition from one active generation to another takes place through a transitory resting generation of extremely short duration. The full-grown swarming-cells finally come to rest within their wide shirt-like envelope, and almost simultaneously divide into two cells, which, without becoming active, divide again into two cells. Thus, within the mother-envelope are produced four daughter-cells (more properly grandchildren), which begin to move soon after they are completely formed, and, tearing open the delicate enveloping vesicle, part company. The whole of this process of development is gone through very rapidly, being completed in one night and the succeeding morning. The second active generation, thus formed, resembles the first, with the single distinction that the active cells are green from the first, and have a smaller red nucleus in the interior. The subsequent active generations bear a general resemblance to the preceding, but many modifications present themselves. Thus, for example, we not unfrequently see the full-grown swarm-cells assume strange two-lobed, or even four-lobed, shapes, beginning to divide before they come to rest; or sometimes a transverse construction and bisection of the cell takes place, caused by a partial protrusion of it from the loose shirt, &c. The formation of cavities (Vacuoles) is a pretty constant phenomenon in the later active generations, and there may be several of them eccentrically placed, with the red nucleus retaining its central position, or a single central vacuole, causing a lateral displacement of the red nucleus. If water-cavities of this kind displace the green mucilaginous layer entirely, in places, so that they come in contact with the primordial utricle, the form is produced which Von Flotow called *Hæmatococcus pluvialis lacunosus*, and has represented in pl. 25, figs. 69 and 70, loc. cit. The red nucleus often becomes very small in the last generations, so that it very much resembles, especially when rendered parietal by the formation of a central vacuole, the red corpuscle occurring in the gonidia of many genera of Algæ, belonging to very diverse families, and which was called the "eye", in the Volvocineæ, by Ehrenberg.*

* I have observed an "eye" of this kind in the swarming gonidia of *Hydrodictyon*, *Ulothrix zonata*, (*vide* Kütz., 'Phyc. gen.,' t. lxxx,) *Uloth. Braunii*, K., *Hormidium variabile*, K., *Draparnaldia*, *Stigeoclonium*, (in several species,) *Chætophora*, (likewise many,) *Coleochæte pulvinata*, *Cladophora glomerata;* therefore in genera belonging to five different families, not

A total disappearance of the red colour not unfrequently occurs. In the later stages of the cycle of generations arrives, finally, the formation of microgonidia, already mentioned (p. 138); many individuals, instead of producing four daughter-cells, undergoing further division, so as to give birth to a brood of sixteen or thirty-two minute cells, which, before they separate, form a mulberry-like body, but, separating at length, commence a very active swarming inside the parent envelope, terminating in the rupture of this coat, and the rapid dispersion of the little "swarmers." These are of longer shape than the large "swarmers," only about $\frac{1}{150}$th, rarely $\frac{1}{100}$th millim. long, of yellowish or dirty yellowish-green colour, with reddish ciliated points.* They do not exhibit increase of size, like the large "swarmers," never become coated with a perceptible and loose membrane, and have no further power of propagation. Most of them die after they have settled to rest, dissolving away; others turn into little red globules, and it is doubtful whether they can grow up to the normal size. If we now further examine how the cycle of active generations is closed and carried over to the resting vegetation, we find that the large "swarmers" of the last active generation, when their growth is completed and they have attained the stage of rest, instead of dividing again, remain undivided, assume a perfectly globular form, and in the course of a few days become clothed by a thick, closely applied cell-membrane, while the earlier, loose, distant membrane gradually disappears. The contents, which at the commencement

counting the Volvocineæ (*Volvox*, *Pandorina*, *Botryocystis Morum*?.) In the genus *Chlamidomonas* there are species with and others without the red point. The red point seems to be absent in *Vaucheria*, *Œdogonium*, *Bulbochæte*, *Conferva bombycina*, *Aphanochæte*, *Gongrosira*, *Ascidium*, *Characium*, *Sciadium*, *Pediastrum*, *Apiocystis*, *Dictyosphærium*, *Tetraspora*, *Protococcus viridis*, *Glœococcus*. The minute size and light colour may have caused it to have been overlooked in many cases.

* *Hæmatococcus pluvialis porphyroccpalus*, Von Flotow, l. c., p. 469, t. xxv, f. 74. I must observe, however, that I have never observed the hammering movement of the slender red anterior end, there described; the motion was effected, as in the large swarmers, by two cilia, which became visible by the application of tincture of iodine.

of the rest were all green, except the little red nucleus, or even often entirely green, now gradually become red again, passing from green through many tints of brown, or of brilliant golden green and golden brown, into red. These globular, thick-coated cells (the same as those with which we began) behave like seed-cells or spores, passing into a state of perfect rest. They do not exhibit any growth, and after the membrane has attained its proper thickness, and the contents their red colour, no further visible alteration takes place, so long as they are kept in water. I have preserved them for several months in water, without any new development taking place; on the contrary, they at length began to be bleached and to die away, if they were not devoured by the rapidly multiplying Rotifer (*Philodina roseola*). A desiccation must take place before a new cycle of generations can begin. This is the peculiarity to which I especially wished to draw attention here. Even a short stage of dryness renews the Rejuvenising power of the resting cells, and this is retained for a great length of time in the dried condition, as might be deduced from the mode of occurrence of the plant, and may also be easily proved by artificial experiments. Perfectly dry specimens placed again in water ordinarily produce active gonidia the next morning. I have made the most remarkable experiments on this point, on specimens which Herr von Flotow was kind enough to send me. Specimens gathered at Hirschberg, in Silesia, in March, 1848, placed in water at Freiburg in April of the same year, exhibited new-born active young within 22 hours; specimens dried in 1846, in about 32 hours; finally, original specimens obtained from the stone slab over the Froschgrabe in 1841, after about three days' soaking. These last had therefore retained their vital force during a preservation of seven years in an herbarium.* In order to complete the main features of the picture of the alternating generations of this multiform creature, I must notice that, in addition

* See Von Flotow, in regard to this, l. c., p. 500.

to the described active generations (macrogonidia and microgonidia) and the concluding generation passing into the spore-like condition of rest, there are other generations which, as compared with the gonidium-like and spore-like conditions, must be regarded as the proper representatives of the vegetative development. These are generations endowed with quiet and slow vegetative growth, which multiply by pure vegetative division, unaccompanied by any swarming movement. It depends solely upon external conditions whether the resting-cells which I have characterised as seed-cells (spores), at once give rise to the new active generations, or to a series of quietly vegetating generations of cells. The former is the case when the seed-cells are totally immersed in water; the latter when they occur on a spot which is at once damp and exposed to the air,* as is the case in the native condition, especially in the milder intervals of winter and in the damp season of approaching spring, but temporarily also, at all other seasons, on the margins of the little basins inhabited by *Chlamidococcus* as often as they are filled by showers of rain. In cultivating it in the house, I have but rarely observed these vegetative generations, while in the native stations they certainly occupy the most important place in the alternations of the various conditions of life, as may be concluded from the thickness of the crusts and membranes formed by such vegetative multiplication.† The formation and multiplication of these vegetative generations also take place by the division of the cell-contents, either by simple division, the first generation being transitory, or by double halving (apparently quartering). But the newly formed cells do not slip out, like the young "swarmers," from the mother envelope; they remain in the same place and position. The membrane of the mother-cell appears to become softened, expands, and becomes gradually

* Probably in such cases no perfect dessication takes place.

† *Hæmatococcus pluvialis*, var. *leprosus*, Von Flotow, l. c.

drawn out to nothing, rather than regularly burst open; it at length vanishes in some indistinguishable way, the daughter-cells meanwhile acquiring a tolerably thick, closely applied cell-membrane of their own. The division is repeated many times in this way, and as the cells all remain in intimate contact, first small families, but by degrees large conglomerates of cells, are produced. The size of the single cells in these groups varies from $\frac{1}{100}$th to $\frac{1}{50}$th millim.; their shape is not truly globular, but partly bounded by flat surfaces, as results from the alternating divisions according to the three directions of space. In this neighbourhood I have ordinarily found the colour light brown. If ignorant of the rest of its history, one would be led, by the form and mode of division of the cells, to regard these crusts as belonging to a *Pleurococcus*.*

In the same crusts occur isolated large cells, loosened from their connection with the others, perfectly globular in form, and appearing to divide no more, but to have past again into the condition of resting spore-cells. They are distinguished from the rest by their darker contents

* In this condition *Chlamidococcus pluvialis* exhibits such a decided vegetable character that the advocates of the widest extension of the animal kingdom, if ignorant of its active condition, could hardly conjecture it to be an animal being. But even the active state of *Chlamidococcus* cannot be regarded as possessed of animal life, if the swarming of the gonidia of the Algæ resulting from ciliary motion—which occurs from the Palmellaceæ upwards to the Fucoideæ, and also has its analogue in the higher Cryptogamia, (Characeæ, Mosses, Ferns, and Rhizocarpeæ) in the movement of the spermatozoids, likewise produced by delicate cilia,—is to be regarded as a phenomenon of vegetable life, which, in spite of our ignorance of the cause and *modus operandi* of this motion, does not seem to admit of doubt, from the way in which it presents itself as a normal condition connected with the vegetative life. Although the phenomena of motion are of longer duration in *Chlamidococcus* than is usual elsewhere in the swarming gonidia of Algæ, the kind of movement is essentially the same, namely, an uninterrupted revolution round the long axis, combined with an advance towards the side of the ciliated point. In *Chlamidococcus* the direction is constantly to the left, as in the gonidia of *Œdogonium*, while the gonidia of *Vaucheria*, as also the oval family-stocks of *Pandorina*, revolve constantly to the *right*. With regard to the duration of the movement, *Protococcus viridis*, the active gonidia of which continue their swarming even in the night, forms an intermediate link between the ordinary behaviour and that of *Chamidococcus* and the *Volvocineæ*.

and thicker cell-membrane. Probably the return of these to renewed resting vegetation takes place by a passage through the series of active generations. Every shower of rain will wash away these loose ripe cells of the crusts of *Chlamidococcus;* carried into collections of rain-water they will soon produce the active brood, which, returning to rest after a few active generations, settles on the margins of the little puddles, and then recurs to the resting mode of vegetative multiplication. At least this seems to me the normal cycle of the life of these little amphibious and amphibolic Algæ. What we intended especially to examine in these, is the appearance and disappearance of a probably oily red colouring matter in connection with the conditions of old age and Rejuvenescence of the cells. We found this most abundantly developed in the resting seed-cells, arrived at the entire pause of the vegetation, we saw it vanish almost entirely in the active generations succeeding one another in rapid Rejuvenescence, and endowed with power of very rapid growth. The red colouring matter seems to play the same part here as we have ascribed to the formation of oil in the instances previously examined. Since the capability of preserving the life in the dried condition, and the necessity of the desiccation as a preparative for future Rejuvenescence, may be supposed to have a similar cause in *Chlamidococcus* and in other minute Algæ, it is not improbable that the red colouring matter is, in this case, either itself of oily nature, or occurs in combination with a fixed oil.* The mode of appearance of this in the cells testifies in favour of this assumption to some extent, to some extent, however,

* Nägeli ('Einzell. Algen.,' p. 9), likewise ascribes the red colour occurring in many Palmellaceæ, partly as a normal (*Pleurococcus miniatus*, *Palmella miniata*) partly as an abnormal phenomenon (*Tachygonium*, *Chlorococcus*, *Endococcus*) to the formation of an orange-coloured oil in the place of the chlorophyll. Probably all these have the power of retaining their life a long time in the dried condition, in *Pleurococcus miniatus*, at least, I am quite certain of it. In the crusts of *Protococcus viridis*, growing on walls, also, the cells of the uppermost layers, most liable, become dried up, often acquire a brownish-red colour, the origin of which is probably to be explained in the same way.

against it, since the red colour does not always present the drop-form peculiar to oil. In completely red resting-cells the entire contents (with the exception of the starch-vesicle) appear saturated with the red colour, no separate red drops being distinguishable; but I sometimes found in the dishes of water in which I cultivated the *Chlamidococcus*, resting-cells (diseased?) in which the brownish-green contents were somewhat retracted from the tough cell-membrane, and between the membrane and contents long flattened drops of decidedly oily aspect and dark yellowish-red colour had been formed. The connected red nucleus, such as occurs especially in the active cells, readily breaks up into many oil-like drops, as, for instance, when diseased cells decay in water, as also when they die from being dried up;* when the cell is crushed; as also, lastly, when sulphuric acid is applied, which moreover gradually gives the red drops a dirty violet colour. Oil of turpentine, on the contrary, in recently dried-up cells, spreads the red colour uniformly through the whole contents, or in a greater abundance at the circumference of the cell.

The formation of oil presents itself with greater clearness in the sleeping state of *Chlamidomonas*. Several species of this genus, hitherto included in the Animal kingdom, but nearly allied to *Glœococcus* and *Chlamidococcus*, present themselves in the beginning of spring, in such abundance that they produce a striking green coloration of the water; a few weeks later they vanish, leaving no trace, and are not noticed again throughout the whole year. I have observed the circumstances attending this disappearance in a species which I call *Chlamidomonas obtusa*.† I brought this home in the

* According to my observations, all active forms die when dried up. I cannot confirm the existence of a *Hæmatococcus pluvialis atomarius*, such as Von Flotow thinks we may believe in. The preservation of *Chamidococcus*, both in the dry and frozen state, certainly occurs only through the resting, thick-walled form.

† *Chlamidomonas* (a name certainly sounding strangely in the vegetable kingdom) is distinguished from the genus *Chlamidococcus* by the closely

swarming condition in April of last year. The large, dark green swarmers, differing from other similar green swarming cells by the remarkable truncation of both ends, multiplied for some time longer, and here and there produced very minute, paler and more brownish-yellow microgonidia; in the course of a few weeks no more active cells could be found in the water, the full-grown swarmers having all gradually come to rest and sunk to the bottom. The originally longish shape of the cells had changed into a perfect sphere with the transition to rest; the colour of these resting-cells, originally still green, now gradually passed into a light yellowish-brown, at

applied membrane (not standing away from the contents) of the old swarming cells; also by the absence of the little starch-vesicles in the interior, while, however, as is usual in most of the Palmellaceæ, a single large "chlorophyll utricle" (starch-utricle?) exists in the interior. There is no central red nucleus, as in the gonidia of *Chlamidococcus*, but some species have a parietal red spot (an "eye"). The motion is effected by two cilia, as in *Chlamidococcus*. As in that genus, there is a growth of the gonidia during "swarming," which lasts over the day and night. There is also a formation of microgonidia. The species of this genus are doubtless very numerous, but the distinction of them among themselves, as well as from the swarming-cells of many other Algæ, is very difficult without a complete acquaintance with the history of their lives. The new species mentioned, *Chl. obtusa*, occurs in the Rhine valley, near Freiburg, in sand-pits, which are occasionally almost completely dried up in summer. The macrogonidia grow during their period of swarming, from $\frac{1}{60}$ to almost $\frac{1}{30}$ millim. long; they are longish, of equal diameter on both sides, and very obtuse, almost truncated, having a colourless place at the ciliated extremity, presenting the form of a notch. In regard to other points, the contents are dark green, finely granular, with a large vesicle at the posterior extremity, a roundish lighter space in front of this, and no red point. They multiply by simple or double halving in several successive generations. Sometimes a further continuation of the division of the full-grown macrogonidia occurs, forming sixteen or thirty-two macrogonidia from $\frac{1}{200}$ to $\frac{1}{120}$ millim. long, of ovate shape, and lighter colour, tending towards brownish-yellow. The resting (seed-) cells are globular, about $\frac{1}{30}$ millim. in diameter, at first green, subsequently light yellowish-brown, finally flesh-red; they have a tough, colourless, and transparent membrane. Another species, *Chl. tingens*, occurs in enormous quantity in the puddles of the sandstone quarries at Lorettoberg, near Freiburg, in the month of March, in mild seasons sometimes even in January and February. The swarming cells are smaller than in the preceding, $\frac{1}{120}$ to $\frac{1}{60}$ millim. long, ovate, lighter green, likewise destitute of a red spot, and the membrane is more distinct in the old age. Increase by double, rarely by simple halving, in the former case with decussating sections. I have seen the formation of microgonidia in this species also, but not minutely observed the resting stage. (See preface.)

the same time a number of small, sharply defined, brilliant globules were formed in the interior, having quite the appearance of drops of oil. In this altered condition the *Chlamidomonada* remained, exhibiting neither growth nor increase. At the end of the month of May, in the hope of causing a renewed development, I allowed the dish to dry up, but it was in vain; even when I poured water on them again about a month after, no perceptible alteration occurred. I let the mass dry up again, and added water again in the middle of December following; towards the end of December, and in the course of January, active *Chlamidomonada* actually reappeared. All the resting globules had meantime changed colour to some extent, appearing light reddish; the first "swarmers," also, formed by the halving or quartering of the contents of the resting globules, and brought to light by a rupture of the tough coat, at first exhibited a reddish or greenish-red colour, which only passed gradually into pure green, the drops of oil vanishing at the same time. Only a small proportion of the resting-cells came to such development in cultivation in the house; others divided, without loss of the reddish colour, into quietly vegetating cells connected in groups, in a manner similar to that I have described in *Chlamidococcus;* others remained unchanged until spring, at which time, however, I did not pursue the investigation any further. There is no doubt that future investigation will detect in the Volvocineæ resting stages for the winter sleep, similar to those here examined in *Chlamidococcus* and *Chlamidomonas*.

Collecting together the phenomena of dissolution we have been examining, connected with the Rejuvenescences in Cell-life, we find that it results from them, that the development and propagation of the Vegetable organism does not consist of a bare series of formative processes, but that processes of de-formation or "undoing" enter as necessary links into the course. The plant, however, differs essentially from the animal in this respect; while in the interchanges of material of the animal organism, formation and deformation intermix in simultaneous occurrence, dissolving and newly shaping in the same epoch, the two processes are more separated in the plant, running into one another in periodical alternations. In the Vegetable kingdom, as in the Animal, the nitrogenous substances (proteine and the substances allied to it) form the especial substratum and active medium of the vital activity,* while the unazotised substances, rich in carbon, play a more passive part in the organism, on the one hand protecting, on the other limiting, narrowing, stupefying, and even extinguishing the vital force. The animal organism frees itself from the superabundance of carbonaceous substances, which it receives for the most part already formed in its food, through the uninterrupted process of respiration, in which the carbon is destroyed (burnt) by the aid of the oxygen derived from the atmosphere, and excreted in the form of gas. It is different with the plant; it does excrete the substances rich in carbon formed in the internal organism of the cell, out of the cell-sap, not, however, destroying them, but depositing them either as organic structures on the confines of the cell-organism (formation of membrane from cellulose, and the allied substances, gelin, amyloid, Lichen-starch, &c.), or it secretes them in the interior of the cell itself as globular, frequently laminated masses (starch or inuline), or in the form of drops (fixed oils). The formation of the cellulose membrane† is especially characteristic, in this respect, of the plant, securing to the cell-formation of the plant, in all cases, its peculiar separateness and independence, however varied the mode of ultimate

* According to Payen, all young organs of plants, in their earliest stages of development, contain a predominance of nitrogenous substances.

† Cell-membranes formed of cellulose have hitherto been found in the animal kingdom only in the sac-shaped envelopes of the Ascidia. See Schmidt, "Zur Vergleichenden Physiologie der wirbellose Thier," (1845) Transl. in "Taylor's Scientific Memoirs;" Löwig and Kölliker, "De la Composition et de la Structure des Enveloppes des Tuniciers," ('Ann. des Sc. Nat.,' 1846, p. 193.)

development may be. It is to this carbonaceous apparatus of the cell that the entire structure of the plant owes its external and internal combination and solidity; but it is at the same time the cause of the gradual fixation of the product, the relative absence of motion, which distinguishes the vegetable structure, in contrast to the internally and externally more mobile animal organism. It is remarkable that the most striking of all the phenomena of motion of plants, the swarming movement of the gonidia and spermatozoidia, occur in such cells as are either yet without their cellulose coating, or which never acquire one. Thus, consequently, the life of the plant becomes fettered by the vegetative process itself; the continuous secretion of cellulose, and the thickening of the cell-wall caused thereby, obstruct more and more the intercourse with the outside, as in like manner the accumulation of highly carbonized deposits in the interior of the cell-contents obstructs the internal movement. Thus all vital activity must at last come to a pause, unless this entombing and suffocating process of formation becomes opposed by a dissolving and emancipating process. It is just this which we have sought to examine in the foregoing pages; we have seen it make its appearance at a definite period in those parts which are destined to carry on or repeat the development, destroying preceding constructions, and making space for new formations, more or less interrupting the old course of completion, and often causing the life to turn off in new directions. We have seen that the solid cell-membrane becomes soft again, bursts, or dissolves away; we have seen the starch dissolved, the fixed oils vanish. But the most important occurrence in this process of destruction is not merely a solution of that which had become solid, not merely a process of transformation of the substances secreted in the formative process, into new material for structure (*e. g.* starch into dextrine and sugar), but, at all events in part, an actual destruction (combustion) of the highly carbonized substances present in excess, similar to that which occurs in animal respiration. It is well-known that in the germination of mealy seeds, as also in the sprouting of mealy tubers, an abundant excretion of carbonic acid is associated with the conversion of the starch into sugar, and that this, connected with perceptible evolution of heat, is caused by a decomposition of sugar; it is well-known that beets and carrots lose the sugar they contain, at the period of the unfolding of the flower, which is accompanied with abundant excretion of carbonic acid; it is further known, through Saussure's experiments, that the internal parts of the flower, in the delicate tissue of which the formative process deposits the smallest quantity of highly carbonised substances, take up oxygen from the atmosphere and excrete carbonic acid more abundantly than any other parts of the plant; again that the anthers are especially distinguished among these, in which organs important processes of solution of the tissue are connected with the ulterior development of the pollen. In the nectaries undecomposed sugar is excreted. There is no doubt but all processes of solution and transformation in plants are accompanied by excretion of carbonic acid. Observations of the lower plants promises much more profit in this respect. In *Hydrodictyon* I have seen cells in the stage preparatory to the formation of gonidia (in which the starch globules had already vanished), secrete gas bubbles in unusual quantity; I neglected to examine these chemically, but they doubtless consisted of carbonic acid, since they were visible very early in the morning and later in the day when the sky was overcast, and since other nets, in a vegetating stage, exhibited at the same moments no such evolution of gas.

The examination of the processes of solution and destruction, which we see introduce the new structure at determinate turning-points of vegetable life, and which are all characterised by absorption of oxygen and excretion of carbonic acid, leads us to the comparison of the nocturnal respiration of plants, in which, according to the facts known about it, we can in like manner perceive nothing else than a periodical interruption of the diurnal process of formation, by a process of deformation and de-carbonisation, although this does not so profoundly affect the plant. It is true we cannot observe in it any perceptible solution of cell-membrane, starch granules, and the like, but there is no doubt of the occurrence of an interruption in the deposition of these structures, probably through the interposition of a process of combustion of the materials out of which they originate, while still dissolved in the cell-sap. It is indeed not very adventurous to refer the lamellar deposition of the cell-membrane, and the concentrically laminated structure of the starch-grain, to this daily periodicity of the cell-life. The great number of layers which may be distinguished by suitable treatment in the cell-membrane even of plants of short life (*Hydrodictyon*, *Cladophora*, *Botrydium*), is not opposed to the assumption that they are *diurnal layers*, and it is imaginable, under this hypothesis, that bright and dull days, as well as the age of the cell and other circumstances, may effect important modifications in reference to the formation of distinguishable layers. Annual rings, or better, annual layers, may doubtless be demonstrated in cells of perennial duration. The lamination described by Mohl,* in the walls of liber-cells, for instance of *Cocos* and *Calamus*, which exhibit the peculiar phenomenon, that the thick and not very numerous layers, which are separated from each other by dilute sulphuric acid, are composed of an outer, broader, and softer, and an inner, thinner and firmer layer, may perhaps be compared with the condition of the annual rings of the wood of Dicotyledons, in which, in correspondence with the reverse order of formation, each yearly ring exhibits an inner, broader, and looser, and an outer, narrower, and denser half. I

* 'Botanische Zeitung,' 1844, p. 309, t. ii, figs. 8, 25, 26. (Trans. 'Scientific Memoirs,' vol. iv, p. 103, pl. i, ii, figs. 8, 25, 26.)

found in the lowest internodes of the stem of the perennial *Chara ceratophylla*, formed in the year previous to that in which it was examined, that the cell-membrane, about $\frac{1}{16}$ millim. in total diameter, was composed of two very distinct portions of about equal thickness; while the thinner cell-membrane of the young internodes of the stem exhibited no such sub-division. In each of the two portions I could make out about 10 subordinate layers, which, however, were themselves of compound nature. The agreement of the nocturnal process of respiration of plants with the phenomena of dissolution, through which we have seen the transition to distinctly new formations prepared, is confirmed by the epoch in which the latter usually make their appearance. Observation of the Algæ has furnished us with most interesting facts in reference to this. Trentepohl* already observed that the expansion of the summits (the preparation for the formation of the germ-cell) in *Vaucheria clavata* took place especially in the night, and the exit of the active germ-cell on the succeeding morning. Unger† confirmed this, for he characterises it as a remarkable phenomenon that the unloosing of the gonidia of *Vaucheria* mostly occurs between eight and nine o'clock in the morning. According to the statements of Thuret‡ and Fresenius,§ the same phenomenon is repeated in other Algæ. I have satisfied myself in all the green Algæ with active gonidia which I have had an opportunity of observing, that the preparation for the formation of gonidia, and particularly the disappearance of the starch-grains mostly connected with this, begins in the night, and in general advances so far in *one* night, that the formation of the gonidia can be completed and their birth take place on the following morning. I will first

* According to Meyen, 'Pflanzenphys.,' iii, p. 430.

† 'Die Pflanze im Momente der Thierwerdung,' p. 27.

‡ "C'est surtout le matin qu'on trouve le plus grand nombre de spores des Conferves en mouvement," Thuret, 'Sur les Organes Locomoteurs des Spores des Algues,' ('Ann. des Sc. nat.,' 1843, p. 268.)

§ 'Zur Controverse über die Verwandlung der Infusorien in Algen,' p. iv.

of all refer again to *Hydrodictyon* as an example. The reason why the mode of formation of the new nets in the cells of the old one has hitherto been so rarely and so inaccurately observed,* doubtless arises from the time at which this process commences. If a single fully-developed net of this plant, or even mere fragments of nets, are placed in a shallow saucer of water, we may almost certainly reckon upon finding fully-formed young nets in some of the old cells on the next, or at all events on the second morning, and these in cells which exhibited no alteration whatever.† If we wish to see the origin of these young nets, we must not lose the earliest hours of the morning, for the tremulous movement commencing after the formation is complete, and the final union of the gonidia into a net (see p. 137) takes place shortly after sun-rise, in the middle of summer between four and five in the morning, at the end of summer between six and eight o'clock, and only in dull days of autumn, in which, however, the formation of new nets rarely occurs, sometimes as late as ten o'clock in the morning. The swarming out of the microgonidia of *Hydrodictyon* always takes place rather later in the day than the formation of the nets, in summer usually between seven and nine, in autumn between ten and two o'clock. As the swarming lasts several hours, the active condition may often be observed late in the afternoon (sometimes at five o'clock in the evening).‡

* The most recent treatise on this subject, by Morren ('Mém. de l'Acad. Roy. de Bruxelles,') xiv, (1841,) is an almost incomprehensible tissue of errors.

† In deeper vessels of water the propagation does not commence so soon, which is certainly explained by the diminished contact with the atmosphere, especially with the oxygen required for the process of solution.

‡ In regard to the relation of the occurrence of the swarming-out microgonidia to the net-forming macrogonidia, I may add that it appears to depend, in part, upon external circumstances. Many days I saw only net-formation, in others both net-formation and swarming, on others, again, especially on dull and rough days, formation of swarmers in unusual quantity unaccompanied by any net-formation. It is strange that the formation of swarmers, on the whole more frequent than the formation of new nets, has not been more frequently observed by earlier investigators. Treviranus saw them but did not observe their origin. ('Beiträge zur Physiol.,' p. 81.)

The gradual changes which take place in the water-nets preparing for fructification, converting the contents of the vegetative cell into thousands of gonidia, must be observed by night; but it sometimes happens that the particular cells do not advance far enough in the dissolving preparation, in the course of the night, to enable the influence of the morning's light to complete the formation. Such cells exhibit the earlier preparatory stages, otherwise rapidly passed through in the course of the night, with especial distinctness. Some thus remain all day without any perceptible alteration, completing the preparatory stages in the second night, and maturing the gonidia on the second morning.

As a second instance, I will bring forward *Ulothrix zonata*, a Conferva frequent in the mountain brooks of the Schwarzwald, descending also into the plains in the Dreisam. The mode of growth and the formation of gonidia have already been examined (pp. 148, 159). If a little tuft of this Alga is placed under the microscope in the morning, filaments of two characters are seen; some (still vegetating) with parietal contents of the clearest, brightest green, leaving the ends of the cells almost free, in which green contents exist scarcely perceptible point-like granules, a few small starch-globules, and a large likewise parietal nucleus, which it is not easy to see; the others (in the condition of fructification) of somewhat torulose aspect, and with more concentrated, darker contents, divided into 4, 8, or 16 masses (gonidia). We rarely find transitions from one structure to the other,—namely filaments with darker and more opake green contents not yet divided, in which the fine granules are more strongly developed, but the starch-granules either lost, or only their little nuclei visible,—because the transitional stages are usually passed through in the night, and the formation of gonidia completed early in the morning. Birth and swarming of the gonidia, which latter mostly lasts more than an hour, may be observed all the morning. All the mature cells are usually emptied by the afternoon; those not emptied by that time develope no further. Once, however, I saw birth of gonidia occur between six and seven o'clock in the evening; it was on a very dull and rainy day in July, on which the weather suddenly cleared up between five and six o'clock. I have made similar experiments on many other fresh-water Algæ; *e.g.*, on *Draparnaldia mutabilis*, in which I observed the birth of the active gonidia in March from eight in the morning, in May from six, and the swarming until eleven, A.M., at most. In *Stigeoclonium protensum* (?) the birth and movement of the gonidia took place in May between six and ten, A.M; in *Chætophora tuberculata*, in August, between eight and two, A.M.; in *Ascidium acuminatum*, in July, from six, A.M. to three, P.M., and even still later, but none so late as dusk. The *Œdogonia* also ordinarily emit their large gonidia in the morning; in summer and in bright weather earlier, in winter* and in dull weather later. Since the swarming of the gonidia lasts several hours, in this genus, it may be often observed in the afternoon. In *Chlamidococcus pluvialis*, both the birth of the first generation of gonidia, and the production of the succeeding generations by division of the earlier, occurs in the morning, after nocturnal preparation, and the same is the case in the formation of new families in the Volvocineæ, for instance in *Pandorina elegans*. What we have here seen in regard to the time of formation of the gonidia of the Algæ, is true also of the vegetative multiplication of their cells. Thus Focke† has observed that the division of the *Euastra* commences early in the morning, and has advanced so far by evening, that the complementary halves acquire their complete form and full size before night. I have made the same observation in regard to the first commencement of the division of the cells in *Spirogyra*. For a long time I could not

* *Œdogonium fonticola*, which vegetates all through the winter in the holes in running brooks, and developes the longest filaments at that season, exhibits formation of gonidia even in winter when brought into the house.

† 'Physiol. Studien.,' (1847,) p. 47, t. ii, figs. 1, 4, 5.

succeed in finding it, although I frequently met with cells recently divided. Not until I selected the earliest hours of morning for the observation, and at last took the precaution of placing specimens in spirit before sunrise, so as to be able to examine them at leisure later, was I able to make out completely the process of division of the cells in this genus. I shall describe it in the next section of this treatise.

All these observations furnish the one common result, that the processes of solution and deformation, the more important as well as the slighter, occur at night, under the influence of determinate degrees of temperature,* while, on the other hand, they confirm the experience that the influence of light awakens the plastic processes, formation of substances as well as production of form, in the plant.† A number of well-known phenomena in the great processes of Rejuvenescence of the Vegetable kingdom have an intimate connection with these facts. It is well known that vegetable life awakening from the winter sleep requires, above all things, warm, dull, and damp days, especially the warm showers of spring, to enable it to dissolve the winter provision of nutriment, on which the influence of light of the increasing days may exercise its newly-shaping force; equally well-known are the effects of the northern summer, which brings many plants into flower and fruit more rapidly than our temperate climate. It is the influence of light, increased by the long days, which causes a more rapid development of all products of form, an abbreviated course of the metamorphosis, just as we see the plants on high mountains also advance with more rapid steps to flower and fruit, through less luxuriant development of the vegetative

* More exact observations are yet to be made on this point in the Algæ. The rapid commencement of the formation of gonidia in Algæ brought into the house, doubtless depends on the slighter degree of cooling occurring during the night indoors.

† See the observations on *Euastrum* mentioned in the preceding page. I shall describe more minutely, in the Appendix, the important changes of form which the new-born cells of *Pediastrum* undergo in the course of the first day, and after a nocturnal rest, again on the second day.

preparatory steps, whence we find many come into flower sooner on the mountains than in the valleys or plains, as is the case with the heather (*Calluna vulgaris*), and *Parnassia palustris*.* In the equatorial regions, on the contrary, where the seasons run into one another, forming as it were an uninterrupted spring, where, day and night being of the same length, the most intense action of light (through the altitude of the sun and the transparency of the atmosphere) is combined with the greatest heat and moisture, where consequently the conditions for both factors of the process of Rejuvenescence in vegetation, dissolution and reconstruction, are united in high and equal degree throughout the whole year,—there we behold the most luxuriant development of the Vegetable kingdom in "stock," flower, and fruit, whose epochs of verdure, blossom, and ripeness, more separated in other zones, are there most intimately interwoven.

III.—RECONSTRUCTION OF THE CELL.

The process of solution and destruction in the cells, which we have just examined, prepares for a renewed process of construction; the slighter and less perceptible the process of solution, the more will the reconstruction appear like a mere continuating formation; the more forcibly and profoundly it takes place, the more distinctly will the reconstruction appear as such, as is most of all the case in the formation of cells of propagation. All formation of new cells, therefore, is strictly a process of Rejuvenescence of the cell; sometimes total, when the entire contents are metamorphosed; sometimes partial, when only a portion of the contents pass over into new cell-formation. If the transformation of the entire cell-con-

* *Parnassia palustris* flowers on the higher mountain tracts of the Black Forest, for instance on the Schauinsland and Feldberg, in spots more than 3000 feet high, by the middle of June, while in the lowlands its flowering does not commence until the middle or end of July.

tents is combined with a division of them, a multiplication of the cell takes place, constituting the basis of the formation of tissues in plants where the cells remain connected together, multiplication of the individual where they separate. The various modes of origin of new cells, which appeared so different and irreconcilcable at first sight, now all come together finally as cases merely differing in degree of an essentially identical process, the re-shaping of the cell-contents. The idea of origin of cells outside, between or on the surface of existing cells, formerly advocated by Mirbel, has proved untenable; neither the vegetative development nor the propagation of plants exhibit anything but production of new cells by transformation of pre-existing ones.* This has been called propagation of cells, but it must be observed here, that in the majority of cases the entire contents, *i. e.* the whole active living organism of the cell, passes directly into the new structure, so that nothing remains behind, unchanged, of the old cell (the mother-cell), except the passive membranous wall. The daughter-cells are therefore not to be considered as young produced by the mother-cell, existing contemporaneously with it, nourished by and gradually developed in it, but as the rejuvenised and metamorphosed mother-cell itself.† This is most strikingly evident in those cases where the entire and undivided cell-contents become loosened from the membrane of the mother-cell, and, shaping themselves in a different way, become a new cell: as is the case, for example, in the formation of gonidia and spores in *Œdogonium*, *Bulbochæte*, &c., and in the formation of the

* Further researches are required to decide the relation of the in many respects enigmatical formation of the yeast-cells, (the first cells of the fermentation fungus,) and other analogous cases of what is termed *generatio spontanea*, to cell-formation in the normal course of development and propagation of plants. (See Schleiden, 'Grundz.,' 2d Aufl. 1, p. 203, 'Principles,' pp. 36, 569, t. i, fig. 9, and Karsten, 'Urzengung, Botanische Zeitung,' 1848, p. 457.)

† I cannot enter at length into the opposite view of Karsten, ('De Cella Vitali,' 1844,) but I may remark that so far as relates to cell-formation it totally contradicts my experience.

pollen-cells in their special mother-cells.* The whole conception of the formation of new cells (daughter-cells) in old ones (mother-cells), as it has grown up since first brought forward by Schleiden,† now requires a further elucidation, since it has been extended from the so-called *free* cell-formation, to which alone it is perfectly applicable, to the far more common cell-formation by division, whence has arisen a nomenclature, to the equivocal character of which I must here direct attention. It is a mistake to apply the word cell sometimes to the *cell with a membrane*, sometimes to the *cell without a membrane*, and sometimes to the *membrane without the cell*. Since the contents of the cell constitute the essential part of it (see p. 155), since it forms, before the secretion of the (cellulose-) membrane (pp. 156—167), a separate entity, possessing its own, essentially proper, membranous boundary (the primordial utricle, pp. 169—173), we must call this internal body the cell proper, unless we restrict the term cell to the enclosing wall or chamber, and give the internal body another name. If the name is restricted to the internal body, we cannot, in the great majority of cases, say that new cells are formed in the old, but merely that they are formed out of the old, for even the primordial utricle shares in the division, in the propagation of cells by division. Therefore when daughter-cells are said to be formed in the mother-cells, or to slip out from the mother-cells, or mother-cells are said to be dissolved and absorbed, these phrases must be admitted only as conveniently abbreviated expressions, "*mother-cell*" being here used instead of maternal *cell-membrane*. Finally, there are cases in which the expression, that daughter-cells are formed in mother-cells, cannot be applied, even in this abusive sense; these are the cases above mentioned (p. 159) of division of cells which pos-

* According to Hofmeister ('Ueber die Entwicklung des Pollens,' Bot. Zeit., 1848, p. 431), the nucleus even survives this transition.

† "The process of propagation of cells by the production of new cells *in their interior*, is the general law in the vegetable kingdom." (Schleiden, 'Grundz.,' 2 Aufl. i, p. 305, 'Principles,' p. 103.)

sess no cellulose layers at all, such as we have undoubtedly observed in the transitory generations of cells, through which is effected the formation of the gonidia of many Algæ, (*Ulothrix*, *Characium*, *Pediastrum*, *Cystococcus*, *Chlamidococcus*, &c.)

Having made these preliminary observations, I shall endeavour to bring together, in a connected summary, the various kinds of reconstruction of the cell, beginning with the cases of entire metamorphosis of the contents.

A. Reconstruction without division of the cell. —Here the character of the rejuvenised cell either remains essentially the same, *i. e.*, the repeated reconstruction appears merely as a development of the cell advancing by periodical Rejuvenescence, as is the case more or less evidently in the completing development of all vegetative cells; or the character of the rejuvenised cell becomes different, the previously vegetative cell acquiring a reproductive destination, at the same time being freed, in its renewed structure, from the envelope previously formed. In the latter case the rejuvenised cell will be regarded as a *new* one, notwithstanding that, if we leave out the inessential membrane which it throws off, it is still the old, in reference to its essential part, the internal body, as much as it is in the former case, only its shape being changed. The intermediate stages to be enumerated will show that these two cases are not so different as they seem at first sight. We accordingly distinguish—

1. *Reconstruction without division in vegetative cells*, prepared by the periodical nocturnal respiration; expressed in the lamellar deposition of the cell-membrane (p. 220).

a. The layers of cell-membrane are intimately adherent together, and form a firmly-united, compound cell-membrane, the layers of which are sometimes clearly evident, but often only to be made out by artificial loosening by means of chemical reagents, *e. g. Hydrodictyon*, *Cladophora*.*

* See H. v. Mohl, 'Vermischte Schriften,' t. xiii, f. 13, 14.

b. The outer layers of the cell-membrane become, sooner or later, cracked and peeled off, which takes place either by rapid growth of the cell, not inclusively of the outer membrane, as in the paraphyses of *Diphyscium* (p. 177), or through more or less abundant secretions of jelly alternating with the lamellæ of the cell-membrane, as already mentioned in the description of the phenomena of "skinning" in *Glæocapsa, Glæocystis, Pleurococcus miniatus, Chroococcus decorticans* (p. 182), *Urococcus* (p. 178), and *Schizochlamys* (p. 181). The last-named example, each new membrane being thrown off by a regular dehiscence before the new one is formed, connects this group of cases very clearly with the succeeding series. The cell, as it were, new-born after every "new skinning," is not regarded each time as a new cell, simply because its character does not suffer any perceptible change.

2. *Reconstruction without division in the transition to fructification, or retrogressively from this to germination.*—In both cases the vital process of the cell acquires with the reconstruction a new direction of the physiological activity, an altered destination; in the former case, a transition from the vegetative growth to the swarming condition of the gonidium, or the sleeping condition of the spore; in the latter, on the contrary, from the sleeping condition to the vegetative development. If in such a transition no throwing off of a membrane formed in an earlier condition takes place, as is usual in the passage of swarming gonidia into germination,* and occasionally happens in the transition of

* What becomes of the very rapidly vanishing cilia in this transition I have not been able to make out with certainty. According to Unger, they are not thrown off in *Vaucheria*, but drawn in and smoothened down. In *Aphanochæte repens* I once saw, on a gonidium passing into the state of rest, in place of the large cilia, two extremely short processes, which exhibited a jerking movement, (alternately stretching forward and retracting,) for a short time longer. The gonidia of *Characium Sieboldii* exhibit, after they have already attached themselves by their ciliated extremities, a tremulous motion lasting for almost a quarter of an hour, and evidently commencing in the delicate stalk. These phenomena certainly speak rather for a retraction than for a casting off of the cilia.

cells formed by vegetative growth into spore-sleep (see *Chlamidomonas*, p. 215), the cell is regarded as one and the same before and after this transition, in spite of the difference of the condition; but if the earlier envelope is broken open or cast off in the transition to the new state, the cell in its altered condition is regarded as a new one. The loosening of the new cell from the old cell-membrane takes place either by a contraction of the whole internal body (including the primordial utricle), as, for instance, in the formation of spores of most of the *Œdogonia;* or it seems, *vice versâ*, to be a swelling up of the contained mass by occurrence of a secretion of cellulose, which separates the primordial utricle from the cell-membrane, as in the gonidia of *Œdogonium*, *Draparnaldia*, &c. The reason of the loosening of the contents of the special mother-cell shaping themselves into a pollen-cell, from the wall of the former, is explained by Hofmeister* by the specific nature of the substance secreted all over the outer surface of the primordial utricle, which substance, not adhering to the thickening layers of the walls of the special mother-cells, forms the primary (subsequently the inner) membrane of the pollen-cell. The following cases may be cited, differing in the behaviour of the new cell to the membranes of the mother-cell:

a. The new cell slips out of the membrane of the parent-cell: as in the active gonidium of *Vaucheria*, *Œdogonium*, *Bulbochæte*, *Draparnaldia*, *Stigeoclonium*, *Chætophora*, *Coleochæte* (see p. 183); the motionless gonidium of *Chantransia* (p. 183); the spore of the Fucoideæ (p. 183).

b. The membrane of the parent-cell peels off the new cell: as in germinating cell developing from the spore of Mosses and Ferns, which throws off a mere incrusting membrane; and of the Zygnemaceæ, which breaks through a multiple spore-coat (p. 180).

* Hofmeister, 'Ueber die Entwicklung des Pollens,' ('Bot. Zeitung,' 1848, p. 431.)

c. The new cell throws off the membrane of the mother-cell by splitting of the latter into uncoiling spiral filaments: as in the spore of *Equisetum* (p. 180).

d. The new cell becomes free by the gradual solution and resorption of the membrane of the mother-cell: as in the pollen-cell of the Phanerogamia, the tetraspores of the Florideæ, and the spores, produced in fours, of the Mosses, Liverworts, and Ferns, so far as they really originate in special mother-cells. In the germs *Archidium*, which produces the largest but fewest spores of any of the Mosses, it appears from Schimper's description that the spores are formed singly in the primary mother-cells, and become free through resorption of the latter.*

B. Reconstruction with division of the cell into two daughter-cells.—Here we find repeated exactly the same variations as we have seen in the reconstruction without division; on the one side, retention of the previous character (at least in essentials), and ordinarily combined therewith intimate connection of the newly-formed cells with the remains of the mother-cell; on the other side, decided alteration of character, mostly connected with emancipation from the membranes of the mother-cell. The first case is again characteristic of the divisions connected with the development of the vegetative tissues, the latter of the transition to the formation of reproductive cells. Leaving out of view the division which occurs, the analogy with the phenomena of reconstruction of the cell without division is perfect. Thus, for example, the membranes of the daughter-cells originating by division, if these retain the character of the mother-cells, bear exactly the same relation to the membrane of the mother-cell, to which they immediately adhere in their origin, as the thickening layers of the mother-cell where no division occurs, so that if it be correct in the one case to speak

* 'Recherches sur les Mousses,' p. 77, t. 7, figs. 1—6. According to Schimper, the capsule of *Archidium* contains 18—20 spores $\frac{1}{5}$th millim. in diameter.

of the formation of *two cells* inside each mother-cell, it will be equally correct in the other to call it a formation of *one* cell inside each mother-cell. In many cases, indeed, it is altogether indifferent as regards the development of the plant, whether such division takes place or not. Compare, for example, H. von Mohl's description of some of the epidermal cells of *Viscum album*,* which is equally fitted to illustrate the inessentiality of individual cell-divisions, and the agreement of the behaviour of the membranous layers of new cells produced by division, with that of simultaneous thickening layers of undivided cells. In like manner it is often indifferent in the formation of reproductive cells, whether the contents of the mother-cell are transformed into a spore or gonidium undivided, or divided into two cells. Thus in *Coleochæte scutata*, *two* gonidia are sometimes formed in one parent-cell (by division of the contents) instead of *one;* in *Aphanochæte repens* (p. 184), on the contrary, it often appeared to me that only one gonidium existed instead of two (through omission of the dividing process); in *Stigeoclonium* there occurs, in addition to the ordinary formation of gonidia, a formation of microgonidia, in which several gonidia are produced, instead of *one*, in a mother-cell (see p. 139).

As to the great, even universal extent of the occurrence of division, and, in fact, halving of the cells, in the development of the tissues of the vegetable organism, all the most trustworthy of modern phytotomists, particularly Mohl, Nägeli, Unger, and Hofmeister, are agreed, although they differ, in some respects, in their ways of conceiving the dividing process;† even Schleiden, who,

* 'Ueber die Cuticula von *Viscum album*,' (Bot. Zeit., 1849, p. 593, t. ix, p. 59.)

† Note the following passages: "These researches have led me to the conclusion, that all vegetative cell-formation is a *parietal cell-formation*" (= cell-division). (Nägeli, 'Zeitschrift,' 1847, p. 49, Transl. in Ray Society's publications, 1849, p. 121.)—"As regards, in the first place, vegetative cell-formation, I believe I am justified by comprehensive researches in the Algæ, Fungi, Florideæ, Mosses and Charæ, in the Vascular Crypto-

starting from the observation of cell-formation in the embryo-sac of the Phanerogamia (the formation of endosperm cells), formerly regarded free cell-formation as the general law, ('Grundzüge,' 1st ed., p. 195,) subsequently, resting upon Nägeli's researches, allowed cell-formation by division a determinate although far too limited a place, ('Grundzüge, 2d ed., p. 201; 'Principles,' pp. 34, 568.) In the vegetative development of the Algæ I have met with no other mode of cell-formation, so that I must agree perfectly with Kützing, when he says, "the origin of the tissue of Algæ by division is universal." ('Phyc. Gen.,' p. 60.) But more than this, the propagative cells of very many Algæ are formed by division, of which I shall hereafter mention examples. In the Characeæ, the development of which I have been working out for several years, all the cells, not only of the vegetative tissue, but those of which the antheridium and the jointed filaments contained in it are composed, and even the spore, are formed by cell-division.

The mode in which the process of division of cells takes place has been represented in different ways. While Unger* explains the division of the cell-contents by the origin of a dissepiment (a partition), Nägeli,† comprehending more correctly the relations of dependence between the formation of membrane and the contents, states, *vice versâ*, that the formation of the septum proceeds from the contents, previously divided into two

gamia, and in the Phanerogamia, in declaring it a general law, that here two daughter-cells originate in a parent-cell, or in other words, that one cell divides into two." (Ibid., p. 66, Trans., p. 137.)—"By formation of septa, (cell-division,) therefore, the body of the plant grows; by formation of septa the mass of the organic elements, the cells, &c., increases. Since every plant is produced out of a simple cell, its growth only division and partial separation (individualization) of the original *one*, it is not to be wondered at that, notwithstanding the multiplication of the One cell, a connection of its parts, intensive as well as extensive, continues to exist." (Unger, 'Ueber Merismatische Zellbildung,' 1844.) See also Hofmeister, 'Die Enstehung des Embryo der Phanerog.,' p. 1, (note,) and p. 61.

* 'Ueber Merismatische Zellbildung,' 1844.

† 'Zeitschrift,' 1844, p. 73 et seq. (Ray Translation, 1845, p. 252); 1847, p. 51 et seq. (ibid., 1849, p. 123.)

halves; and Hofmeister,* in addition, directs attention here more particularly to the primordial utricle, bounding and cutting off the two parts from each other, even before the origin of the cellulose dissepiment.

According to this representation, the septum is formed by the two individualised portions of contents into which the mother-cell divides, and which secrete cellulose upon their whole surface after they become separately constituted, touching by their flat adjacent surfaces; whence of course the cellulose layers formed on the surfaces of contact become united, and thus form what appears a simple septum, which, however, from the nature of its origin, is composed of two plates, standing in unbroken connection with the other parts of the new cellulose lining which coats the sides of the cell turned towards the wall of the mother-cell. Referring to the *ab origine* existing contact of the daughter-cells with the whole internal surface of the wall of the mother-cell, in formation of cells by division of the whole contents, Nägeli calls the formation of cells by division "*Parietal cell-formation.*" Under the hypothesis that the contents become completely divided before the formation of the septum, he regards the latter as simultaneous through its whole extent. In contradiction to this last assertion, Mohl† describes in Confervæ, particularly in *Conferva* (*Cladophora*) *glomerata*, a cell-formation taking place by gradual constriction of the cell-contents, in which the formation of the new layers of cell-membrane begins, before the completion of the division, over the whole surface of the primordial utricle, and, since it penetrates the fold which the primordial utricle forms at the place of constriction, causes the formation of a septum penetrating gradually from the circumference to the centre. In another place,‡

* 'Die Entstehung des Embryo der Phanerogamen,' p. 1; 'Ueber der Entwicklung des Pollens,' (Bot. Zeit., 1848, p. 655.)

† 'Ueber die Vermehrung der Pflanzen-zellen durch Theilung,' (Vermischte Schriften, 1845, p. 362.)

‡ 'Einige Bemerkungen über der Bau der Vegetabilischen Zelle,' (Bot.

where Mohl describes the formation of the cells in young points of stems and roots, and in the cambium layer of Dicotyledons, he expresses a conjecture that the division of the cells he observed in the Confervæ is a totally different process from the multiplication of cells in the higher plants, since in cells dividing in this way no nucleus can be found, while in the cell-formation of the Phanerogamia these play an essential part. In the multiplication of the cells of the Phanerogamia, moreover, he never could observe a gradual constriction of the primordial utricle. In seeking to advance this difficult point nearer to its solution, I remark, first of all, that the essential part of the problem is not so much the question whether the cellulose septum is formed in gradual progression towards the centre, or simultaneously over its entire surface, but the question, whether the cell-contents are divided by gradual annular constriction (with in-folding of the primordial utricle), or through simultaneous separation in the place of the entire sectional plane, and the formation of two new coherent primordial utricles. The succeeding formation of the septum might be simultaneous in its entire extent, even in the first case, if, namely, the formation of membrane on the whole surface of the primordial utricle, did not take place until the division was complete; and, on the contrary, the formation of the septum might advance in annular increments, in the second case, if the secretion of membrane on the newly-formed plate of the primordial utricle, did not take place over the whole surface simultaneously, but at the periphery earlier than in the centre. In the first place, it is certain, notwithstanding Nägeli's objections, that the description given by Mohl of the cell-division taking place in *Cladophora*, by gradual constriction of the contents, corresponds to the truth. I have seen this process so completely and clearly in the large species of

Zeit., 1844, pp. 289, 291,) (Transl. in 'Taylor's Scientific Memoirs,' vol. iv, p. 96.—A. H.)

Spirogyra, that not the smallest doubt could remain of the actual existence of the division completed by gradual advance from the periphery to the centre.* The observation in *Spirogyra* is the more important, since a nucleus exists in this genus, which assumes an equally important part in the division to that it bears in the division of the young cells of the Phanerogamia. Consequently this takes away the principal reason brought forward by Mohl in favour of the total difference of these two modes of cell-formation, so that one might seek to explain the distinction of the ordinary process of cell-formation, characterised by the previous formation of new nuclei and the sudden appearance of a line of fissure between them, from the division by gradual constriction, by the greater or less rapidity of an essentially identical process, and to regard the first even as a gradually completed division, only running through its course so rapidly that the transitional stages are concealed from observation. On the other side, it is true, an objection to such an assumption may be found in the analogy of the process of *cell-division*, such as occurs in young tissues, with *free* cell-formation. In both the new cell-formation is introduced in the same way by the formation of the nucleus, and if, in free cell-formation, a mass of contents situated around the shortly previously formed nucleus, becomes bounded and cut off *simultaneously over the whole periphery* (so far at least as observation reaches), analogy would lead us to suppose that in cell-formation where the entire contents of the cell part into two masses, surrounding the newly-formed nuclei, each of these masses of contents will bring as much of its periphery as is not otherwise previously determined,—therefore its surface of contact with its fellow,—simultaneously to definition and completion in its whole extent. The sharpness of the distinction in the idea of ordinary cell-division, according as we try to bring it into agreement

* See the subsequent description.

with the constrictive division of the Conferva-cells, or with free cell-formation, becomes softened to some extent, if we reflect that the process which we have termed constriction is by no means a mere mechanical process of folding-in, but rather a process of definition advancing in the form of an annularly penetrating incision, that in this case also the external division is preceded by the internal, first expressed in the formation of two new nuclei, as may be demonstrated at least in *Spirogyra*. Consequently the question is, essentially, in which cases does the cell-formation complete the development of the boundaries on all sides and in all parts simultaneously, and in which does it advance gradually and according to definite laws. On this point, I am convinced, nature will be found to exhibit a far greater multiformity than has hitherto been suspected. As the cell in its subsequent development displays sometimes an all-sided growth, sometimes a one-sided, sometimes a two-sided, or a growth regularly distributed in varying intensity in a still more complicated way, there certainly exists a variety of cases of regulated progress in the very first development of the boundaries of the cell. Thus, in the lower plants, there undoubtedly exists a division advancing from one end of the cell to the other. In *Chlamidococcus pluvialis*, in which the division of the cell in the later active generations often begins even before the cessation of the movement (see p. 208), I have very frequently seen the division advance very gradually from the posterior to the anterior, still ciliated extremity. A one-sided advance of the division from the upper end of the cell to the lower (which corresponds to the ciliated extremity of swarming gonidia) may be conjectured of the Diatomaceæ with fan-shaped cells and dichotomous peduncles (*Gomphonema*), as also of the Palmellaecæ with delicate peduncles issuing from the internal cell-mass. (*Dictyosphærium*, Näg.) As regards the ordinary cell-division, apparently taking place simultaneously over the whole surface, it is a question whether or not the primordial utricle of the mother-cell (analogous to the nucleus of it) is here totally dissolved and reconstructed. For the former view, for a total solution and reformation of the primordial utricle, it seems to me that no sufficient reasons can be found, at all events in ordinary vegetative cell-formation; but if a total solution of the primordial utricle does not take place, but merely an interruption of its continuity in the periphery of the place of division, the hypothesis of a completion of the primordial utricle for each of the daughter-cells, through a formative movement issuing and advancing from the parts already formed, which is demonstrated by observation in *Cladophora* and *Spirogyra*, appears to me not improbable, even for the seeming simultaneous division. The principal distinction between these two cases depends evidently on the age of the cell at which the division takes place. There are cells which never become old, but in their earliest age, by dividing, give up their existence again, or rather continue it in a new generation, till age is finally attained in a last generation, which never undergoes division. This is the condition in the cells of the young tissues of the higher plants, which often divide again when scarcely formed, still small, and thin-walled, with comparatively large nuclei, and abundant viscid contents. To such cells, which have not yet lost the character of youth, belongs the apparently simultaneous cell-division. Hofmeister* expressly remarks that this kind of cell-formation takes place everywhere that the volume of the mother-cell does not very considerably exceed (at least about sixteen times) the circumference of the nuclei of the new daughter-cells to be formed. On the other side, there are cells (probably only in the lowest stages of the Vegetable kingdom) which may be said never to be young, since they display from their earliest origin the characters of old cells; for instance, a nucleus (perhaps sometimes altogether deficient) very small in

* 'Die Entstehung des Embr. der Phanerog.,' p. 1.

proportion to their frequently very considerable size, a large internal cavity filled with watery fluid, parietal distribution of the consistent portion of the contents, fully-developed starch-grains, &c. To such old-born cells belongs the gradually advancing multiplying division, as has been described by Mohl.

1. *Reconstruction with division into two daughter-cells, in the domain of vegetative cell-formation.*

a. Halving through evidently gradual constriction; Old-cell-division.—The primordial utricles of the daughter-cells are cut off by a process of formation advancing gradually from the periphery to the centre; the formation of the cell-membrane commences before the conclusion of this cutting off, the septum is consequently formed in the shape of an annular ridge (or properly a double-plate) gradually increasing in breadth, finally closing-in in the centre.

α. *Without a nucleus?* Here refers the cell-division of *Cladophoræ*, in which at least no nucleus has yet been found. It has been described in detail by H. von Mohl,* in *Cladophora glomerata*, as above mentioned.

β. *With a nucleus.*—My observations on this point, to be brought forward here, were made on *Spirogyra nitida* and *jugalis*, which are probably both forms of one and the same species, the former $\frac{1}{11}$ — $\frac{1}{10}$, the latter about $\frac{1}{8}$ millim. in diameter. The position and character of the nucleus of *Spirogyra* are well known; it appears particularly sharply and distinctly when spirit is applied, which however generally disturbs its originally central

* 'Vermischte Schriften,' p. 362, t. xiii. With regard to the many-layered membrane marked *b* in fig. 5, and *c* in fig. 14, I venture to remark that the same is wrongly described at page 365, as a connected tubular envelope of all the cells, as it were a colossal branched cell. Only the gelatinous, slimy investment marked *a*, (fig. 5,) and *d*, (fig. 14,) forms such an universal envelope; the many-layered membrane, on the contrary, forms a very complicated system of encasement, since its innermost layer encloses only two cells, its inmost one but three cells, and so on outward a progressively larger number of cells. In the further description, indeed, especially at pp. 368-69, the assertion made at first is partially corrected by Mohl himself.

position, and draws it to the side, through the contraction and partial tearing up of the radiating mucilaginous threads fixing it in the cavity of the cell. Before the application of iodine it has a homogeneous aspect, and the line of demarcation between its body and the surrounding mucilaginous envelope running out into radiating filaments, is difficult to see; on the application of spirit the outline becomes clear, and the interior acquires a granular-punctate aspect; the large nucleolus always existing also appears punctated in the interior. The nucleus is somewhat lenticularly compressed in relation to the longitudinal axis of the cell, its larger diameter amounting, in *Spirogyra nitida*, on an average, to about $\frac{1}{33}$d, that of the nucleolus $\frac{1}{150}$th millim. The size of both increases somewhat during the ulterior development, and most considerably just before the commencement of the division of the cell, at which time its lenticularly-abbreviated shape is also somewhat elongated. I have not been able to make out clearly whether there is a division of the nucleus here, or a solution of it followed by the formation of two new nuclei, or how the nucleoli behave in this doubling. When the cell is near to division, two new nuclei present themselves in place of the original, considerably smaller than it, and with proportionate nucleoli. The two new nuclei touch at first, but I never saw them lying flat upon one another, as if produced by division; they always had rounded surfaces. The circumstance that the two new nuclei are surrounded by a common, abundant mucilaginous envelope, not existing previously, seems to me to speak rather for a solution of the original nucleus, than for a division of it. Simultaneously with the appearance of the two new nuclei, we discover an extremely delicate line upon the surface of the cell-contents, indicating the division now beginning also at the periphery; this line is, however, so delicate at first, that when we have the margin of the cell in focus, no trace whatever of a grooving or constriction of the primordial utricle can be detected, and the spiral chlorophyll bands, three of which ordinarily exist in *Sp. nitida*, at this period retain their course wholly uninterrupted. The two nuclei now gradually separate from one another, the mass of mucilage still enveloping and connecting them becoming at the same time drawn out lengthways, and finally lost in longitudinal mucilaginous cords running between them; an accumulation of granular mucilage often remains midway between the two. Contemporaneously with the separation of the new nuclei progresses the division commencing at the periphery, and by no means as a coarse constriction or folding, but in the form of an extremely delicate incision, continually advancing deeper into the cavity of the cell, with the sharp edges of the surfaces of section reaching close up to the membrane of the mother-cell, without being rounded off or separated by an annular intercellular passage. In cases where the distance of the two nuclei equalled once or twice their shorter diameter, the separation penetrating from the periphery extended scarcely to a sixth part of the diameter of the cell; where the nuclei were removed to a distance of about four times their diameter, I found the division advanced to $\frac{2}{5}$ths, so that the part still open of the connection between the two daughter-cells, was limited to $\frac{1}{5}$th the original diameter. The process of this gradually incising partition of the daughter-cells can hardly be otherwise explained, than through a gradually progressing formation of two plates of the primordial utricle, gradually shutting off the daughter-cells, these plates starting from the line of limitation which has made its appearance in the primordial utricle of the mother-cell, and advancing towards the centre of the faces of contact of the two daughter-cells. If we cause contraction of the primordial utricle, and loosen it from the cell-membrane, by the application of acids, in these cells also, which are not yet completed, the walls of the incision retreat from each other, to that the mass of contents enclosed by the primordial utricle in such cells, appears constricted in the middle by a widely opened groove, more or less deep according to the degree of division. By this means also we may satisfy ourselves that the secretion of cellulose in the notch of the primordial utricle begins before the termination of division, consequently that the septum is originally an annular ridge, not reaching to the middle. I could already distinguish its rudiment in cases in which the notch occupied about $\frac{1}{6}$th of the diameter. Extremely thin and delicate as the septum is in its earliest rudiments, it separates completely from the walls of the retreating notch of the primordial utricle, and appears as a ridge attached at right angles on the cell-wall, without an intercellular passage, diminishing to inappreciable thickness at the bottom of the notch. That the contents of the two daughter-cells are not merely apparently (by adherence of the two portions to a septum thinner in the middle), but really directly connected, in these stages of transition, follows, not only from the already described connection of the two nuclei by the mucilaginous mass drawn out into a filament, but also from the behaviour of the spiral chlorophyll bands. As soon as the peripherical groove has attained a distinguishable depth, an interruption of the regular course of these bands takes place; they become pushed forcibly into the interior of the cell at the point of transition, becoming, at the same time, loosened from the primordial utricle for some distance from the notch. The more they are bent into the centre of the cell, the more they are attenuated at the point of transition, till at length the connection is dissolved. I could trace their uninterrupted course from one cell to the other distinctly, even in cases where the diameter of the isthmus did not amount to more than $\frac{1}{4}$th of the diameter of the cell. After the division is completed, the position of the nucleus remains excentrical for some time longer, nearest to the newly formed wall; but it soon retreats to the middle of the cell, the mucilaginous filaments radiating from it, which were at first directed in greatest number and thickness to the newly formed septum, finally run principally to the lateral walls of the cell. The imperceptible increase of length during the rapid course of this process, is a proof that the alteration of position of the nucleus is a real change of place, and not effected by a one-sided complementary growth of the cell (like that in the Desmidiaceæ). Hence we ordinarily find the nucleus again in its characteristic central position, as in the older, larger cells, even in newly-formed cells scarcely more than half the length of the mother-cells. When the cells have attained the normal dimensions, by doubling their length, the process of division is repeated, till at length fructification commences. Excepting the processes relating to the nucleus, no perceptible phenomena of solution occur as preparatory to the division of the cells; in particular, no change is detected in the green bands or the starch-grains existing in them. I have a little more to add in regard to the cell-membrane, especially the relation of its different layers to the series of generations of cells. In the larger *Spirogyræ* a double membrane may be clearly detected: an outer, which envelopes all the cells of the filament in common, which I will call the cuticle (*Ueberhaut, cuticula*); and an inner, the true cell-membrane, which, when superficially examined, seems to belong to the individual cells, but, in reality, represents a very complicated system of encasements. Between the outer and inner coat, we may sometimes distinguish by its darker colour a membranous layer, which however is neither a simple nor a special membrane, but belongs to the system of layers of the internal membrane. The cuticle is very thin in *Sp. nitida* and *jugalis*, at most $\frac{1}{900}$ millim. thick, more transparent than the proper cell-coat, from which it is distinguished also by its behaviour with acids and solution of potash, as it does not swell up. On the surface it exhibits very numerous, irregularly scattered, sharply circumscribed, circular bright points, scarcely $\frac{1}{1200}$th millim. in diameter, which in the sectional view of the cuticle appear as streaks running crossways through it. These streaks are still more distinctly seen in *Sp. lubrica*, in which the cuticle ($\frac{1}{150}$) is far thicker than the cell-membrane. When tincture of iodine is applied, the said streaks acquire a brown colour, while the mass of the cuticle remains uncoloured, which, as well as the general aspect, makes them look like little canals perforating perpendicularly through the cuticle. We have no observations on the mode of origin of this cuticle, but I should rather incline to regard it as an incrustation-membrane, than as the primary cell-membrane of the first cell of the filament. The more complicated structure of the proper cell-membrane only becomes evident after long action of solution of potass, when the membrane, about $\frac{1}{400}$th millim. thick, swells up to almost three times the thickness, and displays clearly at least the principal constituents of which it is composed. It consists, as examined from within outward, of a series of layers, the inmost of which clothes one cell only, the second two, the third four, the fourth eight cells, &c. The first and second layers, from within, are most clearly distinguishable, and one or other of them is the thickest of all, according to the age of the cells; the further outwards, the thinner and less distinguishable become the lamellæ, so that usually only four of these can be distinguished, the outermost of which, however, (of course only in old filaments composed of numerous cells,) we must regard as composed of several. These various layers are the membranes of so many different cells encased one within another. The inmost layer alone constitutes the special cell-membrane of the individual actually vegetating-cell; at the time of the full development of the cell, it is thickest of all. The second layer is the membrane of the immediately preceding mother-cell, it therefore encloses two cells, and becomes attenuated by the extension which it must necessarily undergo during the period of growth of the daughter-cells, so that it is only about half as thick as the fully-developed membrane of the daughter-cell. The third layer is the cell-membrane of the penultimate mother-cell (the grandmother-cell); it encloses four cells, and is about half as thick as the second, &c. By the increased expansion and corresponding attenuation, which the cell-membranes of the mother-cells lying further back in the series of generations undergo, it is conceivable that they must become constantly less clearly distinguishable as separate layers, and finally vanish entirely. Each such layer, or rather special cell-membrane, is itself again composed of numerous extremely delicate lamellæ, formed successively during the life-time of the individual cell, which, however, can only be detected in the inner thicker layers, and there very indistinctly. The character of the septa is most intimately connected with this system of encasing of the cell-membranes. Between two sister-cells the septum is composed of the mere continuation of the innermost cell-membrane (that belonging to the individual cell), clearly passing over into this, and increasing in thickness in equal proportion during the growth of the cell. The structure, as composed of two lamellæ, may be detected even in the very thin septa of young sister-cells, in the swollen-up condition. No intercellular passage exists at first in the periphery of the septum, but it is gradually formed during the increase of thickness of the septum, and is situated between the membrane of the mother-cell and the two daughter-cell membranes forming the septum. The septum between two pairs of daughter-cells (between the first-cousin-cells), is formed of the membranes of the daughter-cells and those of the mother-cells, thus of four laminæ; the intercellular passage existing at its periphery is situated between membrane of the grandmother-cell and membrane of the two adjacent mother-cells. The septum between two double pairs of of first-cousin-cells (between second-cousin-cells), is formed of the membranes of the daughter-cells, mother-cells, and grandmother-cells, thus of six layers; the intercellular passage lies between the adjacent grandmother-cell membranes and the membrane of the great-grandmother-cells, which, however, (together with all the membranes lying outside it,) is so thin, that it appears as if in contact with the cuticle. All this may be very exactly traced out in the larger species of *Spirogyra;* and I add, in conclusion, that all the subdivisions of the cell-membrane (exclusive of the cuticle) swell up most strongly in the vicinity of the intercellular passages.

A similar gradual progression of the cell-division will doubtless be found in other Confervæ not yet accurately examined in this respect. Observation of the process of division in *Œdogonium* and *Ulothrix,* which genera have a lateral nucleus, would be very interesting. The relationship which exists between the Desmidiaceæ and the Zygnemaceæ, as also the occurrence of a central nucleus observed in many of the genera of that family, leads to the conjecture that their division corresponds to the process in *Spirogyra.* In the Diatomaceæ the presence of a nucleus is still doubtful; the age at which the division takes place, however, leads us to expect a gradual progress of the division. Most genera of the two families last named, present us, at the same time, with examples of complete separation of the two cells formed by division, the membrane of the parent-cell either gradually vanishing or being peeled off. (See pp. 180, 181.)

b. Halving with (apparently?) simultaneous definition of the entire surface of division. Young-cell-division.—This is the ordinary mode of formation of the cells in young developing organs of the Phanerogamia,* Vascular Cryptogamia, Mosses,† Characeæ, Florideæ,‡ and Fucoideæ.§ The formation of the special mother-cells of the pollen of the Phanerogamia,‖ and of the spores of the Cryptogamia, when this takes place through repeated halving, also belongs here; in like manner the formation

* See, for instance, the course of development of the ovule of *Orchis,* in Hofmeister, 'Die Enstehung des Embryo der Phanerogamia,' pp. 1—3, t. i.

† Nägeli, 'Zeitschrift,' 1845, p. 138, t. ii, iii.

‡ Ibid., 1845, p. 119, t. i, ('Growth of *Delesseria Hypoglossum*') and 1847, p. 207, t. vi, vii (*Polysiphonia.*)

§ Ibid., 1844, p. 73 et seq.

‖ Nägeli, 'Entwicklungsgeschichte des Pollens,' 1842; Hofmeister, 'Ueber die Entwicklung des Pollens,' ('Bot. Zeitung,' 1848, pp. 425, 649.)

of the cells of the embryo of the Phanerogamia, and in many cases even the formation of the endosperm-cells.* Numerous researches on this kind of cell-formation agree essentially in the following points: the nucleus of the mother-cell is more or less completely dissolved; in its place are produced two new nuclei, either near together, or at a distance. Between these suddenly appears a line of division (really a plane of division) which indicates a parting of the cell-contents into two portions, each of which encloses one of the nuclei. The two portions of contents are originally bounded only by their primordial utricles, which immediately secrete a new cell-membrane over the whole of their surface, and thus form a septum between them at the surface of contact. Many observations testify that the two daughter-cells are completely separated, by the shutting off of their primordial utricles, before the origin of the septum. Thus Mohl† frequently observed two primordial utricles in *one* cell, in cambium, as well as in the tips of stems and young leaves of various plants; Hofmeister‡ represents such a case in the embryo of *Leucojum æstivum*, and also, in the description of the formation of the special mother-cells of the pollen of *Passiflora*, and *Pinus*,§ endeavours to show the formation of the septum to be subsequent to the division of the primordial utricle. With regard to the behaviour of the nucleus, it must be remarked, that according to the observations of Mohl and Nägeli, the formation of the two new nuclei takes place in many cases through division of the nucleus of the mother-cell‖ (without solution of this). It seems to

* Hofmeister, 'Die Enstehung des Embryo der Phanerogamen,' 1849, e. g., p. 35, t. xii. (*Monotropa*); p. 40, t. iii. (*Bartonia*.)

† 'Bot. Zeitung.,' 1844, p. 290, (Trans. in 'Sc. Memoirs,' vol. iv, p. 96.—A. H.)

‡ 'Die Enstehung des Embryo,' t. vi, f. 20.

§ 'Ueber Pollen,' 'Bot. Zeitung.,' 1848, pp. 654, 671.

‖ Vide Nägeli, 'Zeitschrift,' 1844, p. 75. (Trans. in Ray Society's publications, 1845, p. 254,) where is described, of *Sphacelaria*, a division of the central nucleus of the mother-cell preceding the division of the cell, while in *Zonaria Pavonia*, and *Cystoseira*, the parent nucleus is said to me very doubtful whether two different conditions of this case really occur, since a rapid reconstruction of the nuclei of the daughter-cells out of the still accumulated mass of the nucleus of the mother-cell, in a state of solution at its periphery, may readily be looked upon as a division of the latter.

How far either the partition of the primordial utricle, or the formation of the dissepiment between them, is really, or only apparently, simultaneous over the whole face, can scarcely be decided in the present stage of observation. Very few observations speak in favour of the latter assumption. In one case, certainly referring here, namely, to the "young-cell-division," in the formation of the stomate-cells (see the preceding note), Mohl asserts that he observed the formation of a septum beginning with the production of an annular ridge. I should consider as an indication that the division of the primordial utricle also begins at the periphery, the formation of the at first simple zone of granules, subsequently doubled by a clear line of division, at the equator of mother-cells of the pollen of *Pinus** preparing for division, and already provided with two nuclei,—a phenomenon which seems to indicate a conflict of the two newly-formed centres, expressing itself first of all at the periphery of the plane of division, when they are defining their boundaries. I shall hereafter mention a structure

vanish, and be replaced by two new ones. Nägeli further describes the division of the nucleus in the cells of the hairs of the stamens of *Tradescantia* (l. c., p. 67; Ibid., 1847, p. 102—Translation in Ray, vols., 1845, p. 246, 1849, p. 168,) while according to Hofmeister, ('Enst. des Embryo,' p. 8, t. xiv, figs. 20, 28) the membrane of the parent nucleus is absorbed, so that only the mucilaginous and no longer sharply defined body of its contents, is divided into two globular balls, which become the new nuclei. According to Mohl, ('Vermischte Schriften,' p. 252,) the nucleus of the mother-cell becomes divided, in the formation of stomates, to form the nuclei for the two boundary cells of the stomatal opening. According to Nägeli, ('Linnæa, 1842, p. 237,) on the other hand, the formation of the two new nuclei is preceded by a disappearance of the nucleus of the mother-cell.

* Hofmeister, 'Bot. Zeit.,' 1848, p. 671, t. vi, f. 22, 24. In *Passiflora*, on the contrary, the zone of granules is replaced by a granular plate occupying the whole surface of division. See t. vi, f. 8, 9.

analogous to this zone of granules in the description of the formation of the gonidia of *Hydrodictyon.*

2. *Reconstruction, with division into two daughter-cells, in the domain of fructification.*

a. The newly-formed cells are neither connected together, nor with the membrane of the mother-cell. The cells produced by division either divide anew (as a transitory generation), without having acquired a cell-membrane, or, if no fresh division occurs, they are set free, naked and furnished with cilia, by tearing of the mother-cell. Here belong the gonidia of many Algæ, of which mention has been already frequently made. Either two gonidia are formed in one mother-cell (by simple division of the contents), as in *Ulothrix Braunii* (see pp. 177, 183), *Aphanochæte repens* (p. 184); or four, eight, sixteen, or thirty-two gonidia, according as the division is repeated once or more times, as in *Ulva, Enteromorpha, Ulothrix zonata* (p. 184), *Characium* (p. 185), *Chlamidococcus* (pp. 184, 206, &c.), &c.

b. The newly-formed cells, free (active) at their birth, become united into a regularly arranged colony after birth. This occurs in *Pediastrum* (p. 184).

c. The newly-formed cells become combined into families before birth, either united by formation of firm membranes, as in *Scenedesmus* (Nägeli, 'Einz. Algen,' t. v. A), or held together by a development of gelatinous matter, as is the case in the Volvocineæ.

B*. RECONSTRUCTION, WITH DIVISION, INTO TWO CELLS, ONE OF WHICH REMAINS AS THE MOTHER-CELL, THE OTHER BEING SHUT OFF (ABGEGLIEDERT) AS A DAUGHTER-CELL.—In the cases comprehended under B, the two cells formed by the division of the mother-cell are either alike in every particular, or, if they differ, take an equal share in the process of Rejuvenescence through which they are formed, appear both equally active agents in the reconstruction, and therefore are regarded as equal daughter-cells of one mother-cell (destroyed by the division). But there are other cases in which the rejuvenising activity appears solely, or at least principally, in a definite part of the mother-cell, which becomes finally cut off, as a newly-formed daughter-cell, by division of the contents and formation of membrane, from the other relatively inactive portion, retaining unchanged the properties of the mother-cell.

The distinction of a shutting off of this kind from ordinary division, is especially evident whenever the behaviour of the nucleus can be observed, as is the case in certain examples described by Hofmeister, which I shall mention hereafter. In such cases, namely, instead of the formation of two new nuclei, a single new nucleus presents itself in some portion of the mother-cell (often a prolongation or bag-like protrusion), upon which the part of the mother-cell containing the nucleus separates as a distinct cell. The original nucleus remains during this process in unaltered existence, or, if it has vanished before the formation of the daughter-cell, no new nucleus is formed in the part remaining as mother-cell during the cutting-off of the new cell. Nägeli* and Hofmeister† have applied to this modification of cell-division the term "tying-off" (Abschnürung), a name, however, only properly applicable to those cases where the daughter-cell becomes externally detached from the mother-cell. Multiplication of cells by the formation of shut-off *branch sprouts* likewise belongs here.

1. *The shutting-off* (*Abgliederung*) *of a daughter-cell, in the domain of vegetative cell-formation.*

a. The apex of the cell is shut-off as separate cell.

α. *Without nucleus?* Here refers the formation of the mother-cell of the active gonidium, as also of the motionless spore of *Vaucheria*, under the hypothesis, that in both these cells a proper membrane is formed (sharing the formation of the septum), before their

* 'Zeitschrift,' 1847, p. 60, (Ray Transl., 1849, p. 131,) 'Einzell. Algen,' p. 18.

† 'Enst. des Embryo der Phanerog.,' p. 61.

contents are metamorphosed into a fructification-cell; therefore that they have a vegetative existence, short though it be, previously to the fructification. In the later behaviour, the difference presents itself, that the gonidium leaves its mother-cell by slipping out, while the spore appears to tear away the membrane of the mother-cell with it. The formation of the fruit-club of *Saprolegnia* also belongs here. The process of shutting off the apex may be repeated many times, in a retrogressive order, in the same cell, as occurs not unfrequently in *Saprolegnia*, where a second, and often a third piece of the cell is developed, underneath the first fruit-club, into a gonidium-case or spore-case (both are met with). Or the shutting off is repeated in an apex reproduced by a growing through of the emptied fruit-sac, as likewise occurs in *Saprolegnia* (particularly *S. ferax*, *S. prolifera*) and in *Vaucheria clavata*.*

β. *With a nucleus.* A remarkable example of this is furnished by the origin of the sacculate appendage of the embryo-sac of *Bartonia*, described by Hofmeister.†

The upper end of the embryo-sac (the mother-cell of the germinal vesicles and endosperm-cells), after three free germinal vesicles have been formed in it, produces a prolongation penetrating into the canal of the micropyle, which, after the previous formation of a nucleus, becomes shut off from the embryo-sac as a separate cell. In general the primary nucleus of the embryo-sac is not dissolved during this process. The first division of the germ-cell (the germinal vesicle) of the same plant‡ affords another example. The originally roundish, nucleated germinal vesicle becomes elongated in the form of a tubular cell, the nucleus at the same time vanishing. In the front part of the cell, turned away from the micropyle, a somewhat flattened nucleus is now formed, and in consequence of this a separation of this anterior extremity as a dis-

* Vide Unger, l. c., fig. 13.
† 'Enstehung des Embr. der Phanerog.,' p. 39, t. ii, f. 34—40.
‡ Hofmeister, l. c., p. 40, t. iii, f. 4—11.

tinct cell, while no new nucleus is formed in the longer, posterior part of the cell. According to Hofmeister,* the second cell of the proembryo (the cellular filament first developed from the germinal vesicle, the suspensor) is formed in a manner essentially the same, in *Monotropa*,† *Gagea*,‡ *Fritillaria*, *Martynia*, and *Linum*.

b. A lateral growth from the cell (*a cell-branch*) *becomes shut-off as a separate cell.* This process also may be repeated in the same mother-cell when several branches arise from it one after another, as occurs in *Cladophora glomerata.* The branches arise sometimes from the upper margin, sometimes from the lower, and sometimes from the middle of the cell; sometimes from the upper and lower border at the same time, as mentioned already of *Chætophora* and *Coleochæte pulvinata* (p. 150). According as the ramification commences in the earliest youth of the cell, or at a later epoch, in somewhat advanced development of the cells, the shutting-off of the branch may exhibit distinctions of mode and kind, analogous to those we have characterised as young cell-division and old cell-division.

α. *Without a nucleus?* Ramification of *Cladophora*, *Chantransia*, *Chroolepus*, *Draparnaldia*, *Chætophora*, &c. In many of these genera the nuclei have certainly been merely overlooked.

β. *With a nucleus.* Here belong the Fucoideæ and Florideæ, in the ramification of which, according to Nägeli's conjecture,§ the original nucleus remains in the cavity of the mother-cell, while a new nucleus is formed in the protrusion becoming the branch-cell.

With these "baggings-out" of the cells, giving origin to the branches of the lower plants, may be compared, to a certain extent, the *thylls*, those remarkable cell-like structures which fill up the wide vessels of wood in old

* Hofmeister, l. c., p. 6.
† Ibid., p. 36, t. xii, f. 9—14.
‡ Ibid., p. 22, t. ix, f. 9—14.
§ 'Zeitschr.,' 1847, pp. 71, 72, (Modes of Cell-formation, 8 A and B.) (Ray Transl., 1849, pp. 141, 142.)

age, and, according to the researches of an anonymous* author, sprout forth as little utricular protrusions from the cells of the surrounding tissue, and penetrate through the thin-walled canals of the dots into the vessels. In these thylls, which appear quite as true, partial, and local Rejuvenescences of the cells, nuclei are formed at a time when those of the mother-cell have long since vanished, never becoming renovated.

2. *Shutting-off of a daughter-cell in the domain of fructification.* The shut-off and detached daughter-cell becomes a spore, while the mother-cell remains vegetative. This case doubtless occurs in the spore-formation of many Fungi, particularly the true Hymenomycetes,† many Gasteromycetes,‡ and most Hyphomycetes.§

The multiplication of the cells in the Algal genus *Exococcus* (Nägeli, 'Algensyst,' 169) and the *fermentation* Fungi,|| also takes place by the shutting off, and frequently complete tying-off (Abschnürung) of either terminal or laterally budding daughter-cells. But as all the cells are of like character here, these cases would be more properly referred to the domain of vegetative cell-formation.

C. Reconstruction, with division into four daughter-cells.—From the pregnant discoveries of Ad. Brongniart¶ and H. v. Mohl,** on the formation of the

* 'Untersuch. üb. die Zellenartig. Ausfullung. der Gefässe,' ('Bot. Zeit.,' 1845, pp. 225, 241, t. ii.)

† See Phœbus, 'Ub. der Keimkornerapparat. der Agariceen,' &c., 'Nov. Act. Nat. Cur.,' xix, 11, (1842,) p. 171, t. 56, 57. Corda, 'Ic. Fung.,' iii, t. 7—9; iv, t. 10, figs. 134—139; v, t. 10.

‡ See Tulasne, 'De la Fructification des *Scleroderma* comparée à celle des *Lycoperdon* et *Bovista*,' 'Ann. des Sc. nat.,' 17, (1842,) p. 5, t. 1, 2, 'Sur les Genres *Polysaccum et Geaster*,' ibid. 18, (1842,) p. 129, t. 6.

§ See Schleiden, 'Grundz.,' ii, pp. 38, 39, figs. 106, 107, ('Principles,' pp. 153, 154, figs. 122, 123; Corda, 'Ic. Fung.,' ii. t. 10, fig. 68, (*Verticillium;*) iii, t. 1, fig. 23, (*Botrytis*); iv, t. 10, fig. 132 (*Isaria*).

|| See *Saccharomyces Cerevisiæ*, in Meyen, 'Pflanzen-physiol.,' iii, p. 455, t. x, f. 22.

¶ 'Sur la Génération et le Développement de l'Embryon,' 'Ann. des Sc. nat.,' 1827.

** 'Ueb. der Bau und die Form der Pollenkörner,' (1834); 'Ub. die Entwicklung und den Bau der Sporen der Kryptogamische Gewächse,' ('Flora,' 1833,) 'Vermischte Schriften,' p. 67.

pollen-grains of the Phanerogamia and the spores of the Cryptogamia, the formation of four daughter-cells in each mother-cell appeared to be a case of very frequent occurrence, widely diffused in the condition of transition to fructification. From more recent researches, however, on the processes which precede the formation of both the pollen-grains and the groups of four spores,* in the mother-cell, the nature of the formation is not so simple as it at first appeared. The pollen-grains and spores are not formed immediately in fours in the mother-cell, but singly in special mother-cells, so that the origin of the number four is to be examined in the latter. According to Nägeli's researches, this takes place in two ways.† The mother-cell either divides at first into two daughter-cells (primary special mother-cells), which then each divide again into two (secondary special mother-cells); or the mother-cell divides immediately into four daughter-cells, in which case, consequently, only one generation of special mother-cells (merely primary) is formed. Only the second case belongs to the present section of our subject. From researches hitherto made, it seems to follow that in the first mode of origin the group of four (secondary) special mother-cells are usually placed in *one* plane; in the latter the four (primary) special mother-cells in two planes, or in the order of the angles of a tetrahedron. If this relation of the arrangement to the mode of origin were constant, it would be an easy means of ascertaining the direct or indirect formation of the group of four special mother-cells, at a later epoch, from the arrangement, nay even in many cases from the form (in a great measure dependant on the original position) of the spores or pollen-grains.‡ But this relation is not constant. Ac-

* Here belong the formation of the species of the Ferns, Mosses, and Hepaticæ; both kinds of spore-formation in the Lycopodiaceæ, Isoëtaceæ, and Rhizocarpeæ; and one kind of spore-formation in the Florideæ.

† 'Zur Entwick. des Pollens der Phanerog.,' 1842.

‡ Quadratic (situated in one plane) position and elongated form of the pollen-grains occurs principally in the Monocotyledons; tetrahedral position and roundish form almost universally in the Dicotyledons, (Mohl, l. c., p. 34.) Both cases are likewise repeated in the spores of Ferns, the former (longish

cording to Nägeli's* observations (on the formation of the pollen of *Lilium*), the tetrahedral arrangement of the four special mother-cells occurs also when they are formed in the second generation, when the two primary special mother-cells first produced are divided, not in the same, but in a different direction, producing a decussating arrangement of the two pairs.† On the other hand, it follows from Hofmeister's description of the formation of the pollen in *Pinus*,‡ that four special mother-cells lying in *one* plane may be produced by simultaneous formation. But what seems to us of still more importance here, is the observation, that not merely the various modes of arrangement, but even the cases, which we should suppose very essentially different in their mode of formation, of primary and secondary, direct and indirect formation of special mother-cells, are not exclusive of each other in their natural occurrence, since they sometimes occur in substitutive alternation in one and the same plant. Nägeli has named *Althæa rosea* as a plant in which the special mother-cells are formed in one generation (four at a time), and also sometimes in two successive gene-

shape, with a longitudinal keel,) *e. g.*, in *Polypodium vulgare*, *Ceterach officinarum*, *Asplenium Ruta muraria*, *Aspidium Filix femina*, &c.; the latter (producing the form of a triangular pyramid rounded at the base,) in *Pteris longifolia*, *serrulata*, *Allosorus crispus*, *Notochlæna marantæ*, *Osmunda regalis*, &c. (H. von Mohl,' 'Verm. Schrift.,' 69, 70.) In the Mosses and Hepaticæ the tetrahedral arrangement seems to be predominant, likewise in the Lycopodiaceæ and Rhizocarpeæ, in the latter of which this is indicated by three short lines united in the form of a tripod, both on the small and imperfectly developed large spores, (Mettenius, 'Beiträge zur Kenntniss der Rhizocarpeen,' t. i, of Salvinia.) In the Florideæ there occurs a third mode of arrangement, in addition to the quadratic and tetrahedral, namely, the linear, (Kütz., 'Phyc. gen.,' p. 100,) "spermatidia quadrijuga." See, for instance, t. 60, iv, *Hypnophycus musciformis*, and t. 62, iii, *Calliblepharis ciliata*.

* Nägeli, 'Entwick. des Pollens,' p. 18, t. ii, f. 19, 20, 21.

† The shape of the four secondary special mother-cells, (and consequently of the pollen-grains or spores,) is in this case, however, different from that in the tetrahedral arrangement through direct formation; in the former case the four portions, (as in the quadratic arrangement,) have the form of quarters of a sphere, in the latter the form of a three-sided pyramid with a rounded base. If the two modes of arrangement require to be distinguished, the former may be called the *decussate*, the latter the *pyramidal* or *tetrahedral* in a restricted sense. (See also Nägeli, 'Neueren Algensysteme,' p. 190.)

‡ 'Bot. Zeitung.,' 1848, 671.

rations (two and two). Hofmeister mentions the opposite case as occurring in *Tradescantia*, in which the special parent-cells are usually formed two and two (in one plane or decussating), sometimes, however, all four simultaneously (in tetrahedral position).* This remarkable circumstance indicates an intimate connection of the two cases, to which we are still more definitely attracted by certain observations on the behaviour of the nucleus before the direct quartering. In the first place, we must here recall the remarkable course of development of the spores of *Anthoceros*, described by H. von Mohl,† and also by Nägeli.‡ At the sides of the central nucleus of the mother-cell, here, as an exception, not vanishing, two new nuclei are formed (called by Mohl, from their granular contents, "granule-cells"), which after some time divide, thus producing four nuclei, which, gradually retreating from each other, assume a tetrahedral arrangement. Around these four nuclei the special mother-cells are simultaneously formed, by division of the entire contents of the general mother-cell. Still more expressive are the observations made by Hofmeister on the formation of the pollen of *Pinus*.§ The large nucleus becomes dissolved; two secondary nuclei are formed; between these two the granules of the cell-sap accumulate as an annular zone at the equator of the cell; the zone of granules soon splits into two parallel zones, indicating the separation of the primordial utricle into two halves. Up to this point all the mother-cells behave alike, but the subsequent development takes place in two different ways. Either the indicated division into two primary special mother-cells is carried out, and two secondary special mother-cells are formed again in each of them; or the commencing halving of the primordial utricle is inter-

* 'Bot. Zeit.,' 1848, p. 430, t. iv, f. 22—25.

† 'Ueber die Entwick. der Sporen von *Anthoceros lævis*,' (Linnæa, 1839;) 'Verm. Schrift.,' p. 84, t. iv.

‡ 'Zeitschrift,' 1844, pp. 49—54, t. i, f. 31—40. (Ray Transl., 1845, pp. 229—233, t. vi, fig. 31—40.)

§ 'Bot. Zeit.,' 1848, p. 671.

rupted, the two secondary nuclei vanish, and in place of each one of them appear two tertiary, making four nuclei in a cell, which either lie in one plane, or are arranged like the angles of a tetrahedron, and the formation of the four special mother-cells now takes place directly around these. Supported by these observations, we might certainly conjecture, that all those processes of cell-formation which, according to the external definition of the cells, appear as direct quarterings, are essentially the same as the double halving, only distinguished from the latter by skipping over one step of the course of the formative process, advancing, namely, from the first halving, already indicated by the formation of two secondary nuclei in the interior of the cell, without completing this, to the succeeding halving.

In the multiplication of the Unicellular Algæ, especially in the family of the Palmellaceæ and those nearest allied to them, we meet with undoubted cases of true quartering (in the sense just explained), together with apparent quartering. The latter results from the first halving, which produces merely a transitory generation of cells, being followed immediately by a second.* Here also the arrangement of the cells in one plane not unfrequently alternates with the decussate, as I have observed, for example, in *Chlamidococcus pluvialis*. Nägeli gives genuine (and tetrahedral) quartering as the character of the genus *Tetrachococcus*, the independence of which he, however, doubts himself, placing it as a sub-genus under *Pleurocococcus*, and leaving it undecided whether the form of Alga thus characterised does not belong to *Pl. vulgaris*.† I have observed intermingled, in *Protococcus viridis*, mere halving, apparent (decussating) and true (tetrahedral) quartering; the latter two distinguishable by the form of the cells, from which alone I could draw inferences as to the mode of formation in this case.

* I have already directed attention to the circumstance, above, (p. 160, note.)

† Nägeli, 'Zeitschrift,' 1847, p. 70, (Ray Transl., 1849, p. 140,) 'Neuer. Algensyst.,' p. 127.

D. Reconstruction with division of the contents of the mother-cell into an indefinite number of daughter-cells.—The cases to be mentioned here all belong to the fructification of the Algæ, Lichens, and Fungi; they have hitherto been included, especially by Nägeli, not under cases of cell-formation by division, but of free cell-formation, from which, however, they are essentially distinct. While, in free cell-formation, the mother-cell, notwithstanding the formation of daughter-cells taking place in it, preserves its own vitality, that is, continues to exist as a living cell, consequently possesses, in addition to the daughter-cells, vitally active contents bounded by the persistent primordial utricle, and often still furnished with a well-preserved nucleus;—in the cases to be examined here, as in all formation of daughter-cells by division, the mother-cell dies at the very first formation of daughter-cells: which is especially indicated by the constant dissolution of the primordial utricle of the mother-cell. The entire contents of the mother-cell, at most with the exception of a watery fluid containing but few organic constituents, become applied to the formation of the daughter-cells, and not by actually existing daughter-cells gradually consuming it, but in such a way that the whole contents (so far as available for reconstruction) are divided among the daughter-cells at the earliest definition of the boundaries of the latter. Hence the cells do not originate with free bounding surfaces, but in original contact both with each other and with the wall of the mother-cell; but they may separate subsequently, or, if the watery contents of the mother-cell are excluded from the new structure, even at the first completion of their formation.

1. *The daughter-cells are formed by the division of contents filling the entire cavity of the mother-cell.*—This case presupposes that the whole contents are mucilaginous, and capable of sharing in the process of reconstruction.

a. The daughter-cells lie in one row in the mother-

cell.—The cylindrical cell of *Sciadium* (see p. 187) possesses uniformly distributed green contents, which are interrupted in perfectly developed cells by light cross streaks, and are divided into a row of 5—8 about equal masses, which become gonidia. I could not detect nuclei in the individual segments of the contents passing into the formation of gonidia. Probably the conditions are similar in *Ophiocytium* (Näg. 'Einz. Alg. iv, A). It seems to me probable that the formation of spores in the cylindrical or fusiform mother-cells (*asci*) of the Lichens, Pyrenomycetes, and Discomycetes, belongs to this kind of cell-formation. The greater concentration of the contents which accompanies the formation of resting spores, causes the exclusion of the watery portion of the contents of the mother-cell, and hence a detached position of the spores presenting itself in the earliest period of their isolation. The development of the spores of *Peziza Acetabulum*, as described by Corda,* leaves scarcely a doubt in this respect. In the equably diffused, opake, and granular fluid contents of the mother-tube is formed a row of globular structures, standing at regular distances, called by Corda drops of oil, which, from their relation to the subsequent formation of the spores, appear to be nuclei. Around these nuclei a lighter atmosphere is formed, the darker granular mass accumulating in the form of zones between them: which reminds us of the analogous phenomena in *Hydrodictyon*, and in the formation of the pollen of *Pinus* and *Passiflora*. Soon after this, the individual globular nuclei appear surrounded by masses of contents and membranes, consequently as the central structures of so many longish spores, which are separated by a light, watery fluid, containing but very few granules.

b. The daughter-cells fill up the mother-cell irregularly.—I think we may reckon here the formation of the gonidia of *Chlorococcus* (according to Nägeli),† also of

* 'Icones Fungorum,' iii, p. 38, t. vi, figs. 95, 96.

† 'Zeitschrift,' 1847, p. 23, (Ray Transl., 1849, p. 96,) 'Einz. Alg.,' p. 17.

Chytridium (p. 185), in which genus the nuclei scattered through the whole contents of the mother-cell, are clearly distinguishable before the formation of the boundaries of the gonidia. Perhaps the formation of the spores of many Fungi, in particular the genus *Erysiphe*,* belongs here.

2. *The daughter-cells are formed by the division of a mucilaginous layer coating the inside of the wall of the mother-cell.*—Since this by no means very rare mode of cell-formation—to which the term " parietal cell-formation would seem apt, were it not already used in another sense—has never yet been acurately described, I shall give a somewhat detailed account of it, as I observed step by step in the formation of the gonidia of *Hydrodictyon.* I have already spoken of the strange mode of reproduction of the Water-net (pp. 137, 222); and the characters of the cell-contents (pp. 171, 197) and the cell-membrane (p. 190), before the commencement of reproduction, have also been explained; so that, taking up the subject at that point, I may commence immediately with the description of the phenomena through which the beginning of the formation of gonidia is announced. The *first stage,* introducing the formation of the gonidia, comprises the period of solution and disappearance of the starch-grains. The mucilaginous layer (*i. e.* the more consistent, formative contents resting against the cell-membrane, the subordinate divisions of which have been described above, and which retain their parietal position up to the completion of the formation of the gonidia) changes its aspect in a remarkable manner at this period. The fresh transparent green becomes more opake, and the entire mucilaginous layer acquires, even before the solution of the starch-granules is completed, a peculiar, regular appearance, closely beset with lighter spots, which appearance, however, is only distinctly perceptible when the focus is adjusted to the bottom of the

* See Corda, 'Icon. Fung.,' ii, t. xiii, f. 100.

mucilaginous layer. These spots are not the starch-grains undergoing solution, as might be conjectured, for their number is much larger than that of the latter, the not quite lost nuclei of which may still be remarked here and there, and not in, but between the spots. The little green granules of the contents, which, for the sake of brevity, I shall call chlorophyll-granules,* do not disappear with the starch-grains, but separate from each other at the period of the formation of the spots, and become accumulated as darker boundary lines between the brighter spots. By adjusting the focus up and down we may ascertain that scattered chlorophyll-granules occur also above and beneath the light spots, while the spots themselves are roundish spaces, free from granules, existing in the thickness of the mucilaginous layer. Simultaneously with these processes the green colour of the mucilaginous layer passes more into a brownish, a change of colour which shows itself still more clearly in the next stage, especially in those cells in which microgonidia (swarmers) are to be formed. Still more striking alterations present themselves in the *second stage* of the formation of gonidia, in which the mucilaginous layer exhibits a picture diametrically opposed to that just described. The granules retreating towards the bright spaces, the earlier dark net-work of the granules is replaced by a net-work of lighter boundary lines; the former bright spots, on the contrary, become darker areolæ through the collection of granules into groups. When the new distribution of the contents is complete, the light intermediate streaks appear as everywhere pretty equally broad, light-yellowish (not green) lines, sharply defined upon the dark field; the latter displays little polygonal (mostly hexagonal, rarely pentagonal or heptagonal) green plates, with

* These granules are not chlorophyll-vesicles, as in *Vaucheria*, *Chara*, &c., they have more the aspect of dense, mostly longish granules, without any enveloping membrane. When the chlorophyll is extracted by spirits of wine, these, like the remainder of the contents, become bleached, but remain distinguishable; the shape, however, becomes irregular through the action of the spirit.

a more or less brownish tinge, sometimes appearing wholly filled with granules, sometimes displaying a lighter space, free from granules, in their centres. In correspondence with the shape and the (in the same mother-cell) tolerably equal size of the plates, they are so arranged that mostly six are grouped round a central one. The size of the plates varies according as they are to form macrogonidia (net-formers) or microgonidia (swarmers); in the former case the diameter amounts to about $\frac{1}{100}$th millim., in the latter to $\frac{1}{200}$th or $\frac{1}{150}$th; the latter, moreover, exhibit a less regular, more oblique shape, and less numerous (only 4—10) chlorophyll granules. The membrane of the parent-cell begins to thicken by swelling-up in this stage. In the *third stage*, finally, is effected the complete separation of the little plates, and the formation of the gonidia. The plates, already previously clearly defined against the light intermediate streaks, begin to round off at the corners, and to become convex at the surface, previously lying flat against the cell-membrane, so that the tabular form passes, not at once into a globular, but into a lenticular form, which compression may still be observed in a slight degree subsequently, in the stage of motion. During this rounding, the lighter intermediate streaks vanish, the gonidia come into direct contact, triangular intercellular spaces only appearing at each point where three meet. This stage is ordinarily of very short duration, passing at once into the *fourth*, that of the movement of the gonidia, which differs in degree and duration, according to the kind and destination of these. Although the phenomena of the motion of the gonidia of *Hydrodictyon* have been spoken of already, we cannot pass them over entirely here, since certain points come under consideration in it, which have an influence on our judgment respecting the mode of cell-formation which we are now engaged with. Both in the macrogonidia and microgonidia the movement at first presents a mutual, originally scarcely perceptible crowding and pushing, which, when in full course, is comparable with the movement of a dense crowd of people in which no one can leave his place. The signal for freer and more active motion is given by the processes taking place about this time in the membrane of the mother-cell. The cell-membrane has begun to thicken even in the second stage of the formation of the gonidia, and the swelling-up made still further progress in the third, but the resistance of the cuticle hinders the extension of the circumference of the cell-membrane. This obstacle is now removed by the cuticle cracking, first in one, and soon in several places, which gives the cell-membrane, now becoming soft and limp through the swelling-up, room to expand. This is the epoch in which the movement of the gonidia changes, either simultaneously throughout the cell, or more frequently gradually spreading from the spot where the first dehiscence of the cuticle occurred, into a lively trembling and jerking, which Treviranus not inaptly compares with the ebullition of boiling water. But even in this very rapid motion the actual locomotion of the gonidia is extremely slight, so that, for example, free spaces, such as occur in cells where vacuities existed in the mucilaginous layer, are not filled up by gonidia. In the macrogonidia, destined to form nets, the motion stops here; in the microgonidia, on the contrary, a whirling is added to the trembling motion. While, namely, up to this time, the whole mass of microgonidia had retained their peripherical position, representing as a whole the form of a sac, corresponding to the form of the mucilaginous layer, even in their movement, this strange bond is now dissolved, the gonidia leave the periphery, and whirl about in varied intermixture through the whole cavity of the cell, till at length, through the bursting of one or more bulging protrusions of the cell-membrane, they leave the cell in a dense swarm, and continue the swarming motion for a long time in freedom. Both the macrogonidia and microgonidia exhibit various peculiarities, during the period of motion, which were not perceptible before its commencement. The macrogonidia retain their roundish or rounded polygonal form, but exhibit at one side a hyaline margin, which occupies about a third part, or even half of the circumference; the microgonidia, on the other hand, become distinctly longish, the more acuminated end, at the same time, appearing transparent. The green granules enclosed in the interior are still distinguishable in both, but less sharply, since they begin to blend together; the colour is again bright green, in the net-formers darker, in the swarmers more of a yellowish-green. The *fifth stage*, that of rest, is connected in the macrogonidia with their union into a young net, which union begins even in the last period of the movement, so that gonidia, already united in groups, are seen still jerking and pulling backwards and forwards. When they have come to complete rest, and united perfectly into a new net, the elongation of the previously roundish gonidia begins; the green granules in their interior become completely blended into a homogeneous mass; the rudiment of the first starch-grain makes its appearance; the newly formed cell-membrane becomes distinguishable. The microgonidia, also, which swarmed-out, and which never unite into nets, but merely become irregularly heaped together, exhibit, after they have come to rest, this transition of the granular contents into a homogeneous green mass, as well as the formation of a small starch-grain and the production of a distinct cell-membrane, by means of which they often become coherent together in groups; on the other hand they show no trace of elongation, and in general do not increase in size,* while in the young nets the increase of

* I cannot let this opportunity pass without mentioning one observation, which perhaps somewhat modifies what has been said above. In the vessels of water in which I cultivated *Hydrodictyon* I frequently found isolated *Hydrodictyon*-cells, in groups of four united irregularly together, which became developed, but under these circumstances assumed irregular, bulging, nodulated, or even branched forms. Whether these hermits arose from individual microgonidia, which, as an exception, had arrived at a development, or from macrogonidia scattered through accidental rupture of the mother-cells in the stage of motion, I could not decide by direct observation,

size advances with astonishing rapidity, the cells of the net, under favorable circumstances, increase to 600 times the length, and 240,000 times the volume in the course of a few weeks.*

After this description of the processes taking place in the course of the formation of the gonidia of the Water-net, it is not difficult to perceive its similarity to other modifications of cell-formation by division. Seeking, in the first place, the import of the light spots which characterise the first stage of the new cell-formation of the Water-net, it is beyond doubt that they represent the centres of so many new cells, consequently are either actual nuclei, or, since we cannot detect any defined outlines, accumulations of albuminous substance analogous to nuclei. The net-work of granules between the light spots, occupying the boundary-lines of the future gonidia, reminds us of the formerly mentioned production of a zone or plate of granules, appearing in the division of the mother-cells of pollen, as also of the zones of granules in the mother-cells (*asci*) of the spores of *Peziza*, and shows that the regions becoming parted off to form new cells are in contact at first. The light streaks which are displayed in the second stage, between the concentrating and isolating tabular portions of the contents, appear to be formed by a secreted matter, which is immediately re-dissolved and destroyed, but which effects the solution of continuity between the individual gonidia, and between them and the membrane of the parent-cell.

but the latter seems to me more probable. I have also observed similar hermits in *Pediastrum*.

* The entire development of the Water-net to the period of repetition of the formation of gonidia, is completed in about 3—4 weeks in cultivated specimens; in the wild state, with more vigorous vegetation, a longer time may perhaps be necessary. The size of the cells at the period of the production of the net, at which time their shape is almost globular, amounts to $\frac{1}{100}$ millim.; the fully developed cells frequently exhibit, in the wild state, a length of 5—6 millimetres, a thickness of $\frac{1}{6}$—$\frac{1}{3}$ mill.; when cultivated in-doors, on the contrary, they attain only 1—1$\frac{1}{2}$ mill., in subsequent generations even only $\frac{1}{3}$—$\frac{1}{2}$ mill. in length, but the propagation, nevertheless, happens at the proper time.

Perhaps it is the same substanee in a state of solution, but still viseous, which retains the aetive gonidia for some time at the periphery of the eavity of the mother-eell, so that the maerogonidia, in whieh the stage of rest and mutual attaehment begins pretty soon, eannot unite otherwise than in the tubular form given by their mode of origin, into a net-like colony. We sometimes pereeive in the interior of newly-formed nets, still enclosed in the membrane of the parent-cell, eolourless balls of mucilaginous consistence, without distinet outlines, whieh are coloured yellow by iodine. In the swarm-like eseape of the microgonidia, through the burst dehiseence-saes of the mother-cell, likewise, we sometimes see the swarm interrupted by a mass of mueilage mixed up with and clogging them. Whether these masses of mucilage are the still undestroyed remains of the above-mentioned secreted eonnecting substance of the gonidia, I do not venture to decide. Ordinarily, after the eomplete formation of the gonidia, the contents of the mother-eell exhibit, besides the gonidia, nothing but water-elear fluid.

As a proof that the gonidia of the Water-net do not originate free in the contents of the mueilaginous layer, but separate from one another by mutual demareation of boundaries, out of an originally eontinuous mass, I may mention the not unfrequent oeeurrenee of twin-gonidia (even of triple groups) in whieh, on swarmers, two (or three) ciliated points may be distinguished, whieh are sometimes side by side, sometimes placed at right angles to each other, or are even on directly opposite sides. It is easy to make certain that such forms are not produced by blending of previously separate gonidia, but that the light line of division, as formed in the second stage, is omitted between the two plates or groups of contents; that, consequently, the mutual external definition between two (or three) inwardly separated eells, has not, or only imperfectly, been effected.

The formation of the gonidia of *Ascidium* (p. 128), *Cladophora*, and probably also of *Chætomorpha* (p. 185), agrees essentially with the mode of cell-formation here described; moreover, judging from the statements of authors, those of *Endococcus* (Nägeli, 'Einz. Algen.,' p. 17) and *Bryopsis*, in which genus the accurate tracing of the process, especially in reference to the behaviour of the chlorophyll vesicles, would be especially important. The formation of the gonidia, as well as the spores, of *Saprolegnia*, likewise referring here, deserve a more minute examination, on account of their somewhat aberrant character. The apices of the filaments, swelling up into longish clubs or cylinders, and becoming shut off as separate cells, in which the gonidia of *Saprolegnia* are formed,* are filled at their formation with a granular mucilage. Subsequently several cavities present themselves in the interior of the mucilaginous mass, along the axis of the club, which cavities, gradually increasing in size, become blended into a single cavity traversing the entire tube, not, however, of very large size. The contents thus converted into a thick parietal mucilaginous layer, soon acquire an undulated surface, forming little rounded eminences, which project more and more, while the intermediate furrows continually cut in deeper until they at length reach the cell-wall. In this manner the mucilaginous layer becomes divided into numerous hemispheres, attached by their flat sides upon the cell-wall; these, however, immediately become rounded into globules, separating simultaneously from the cell-wall. This completes the formation of the gonidia, which immediately commence their movement, continuing it for some time after they have been expelled from the mother-tube.

* The formation of *free* sporangia in the interior of the swollen points of the filaments, described and figured by Nägeli, ('Zeitschr.,' 1847, p. 28, t. iv, figs. 1—6,) is totally different from this. I have likewise seen it, so rarely, however, that I could not trace the whole course. It seemed to me not to belong to the sphere of the normal phenomena of development of *Saprolegnia*, and is just as enigmatical as the occurrence of sessile globular excrescences with rotating and subsequently repeatedly dividing contents, observed in the same plant.

During the time they are in motion, the gonidia exhibit a longish shape, in the transition to rest they re-acquire the original globular form. The rest is followed immediately by germination. All these processes, from the formation of the clubs to the swarming out of the gonidia, are the work of a few hours.* The occurrence of large resting spores, which has escaped most observers,† is a normal phenomenon in the later period of the existence of *Saprolegnia*, occurring sometimes simultaneously with the formation of the gonidia, usually, however, after that is terminated. The spores are formed in globular or pear-shaped, expanded cases, at the tips of slender divaricated lateral branches; the tips of the erect shoots more rarely swell up into such bulging spore-cases. In exceptional cases spores are formed also in cylindrical terminal tubes, agreeing in form with the gonidium-cases. The mode of formation of the spores agrees in all essentials with that of the gonidia. The granular mucilaginous contents of the future spore-cases become darker and more opake than those of the gonidium-clubs, but, as in them, become applied upon the wall of the cell. In this stage several large vesicles, arranged at regular distances, make their appearance in the dark mass of the mucilaginous layer.

When we compare the number and distance of these vesicles with those of the future spores, it scarcely admits of doubt that they are nuclei, from which proceeds the formation of the spores, especially since we may often distinguish a similar lighter vesicle in the developed spores. The formation of nuclei is followed by the production of elevations on the internal surface of the

* The statement of Meyen, ('Pflanzen-physiologie,' iii, p. 457, t. 10, f. 19,) that the active gonidia are formed in separate mother-cells inside the club, is incompatible with my observations. Perhaps the key to this difficulty lies in the above-mentioned observation that the gonidia of *Saprolegnia capitulifera* acquire a membrane shortly after birth, (see p. 188.) It is conceivable that Meyen's observation was made on another peculiar species in which the gonidia acquire a membrane even before birth.

† I find it mentioned only by Schleiden, ('Grundz.,' 1te Aufl., ii, p. 36.)

mucilaginous layer. The somewhat distant elevations become more and more rounded, and the mucilaginous layer, drawing itself apart between them, becomes finally wholly contracted into them. The hemispheres thus formed are therefore not closely crowded, as in the formation of the gonidia, but separated by largish interspaces. The next process is the rounding and detachment from the cell-wall, in consequence of which the spores lie free and loose in the interior of the spore-case, and are not scattered until this decays. The form of the spores is always globular; the size varies in *Saprolegnia prolifera* from $\frac{1}{50}$ to $\frac{1}{30}$ millim., while the gonidia in the stage of motion are only $\frac{1}{100}$ milim. long; the colour is brown; the contents are at first finely granular, subsequently intermingled with drops of oil; the membrane is at first imperceptible, when fully developed thick and evidently double. In the cylindrical spore-cases, the hemispherical elevations are formed in pretty regular alternate order on the two opposite sides of the cell-wall, so that they are interposed like the teeth of two wheels or racks; but the detached spores fall into a single linear row. In the expanded cases the arrangement of the spores does not exhibit any definite order. The number varies very much according to the size of the cases. I have seen as many as twenty spores in one case, while in many other instances there were only four, three, two, and not very unfrequently there was only one.

The formation of the spores of *Leptomitus lacteus* resembles that occurring as an exception in the cylindrical cases of *Saprolegnia;* the spores detached from the wall of the mother-tube are arranged in a single row.* The formation of the spores in the sporangia of *Coleochæte* takes place in a manner similar to that in the

* *Leptomitus lacteus* is in every respect allied to *Saprolegnia*. The dichotomous filaments are not articulated any more than those of *Saprolegnia*, but only divided into sections by regular strictures; these sections have been taken for closed cells. It is only in the fructification that isolated, mostly terminal sections are actually shut off, swell up to some extent, and become spore-cases. No active gonidia seem to occur.

globular cases of *Saprolegnia*. The spores are flat-compressed, however, before their separation, longish afterwards; their colour is green at first, subsequently brown. The number of spores in *C. pulvinata* amounts to 5—8.

Finally, I mention here the formation of spores in *Sphæroplea*, already described (see p. 164),* as a case which connects the two sections D. 1. and D. 2., the formation of an indefinite abundance of new cells through transformation of contents filling up the entire cavity of the cell, on the one hand, and of contents excavated into a parietal investment, on the other. Before the commencement of fructification, the cell-contents of *Sphæroplea* represent a parietal investment, which, however, does not maintain itself as such in the preparatory stage of formation of the reproductive cells, as in the foregoing examples, but collapses entirely, whence the spores produced by its transformation are not seated upon the cell-wall even in their earliest state, but lie free in the cavity of the cell, arranged, according to the proportion of their size to the diameter of the long tubular mother-cell, either in *one* row, as in *Sph. Leibleinii*, K., or in two or more, as in *Sph. Trevirani*, K.† and *Braunii*, K. From the position of the spores, it would be more correct to apply the term free cell-formation to this, than to the preceding cases; but even here it is the entire contents, with the mere exclusion of a watery fluid, which break up into a number of newly individualised masses. That these masses separate at their first production, only loosely fill the mother-cell, and are little or not at all in contact, arises from the condensation of the contents connected with the formation of resting spores, and the abundant quantity of watery fluid which is thus excluded. All the more consistent portions of the contents, the viscid mucilage, the previously annularly arranged chlorophyll, with the

* (See also Fresenius, on *Sphæroplea annulina*, 'Bot. Zeitung,' 1851, vol. ix, p. 241.—A. H.)

† Meyen, 'Pflanzen-phys.,' iii, t. 10, f. 17.

extremely minute green granules in it, as well as the starch-grains* (not vanishing in the process of solution), are taken up at the very first origin of the spores. They are not gradually consumed, but enclosed in the first structure, which also explains the phenomenon that the spores do not commence with minute rudiments, and gradually increase in size in the mother-cell, but, on the contrary, are larger in the first epoch of their formation than they are subsequently, when their mass has become more condensed. Thus this case appears as a reformation of the whole cell-contents combined with division, peculiarly modified by the condensation of the newly-formed cells, and the retraction from the wall of the mother-cell connected with this, a retraction such as we have also seen in reconstruction without division in the spore of *Œdogonium*, or as we are acquainted with in the family of the Zygnemaceæ (in the intermixture of the contents of *two* cells to form *one* spore).

E. Partial reconstruction through formation of daughter-cells in the contents of surviving mother-cells.—This kind of cell-formation is distinguished from all the preceding by the circumstance that the mother-cell is not lost in the reconstruction, but survives the formation of the daughter-cells, the contents of the mother-cell being only partially, not entirely, applied to the formation of new cells. While in all the foregoing cases the newly-formed cells appear as more or less considerable transformations of the mother-cell, we behold here a re-production or new-formation in the most complete sense, since the old cell persists as such, in spite of the reproductions taking place in it. In all the foregoing cases, nothing remains of the mother-cell after the formation of the daughter-cells but the inessential membrane; here, on the contrary, we see the daughter-cells enclosed in the living, undividedly persistent contents of the mother-cell.

1. *The daughter-cells originate* (*without a nucleus?*)

* Each single spore encloses *several* of the existing starch-grains in its structure.

close to the cell-wall, against which they are firmly applied during their completion.—This is the character of the formation of the germ-cells of *Valonia* described by Nägeli. In the long tubes, when full-grown measuring ½ to 1½ inch in length, of this unicellular marine Alga, the organic contents form a thin investment to the wall, while the large cavity is filled with salt water.* The mucilaginous layer is beset with reticularly arranged or scattered chlorophyll-vesicles. At particular spots, especially at the bottom, more rarely in the apex of the cell, are formed the germ-cells, sometimes singly, sometimes connected in groups. According to Nägeli, they originate as minute colourless globules, which acquire as they grow an evident membrane and green granular contents, chlorophyll-vesicles being formed in their interior. The fully-developed germ-cells adhere as flattened disks to the wall of the cell. Those which occur at the upper end of the mother-cell usually germinate in the still surviving mother-cell, breaking through its membrane, probably locally softened, stopping up the orifices again with their bases. The peculiar ramification of *Valonia* arises from this growth of the young individuals out of the old one. The germ-cells at the lower part of the tube, remaining undeveloped, probably only become free through the decay of the parent individual, to become developed as separate individuals forming new family-stocks. The case here mentioned is distinguished from the mode of cell-formation minutely described in *Hydrodictyon*, under D. 2, by the circumstance that only particular points, and not the whole of the parietal mucilaginous layer, passes into new cell-formation; moreover that the new cells exhibit a gradual increase in size in the surviving mother-cell, while in *Hydrodictyon* they attain at their first production the full size which they are destined to acquire inside the mother-cell. Nägeli's description affords no information as to the behaviour of

* 'Neueren Algensyst.,' pp. 155—157, t. ii, f. 7—24.

the chlorophyll-vesicles on those parts of the wall of the mother-cell where the formation of the germ-cells occurs.

Botrydium doubtless belongs to the same family as *Valonia*. My observations on the formation of the germ-cells of this genus, already mentioned (pp. 128, 193), are not sufficiently complete to decide whether it can be properly cited as an example here. In *Botrydium* the germ-cells are sessile all over the inside of the wall of the vesicular epigæous portion of the cell, placed pretty close together, yet not in contact. They exhibit a rather considerable difference of size in the same individual, which seems to indicate a growth inside the mother-cell. Simultaneously with their completion the mother-cell swells up, softens, and collapses. According to Kützing,* however, the spores often germinate before the collapse of the mother-cell, breaking forth on its surface as a granular coating.

2. *The daughter-cells* (mostly several, rarely only one) *are formed* (*around nuclei*) *free in the contents of the mother cell.*—The term "free cell-formation," which certainly meets most of the modifications to be examined here, has hitherto been applied to many other kinds of cell-formation already treated above. Looking at the mere words, we may use this expression in two very different significations, according as we intend to call the cell-formation free in its result or in its origin. In the first sense we speak of free cell-formation in contrast to the formation of connected tissue, under which circumstances the daughter-cells may stand originally in most intimate contact with the mother-cell and with each other, but not be grown together, or not so firmly that they cannot finally become free by the rupture or resorption of the mother-cell. We have seen such formation of free cells under A. 2 (formation of the gonidia of *Œdogonium*, of the pollen-grains, &c.), B. 2 (formation of the gonidia of *Ulothrix*, *Characium*, &c.), D. 1 (*Sciadium*, *Chytridium*),

* On a new *Botrydium*, in 'Nov. Acta.,' xix, ii, 388, t. 69, 4.

D. 2 (*Ascidium, Cladophora*). Free cell-formation in the second sense, in which it was used for instance by Nägeli,* likewise comprehends two very different series of cases, viz., either the origin is only so far free, that the daughter-cells formed through the transformation of the whole contents of the mother-cell (with or without division of them), separate at the very moment of their constitution, from the membrane of the mother-cell, by contraction of their mass, and separate from each other in the same manner, as we have already examined under A. 2 (formation of spores of *Œdogonium*), D. 2 (*Sphæroplea*); or the origin is free even in relation to the definition of the boundaries of the original mass of contents from which the new cell is formed, the daughter-cells being formed, not out of the whole contents of the mother-cell, but out of the separate, unconnected portions of them. It is this last series of cases that especially merits the name of *free* cell-formation, if this term is to be retained; and then the circumstances whether the newly-formed cells are applied upon the mother-cell (E. 1), or not,—and, in like manner, whether they subsequently become connected together into a continuous tissue (as we shall see in the endosperm-cells), or not,—are to be regarded as less essential.

a. A free daughter-cell is formed around the primary nucleus of the mother-cell.—The case here mentioned differs from those examined under A. 2, *e. g.* the formation of the pollen-grain in its special mother-cell, in the circumstance that the daughter-cell does not take in the whole of the contents of the mother-cell, but lies free in the contents of the latter, so that other daughter-cells may subsequently originate in the contents of the same mother-cell. This strange and most rare case was

* 'Zeitschrift,' 1846, p. 51, (Ray Translation, 1849, p. 123.) "In *free* cell-formation *a greater or smaller portion of the contents becomes isolated, or even the whole contents of the cell. On the surface of this is formed a complete membrane, altogether free at its outer surface*, (in contact neither with the wall of the mother-cell nor those of its sister-cells.)"

observed by Hofmeister in the embryo-sac of *Funkia cærulea*,* and described in the following manner. About the time of the opening of the flower, before fertilisation, but after the germinal vesicles have been formed, a new cell is formed around the still existing primary nucleus of the embryo-sac, which cell only occupies a small portion of the internal cavity of the embryo-sac, in its lower third. After the formation of this cell the original nucleus becomes dissolved, and two or more nucleus-like structures appear in its place in the daughter-cell, but no further cells seem to be formed around them. The formation of this central daughter-cell belongs to the many structures occurring in the embryo-sac which vanish again very quickly. The same observer describes a similar process in the endosperm-cells of *Ornithogalum sulphureum*,† in which, after they have become parenchymatously connected, a new daughter-cell not filling up the mother-cell is likewise formed around the still present primary nucleus, which cell sometimes becomes doubled by division, and around which still other free cells appear subsequently to be formed.

b. Several free daughter-cells are formed around newly-formed nuclei.‡—The nucleus of the mother-cell frequently survives during the formation of free daughter-cells of this kind, indicating persistent vitality in the contents of the mother-cell by the mucilaginous radii proceeding from it. The number of daughter-cells appears never to be accurately defined. All the cases referable here occur in the embryo-sac of the Phanerogamia, in fact, it is doubtful whether anything similar occurs anywhere else in the development of plants. We have to examine:

a. The formation of germinal vesicles.—The embryo-sac, or germ-sac, as it is termed, is the last cell of the

* Hofmeister, 'Die Enstehung des Embr. der Phanerog.,' p. 13, t. viii, f. 8, 9, 10. A similar phenomenon is described in *Asphodelus luteus*, p. 10.

† L. c., p. 14, t. xiv, f. 17—19.

‡ Hofmeister, l. c., p. 11, is especially to be consulted regarding the origin of the nuclei themselves.

mother-plant, the uppermost in the axial row of cells of the ovule, destined to become the focus of the reproduction, the mother-cell of new individuals; the germinal vesicles forming in it are the real rudiments of the new individuals, the unicellular germs of new plants. They are formed already before the period of the scattering of the pollen, free nuclei originating in the upper part of the embryo-sac (the end turned to the apex of the nucleus and the micropyle), in which the protoplasm is principally accumulated, around which nuclei soon appear sharply defined masses of contents, which are, as it were, "cut out" of the general mass of contents of the embryo-sac. The number of germinal vesicles is mostly three,* rarely more,† sometimes only two,‡ and very rarely only one exists, in which case, however, the larger number is indicated at the earliest period of formation by their nuclei, two of which disappear again without cells having been formed around them.§ The newly-formed germinal vesicles are roundish at first, but soon extend longitudinally; at first they are only slightly in contact, but as they increase in size become crowded together more closely in the upper end of the embryo-sac. Ordinarily only one of them becomes developed into an embryo, this outstripping the others in growth even before fertilisation,‖ or the latter even die away and dissolve about that epoch.¶ At the period of fertilisation the germinal vesicle destined to development presses its end lying next the micropyle firmly against the inside of the wall of the embryo-sac, against the outside of which the pollen-tube is applied, which double connection may go as far as actual growing together. In other respects the germinal

* Hofmeister, l. c., *Sorghum*, t. xi, f. 22, 23; *Canna*, t. iv, f. 3, 5; *Godetia*, t. v, f. 5.

† L. c., *Funkia cærulea*, p. 16.

‡ L. c., *Polygonum orientale*, t. xii, f. 18—20.

§ L. c., *Agrostemma Githago*, t. ii, f. 20—22.

‖ L. c., *Zea Mays*, t. xi, f. 4; *Godetia*, t. v, f. 5, 6, and 'Botanische Zeitung,' 1847, t. viii, f. 10, (*Godetia*.)

¶ L. c., *Canna*, t. iv, fig. 6.

vesicle remains wholly free during its development into suspensor (vorkeim) and embryo, becoming developed without any connection with the other phenomena of cell-formation in the embryo-sac, even interfering with and displacing and destroying them, so that it affords us, not merely in its first formation, but also in its further behaviour, the example of the freest and most independent cell-formation which the plant exhibits.

β. *Formation of transitory cells in the embryo-sac.*—In addition to the germinal vesicles not arriving at development, already mentioned, other cells are met with in the embryo-sac which only show themselves for a short time; free cells, which are dissolved again and vanish without leaving a trace when scarcely formed, or even before completion, as mere nuclei. Among these are especially the cells presenting themselves at the lower (chalazal) portion of the embryo-sac, agreeing more or less in number and form with the germinal vesicles, but never developing into embryos, and which are described in Hofmeister's often-cited essay in the majority of the plants investigated by him.* These strange antipodes of the germinal vesicle originate either simultaneously with the latter, or somewhat later,† and, in exceptional cases, even earlier;‡ they mostly disappear again before fertilization,§ often even as mere nuclei; in rarer cases they persist for some time after the fertilization, and vanish during the formation of the endosperm-cells.||

γ. *Formation of the endosperm through free cell-formation in the embryo-sac.*—The vitality of the embryo-sac is retained uninjured as a whole, in spite of the

* They appear to be absent from *Polygonum orientale*, (t. xii, f. 18, 19), *Agrostemma Githago* (t. ii, f. 18—22) *Godetia*, (t. v, f. 4, 5); they are especially numerous in *Sicyos* (t. xiii, f. 3—5); often only a single one, but of unusual size, presents itself in *Hyacinthus orientalis* (t. vi, f. 3).

† L. c., *Orchis*, t. ii, f. 2, 3, 4.

‡ L. c., *Crocus*, t. iv, f. 14.

§ L. c., *Ecbalium*, t. xiii, f. 6—9.

|| L. c., *Hyacinthus orientalis*, t. vi, f. 4, *b*; *Helianthus annuus*, t. xiii, f. 18—20.

formation of germinal vesicles and transitory cells taking place in both its ends; its primary nucleus ordinarily survives,* or even increases considerably in size after the formation of the germinal vesicles.† The nucleus of the embryo-sac is only dissolved during or shortly before the period of fertilisation, and then a profound reconstruction commences in the interior of the embryo-sac, expressed in the production of daughter-cells, likewise free,‡ but so numerous that they soon exhaust the independent life of the former, and the entire cavity becomes filled up by the cohering newly-formed cells. The tissue produced in this way is the endosperm, or, as it is called, the albumen of the seed, in which the developing embryo of the new plant then becomes imbedded. The endosperm-cells, like the germinal vesicles, originate as free nuclei in the fluid of the embryo-sac,§ which subsequently become surrounded by masses of contents and clothed with membranes. The cells thus formed very soon combine into a continuous parenchyma, in which there is no longer evidence of the origin from free cells.‖ The cellular filling-up of the embryo-sac with endosperm-cells is not however completed at once, but proceeds gradually from the periphery to the centre, the successively formed endosperm-cells applying themselves in layers upon the inside of the wall of the embryo-sac.¶ The formation of

* L. c., *Sorghum*, t. xi, f. 22; *Hyacinthus*, t. xiv, fig. 2; *Erodium*, t. iii, f. 17; *Helianthus*, t. xiii, f. 17. More rarely the nucleus of the embryo-sac vanishes before the formation of the germinal vesicles, *e. g.*, in *Orchis*, t. i, f. 32.

† L. c., *Agrostemma*, t. ii, f. 18—22; *Bartonia*, t. ii, f. 34—40; *Fritillaria imperialis*, t. viii, f. 6—9.

‡ The rarer case of formation of endosperm by cell-division has been mentioned previously, (p. 248.)

§ See Hofmeister's figures of *Godetia*, ('Bot. Zeitung.,' 1847, t. viii, f. 25, *a*;) *Fritillaria imperialis*, ('Enstehung des Embryo,' t. viii, f. 11;) *Ecbalium*, (l. c., t. xiii, f. 11;) *Helianthus*, (t. xiii, f. 20;) *Linum*, (t. xiv, f. 4, 8.)

‖ See Schleiden, 'Beiträge zur Botanik,' t. vi, f. 69, 76, 77. (From the albumen of *Chamædorea Schiedeana*.) (See transl. in Taylor's 'Sc. Mem.,' vol. ii, p. 281, t. xv, f. 1—10.—A. H.)

¶ See Schleiden and Vogel, 'Ueber das Albumen,' 'Act. Nat. cur.,' xix, ii, t. 42, f. 42, 43 (*Tetragonolobus purpureus*,) and f. 49, 50 (*Baptisia* these layers appears to take place with especial regularity in the Graminaceæ. According to Hofmeister's observations,* the nuclei imbedded in the mucilaginous layer which lines the embryo-sac arrange themselves with a certain regularity, becoming distributed at equal distances on the inside of the wall of the embryo-sac. As a cell is formed around each of these nuclei, and on all simultaneously, the embryo-sac becomes lined with a layer of cells, the first of the endosperm. On the inside of this a second layer of cells is soon deposited in a similar manner; this is followed by a third, and so on. Leaving out of view the lamellar repetition, this process of cell-formation clothing the wall reminds us very much of that examined under D. 2; the exhaustion of the contents of the embryo-sac (*i. e.* the mother-cell) occurring with the formation of the last, innermost endosperm-cells, is related to D. 1.

When we consider the whole of the phenomena of cell-formation in the embryo-sac connectedly, we behold the case, unique in its kind, of a mother-cell in which different kinds of daughter-cells are produced at different periods. None of these daughter-cells belong any more to the tissues of the mother-plant; all, as cells originating free, are in a certain sense reproductive cells, new individuals; but of the many sisters, only one, the first-born, is ordinarily destined to become perfectly developed, while the majority of the others are compelled, in their earliest childhood, to perform nursing-service to the chosen one. The difference of the cells formed in the embryo-sac may indeed be compared with the occurrence of bimorphous, partly fertile, partly sterile gonidia in the Algæ; the parenchymatous conjunction of the originally free endosperm-cells reminds us of the regular combination of the previously free gonidia of *Hydrodictyon* and *Pediastrum*.

exaltata;) also Hofmeister, l. c., t. xii, f. 25 (*Polygonum orientale;*) and t. xiii, f. 21, (*Helianthus annuus.*)

* L. c., p. 30, t. xi, f. 25, 26, 29, (*Sorghum bicolor.*)

Nägeli* treats, in the section on *free cell-formation*, the phenomena of abnormal cell-formation, which are observed in decaying contents of old cells. The mode of formation of these abnormal cells certainly agrees most of all with the cases last discussed, but has the peculiarity that the new structures escaping the solution and decay of the rest of the cell-contents are incapable of development, or only of abnormal development, descending into diseased structures or pseudo-organisms. The character of these abnormal cells is most varied and changeable; especially remarkable is the occurrence of globular, resting, spore-like cells (*e. g.* in old *Closteria*),† as also the appearance of active, Infusorioid structures, which occur not unfrequently in the interior of decaying cells of green fresh-water Algæ (*e. g. Œdogonium, Spirogyra*),‡ and are distinguished from normal swarming-cells by their irregular form, varying size, slower motion, and mostly brownish-yellow contents, succeeded by hyaline, finely granular mucilage. In *Sphæroplea* I have often seen such pseudo-gonidia formed in the same cells with normal spores. Abnormal structures of this kind have doubtless often been confounded with the normal reproductive cells of the Algæ. The future will certainly unfold many interesting phenomena in this hitherto little-worked field.

In the preceding summary of the modifications in which the process of Rejuvenescence of cells advances to new constructions, we have seen division of the cells occur as a very ordinary accompaniment of the reconstruction, and this in manifold ways. With these pro-

* 'Zeitschrift,' 1847, p. 24, t. iii, f. 1—3 (*Bryopsis Balbisianum.*) (Ray Society's transl., 1849, p. 98, t. ii, f. 1—3.—A. H.)

† Meyen, 'Pflanzen-phys.,' iii, t. 10, f. 24, (also figured by Focke, 'Physiol. Studien,' pl. iii, f. 12.—A. H.)

‡ (See Pringsheim, on *Spirogyra*, Transl. in 'Annals of Nat. Hist.,' 2d series, vol. xi, p. 210. Also consult on this point Itzigsohn, 'Bot. Zeit.,' 1853.—A. H.)

cesses of division are connected, in the first place, the development of the tissue with its varieties, even the development of the contrasts of the external organs (in the higher plants), and, lastly, the multiplication of the individuals, both through vegetative increase, and through true reproduction. The formation of free reproductive cells, may also be termed division, in so far that their origin depends upon a parting of the contents of the mother-cell. In opposition to this effort towards division and separation, towards the development of multiplicity, both from the repetition of the like and the shaping out of the various vital tendencies in structures of many kinds—the plant manifests, on the other hand, in certain periods of conclusion and transition, an effort toward reunion of the divided, either by gathering up and combining the homogeneous, or bringing together opposites. In the higher divisions of the vegetable kingdom we meet with this phenomenon in many forms. The intimate combination of the organs at the higher steps of the metamorphosis, the fusion of parts in the individual whorls of the flower, adherence even of entire whorls to each other,* but in particular the blending of the carpels into closed germens, exhibit the effort at reunion of the separated in the morphological field, as the phenomena of fecundation do in the physiological. But even in the lowest plants, which do not possess the variety of organs and the contrast of sexes, whose whole cycle of vegetative life is limited to the development of a single cell, or a series of similar cells, we find acts of this uniting and collecting vital tendency. Among the principal of these is the phenomenon occurring in the Algæ and Fungi, to which the name of *conjugation* of the cells has been applied; a phenomenon which always occurs at the close of the vegetative development, ordinarily at the termination of a series of unicellular generations produced by dividing-increase, and is for the purpose of forming, directly or indirectly,

* Whence arise the perigynous and epigynous insertions.

reproductive cells, the transition-cells to a new vegetative cycle.* In the preceding summary of the conditions of cell-formation, I have purposely avoided mixing up those caused by conjugation; as the opposite of all kinds of cell-formation combined with division, they deserve a separate examination, through which, from the insufficiency of most of the descriptions of the cases belonging here, I purpose, at the same time, an attempt at placing the subject in its proper light (Orientirungs-versuch), to guide in future investigations. In the following collocation we restrict the idea of conjugation to those cases in which: 1, two previously really separate cells unite;† 2, the combination takes place by actual anastomosis, not by mere application together of the cell-walls;‡ 3, an immediate intermixture of formative cell-contents occurs.§ Thus, in true conjugation, two previously separate cells are united in such a manner that in the combined state they can only be regarded as *one* cell, the two halves of which sometimes remain distinguishable, connected by a narrow isthmus or by a canal (trabecula), but sometimes coalesce so completely that the earlier boundaries entirely disappear. In such union, either all parts of the combining cells (membrane and contents) enter into conjugation, or the cell-membrane, and then either the whole or only the outer, remains out of the combination, bursting so as to let the inner membrane or merely the contents (with the primordial utricle) conjugate. In this case it may happen that the contents divide within the cell-membrane shortly before the conjugation, so that two cells are formed

* See above, p. 132. (Diatomaceæ); pp. 133—135, (Desmidiaceæ, Zygnemaceæ.)

† This excludes the phenomena in the formation of the spores of *Melosira*, *Œdogonium*, and *Bulbochæte*, subsequently to be examined more closely, which have been mixed up with conjugation.

‡ This excludes the mere application of other cells upon the mother-cell of the spores, such as occurs in *Coleochæte* and *Saprolegnia*, as also the union of the pollen-tube with the embryo-sac.

§ This excludes the anastomosis of the colourless cells of the leaves of *Sphagnum*, *Dicranum glaucum*, and certain other white-leaved Mosses, as also the union of long tubular spiral-fibre-cells to form vessels.

through double conjugation of the contents of two dehiscing mother-cells, which extrude their contents. The conjugation-cell formed in either of these ways, is either itself a reproductive-cell, or the latter is formed by a further metamorphosis of the combined contents within the conjugation-cell, and this mostly takes place either in one of the halves of this, or in the connecting piece between the halves; it is mostly a resting spore, more rarely an active gonidium, rarest of all the combined contents divide into a number of cells in their transformation for the purpose of fructification. These, and other less essential differences, produce the multiformity of cases in which the phenomenon of conjugation presents itself, especially in certain families of the Algæ, while as yet it has only been observed in one genus of the Fungi, here, however, in a modification deviating from all the rest. In the following summary I shall endeavour, as far as possible, to place all the known examples.

A. Conjugation of similar cells.—The uniting cells may be either free and isolated, as in most Diatomaceæ and Desmidiaceæ, or they may be links of a many-celled filament, as in the Zygnemaceæ. In isolated cells the union mostly takes place by the sides of the cells, either by parallel or by crossed approximation (*copulatio lateralis parallela, s. decussata*); very rarely by the apices of the cells (*copulatio apicalis*). In the jointed (many-celled) filaments the union takes place either by each two successive cells of the same filament anastomosing with their adjacent ends by lateral processes, which we will call *chain-union* (*copulatio catenativa*); or by the links of two different filaments (or, as may equally happen, different parts of the same filament overlying through bending), uniting by their sides: *yoke-union* (*copulatio conjugativa*), in which case the cells may be either bent like a knee in order to reach each other (*conjugatio genuflexa*), or be united without bending, by processes growing out to meet each other and coalescing into a transverse canal: *ladder-like union* (*copulatio scalaris*). These distinctions, however, are less essential than those on which the following subdivisions are founded:

1. *The conjugating cells unite entirely* (*with membrane and contents*), *and, completely coalescing without throwing off a membrane, form a seed-cell* (*spore*).—The spore originates here as the direct result of conjugation, not subsequently through a further transformation of the contents after the conjugation; the conjugation-cell is itself the seed-cell, and does not produce the latter as a new cell within itself. Here refers *Palmoglœa,* the remarkable, of its kind unique,* conjugation of which was only represented in its commencement by Kützing,† described in its further course by Thwaites, but, since he assumed an absorption of the cell-membrane of the combining cells, mistaken by him exactly in its most essential peculiarity,‡ I have mentioned my own observations on the conjugation of *Palmoglœa* above;§ the minute description of the process, with remarks on the species in which the observations were made, will follow in the description of the plates.

2. *The conjugating cells, leaving behind the outer membrane, unite directly to form a reproductive cell.*—The occurrence of this case is not improbable, but has not yet been made out with certainty.

3. *The conjugating-cells combine merely their contents* (*bounded by the primordial utricles*), *to form the reproductive cell; the dehiscent cell-membrane is deserted.*—The conjugation of many Diatomaceæ|| very probably belongs here. The mode in which, according to the

* Similar cases occur in the animal kingdom, in the Infusoria. See Kolliker on *Actinophrys Sol,* in Siebold and Kölliker's 'Zeitschrift,' 1849, b. i, p. 207, (Transl. in 'Quarterly Journal of Microscopic Science,' vol. i, p. 98, *et seq.*) The forms figured as *Actinophrys difformis,* by Ehrenberg, ('Infusionsthierchen,' t. xxxi, f. 8,) doubtless represent conjugating states of *Actinophrys Sol.*

† Assuming that his *Palmoglœa Meneghinii,* ('Tab. Phycol.,' 24, iii,) actually belongs to this genus, and not to *Cylindrocystis.*

‡ 'Annals of Nat. History,' 1849, 2d series, vol. iii, p. 243, t. viii, f. *c,* (as *Coccochloris Brebissonii.*)

§ See pp. 135, 202, and pl. i, figs. 1—28, pl. ii, figs. 1—14. || See p. 132.

descriptions of Thwaites,* the cell-contents emerge from the splitting siliceous cell-coats, and, speedily uniting between the emptied shells of the mother-cells, acquire the globular form, renders the assumption tolerably safe, that the masses of contents unite here. No membranous canal formed by an internal cell-membrane, inside which the masses of contents unite, seems to exist here. Since the conjugating individuals are always held together by an abundant gelatinous secretion appearing at this time, it is not difficult to conceive the persistence of the pair of cells in their approximated position, even without the formation of membranous tubes of conjunction. The reproductive cells of the Diatomaceæ formed through conjugation have no seed-sleep, but, although not active, pass directly, in the manner of gonidia, into vegetative development.

a. The contents of the two cells unite without previous division;—in this way *one* gonidium is formed by two mother-individuals. Thus in *Himantidium.*†

b. The contents divide in both cells before the union into two masses;—in this case two gonidia are formed by two mother-cells through double conjugation. According to Thwaites's representation, the division of the contents preceding conjugation is transverse in *Eunotia,* crossing the direction of division in vegetative increase.

α. The new individuals developed from the two gonidia, soon surpassing the mother-cells in size, cross the shells of the mother-cells. Thus in *Eunotia turgida.*‡

β. They take a position parallel to the shells of the mother-cells. Thus in *Cocconema,*§ *Gomphonema,*‖ and *Schizonema.*

4. *The conjugating-cells unite with participation of*

* 'Annals of Nat. History,' 1847, vol. xx, pp. 9, 343; 1848, ser. 2, vol. i, p. 161.
† Thwaites, l. c., 1847, vol. xx, p. 22, f. A, 1—7.
‡ Ibid., t. iv.
§ Ibid., t. xxii, f. C, 1—3.
‖ Ibid., t. xxii, f. B, 1—5.

the external membrane; the reproductive-cell is formed through contraction of the contents clothed by the internal cell-membrane.—The formation of the reproductive-cell (in the cases to be mentioned, of a spore) is consequently here not a direct result of the conjugation, but it is formed subsequently in the interior of the conjugation-cell, in the strongly expanded isthmus of this. The delicate internal membrane, with the contents enclosed by it, drawing itself out of the (on account of the thickness of the outer membrane, rigid) extremities of the double-cell, forms a seed-cell, at first cruciate-four-lobed, then bluntly quadrangular, and finally globular, clothed by a many-layered thickened membrane, within the persistent four-horned conjugation-cell. From Ralfs's representation this is most probably the way in which the process is to be understood in *Cylindrocystis Brebissonii*, Menegh. (ex. p.)* The participation of the outer membrane in the conjugation is beyond doubt; this is the principal character distinguishing the genus *Cylindrocystis* from *Penium*. The resemblance of the quadrangular internal cell to that of *Tetmemorus*, in which this is undoubtedly formed of a delicate cell-membrane, testifies in favour of the existence of the latter in this case also. From the cruciate or quadrangular shape of the spore, it may be conjectured that the conjugation of genus *Staurocerus*,† likewise belonging to the group of Closterina, as also that of the Zygnemaceous genus *Staurocarpus*,‡ Hassall (*Staurospermum*, Kg.), belong here.

5. *The conjugating cells unite with participation of the outer membrane; the reproductive-cell is formed out of the mere contents, as a new cell, inside the mother-cell.*—This case (occurring in the majority of the Zygnemaceæ) differs from the preceding by the non-participation

* *Penium* (*Cylindrocystis*) *Brebissonii*, Ralfs, 'British Desmidieæ,' p. 153, t. xxv, f. 6.

† Ehrenberg, 'Infusionsth.,' tab. vi, f. 94. Ralfs, l. c., t. xxx, f. 4, *Staurocerus subulata*, K.;) ibid., f. 3, (*St. Acus*, K.;) f. 5, (*St. acutum*, Breb.)

‡ Hassall, 'British Freshwater Algæ,' t. 47—49.

of the inmost lamella of the cell-membrane in the formation of the reproductive cell.

a. With ladder-like (scalariform) yoke-conjugation.

α. The spore in the connecting canal or middle piece of the double cell. In *Zygogonium.**

β. The spore in one half of the double cell (in the cavity of one of the two conjugating mother-cells). Ordinarily the case in *Spirogyra,*† and *Zygnema.*‡

γ. A spore in each half. This case occurs only as abnormal in *Spirogyra,* and appears to depend upon an incomplete carrying through of the conjugation, the union-processes coming into contact, but not anastomosing.§

b. With knee-shaped (geniculate) yoke-conjugation.

α. The spore in the uniting canal or middle piece. In *Mesocarpus.*‖

β. The spore (or the gonidium) in one of the halves of the double-cell. Here belong *Sirogonium,*¶ with a spore formed exactly as in *Spirogyra,* and the genus *Mougeotia*** still enigmatical in its mode of reproduction, probably possessing an active gonidium, leaving the mother-cell directly after its formation.

c. Chainlike (catenate) union of the cells of the same filament.

α. The spore in the lateral connecting-canal of the conjugated-cells. This case is not yet known, but it is

* Vaucher, 'Histoire des Conferves,' t. vii, f. 3—4; Hassall, l. c., t. 39.

† Vaucher, l. c., t. iv and v; Hassall, l. c., t. 18, 25, and 27—32.

‡ Vaucher, l. c., t. vi, f. 4; t. viii, f. 1, 2; Hassall, l. c., t. 38.

§ Vide Kützing, 'Phyc. General,' t. 15, f. 1, 3, 4, 6 (of *Spirogyra quinina.*

‖ Hassall, l. c., t. 42—45.

¶ Hassall, l. c., t. 26.

** Hassall, (l. c., p. 172,) indeed, asserts that *Mougeotia* is propagated by zoospores, but gives no further information regarding their formation. Vaucher (l. c., p. 79, t. viii) formed out of *Mougeotia* the section "conjugées à tubes intérieurs," and describes the emergence of already elongated many-celled young filaments from the old cells, a phenomenon which may be explained as accidental development of gonidia remaining in the mother-cell.

conceivable that Hassall's strange *Mesocarpus notabilis** belongs here; this would require the assumption, that the uniting canal, becoming filled with the contents of the two conjugated-cells, pushed aside completely the septum between them.

β. The spore in one half of the double-cell (in the cavity of one of the mother-cells). This is the case in Hassall's second division of the *Spirogyræ*,† which Kützing has distinguished as a peculiar genus, under the name of *Rhynchonema*.‡

d. Lateral, parallel union of isolated cells.—Here belongs the conjugation of *Closterium Lunula* (see p. 140), in which, according to Morren's express statement,§ three different membranes take part in the formation of the canal of union, an inner and an outer cell-membrane, and a membrane (the primordial utricle) immediately enclosing the green mass. The globular reproductive-cell formed in the connecting canal, is an active gonidium, which begins to revolve even while within the canal, and soon breaks through the gelatinously swollen membrane of the latter. Very often two approximated individuals divide again and conjugate before they have become completely separated: whence result conjugated double-pairs.‖ According to Ralfs' description of the conjugation of *Penium Jenneri*, it resembles that of *Cl. Lunula*, a large globular spore being formed in the interior of a connecting canal, narrow at the points of issue, like that of *Mesocarpus*.¶

* Hassall, l. c., t. 46.

† Hassall, l. c., p. 152, t. 33 and 34; Nägeli, 'Algensysteme,' p. 151, t. iii, f. 22—25.

‡ 'Spec. Alg.,' p. 443. The genus *Rhynchonema*, although based on a very remarkable character, is scarcely natural, since both kinds of conjugation sometimes occur in one and the same species. I have observed this especially in *Spirogyra Weberi*, in which, however, the chain-union is more common than the yoke-union.

§ 'Mém. sur les Closteries,' 'Ann. des Sc. nat.,' 2 ser., v, 325, t. 9 (1836.) (See also Smith, on *Closterium*, 'Annals of Nat. History,' sec. ser. vol. v, p. 8, t. i.—A. H.)

‖ Morren, l. c., t. 9, f. 22, 23, (Smith, l. c.)

¶ Ralfs, l. c., p. 153, t. 33, f. 2.

c. Conjugation of branched filiform cells by club-shaped branches, which unite at their points.—The only known example is the remarkable genus of Mildew Fungi *Syzygites,* discovered and figured with a master's hand by Ehrenberg.* Erect, dichotomously branched, inarticulate flocci, therefore unicellular filamentous little plants, grow side by side in dense tufts. The uppermost branches of the forks curve, like a pair of tongs, towards each other, and send out (usually on the inner side of the arms) clavate or pear-shaped branchlets. These fruit-clubs, sometimes the opposite ones of the same fork, sometimes those of different forks intermingled through the social growth, unite by their apices. Ehrenberg could not detect an actual anastomosis with certainty, but it most probably does occur. In the middle of the spindle-shaped conjugation-body thus produced, the granular contents of the filaments ascend in a current from both sides, and collect into a globular mass, which becomes intimately combined with the membrane of the middle-piece of the spindle, and shut off from the lateral pieces by septa, and finally becomes free between the two lateral portions, without these being torn. The globular body becomes brown, and at length black, during its development, and is a thick-walled cell, in which, if we may put faith in Corda's figure, free spores are formed, imbedded in a soft amorphous mass.†

6. *The conjugating cells, after dehiscence of the outer membrane, unite through the inner; the reproductive cell is formed out of the mere contents, as a new cell inside the conjugation-cell.*—This is undoubtedly the condition in the majority of Desmidiaceæ. The union almost always takes place between isolated cells in this family; even in the genera with the cells connected into filaments

* 'Verhandl. der Gesellsch. naturforsch. Freunde zu Berlin,' 1 band., p. 98, t. ii, iii (1829.)

† Corda, 'Prachtflora Europaischer Schimmelbildungen,' (1839,) p. 49, t. 23.

or ribands (*Hyalotheca, Didymoprium, Isthmosira*), the conjugation does not commence until the filaments have broken up into their individual links. In *Bambusina* alone, according to Ralfs, occurs the case of isolated cells conjugating with others still constituting links of continuous filaments, and thus becoming attached, like parasites, upon the filaments. The dehiscence of the external cell-membrane is especially evident in *Tetmemorus* and most *Closteria;* it always takes place in a transverse direction, in the middle between two halves. While the dehiscing outer membrane opens more or less widely on one side (like the dehiscing cells of *Œdogonium*), the delicate internal membrane protrudes as a tubular process, to unite with the corresponding process of the other cell. If, at the same time, the internal cell-membrane remains connected with the outer cell-wall, the halves of the dehiscent cell-membrane mostly remain approximated together and connected with the uniting canal and the spore, which usually fills this up (*e. g.* in *Closterium acerosum, lineatum*, &c.); but if the loosened internal cell-membrane gradually extricates itself from the outer, the halves of the latter become separated and are readily thrown off (*e. g.* in *Tetmemorus*).

a. Conjugation in a parallel position.—This is peculiar to the group of *Closterina*. In the species with curved cells the union takes place (with rare exceptions) by the convex side, so that the conjugated specimens have their points diverging.

α. The halves of the dehiscent cells separate from each other all round, the internal cell-membrane entering into conjugation gradually emerging wholly or almost entirely. The spore formed from the contents lies loose in the delicate conjugation-cell. This is the case most evidently in *Tetmemorus;** according to Ralf's figures, *Docidium*,† and a section of the *Closteria* having longitudinally

* Ralfs, l. c., p. 146, t. 24, f. 3.
† Ibid., t. 26, f. 4.

striate and truncated ends,* seem to exhibit a similar behaviour.

β. The halves of the dehiscent cell only separate a little on the side turned towards the other individual, at which the internal membrane emerges, while they remain connected on the outer side; the internal membrane remains as an internal investment in the outer; the spore mostly fills the uniting canal so completely, and is in such close contact with its walls, that the latter is scarcely distinguishable. This is the condition in *Penium*† (with the exception of the species mentioned previously), and the unstriped *Closteria*‡ (with the exception of the above-mentioned *Cl. Lunula*).

Closterium lineatum§ also belongs here, but with the peculiarity, known only in it, that *two* spores are formed between two individuals. As I have had an opportunity of observing the process of conjugation minutely in this very species,‖ I am able to explain the mode of origin of the really double spore (not two-lobed, as Ralfs terms it). The very much elongated, only slightly curved specimens of *Clost. lineatum*, lie close together in pairs before conjugation, sometimes with both the convex sides in contact, sometimes with the convex side of one touching the concave side of the other. The cell-membrane dehisces transversely, either simultaneously in both, or in one earlier than the other, in the middle of the cell, previously marked outside by an annular line, and inside by an interruption of the green contents,¶ but this takes place in such a manner that the two halves only separate a little on the side turned towards the other individual, remaining connected on the opposite side, so that the

* Ralfs, l. c., t. 29, f. 2, (*Closterium striolatum*); fig. 6, 7, (*Closterium juncidum*.)

† Ibid., t. 25, f. 1 and 5, *Penium margaritaceum* and *truncatum*.)

‡ Ibid., t. 27, f. 2, (*Clost. acerosum*;) t. 28, f. 4, (*Clost. Leibleinii*.)

§ Ehrenberg, 'Infusionsth.,' t. 6, f. viii, 4.) Ralfs, l. c., p. 174, t. 30, f. 1.

‖ In the middle of May, 1848, in specimens from the peat-holes of the Mooswald, near Freiburg, especially rich in Desmidiaceæ.

¶ The two pieces are mostly of unequal length.

cell becomes broken geniculately, though only at a very obtuse angle. The opening produced by the slight dehiscence of the outer cell-membrane, forming a cross-slit in one side, is immediately occupied by two thickened projections of an internal cell-membrane issuing out. These two thickened processes are the ends of two delicate-walled daughter-cells, meeting in the centre of the mother-cell, and which are probably formed by division of the contents of the mother-cell very shortly before the beginning of the conjugation. Since only these internal cells enter into the conjugation, we have here, not, as appears at first, a simple conjugation of two cells, but, strictly speaking, a conjugation of two pairs of cells; since, moreover, the two issuing processes, which unite with the two coming to meet them from the other side, are the *ends* of the two internal cells, *Closterium lineatum* affords the rare example of a *copulatio apicalis*. The individuals destined to conjugation lying near together, the thickened projections do not grow out into long processes, but apply themselves, in the form of everted lips, directly upon the corresponding parts of the other individual, or, if this has not yet pushed out its thickened processes, upon its closed external cell-wall. This process of the commencement of conjugation cannot be described better than by comparing it to the contact of four thickened firmly appressed lips in a kiss mouth to mouth. The thickened projections are originally transparent and almost colourless, since only a few green granules can be observed in them, often in distinctly circulating motion, entering at the back and retiring from the front into the interior of the cell; the green contents soon follow, however, in abundant quantity. The four protuberances next become so densely filled with green matter and pressed so closely together, that the coupling growth and anastomosis taking place during this crowding up cannot readily be traced, but it is clearly shown by the result. Sometimes the delicate membrane of the protuberance bursts under the pressure of the contents, so that the latter become diffused, or form an irregular accumulation between the two mother-individuals, which of course frustrates the formation of the spores. In normal development the whole mass of green contents enters in a short time into the two connecting canals, which swell up from the middle, where they are in contact, out, in opposite directions, into obovate or almost globular sacs, which wedge themselves in closely between the four legs or horns of the conjugated individuals. In each of these sacs the contents become balled into a globe, which becomes clothed with a cell-membrane, at first delicate and smooth, afterwards thick and granulated. In this way, therefore, two spores are formed, completely separate in their origin, which so closely fill up the delicate sac-like canals of union in which they are formed, that as they lie between the mother-individuals, they appear like free globules, but are persistently connected with the mother-cells by the empty and colourless lateral parts of the two closely approximated uniting-canals, which extend into the valve-like openings of two empty shells. These connecting pieces, formed from the inner membrane, are readily distinguished, by their want of colour, from the outer membrane or shell, which appears straw-coloured after the contents are emptied out. A not unfrequent abnormity affords a further proof of the origin of the two spores through conjugation of opposite, completely distinct pairs of cells; this is the occurrence of only one spore between two mother-individuals. In this case only two corresponding halves (or horns) of the mother-individuals become emptied, while the two others remain densely filled with green contents, which, in spite of the dehiscence of the outer cell-membrane, cannot flow out.

b. Conjugation in crossed (*decussate*) *position.*—This occurs in the entire group of forms allied to *Euastrum*, and also in many genera formerly united with *Desmidium*.

α. The halves of the dehiscent cells separate by an annular slit, the protruded internal membrane entering into the conjugation becomes very strongly developed. The spores become free by the disappearance of the enlarged saccate conjugation-cell; this also sets the halves of the old cell-membrane free, from which the internal membrane does not seem to be drawn out as in *Tetmemorus*. This case occurs in *Euastrum** and the genera intimately allied to, and difficultly separable from it, *Micrasterias*,† *Cosmarium*,‡ *Xanthidium*,§ *Staurastrum* (*Phycastrum*, K.)‖ The complete separation of the halves of the mother-cell membrane does not, however, seem to be constant, for Ralfs gives figures of the same genera, and even of the same species, as those above cited, which exhibit halves connected together at one side.¶

β. The halves of the dehiscent cells separate only at one side, in order to emit the connecting canal formed out of the internal membrane, not expanded into a sac; they do not become detached. The spores are formed either in the middle of the connecting canal (as in *Hyalotheca*,** *Bambusina*,†† and *Isthmosira* (*Sphærozosma*, Ralfs),‡‡ or in one of the halves, in a manner similar to that we have seen in *Zygnema* and most of the *Spirogyræ*, a case which is only known with certainty in *Didymoprium*§§ among the Desmidiaceæ, but perhaps occurs also in the genus *Desmidium*.‖‖

* Ralfs, l. c., t. 12, (*Euastr. oblongum;*) t. 14, f. 5, (*E. pectinatum*,) &c.

† Ibid., t. 6, f. 1, (*Micrasterias denticulata*, with the mace-like spores beset with forked spines; the conjugation itself is not represented.)

‡ Ibid., t. 16, f. i, (*Cosmar. Botrytis;*) f. 2. (*C. margaritiferum*) &c.; Nägeli has also described the conjugation in a species of this genus, his *C. rupestre*, (l. c., p. 118, t. vii, f. 6.)

§ Ibid., t. 18, (*Xanth. armatum.*)

‖ Ibid., t. 20, f. 5, (*St. dejectum;*) t. 21, f. 5, (*St. orbicnlare;*) t. 22, f. 3, (*St. hirsutum;*) f. 9, (*St. polymorphum;*) t. 23, f. 9, (*St. brachiatum*,) &c.

¶ *E. g.*, of *Cosmarium margaritiferum*, t. 33, f. 6; *Cosm. Broomei*, t. 33, f. 7; *Arthrodesmus Incus*, t. 20, f. 4.

** Ralfs, l. c., p. 53, t. 1.

†† Ibid., p. 59, t. 3, (as *Didymoprium Borreri.*)

‡‡ Ibid., p. 67, t. 6, f. 2 (*I. excavata;*) t. 32, f. 2, (*I. vertebrata.*)

§§ Ibid., p. 55, t. 2, (*Didym. Grevillii.*)

‖‖ Ibid., t. 4, where Ralfs represents spore-like globules in the interior

7. *The conjugation takes place with participation of the entire membrane; inside the double-cell thereby formed the internal membrane contracts into narrower limits, away from the wall of the expanded isthmus, forming a cruciform or quadrangular internal cell; inside the latter the contents contract again to form finally a globular spore.*—This case is required by the preceding as conclusion of the series. If we have placed *Staurocarpus* properly under 4, and if it be correct that, as Ralfs* remarks, in passing, in the description of the conjugation of *Telmemorus,* there exists a species of *Staurocarpus* in which a globular spore is formed inside the quadrangular cell by further contraction of the contents, this case does really occur.

B. CONJUGATION OF DISSIMILAR CELLS.—I know of no other cases to place in this entire second section, but the conjugation of *Vaucheria* asserted by Nägeli,† which case, however, although I cannot but confirm Nägeli's observations, is not yet placed beyond doubt in my mind. A certain reciprocal action of the slender hook-shaped sterile branchlets or horns as they are called (the anthers of Vaucher), and the thick inflated lateral branchlets which produce the spore in the extremity, cannot well be denied. Even Vaucher‡ described the application of the former upon the latter, and figured it in *Vaucheria sessilis;* Hassall§ observed that in those species in which the spore-forming branchlets emerge in considerable numbers from the base of a simple horn, as in *Vaucheria geminata,* the spore-forming branchlets, *vice versâ,* apply themselves upon the horn, and subsequently remove again and curve backwards. According to Nägeli's and my own observations on *Vaucheria*

of the cells of an unconjugated piece of *Desmidium Swartzii.* Might another filament have been connected with this, and again detached after being emptied?

* L. c., p. 146.

† See 'Algensyst.,' p. 175, t. iv., f. 21, 22.

‡ 'Hist. des Conferves d'Eau Douce,' (1803,) p. 17, t. ii, f. 7.

§ Hassall, l. c., p. 49, t. 3, f. 1.

sessilis, after the separation of the horn from the spore, the former appears open at the point, and a considerable space, doubtless shut off as a separate end-cell before the separation, empty; the spore is at this time likewise surmounted by a more or less distinct tube, empty and open at the summit, which undoubtedly is the open end of the mother-cell of the spore. The open end of the emptied end-cell of the horn on one side, the open end of the mother-cell of the spore on the other, together with the fact that the two were previously connected, certainly render it very probable that this connection is a real conjugation, that, therefore, the contents of the end-cell of the horn are united with those of the mother-cell of the spore to form the spore itself. The application of the horn upon the spore-bearing branch ought then to take place *before* the formation of the spore, on which point my observations are deficient, but which is in agreement with Nägeli, figure 21.* However, on the one hand, the circumstance is puzzling that many species seem to possess no trace of the said open tube surmounting the spore,† while other species exhibit open tubes in the spore-branchlets with no horns corresponding to them, as, for instance, *V. polysperma,* Hassall,‡ with very numerous, linearly arranged spores, but only very few

* See, on this point, Karsten on '*Conferva fontinalis,* L.,' in the 'Botanische Zeitung,' 1852, p. 89, *et seq.*, pl. 1, wherein he describes the conjugation in all its stages.—A. H.

† Thus, for example, in *Vaucheria terrestris* and *hamata,* in which, at the same time, in spite of the strange position of the spore on the back of the horn, an union of the inrolled point of the horn with the spore does occur, as is represented very beautifully, and even with emptying of the end-cell of the horn, by Thuret, ('Sur les Org. Locomot. des Spores des Algues,' 'Ann. des Sc. nat.,' 2d ser., vol. xix, t. 15, f. 49, (1843,) in a form doubtless belonging to *V. hamata.* In *V. geminata* the little tube above the spore is likewise wanting, but Nägeli has seen a scar on the summit of the spore, which indicates the previous union with the horn, and indeed, according to Hassall's observations, not with the point but with the side of the horn. The form of the horn in *V. cruciata,* (Vauch., l. c., t. ii, f. 6,) nearly allied to *V. geminata,* is interesting, since two little side horns issue from the principal horn, from their position evidently destined to union with the two spores.

‡ L. c., t. 4, f. 6. I have observed this species also near Freiburg.

horns, which, moreover, as in *Vauch. sessilis*, exhibit an empty open end-cell at the period of maturation of the spores. The genus *Vaucheria,* which has already so much occupied naturalists, still requires, therefore, further and more minute investigations in reference to the formation of its reproductive organs. In conclusion, I will mention certain other cases which bear some resemblance to the phenomena of conjugation, and have been, in fact, really regarded as such. In *Saprolegnia,* which exhibits so much likeness to *Vaucheria* in morphological respects, we find a structure similar to the horns of *Vaucheria.* At the period of the formation of the resting-spores, between the lateral branches swelling up into pear-shaped spore-cases, appear frequently, but not constantly, slender vermiform branchlets, which, when they reach the spore-cases, apply themselves firmly upon these, and indeed sometimes twine round them in irregular coils; no actual anastomosis takes place however. *Coleochæte pulvinata* (see page 161) exhibits a phenomenon which may be compared with this. The sporangium of this species originates by the expansion of the last or last but one cell of a filament, and is, in itself, a simple cell, which, however, acquires a most complete cellular envelope through the close application upon it of cellular branchlets, partly arising from the cell immediately preceding it, partly reach over like bridges from branches situated lower down or neighbouring filaments. The direction, differing from the ordinary erect growth, in which the branches combining with the sporangium come in from all sides, sometimes horizontally, and sometimes even descending, shows, although there may not be so intimate a connection and so direct a co-operation for the formation of the spore as in conjugation, that there is, nevertheless, here, a similar reciprocity of attraction and seeking-out of the parts, as well as a material assistance in the spore-formation, through the connection of the mother-cell of the spore with the numerous smaller cells forming the envelope, doubtless effected through the process of endosmose.

Distant as the physiological importance of these phenomena of application just described stands, from the application of the pollen-tube on the embryo-sac, and through the medium of this, on the germinal vesicle, connected with the fertilisation of the Phanerogamia, the resemblance between the processes of the two phenomena is unmistakeable.

Some of the Diatomaceæ afford another case, to be placed here as it were in an appendix, which perhaps might be regarded as an instance of arrested conjugation. While I have seen in many genera of this family an actual conjugation of completely separate cells (p. 286), in the group of the *Melosireæ* the large reproductive-cell which commences the new series of generations (the sporangium,* as it is termed), is formed out of the contents of a single grown-out cell, the shell or membrane of which, dividing in the middle, separates to allow space for the expansion of the newly-formed, more vigorous primary-cell. Thwaites,† who describes this process in several species, thinks that it may be brought into agreement with the conjugation occurring in other groups of the same family, by assuming the division of the contents of the mother-cell into two portions previously to the formation of the new cell, these portions, instead of developing into separate cells, as in the vegetative increase by division, combining together again immediately in order to produce the reproductive-cell. Although this hypothesis is not yet substantiated by direct observation, it deserves attention, since it opens a common point of view for the phenomena of reproduc-

* See p. 141, note.

† See Thwaites, 'Further Obs. on Diatomaceæ,' 'Annals of Nat. Hist.,' sec. ser., vol. i, p. 161, t. xi, xii, (1848.) The reproductive cell is formed either between the halves of an isolated cell, separating from them in the subsequent development, (*Cyclotella*, t. xi, f. D,) or between the halves of a cell which is a link of a filament, sometimes parallel and becoming developed in connection with the old filament, (*Melosira*, t. xi, f. A, C, and *Orthrosira*, t. xii, f. E,) sometimes pushing aside the halves of the mother-cell by secretion of gelatinous matter, and developing at right angles to the old filament, (*Aulocosira*, t. xi, f. B.)

tion of the Diatomaceæ, and in itself presents nothing impossible. The transition from a still incomplete division to conjugation, is quite as conceivable as the advance from a first incomplete division to a second, such as we have become acquainted with in the quartering of cells (p. 254). I will mention one more case here, which can scarcely be explained otherwise than as a reunion of two cells which have begun to divide, namely, the not very rare abnormal occurrence of division of individuals into three parts by two constrictions, in *Euastrum* and allied Desmidiaceæ. Nägeli has figured such a specimen of *Euastrum* (*Cosmarium*) *Meneghinii*, Bréb.* The formation of the spores of *Spirogyra mirabilis*† might be caused by a process similar to that in *Melosira*, if that species really, as Hassall states, forms spores in all the cells of filaments which do not enter into conjugation with others; this would be the more conceivable in *Spirogyra*, since the external division of the cells is preceded in this genus by the division of a nucleus, and since the division is gradual.

Lastly, the supposed conjugation of the contents of two adjacent cells in the formation of the spores of *Œdogonium*, and of *Bulbochæte*, with which it has a very peculiar relationship, deserves an explanation. Decaisne‡ and Hassall§ have noticed the strange circumstance, that in the said two genera, the cell which immediately precedes the swollen mother-cell of the spore, has little or no green contents. Hassall thinks we may deduce from this a passage of the contents of the lower cell into the upper, and hence compares the process of spore-formation of *Œdogonium* with that of the *Spirogyræ* of the section *Rhynchonema*, with the distinction, however,

* Nägeli, 'Einz. Algen.,' t. vii, f. 7, *b*, (as *E. crenulatum*, Ehrenb.?)
† *Zygnema mirabile*, Hassall, l. c., p. 156, t. 35.
‡ 'Essai sur une Classification des Algues,' (1842,) p. 39. The figure given at t. 14, f. 5, belongs to *Bulbochæte sphærocarpa*, A. Br., (*setigera*, Auct., ex. p.)
§ L. c., pp. 180—194, t. 50—53, (*Œdogonium*; t. 54, (*Bulbochæte*.)

that the contents of the one cell do not make their way into the next cell by a lateral connecting canal, as in the said *Spirogyræ*, but probably through an opening in the partition separating the two cells. Leon le Clerc* has already correctly objected to the idea of such a conjugation of the contents of the two adjacent cells, in the *Œdogonia*, that we not unfrequently find the lower as well as the upper neighbour-cell of the sporiferous cell filled with unattenuated green contents, and that sometimes two, and even three and four cells containing spores follow in immediate succession. These statements are perfectly accurate, and Hassall's endeavours, partly to set them aside, partly to turn them so that they shall not oppose his theory, are unsuccessful. In the first place, as regards the occurrence of several sporiferous cells in succession, it must be remarked that two adjacent spore-cells are met with more or less frequently in all species, and I have often observed three to four in succession in *Œdogonium apophysatum* and *Landsboroughii*.† If there were only two, it might still be asserted that one had attracted the contents of the cell next below it, the other the contents of the cell next above it, in order to form the spore out of coupled contents; but when three or four sporiferous cells follow in succession, such a coupling is no longer conceivable. In reference to the contents of that cell which precedes a single, or several successive spore mother-cells, it must be noticed of *Œdogonium*, that these are certainly ordinarily, but not unvariably, poorer in solid constituents, particularly in chlorophyll, than those of other sterile cells, but at the same time are never wholly devoid of colour or of granules, as, on the contrary, is generally the case in *Bulbochæte*. A similar,

* 'Sur la Fructification du Genre *Prolifera* de Vaucher,' 'Mém. du Muséum,' iii, (1817,) p. 462. The old name of *Prolifera* was founded on an error, and was therefore changed to *Œdogonium* by Link.

† *Œdogonium Landsboroughii*, (Hassall,) is the species described and figured, (t. 23, f. 1,) by Le Clerc, as *Prolifera rivularis*. Le Clerc represents four adjacent sporiferous cells in *Œd. Rothii* also, l. c., f. 8.

only less striking alternation, of more richly filled and poorer, darker and lighter cells, occurs also in the sterile or merely gonidium-bearing filaments of most of the *Œdogonia ;* in those species, moreover, which have the formation of microgonidia mentioned above,* the longer cell which precedes every group of the short cells in which the small swarmers are formed, is found poor in contents, like the ante-cell of the mother-cell of the spore. None of these phenomena can be explained by a subsequent wandering of the cell-contents, produced by union of previously separate cells, but are all caused by the distribution of the contents in the very formation of the cells. For in *Œdogonium* occur secondary processes of cell-formation in the filaments, possessing the peculiarity that the individual cells of the filament divide, not into like, but more or less strikingly unlike cells, and in such a way that the upper of the two cells produced by division is the shorter and richer in contents, the lower the longer and poorer in contents. The difference of the two sister-cells is slighter in filaments or fragments of filaments remaining sterile, as also in those in which merely macrogonidia are to be formed, and it is mostly very striking, on the other hand, where the formation of spores (or microgonidia) is to take place. The anterior shorter cell, filled with more concentrated contents, becomes, in this case, the mother-cell of the spore. This process of cell-formation, division into unlike halves, is frequently repeated in the lower cell, this again dividing into a shorter, fuller, upper, and a longer, lower cell, &c. Thus, in sporiferous filaments, a second, third, and fourth spore mother-cell may be added successively to the first. The same is exhibited in the formation of microgonidia, wherein I have seen the number of short mother-cells of

* *Œdogonium echinospermum* and *apophysatum*. See p. 141. The numerous, closely superstratified little cells, which Le Clerc, l. c., f. 9, figures between the larger cells, in a filament supposed to belong to *Prolifera rivularis*, (*Œdogon. Landsboroughii*,) and in the explanation of the plate takes for spiral-filaments, are doubtless emptied mother-cells of microgonidia. (See Thuret.)

microgonidia, added on to one another in this way, amount to six or seven, which indicates a five- to six-fold repetition of the division in the descending order. The formation of the globular or ellipsoidal expanding mother-cell of the spore of *Bulbochæte* is peculiar, and deviates somewhat from the similar process in *Œdogonium*. The spore-bearing cell (the sporangium) usually presents itself in this genus as a branch at the upper margin of a stem-cell, and mostly as the first (more rarely the second) cell of the branch, surmounted by a small bristle-bearing cell, or even by two cells, one narrowly tubular, and filled sparingly with green contents, on which the second, hyaline and bristle-bearing, is seated like a little lid. The origin of the branch becoming developed into a sporangium, takes place, as in *Cladophora*, through formation of a bagging out process at the upper margin of the stem-cell. Into this protruded sac the densely-fluid, green contents of the stem-cell (containing starch-granules) gradually travel, and this in two portions. In the first place merely the lower half of the stem-cell loses its coloured contents, and then it is shut off from the upper, still green half, by a delicate horizontal partition; soon, however, since the protruded sac, not yet shut off from the stem-cell, continues to grow and to expand toward a globular form, the green contents travel out of the upper half of the stem-cell, into the sac-like branch, after which the partition is formed between this and the stem-cell. The stem-cell bearing the sporangium often appears perfectly hyaline after this process, and always divided in the middle by a horizontal septum, a division which never occurs in the other stem-cells. Only as an exception have I seen stem-cells more or less densely filled with green contents, notwithstanding that they bore a sporangium at the upper margin; the division of the cell did not exist in this case. The formation of the one to two little cells beside the bristle, at the tip of the sporangium, does not take place until after the protruded sac is shut off from the stem-cell. From this sketch of the process it will be clear, that in *Bulbochæte*, as in *Œdogonium*, a concentration of the formative contents, at the cost of the sterile sister-cell, is connected with the production of the cell destined to form a spore, but that there is not any union of the contents of two previously separate cells. These cases, therefore, are allied, not so much to the phenomena of conjugation, as to the phenomena of division into cells of unequal power and of different destination, mentioned under B* (p. 250).

CONCLUDING REFLECTIONS.

Thus have we completed our design of subjecting to minute inspection, in the example of the development of the Vegetable Organism, the phenomenon of Rejuvenescence, a phenomenon profoundly connected with the essence of natural life, and lying at the base of all progressive movement of life and development, with its multifariously complicated ascending and descending vibrations, in the largest as in the smallest circle of Nature, since this movement is sustained in every case only by renovation. We have examined it in the *Formation of Sprouts*, by which the individual vegetable stock is expanded into the trunk of a family, which, in essential or inessential combination, distributes the individual functions amongst its members; we have traced it in the sprout itself, in the formation of its graduated and articulated interlinked structure, in the great tide of the graduated metamorphosis, as in the individual waves of this, the *Leaves;* finally, we have recognized again in the smallest sphere of formation, in which the vegetable strives to establish its everywhere only imperfectly attained individuality, in *Cell-formation*, with which every cycle of development commences, and by the divided or undivided, homogeneous or heterogeneous, combined or free renovation of which, the plant carries to fulfilment the multiplicity of structure of all its organs, and indeed lays the foundation for the vital continuation of the species beyond the limit of the old structure, in renewed construction of the organism. The examination of Cell-formation leads back, therefore, in all the wider circles of Rejuvenescence, into the plastic life of the plant, nay, it leads us even beyond the circle of the individual development and the related close family union in the sprouting vegetable stock, to the true reproduction of plants, which presents itself, in connection with the less perfect renovations of Cell-formation in the preceding circles of development, as the most decided and freest reconstruction of the cell, and at the same time as the recommencement dating itself furthest back, the most complete Rejuvenescence. As in the formation of the individual, each new stage arises with a new section of Cell-formation, so also does the transition of one individual developmental process to another; and thereby the intercalation of the individual life in the compound life of the species, in every case, takes place through a new impulse in the cell-formation. Consequently Cell-formation is not merely the commencement of, and the means to, the production of subordinate tissues; it is, at the same time, through the law of alternation of generations, subordination and serial arrangement, prevailing in its progressive renovation, the commencement of every comprehensive complication in the organism of the plant, of the single organ as of the special stage in the series of organs, of the single lines of development or the subordinate axes of the vegetable stock, as of the individuals becoming developed into separate stocks. Thus the consideration of the Cell-formation in the Rejuvenescence of the Individual is most intimately connected with that of the Rejuvenescence of the Species; indeed so intimately that the boundary between the two is often difficult to draw, as we have seen in the foregoing pages, at the lowest stage of the Vegetable Kingdom, in a portion of what are termed Unicellular plants, plants with generations of vegetative cells separating from each other (p. 125, &c.) And, just as we see here, at the lowest stage, the cell-division (p. 233) elsewhere belonging to the development of the combined organism, appearing as a mode of reproduction, so also in the higher groups of the Vegetable Kingdom, we see Sprout-formation extricated in most varied ways from the subordinate relation to the "whole" of the vegetable stock, and serving for the formation of independent individuals.*

The interweaving of the reproduction and the individual development is exhibited in a very strange manner in that division of the Vegetable Kingdom in which a decided contrast of sexes first appears,† namely, plants of the Moss and Fern kind, in which the fertilization,—which we have been used, from its mode of occurrence in the whole realm of the Phanerogamia, as well as in the Animal Kingdom, to imagine connected with the origin of new individuals,—does not coincide with the commencement of the individual cycle of development, but on the contrary falls in the middle of this, becoming the means of transition from a lower to a higher stage of the metamorphosis. In both cases it is a single cell in which the subsequent development is called forth through the influence of the male sex, but in one case it is the primary cell of the entire generative cycle, *i. e.* of all the cells which, by their connected succession, represent the individual; in the other case it is a cell occurring within the cycle itself, and merely forming the beginning of a new segment of it. In the Phanerogamia it is the germ-cell,‡ formed, after the entire accomplishment of the metamorphosis, in the uppermost central cell of the seed-sprout, (the embryo-sac of the ovule,) which receives the impregnation by means of the advance of the pollen-tube up to the embryo-sac; with it the entire individual

* Reproduction by propagula, (in the Mosses and Liverworts,) by bulbels, runners, tubers, &c., see p. 40.

† (This expression, as well as various other references of the same nature, must be checked by comparison with subsequent researches. Thuret, Nägeli, Itzigsohn, Tulasne, Berkeley, and Broome, have pointed out conditions indicating that sexuality is universal.—A. H.)

‡ See p. 276.

development recommences. In the Mosses and Ferns it is the central cell of the archegonium,* (a sproutlet which may be compared with the nucleus of the ovule,) which is impregnated, in a manner not yet accurately known, through the spermatozoids formed in the antheridia; the development of this, however, is not a recommencement of the entire cycle, but only an advance to a new and higher stage of the metamorphosis, which, unfolding in connection with the pre-existing preparatory structure, carries over the individual life only after more or less complex intermediate stages of formation, to the production of the true reproductive cells (spores), with which, and without further impregnation, the new cycle of development commences. The point of transition marked by the occurrence of impregnation, is, again, different in the Ferns and Mosses. In the Mosses, the transition from the Algoid prothallium to the leaf-forming stem takes place before the impregnation, which causes only the development of the spore-forming capsule; in the Ferns, on the contrary, the preparatory structure does not go beyond the leafless prothallium, and the advance to the leaf-forming stem depends upon the impregnation. This mode of viewing the case, very strange as the introduction of the impregnation into the midst of the cycle of the individual development may be, appears to me more in accordance with nature, to interrupt less the natural connection and to correspond better with the graduated course of the metamorphosis, than that given by the discoverer of the archegonia of the Ferns,† according to which the thalloid product of germination of the spore of the Ferns is compared, as the bearer of the impregnation organs, to the flower of the Phanerogamia, while the spore from which it is developed is termed a

* See Gottsche, on the 'Fructification of the Jungermanniæ geocalyceæ,' 'Nov. Act.,' xxi, ii, 445, t. 30, f. 8. The bicellular condition of the endogonium of *Calypogeia Trichomanes* there represented is certainly preceded by a unicellular stage.

† Leszczyc-Suminski, 'Zur Entwickl. der Farrnkräuter,' Berlin, 1848.

flower-bud detached from the mother-plant. On such a theory, the new individual cycle of development would not begin with the spore, but with the central cell at the base of the archegonium.* Applying this view to the Moss, the first (lowest) stage in the cycle of its individual life would be the formation of the sporangium, the second stage that of the confervoid prothallium, the third that of the leafy stem, which would finally bear, as the term of the development, the impregnation-organs, antheridia and archegonia. The more minute investigation of the still imperfectly ascertained processes of impregnation in the Rhizocarpeæ and Lycopodiaceæ, as also those of the Gymnosperms, (Cycadeæ and Coniferæ,) aberrant among the Phanerogamia, and perhaps having an affinity to the higher Cryptogamia, will certainly enable us to place the strange conditions in the reproduction of the Mosses and Ferns in clearer connection with the reproduction of the Phanerogamia, while the investigation of the Characeæ and Florideæ promises a new point of attachment for the lower department of the Cryptogamia.†

That an actual impregnation does occur in the Mosses and Ferns is indicated not merely by the well-known experience of bryologists on the dependence of the fructification of diœcious Mosses on the social growth of the two sexes,‡ but also the occurrence of hybrids, which were known in the Ferns even before the discovery of the

* According to Suminski's here certainly incorrect representation, the embryo of the new individual is formed in the central cell of the archegonium, through the penetration of the tail of a spermatozoid into it.

† (The above was printed in 1850; the speculation then put forth has been realized to an extent scarcely to have been expected so soon; the researches of Mettenius, Nägeli, and above all Hofmeister, have carried on this subject almost to completion in its main features in the higher Cryptogamia; the lower Cryptogamia, (Thallophytes,) still require extensive investigation. For the facts, as also the literature, see the 'Report on the Reproduction of the Higher Cryptogamia,' by the present translator, in the 'Annals of Nat. Hist., 2 ser., vol. ix, p. 441.—A. H.)

‡ See Schimper, 'Recherch. sur les Mousses,' p. 55.

impregnation organs,* and have lately been observed in the Mosses.† I mention this occurrence of hybrids among the Ferns and Mosses, in order to adjoin some remarks leading us back to our subject. If hybrids are formed in Mosses and Ferns, this takes place in a preparatory structure which belongs to the mother-plant; the individual entering into the state of hybridation, (according to the ordinary acceptation of the term,) becomes composed, consequently, of one part which is mother-plant, and one part which is hybrid. The hybrid must develope, as it were, grafted on the mother-plant. Not until the second generation, that developed from the spores of the hybrid, can the preparatory structure assume the hybrid nature, and this, according to the analogy of most Phanerogamous hybrids, might be sterile by itself, and only in case of impregnation from one or other parent species, develope to an ulterior structure recurring more or less to this. The prothallia of the

* The discovery of the antheridia of the Ferns was made by Nägeli in the year 1842, and published in 1844, ('Zeitschr. fur Wiss. Bot.,' heft 1, p. 168;) the above-mentioned treatise of Suminski, in which the archegonia were first described, dates from 1848; the first observation of a hybrid fern was published by Martens, in 'Bulletin de l'Acad. Roy.' de Bruxelles, 1837. The hybrid there mentioned of *Gymnogramma* (*Ceropteris*) *chrysophylla* and *calomelana*, subsequently named *G. Martensii*, was soon followed by a second between *G. chrysophylla* and *distans*, (*G. Massoni*, Auct.,) described by Bernhardi in Otto and Dietrich's 'Gartenzeitung,' 1840, p. 249; Regel has enumerated several more hybrids from the same genus in the 32d No. of the 'Botanische Zeitung,' for 1843. I myself found, in the year 1834, in a mountain valley near Baden, among *Aspidium Filix mas*, and *A. spinulosum*, (the normal form together with the variety *dilatata*,) several rhizomes, all within a small space, of a fern which stood about mid-way between the two species named, and probably was to be regarded as a hybrid product of them. I called it *Aspidium remotum*, and formerly regarded it, doubtfully, as a variety of *A. rigidum*, which it resembled, not only in habit, but in degree of formation and mode of decrease of the pinnæ. I have never since been able to find it again, either in the original station or anywhere else in the Black Forest, but it has maintained its existence in the Botanic Garden of Carlsruhe, whence it has passed into the gardens of Freiburg and Leipsic. See Döll, 'Rhein. Flora,' p. 16.

† See Bayrhoffer, 'Uebersicht der Moose, Lebermoose und Flechten des Taunus,' ('Jahrbuch. des Vereins f. Naturkunde im Herzogth. Nassau,' 5 heft, 1849,) where two supposed hybrids are mentioned, namely, 1, of *Physcomitrium fasciculare*, and 2, of *Physcomitrium pyriforme*, with *Funaria hygrometrica*.

Ferns are so alike, and at the same time so transient, that it would scarcely be possible to institute profitable observations; so much the more is investigation of the hybrids of the Mosses, which, when once attention is directed to them, will certainly be found in greater numbers, to be recommended to bryologists. The two hybrid Mosses observed by Bayrhoffer, seem, from his account, actually to have possessed the characters of the mother-plants, (*Physcomitrium fasciculare* and *pyriforme*,) in respect to the vegetative organs, while the fruit is stated to have exhibited, especially in the structure of the peristome, a distinct approximation to the character of the supposed father, *Funaria hygrometrica*. From the occurrence of numerous archegonia upon one and the same moss-plant, we might expect even to find, when the hybrid impregnation only affected particular of them while others were fertilized by the proper species, two kinds of fruit perfected on the same "stock," normal and hybrid fruits.

Supposing these views to be actually true of the hybrids of the Mosses and Ferns, it might afford us a further confirmation of the hypothesis, that the individual cycle of development of these plants does not begin with the spore, but with the central cell of the archegonium, which is called into life by impregnation. If, on the other hand, we keep to the old conception of the commencement of the individual with the spore, these strange processes will appear merely as a further proof of the intimate connection and interlacement of the individual development and reproduction, in which respect they are of especial interest here, particularly when we place them in relation with the cases already mentioned,* which indicate the possibility of the occurrence of aberrations ordinarily connected with the reproduction, in the midst of the individual development, (in the wider or narrower sense!) in the higher divisions of the Vegetable Kingdom.

It is well-known that those very varieties of plants which are most important and interesting, those in which

* See page 24.

the most considerable deviations from the normal character of species occur, are not produced on the individual stock, to whatever influences of nature and art this may be exposed, but are connected with the reproduction in their origin, since they grow up, as it were accidentally, from seeds. Among these are many varieties very striking in reference to the degree of division of the leaves, *e. g.* simple-leaved forms of plants which, in the parent-form, have ternate or pinnate leaves (*Fragaria vesca monophylla*,* *Fraxinus excelsior simplicifolia*),† and *vice versâ*, divided-leaved modifications of plants, with normally undivided leaves or leaflets (*Alnus glutinosa laciniosa*, *Betula alba laciniata* v. *dalecarlica*),‡ *Corylus Avellana laciniata*, *Cytisus Laburnum quercifolius*, *Vitis vinifera laciniosa*;§ also unarmed varieties of normally spinous plants (*Robinia Pseudoacacia inermis*); ‖ varieties in reference to the colour of the leaves (*Fagus sylvatica sanguinea*,¶ *Corylus tubulosa*

* Raised by Duchesne, in the year 1761, from seeds of the common *Fragaria vesca*, and usually returning, when the seeds are sown, to the parent-form with ternate leaves. Duchesne, 'Hist. des Fraisiers,' p. 124; Godron, 'De l'Espèce et des Races,' p. 36.

† *Fr. simplicifolia*, W., (*heterophylla*, Vahl.) In De Candolle's 'Prodromus,' (viii, p. 276,) it is mentioned as a peculiar species, occurring in England and Ireland, while Sprengel, ('Syst. Veget.,' i, 97,) places its nativity in North America! De Candolle, to establish the specific distinction, gives, in addition to the form of the leaf, certain characters derived from the size and form of the fruit, which, however, I am compelled to regard as an unimportant individuality of De Candolle's specimens, since the trees of the simple-leaved ash, cultivated in the Botanic Garden of Carlsruhe, agree exactly with the common ash, (*F. excelsior*,) in their fruit. Persoon, in reference to the origin of this variety, says expressly, ('Syn.,' ii, 604,) "e seminibus Fraxini elatioris vulgaris ortam vidi." Spenner found, on the Schienberg, near Freiburg, a completely analogous variety of *Rubus Idæus*, with leaves resembling those of *R. arcticus*.

‡ Both occur, probably only isolated, in Sweden and Lapland. In gardens they are increased by cuttings, and when sown probably recur to the entire-leaved parent forms. The other examples named are known only as garden-plants.

§ The parsley-vine, as it is called. See Babo and Metzger, 'Wein u. Tafeltrauben,' p. 33, h. ii, 10.

‖ A single specimen of this was obtained by Descemet from a sowing in 1803, and it is now generally diffused. Its seeds furnish the spiny parent-form again. (See Chevreul, 'Considérations gén. sur les Variations,' &c. 'Ann. des Sc. nat.,' 3me sér., vi, 157, 1846; Trans. in 'Journ. Hort. Society,' vol. vi, p. 61, 1851.)

¶ The copper-beech universally diffused in gardens is derived from a *atropurpurea*), colour and doubling of the flower (*Tulipa, Dianthus, Primula, Dahlia*, &c.); as also, finally, the numerous varieties, chiefly marked by the condition of the fruit, which we have among our cultivated orchard and other fruits. The origin of the varieties mentioned here does not depend so much upon an alteration gradually insinuating itself into the external conditions of existence, as upon a development, under favorable conditions, of the multiformity possible within the limits of a certain type, which is implied especially in the fact that very different varieties may arise from one and the same sowing, even from the seeds of one and the same fruit, and this without influence of impregnation from a foreign source, and under equal external circumstances.* The development of this multiplicity takes place ordinarily, as stated, by means of reproduction, and it may disappear in the same process; the new varieties grow up from seed, and may in like manner return to the parent-form by sowing. But sometimes a similar production and a similar retrogression of the variety takes place by means

forest near Sondershausen, in Thuringia; it is propagated by cuttings, since when sown it mostly returns to the common green beech. See Bechstein, 'Forstbot.,' f. 1, p. 229. Ibid., (267,) mention is made of a copper oak, (*Quercus pedunculata sanguinea*,) of which a single tree is said to exist in the Lauchner Forest, near Gotha.

* According to Van Mons, this sometimes goes so far that a peculiar variety springs from each single seed, *e. g.*, from the ten seeds of a pear, were developed an equal number of new sorts of pear. Cultivation of course has an influence upon the production of new varieties, yet not on the individuals directly exposed to its effects, but on their progeny. In most cases it is impossible to demonstrate a definite relation of the influence of cultivation upon the qualities of the varieties thence arising; it appears rather, on the whole, as if the unusual conditions, favorable to a luxuriant state of development, afforded by cultivation, awakened in the plant the inward impulse to the display of all those variations possible within the more or less narrowly circumscribed limits of the species. According to the experience of gardeners, in particular of the celebrated Belgian orchard-fruit grower, Van Mons, this impulse is only gradually awakened in the wild plant subjected to cultivation, often requiring several generations, until it has attained its maximum and is finally extinguished in the formation of constant varieties. At the same time, the fact of experience is remarkable, that improved varieties propagated by cuttings acquire so much the more inclination to return to the parent form the longer they are propagated in this way. (See Godron, 'De l'Espèce et des Races,' p. 83, where also are enumerated the treatises of Van Mons not within my reach here.)

of mere vegetative development, so that even the individual vegetative "stock" may comprehend several varieties within its limits at successive points in time, or at collateral points of space. Here refer many well-known facts, as, for example, that the wild Hepatica (*H. nobilis*) with its lovely blue six-leaved flowers, if transplanted from the shady mountain-groves into a garden, usually produces, even in the next year, double and in addition mostly red flowers; in like manner that the Periwinkle (*Vinca minor*) often acquires white or brownish-violet flowers in place of its blue ones, in gardens. If we sum up mentally the successive annual products, such stocks striking into variety appear composed of two modifications of the species; the Hepatica, for instance, the annual Rejuvenescence of which is effected by direct continuation of the main axis,* looked at in this way, represents a stem bearing simple blue flowers at its lower parts, and double red ones above. But that which we only see here by the mental combination of what is separate in time, meets us in actually united in other cases, in which the formation or retrogression of the variety only occurs on particular sprouts of a branched stock, or in which several of the modifications in which the species may appear, present themselves so distributed on different parts of one and the same stock, that it is impossible to determine to which modification the stock originally belonged. Cases of both kinds are known in Vines and Currants, which bear two kinds of bunches of fruit,† of Melons with two kinds of fruit,‡ of Rose "stocks" which bear two kinds of flower,§ &c. I have observed cases of the first kind in

* See p. 54.

† See Metzger, 'Landw. Pflanzenk.,' ii, 913 and 917, where it is stated of the red *Traminer* that it often brings forth white bunches when old, and of *Klavner*, (Burgundy,) that it not unfrequently bears blue and red bunches on the same "stock;" I have often seen isolated red-berried bunches on "stocks" of *Ribes rubrum* with white berries.

‡ See Sageret, 'Ann. des Sc. nat.,' t. viii, 309, (1826.)

§ On the variety of *Rosa Eglanteria*, with flame-red flowers, (*R. bicolor*, the Laburnum with incised leaflets (*Cytisus Laburnum quercifolius*), as also in the more or less incised variety of the Beech (*Fagus sylvatica asplenifolia*) in the Carlsruhe Botanic Garden, the ordinary parent-form reappearing with the perfectly marked variety, on isolated sprouts of these plants. The same phenomenon has also been observed in the Parsley Vine.* The strangest cases belonging here are not those in which the modifications are combined with the sprouts, as subordinate individuals of the "stock," but those where the process of separation of the varieties extends only to some limited part of the organs, or even to single groups of cells, and perhaps even to the individual cell, as exhibited by the phenomenon so frequently occurring among cultivated plants, of plants with variegated leaves (*e. g.* in Cabbages,†) divided irregularly into several colours, striped or dappled flowers (in Tulips, Pinks, Roses)‡ and fruits (in Gourds, Apples, Grapes, &c.)§ One of the most beautiful examples of this kind is offered by *Mirabilis Jalappa.* The three varieties, with deep-red, nankin-yellow, and white flowers, are not unfrequently found two or even all three united on the same "individual," in such a manner that there are stocks with the flowers striped with: 1. red and yellow, 2. red and white, 3. yellow and white, and 4. red, yellow, and white; and not unfrequently, also, isolated single-coloured flowers present themselves on the same stock, these being

Jacq.,) I have often seen isolated shoots bearing pure sulphur-yellow flowers, (*R. lutea*, Mill.,) sometimes even flowers divided into the two colours.

* See Babo and Metzger, l. c., p. 35, where the authors state that they have detected, on vigorous stocks of this variety, isolated branches with leaves which were merely five-parted and undistinguishable from the leaves of the white *Gutedel.*

† Here belongs what is called the *federkohl,* a variegated winter cabbage (*Brassica oleracea acephala,*) which represents a mixture of the green and red cabbages, (Metzger, 'Kohlarten,' 20.)

‡ The striped rose, frequent in gardens, is a *Rosa gallica,* with white, red-striped flowers, on which sometimes occur half or even entirely red flowers.

§ Thus in the two-coloured Morillon, (*Morillon panaché.*) See Babo and Metzger, 'Wein. and Tafeltrauben,' 169, heft. ix, t. 4.

of three kinds, red, yellow, and white, in the fourth case.

Analogous cases of heterogeneous composition of the vegetable stock occur in *hybrids* of Phanerogamous plants, through return to the parent form on the hybrid stock itself, whereby it may happen that two specifically different species may present themselves united, together with the hybrid, upon the same stock. This, however, is a far rarer phenomenon than the occurrence of several varieties on the stock, for hybrids, as the celebrated experiments of Kölreuter* showed, ordinarily return by way of reproduction, to one or other parent species, after having been impregnated by this for several generations. The only certainly known instance of the recurrence of a hybrid plant to the parent species on the stock itself, has been found recently in the generally diffused garden intermediate species, between *Cytisus Laburnum* and *C. purpureus* (*C. Laburno-purpureus*, Walpers,† *C. Adami*, Poiret),‡ the hybrid nature of which, in spite of the contrary assertions of Loudon§ and Reissek,‖ cannot well be

* See his preliminary reports ('Vorlaufige Nachrichten) of experiments relating to the sexes of plants, particularly the third series, (1766,) p. 51, where is described the "complete conversion of one natural species of plant into another," namely *Nicotiana rustica* into *N. paniculata*. The first impregnation of *N. rustica* with *N. paniculata* produced a hybrid, which assumed completely the character of the parent plant in the "fourth ascending step," *i. c.*, after three transitional generations produced by repeated impregnation with *N. paniculata*.

NICOTIANA RUSTICA ♀ }
paniculata ♂ } ♀ }
paniculata ♂ } ♀ }
paniculata ♂ } ♀ }
paniculata ♂ } ♀ }
paniculata ♂ } N. PANICULATA.

† 'Repertorium,' i, 634, (1842,) where two figures of it are cited. (The 'Botanist,' i, t. 7. 'Bot. Register,' t. 1965.)

‡ The authorship of the name *C. Adami* is thus stated everywhere; where Poiret has given a notice or description of Adam's new plant, I do not know.

§ According to Loudon, (as appears from a note in the 'Bot. Zeitung,' 1843, p. 133,) Adam obtained his new *Cytisus* by grafting a bud of *C. purpureus* on *C. alpinus* (?). I cannot consult the source of the statement here cited, ('Gard. Mag.,' xii, 225, and xv, 122.)

‖ According to Reissek, (Haidinger, 'Berichte über die Mittheil. von doubted, since the French authors* unanimously assert it, and this assertion finds strong support in the sterility of *C. Adami*, observed by Hénon and Seringe, and confirmed by the behaviour of the specimens in the Carlsruhe and Freiburg Gardens. *C. Adami* bears its name after the nurseryman Adam, of Vitry, near Paris, who raised it in the year 1826. The mother-plant is said to be *C. Laburnum*, the father *C. purpureus*.† In its arborescent growth and many-flowered racemes it far more resembles the common Laburnum, than the low shrubby *C. purpureus* with its two-flowered inflorescences hidden between the leaves; but the racemes are shorter and not so full of flowers. The dirty red colour of the blossom, the smoothness of the leaves, calyx, and germens, which are villous in *C. Laburnum*, remind us more again of *C. purpureus*. During the last ten or twelve years it has been observed in most diverse places (thus in Lyons,

Freunden der Natur in Wien,' i, p. 12, extracted in the 'Flora,' 1846, p. 623, and 1848, p. 26, in Hornschuch's essay on the 'sporting' of plants, with which extract alone I am acquainted,) a shrub of *Cytisus Laburnum*, in the Vienna Botanic Garden, which had previously always borne only the yellow blossom proper to this species, suddenly produced, in the spring of 1846, on some of its branches, the red flowers of *C. Adami*, and here and there red and yellow flowers mingled in the same racemes; nay, a twig perfectly representing *C. purpureus* is said to have sprung from a yellow-flowering branch of this shrub. Hornschuch found, in the occurrence thus narrated by Reissek, an analogue of the many other remarkable stories of transformation which he reported from old and recent sources, (for example, the growth of a *Lolium* branch from a wheat stock, the occurrence of isolated oat spikelets on wheat spikes, the transformation of oats into rye by a particular mode of treatment, &c.,) and a striking proof of the possibility of conversion of one species of plant into another. Without entering generally into the contested question, the present case admits of a simple, and I think not very hazardous explanation, in the assumption that an unknown hand had engrafted scions of *C. Adami* in the said shrub of *C. Laburnum*, that at the time of the observation there existed recurrences of the *C. Adami* to *C. Laburnum*, and that the shoot of *C. purpureus* mentioned grew out of such a graft, (certainly not out of a Laburnum branch.)

* Hénon (and Seringe,) 'Ann. des Sc. phys. et nat. de la Soc. d'Agricult. de Lyon,' ii, 375, (1839.)—Buchinger, 'Flora,' 1842, i, 378.—Kirschleger, 'Institut.,' 1843, p. 372, and 'Essai de Tératol. Vég.,' 71, (1845.)—Chevreul, 'Ann. des Sc. nat.,' 2 sér., vi, 186, (1846.)

† Kirschleger, l. c.

Strasburg, Schiltigheim, Munich, Vienna, Carlsruhe, Freiburg (and England), that single shoots present themselves upon the stocks of *C. Adami*, which (without any mediating transitions)* represent quite purely the yellow-flowered and villous *C. Laburnum*, or, what is much more striking from the great difference of the habit, branches perfectly characterised as *C. purpureus*. Ordinarily only one or other of the two parent species appear in this way,† but sometimes both on the same stock.‡ The formation of sprouts, and indeed the formation of twig-buds, is consequently the turning point here, with which the recurrence of the hybrid into the parent-species occurs; the recurring buds develope into stronger or weaker twigs, which in all parts belong entirely to one or other parent-species (stem-, leaf-, flower-, and fruit-formation). Sometimes, however, the case occurs of the recurrence to the parent-species first in the small twigs of the inflorescence, *i. e.* in the transition to the single lateral buds of the raceme, whereby the flowers belonging to the parent-species originate in the inflorescence of the hybrids and *mixed racemes* are formed. Three kinds of these are possible, namely: 1, *C. Adami* mixed with

* Kirchleger says, indeed,—"J'ai pu même, en 1844, observer toutes les transitions de ces trois sortes de branches (avec leurs inflorescences et leurs fleurs) les unes aux autres," but this assertion is certainly incorrect. Kirschleger was certainly deceived by the mixed inflorescences and flowers, which I shall describe more minutely.

† I have observed this in Carlsruhe and Freiburg, where I never saw both parent species produced out of the same stock. Buchinger found the same. I mention this circumstance expressly in order to remark that the explanation given by Chevreul, (l. c.) by which the recurrence of *C. Adami* to its parent species as a decomposition of the hybrid into its two portions (somewhat as in a chemical decomposition) is inapt.

‡ This is expressly asserted of the tree occurring in the garden of Prof. Schweighäuser, at Schiltigheim, which was described by Kirschleger. (This occurred also in the specimen in the garden of L.W. Dillwyn, Esq., of Swansea, where the shoots bearing the blossoms of the parent species were fertile, ripening seed, while the hybrid blossoms were sterile as usual.—A. H.) Since it is probable that all the specimens of *C. Adami* diffused in gardens are cuttings of a single mother-stock, the distinction, whether only one or both parent-species present themselves, becomes of less importance.

flowers of *C. Laburnum*; 2, *C. Adami* mixed with flowers of *C. purpureus*; 3, *C. Adami* mixed with flowers of both parent-species. Hitherto I have only observed the first of these three cases, to which also belong the mixed racemes described at Hénon, the isolated yellow flowers (belonging to *C. Laburnum*) being displayed among the ordinary rose-red flowers of *C. Adami*.* These mixed racemes, at the same time, exhibit the peculiarity that the yellow flowers set fruit, while the rose-red fall off immediately after the flowering, so that in the recurrence of *C. Adami* to one or other parent-species, the fertility lost in the hybrid reappears. But the strangest thing that happens in the recurrence of *C. Adami* to *C. Laburnum*, is the phenomenon of *mixed flowers*, which belong, both in the calyx and the corolla, partly to *C. Adami*, partly to *C. Laburnum*, in which even single segments of the calyx and single petals are halved, the former appearing half reddish-brown and smooth (*C. Adami*), half grey-green and villous, the latter half red (*C. Adami*) and half yellow (*C. Laburnum*). A raceme in which this occurred† exhibited, carefully counted up, among the 32 flowers it bore, 21 unaltered flowers of *C. Adami*, 3 pure flowers of *C. Laburnum*, and 8 mixed flowers, the 7 of which, compared in the subjoined table,‡ exhibited the following conditions of intermixture in calyx and corolla.§

* In reference to the hybrid nature of *C. Adami* it is not unimportant to remark that the reverse phenomenon, namely, racemes of *C. Laburnum* intermixed with single flowers of *C. Adami*, has not been observed either by others or by myself. If these mixed racemes depend on a partial recurrence of the hybrid to the parent-species, this case cannot occur at all.

† In the Carlsruhe Botanic Garden, May 1843.

‡ Compare here the outlines in plate V and the accompanying explanations. The eighth mixed flower was not in perfect preservation.

§ I neglected to examine accurately the condition of the stamens and ovaries of these flowers.

No. of the Flower.		Sepal.	Petal.	Together.
I.	Adami	$4\frac{1}{2}$	$3\frac{1}{2}$	8 } 10
	Laburnum	$\frac{1}{2}$	$1\frac{1}{2}$	2
II.	Adami	4	4	8 } 10
	Laburnum	1	1	2
III.	Adami	$2\frac{1}{2}$	$3\frac{1}{2}$	6 } 10
	Laburnum	$2\frac{1}{2}$	$1\frac{1}{2}$	4
IV.	Adami	$2\frac{1}{2}$	3	$5\frac{1}{2}$ } 10
	Laburnum	$2\frac{1}{2}$	2	$4\frac{1}{2}$
V.	Adami	$2\frac{1}{2}$	2	$4\frac{1}{2}$ } 10
	Laburnum	$2\frac{1}{2}$	3	$5\frac{1}{2}$
VI.	Adami	$2\frac{1}{2}$	1	$3\frac{1}{2}$ } 10
	Laburnum	$2\frac{1}{2}$	4	$6\frac{1}{2}$
VII.	Adami	1	0	1 } 10
	Laburnum	4	5	9

It need scarcely be remarked, that these mixed flowers appearing on *Cytisus Adami*, are fully analogous to the previously examined examples of mixed flowers (and fruits); the only distinction is that there it was partial sporting of one variety into the other, here a similar reversion of the hybrid form into the mother-species.

We have devoted our attention to this entire series of strange cases, in which the ordinary law of the invariability of the specific and individual character within the vegetable stock appears to be suspended, because they serve us as a proof of the intimate connection of the course of development of the individual with the history of the species. As the aberrations in the course of the individual metamorphosis are especially fitted to afford us an insight into its law,—since they reveal the internal connection and the essential similarity of its foundation, through unusual transitions, through anticipatory* or retrogressive† interweaving, or finally by complete return

* Compare the frequent cases of a petaloid uppermost euphyllary leaves in Tulips, *Caltha*, *Trollius*, the petaloid calyx of the double Primroses, of *Rubus cæsius* with petaloid inner sepals, (Act. Nat. Cur.,' xv, i, t. 31, f. 2,) of *Sempervivum tectorum* with stamens of the inner circle passing into carpels, &c.

† *Rosa*, *Ranunculus*, *Adonis*, with the outermost sepal passing into euphyllary formation; similarly *Rosa* and *Linum* with sepaloid first petal; the half double flowers with partial conversion of the stamens into petals, &c.

of the formations to the starting point,*—so must the last-examined deviations from the usual mode of transition to new organic destinations, belonging ordinarily to the cycle of development of the species, not of the individual, point to the common characters, which connect the transition from individual to individual, with the transition from one structure to another within the individual organism of the plant.

In the Introduction we endeavoured to seize the points common to these two domains, as the process of *Rejuvenescence,* and the minute investigation of the phenomena of Rejuvenescence in the course of life of plants, carried out in the three main sections of our reflections, enable us now the more readily to examine from the same point of view the Rejuvenescences of the species through reproduction. The transition to the new individual finds its analogue within the species, in Cell-formation, as the freest modification of it, as we have seen especially in the formation of the germ-cells (germinal vesicles) of the Phanerogamia; it finds its analogue, further, in Sprout-formation, here again representing the most independent modification of it; for while the sprouts belonging to the cycle of development of the "stock" are unfolded, either in permanent combination with the mother-stock, or if they separate from it, are connected with it in the earliest period of development, yet the embryo, as primary sprout of a new vegetable "stock," is always free from its earliest formation. As in the various gradations of the interlinking (*Gliederung*), which the vegetable stock acquires through its Rejuvenescences in Cell-formation, Leaf-formation, and Sprout-formation, we could not avoid recognising subordinate kinds of reproduction, since we could not deny even to the cell, but especially to the sprout, a certain individual import;—so, on the other hand, the series of individuals produced by true reproduction appears as an

* As in the cases of flowers appearing green, (*anthochloroses,*) in which all parts of the flower often return more or less perfectly into the euphyllary formation.

interlinking (Gliederung), only in a free condition, and the species as a whole, developing itself in this formation of links, as it were a vegetable "stock" of a higher kind.

That we might go still further in this direction, in the attempt to seize the conception of the natural continuity of the essence, we have already indicated in the Introduction. For as the individual appears as a link of the species, so does the species as a link of the genus, the genus as a link of the family, of the order, the class, of the kingdom; the kingdoms of Nature even as the great principal links of the organism of Nature; a view with which, indeed, we give to the Natural System its true and objective import, which is entirely lost in the mere subjective abstract conception of the natural divisions.*

* The true recognition of the organism of Nature and its composition of members or links, as objective facts, expressed by Nature itself, is essentially necessary to the higher shaping of Natural History as a unity. The tendency existing in the contrary direction, disregarding one-sided philosophic hypotheses, is caused among botanists chiefly by the previously prevailing cultivation of the Artificial system, and the difficulty of the construction of the truly Natural. Linnæus himself, moreover, the founder of the most important Artificial system in botany, regarded species and genera, emphatically, as objective works of Nature, ('Phil. Bot.,' § 162,) and explained the classes and orders of the Artificial system as a makeshift, until the Natural were detected, (§ 161.) It is remarkable to find even such authors as are inclined to an objective view of the conceptions of the genus and species, making the assertion that *merely the individual really exists*, (thus *e. g.* in Spring, 'Ueber die Naturhist. Begriffe von Gattung, Art und Abart," 1838, p. 22, 23.) To acknowledge the individual as really existing, and deny the natural actuality of the more comprehensive complexes of the organism of nature, is an inconsequence, depending on the deception by which the individual seems to be immediately given in the phenomenon, while it is easy to see that the individual, as such, *i. e.*, as a *single* being, can only be conceived mediately, in the recognition of the inner unity which runs through the series of phenomena, in which it displays itself. Child, youth, and man, caterpillar, chrysalis, and butterfly, are not to be conceived from external appearance, but only in consequence of their immaterial essence, as one and the same single being. The external continuity of the successive series of appearances of the individual, affords no ground for regarding it essentially differently from the comprehensive systematic complexes, for the same recurs even in the successive appearances of the species, where successive links (the individuals) stand in direct connection in the reproduction. That the individual has no right to be considered as real in other senses than the species, genus, &c., is indicated especially in the alternation of generations, as it is called, which exhibits the remarkable case of the individual, in the higher sense, (the biological individual,) breaking up into a limited or unlimited series of subordinate

It is true that the common origin and the historical connection among the links of the more comprehensive divisions of the Vegetable Kingdom, cannot be so readily demonstrated as is the case with the history of the individual in Cell-, Leaf-, and Sprout-formation, and the history of the Species, the formation of the Individuals

(morphological) individuals, which sometimes are developed in permanent connection, as compound family-stocks, as in the "stock" formation of the zoophytes and plants, caused by sprout-formation, sometimes separate completely, as in the Entozoa, Aphides, Medusæ, and in the case not unfrequent in the Vegetable Kingdom, of natural separation of the buds. Indeed Nature goes still further in plants, for it gives to the smallest circles of formation subordinate to the morphological individual, usually called the cells, such an independence of the vital functions, that these may be regarded in a certain sense as individuals, which, in the higher plants, lead a life interwoven in the totality of the organism, but in the lower, separating, often acquire an isolated individual existence, (pp. 124, 125, et seq.,) in both cases representing an alternation of generations of subordinate kind in their succession and multiplication, effected by a process analogous to reproduction. According to the axiom that merely the individual really exists, those who recognise the individual of the plant in the cell, must interpret the cells of the plants as alone real beings, and the stock, the sprout, the leaf, &c., as inessential aggregates. But where remains the individuality of the cell, as external appearance, when we see that even this has its transformation, its successive renovation, so that, externally regarded, it does not remain the same, but constantly becomes another, so long as the vitality endures in it, (pp. 176 et seq., 226 et seq.)? The reality, therefore, cannot be immediately conceived, not even the smallest circle, in the detached phenomenon, but in every case only mediately in the recognition of essence on which the continuity of the phenomenon depends. Now just as the individual is realised through a chronological succession of formations and material division into subordinate links, this is likewise realised in a complex of a higher order, represented by the individuals, by means of which, just as in the individual, it runs through its circle of forms in chronological succession and material extension; in like manner the genus, as a more highly generalised whole, is realised through the circle of the species, the family through the genera, &c.; so finally Nature, as a whole, is realized through the process of development, which brings into existence all the links of its organism, successively and contemporaneously, and the totality of each system of links in all these circles certainly cannot be called less real, in its representation through the links, than the parts which, without the whole, would not exist. For the assertion that merely the individual is real to have any meaning, the species, genera, families, classes and kingdoms, must be regarded as individuals of a higher order: a view which may be considered well founded, in so far as all these complexes depend upon special practical destinations of natural life, just as Nature, as a whole, as shaped out upon our planet, is to be regarded as an individual, which, although created according to the same eternal primary type, certainly possesses its own mode and way, different from the Nature of the other celestial spheres.

effected by reproduction, and the circle of Varieties which come into existence in the course of reproduction; but the flora of the ancient world,* and the geographical distribution of the plants of the present epoch,† afford us important indices at least, pointing to the connection in time and space of the history of development of the Vegetable Kingdom as a whole and in its parts.

We have examined Rejuvenescence in general and more particularly in the processes of Vegetable life, and rising from the narrower circle of the development of the single being, we have sought for it again in the wider circles of the Organism of Nature, and in this way arrived at the conviction, that it lies at the foundation of all sub-division in life, all graduated development; that it is this, through which not only the single being progresses from one formation to another, but the whole chain of being is carried onward from generation to generation; through which the smallest step of the organic structure is introduced, the greatest transitions of Nature carried into effect, and the metamorphosis in the individual, like the transformation of Nature as a whole from age to age, brought about. At the conclusion, then, of our reflections, the question will not appear premature, if we ask, What property of life it really is which declares itself in the Phenomenon of Rejuvenescence? In the first place, a general acknowledgment must be made that the orderly succession of phenomena of Rejuvenescence, which presents itself to us in every natural development, cannot be explained through the effort of external natural forces, but points to an internal cause. Every train of development exhibits in its course an adherence to plan which

* See pp. 7—9. The law of development becomes more and more evident in the newer works on the character of the vegetable kingdom in ancient epochs. See, in reference to this, the latest comparative view by Ad. Brongniart, in his 'Tableau des genres de Végét. Fossiles,' p. 93, (1849.)

† Note, for example, the native country of the family of Cacteæ, the cactus-like Euphorbiæ, the Epacrideæ, the group of the Heliophileæ in the family of the Cruciferæ, the rich genera *Stapelia*, *Pelargonium*, *Aloë*, *Agave*, &c.

can only have its ground in an internal vital destination; it exhibits, at the same time, an independence of all external influences which testifies to the internally given force of vitality. The manner and way in which the internal immaterial nature of life manifests itself more particularly in the Phenomenon of Rejuvenescence, we may call, in the true sense of the word, a *reminding* (*Erinnerung*), being the exertion of a power which, in opposition to the outward revelation and superannuation of life in appearance, grasps anew the *ideal* (*innere*) destination and turns it outward with new force, in order to carry it over every onesidedness or imperfection in the external representation, to repeated (and in proportion to the progress of the development) more and more refined complication of the original vital purpose. The recollection (or reminding) of the inherent design of life presents itself to us within the determinate stage of development in the repeated representation of the same vital form; it presents itself to us, retrogressively, in the reproduction of long overpassed, or, in advancing development, in the production of new vital forms, which are, in both cases, however, involved in the original destination. Must we not call it a reminding (or recollection) when, in the course of generation, the old specific nature returns to life with each new individual? It is not still more strikingly a reminding when, in the course of the Rejuvenescences, a long-relinquished parent-form suddenly returns to existence? as we have seen in the striking back of varieties and the recurrence of hybrids into the mother-species, with so remarkable an instance of which we have become acquainted in *Cytisus Adami?* The advance to new shapes, proportioned to the course of development, brought about through the Rejuvenescence, has been minutely examined in the metamorphoses of the individual being, where it is most accessible to our limited observation; does not this reveal most distinctly the internal preservation and making good of the original vital destination, through all intermediate destinations which are required for its entrance into combination with the lower steps of nature, from which the development starts? As in the Individual, then, so certainly in all Nature, with which the individual is combined through the common destination lying at the very foundation of all life. This connection is testified to us by the unity of the final term, in which we see the structure of entire Nature receive its key-stone. Is it not here again the recollection of the original destination of created life, which carries up step by step the development of Nature, from the first stirrings of life, through infinitely numerous links of Rejuvenescence, to the appearance of Man? Finally, is it not this which impels even Humanity to Rejuvenise itself from race to race in ever more deeply searching recollection of its high purpose, comprehending that of all Nature, and connecting it with the Eternal Source whence all internal Law and Force of Life derive their origin?

Pl I

PALMOGLŒA MACROCOCCA. Kutz?

Tuffen West Chromo Lith

Ford & West Chromo Imp

EXPLANATION OF THE PLATES.

PLATE I.

Palmoglœa macrococca, Kützing?*
(*Coccochloris Brebissonii,* Thwaites).

All the figures are from specimens from the Höllenthal, near Freiburg. The figures 21—28 and 1—13 of Pl. II represent the conjugation of the cells, and the consequent formation of the spores, as described at pp. 135, 202, and 285 of the text. Magnified 350 diam.

Fig. 1. A cell with a distinguishable gelatinous envelope.

Fig. 2. A cell which has attained the maximum of longitudinal growth.

Fig. 3. A cell beginning to divide.

Fig. 4. A pair of cells produced by division, the two portions still in contact.

Figs. 5 and 6. The same, but the two daughter-cells, still enclosed by the common enveloping membrane of the mother-cell, have already separated, without however exhibiting distinguishable special envelopes.

Fig. 7. Two cells, considerably elongated and possessing special coats, enclosed by the common mother-envelope.

Fig. 8. A cell of moderate length with two vesicles in

* The species of the genus *Palmoglœa*, established by Kützing, cannot be certainly determined either by the characters given in the 'Spec. Algarum,' or by the figures given in the 'Tabulæ Phycologicæ.' In the species represented in our plate, the jelly-like cell-envelopes are sometimes distinguishable singly, sometimes not, which renders doubtful even the section in which we are to seek the species. The germ-cells vary in length from $\frac{1}{60}$ to $\frac{1}{20}$ millim., average, therefore, $\frac{1}{142}$ to $\frac{1}{45}$ of a line, so that the distinctions founded on size, given by Kützing, likewise furnish no safe criterion. From the variability of the characters, it is not improbable that many of the species brought forward by Kützing, in particular *P. rupestris, macrococca, vesiculosa, lucida, rufescens,* and *crassa,* will have to be combined as forms of one and the same species.

the interior, the nature of which is doubtful; between the two, and more to the side, exists a lighter space (frequently observable).

Fig. 9. A similar cell, in which the dark-green portion of the contents forms a pretty sharply circumscribed mass with a constriction in the middle.

Fig. 10. The same cell turned one quarter round, the green mass appearing narrower and with a bright spot beside it.

Fig. 11. Another cell in the same position, with a still more compressed green body in the interior, reminding us of the genus *Mesotænium*, Näg. ('Einz. Algen.,' t. iv, B.)

Fig. 12. The same cell seen from above.

Fig. 13. A similar cell, in which the plate-like green mass is interrupted in the middle.

Fig. 14. Two very short cells, shortly after their production by division, with plate-like compressed green masses placed obliquely in the interior.

Figs. 15—16. Rows of cells in contact, without distinguishable enveloping membranes, such as are sometimes produced by rapidly succeeding divisions in very active vegetation. The arrangement of the cells in this case shows that the division constantly occurs only in one direction.

Figs. 17—20. Cells treated with tincture of iodine, whereby the green masses in the interior are coloured brownish, and a dark brown nucleus becomes visible, which, however, does not appear sharply defined, and certainly contains no starch.

Fig. 21. A cell preparing for conjugation, furnished with a lateral wart-shaped projection.

Fig. 22. Two similar cells in contact by their wart-shaped projections.

Figs. 23—27. Cells conjugated by union and anastomosis of the lateral processes, with the connecting piece of variable length.

Fig. 28. The same, but one cell crossing the other.

Pl II.

Tuffen West Chromo Lith.

Henry Denny Sculp.t

1–14 PALMOGLŒA MACROCOCCA 15–22 SCHIZOCHLAMYS GELATINOSA

PLATE II.

Figs. 1—14. *Palmoglœa macrococca.*

(*Continued from* Pl. I.)

Fig. 1. Two cells, laterally connected, pushed aside in opposite directions.

Figs. 2—4. Conjugated cells, in which the end of one is attached to the side of the other.

Fig. 5. Conjugation carried further, by the widening of the connecting piece. (The cells from fig. 21, pl. 1, to this figure, already exhibit evident drops of oil in the interior.)

Figs. 6—9. Transitional forms produced by still further advanced conjugation, but still two-lobed; they often persist in this form.

Figs. 10—12. Seed-cells formed by complete union of two conjugated cells. These, as also those represented in 6—9, are almost filled with large drops of oil, and have a thicker coat than before the conjugation.

Fig. 13. Seems to be an union of three cells, which I only met with once.

Fig. 14. A group of four cells, enclosed by a tough coat, probably produced by the division of the contents of a seed-cell.

Figs. 15—22. *Schizochlamys gelatinosa*, A. Br.

This forms a gelatinous coating over water-plants, as also swimming masses, on the peat-moors of the Black Forest. (See pp. 181, 230, in the text.) Magnified 600 diameters.

Figs. 15—16. Two cells which throw off their cell-membrane by regular splitting into two halves, without themselves dividing.

Fig. 17. A cell which, after throwing off its earlier

cell-membrane, has formed a new one, somewhat removed from the green internal cell at one side.

Fig. 18. The cell-membrane thrown off by splitting into four pieces, with simultaneous division of the cell into two daughter-cells.

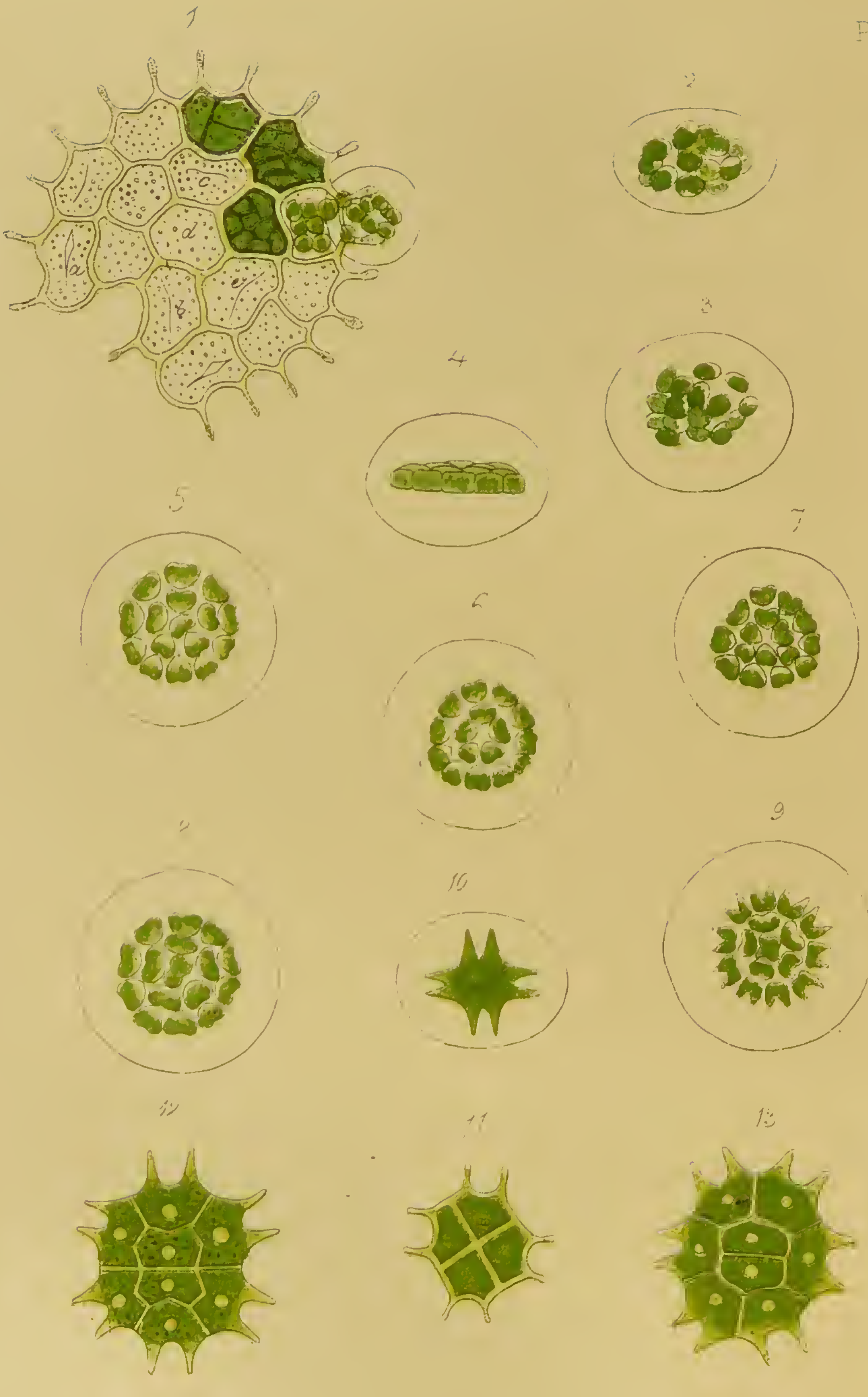
Fig. 19. As in fig. 18; but the two new cells have already become coated with cell-membrane.

Fig. 20. The same; but the detached cell-membrane split only into two parts.

Fig. 21. The detached cell-membrane has broken up into four portions, the internal cell has become transformed by double halving into a group of four decussating cells.

Fig. 22. The same; but the cells have already separated and become coated with new cell-membrane.

Pl. III



PEDIASTRUM GRANULATUM

Tuffen West Chromo Lith

Ford & West Chromo Imp

PLATE III.

Pediastrum granulatum, Kütz.*

Numerous modifications, all derived from one and the same little pool of water, near Freiburg. Figs. 1—9 represent the reproduction. (See pp. 161, 184, 200, 250.) Magnified 400 diameters.

Fig. 1. An old disk, in great part emptied by birth of gonidia. The emptying of the cells of this specimen, the first in which I observed the reproduction, took place before my eyes in the order of the letters *a* to *e;* this was on a day in autumn, (Nov. 24, 1848,) in the afternoon; the empty cells not marked had lost their contents before the commencement of the observation, probably in the morning of the same day. Several of the empty cells, (for instance, *a, b, c, e,*) distinctly exhibit a cross slit, through which the contents have been discharged; in the rest the emptying has taken place on the opposite side, so that the slit is invisible in this position of the disk. One cell is in the act of discharging the gonidia, these having in part entered into the projecting portion of the hernia-like vesicle formed by the swollen innermost lamella of the mother-cell membrane, in part still remaining in the internal cell-cavity. Three other cells still possess their perfect contents, but in different conditions. Two of them are filled by sixteen extremely closely crowded gonidia, only half of which are visible, as they form a

* In giving a name to this species I select that determination which seemed least doubtful; I must observe, however, that several of the species distinguished by Kützing probably belong to the same species, so particularly *P. Boryanum*, K.; *subulatum, cruciatum*, K.; and also in part *P. Selenæa*, Auct., namely, with the exclusion of *P. Selenæa*, Ralfs., (*lunare* and *elegans*, Hass.); and *P. Selenæa*, Näg.; (*pertusum*, K.) The length of the horns, as also their clavate rounding off, is variable; punctated condition of the cell-wall, on the contrary, I found constant; but it is only distinguishable in full-grown and empty specimens.

double layer. The third, not yet emptied cell, is in the actual transition to the formation of gonidia; it exhibits the first divison of the contents into two halves, one of which already appears halved again.—The arrangement of the sixteen cells of the entire disk is an unusual one, 1+6+9, the outer circle in this case being incomplete, and a cell of the inner circle, opposite the break in the outer circle, possesses one horn.

Fig. 2. The new-born family, immediately after the birth, seen from the corner. It is derived from the cell *a* of the disk represented by figure 1. The innermost lamella of the mother-cell has wholly emerged from the old cell as an extremely thin vesicle enclosing the gonidia; the gonidia in the interior of the mother-vesicle moving actively.

Fig. 3. The same family, in the same stage, seen on the surface.

Fig. 4. The same, in a later stage, namely, a full quarter of an hour after birth, in the same position as fig. 2. The gonidia, now at rest, have arranged themselves in a plane in the plane of section of the equator of the mother-vesicle.

Fig. 5. The same, in the same stage, showing the surface. The sixteen gonidia, united into a colony, form a circular sixteen-celled disk, in the arrangement 1+5+10; but they do not adhere firmly together. A slight emargination is already visible on the outside border of the cells.

Fig. 6. Another young family in the same stage as fig. 5, about half an hour after birth. The arrangement 5+11.

Fig. 7. Another of the same age, exhibiting the arrangement 6+10.

Fig. 8. The families represented in figs. 2, 3, 4, 5, one hour after birth. The emargination of the cells has advanced further.

Fig. 9. The same again, but four hours after the gonidia ceased to move, (four hours and a half after

birth.) The emargination of the border-cells has passed into the formation of horns. The cells are not even yet closely connected together, but exhibit spaces between them, so that in this stage the disk exhibits a resemblance to that of *Pediastrum pertusum*, (Näg., 'Einz. Alg.,' v. 2, as *P. Selenæa*,) which species, however, does not lose the orifices in the full-grown condition. Not until the second day, after an interruption during the night, of the rapid changes of form of the cells, do the cells become closely applied together; the horns acquire their proper shape and length at the same time.

Fig. 10. A half-grown disk of four cells, two of which meet in the middle. A starch-grain is visible in each cell, as is usual in the middle age. The mother-vesicle is still visible here, while in ordinary cases it disappears altogether by the second day.

Fig. 11. An older four-celled disk, the four cells meeting in the middle. The families formed of four cells are extremely rare in this species.

Fig. 12. Disk of eight cells, in the arrangement 2+6, which is more frequent in this species than the arrangement 1+7. The inner two cells are notched on the outer border, which is connected with the position of the two outer cells opposite to them.

Fig. 13. A similar disk, but with the inner two cells not notched, but interposing an obtuse-angled prolongation into the commissure of the outer cells alternating with them.

PLATE IV.

Pediastrum granulatum, Kg.

(*Continued from* PL. III.)

Fig. 1. Disk of eight cells, placed 1+7, derived from the same mother-disk as the four-celled disk represented in fig. 11, of Pl. 3.

Fig. 2. Full-grown eight-celled disk, 1+7. The contents of the cells dark green, and granular; the starch-grains no longer visible. The cell-walls in the interior of the disk are tinged slightly crimson, which colour, however, only occurs sometimes in full-grown specimens.

Fig. 3. Eight-celled disk arranged 1+6+1, a very rare exceptional case.

Fig. 4. Disk in 1+5+10, which is the most frequent case with sixteen cells, (see fig. 5, Pl. III.)

Fig. 5. Disk of sixteen cells, 6+10, the inner six differently arranged from those of fig. 7, Pl. III.

Fig. 6. A similar one, but the outer circle so closely adjoined to the inner that the arrangement appears spiral.

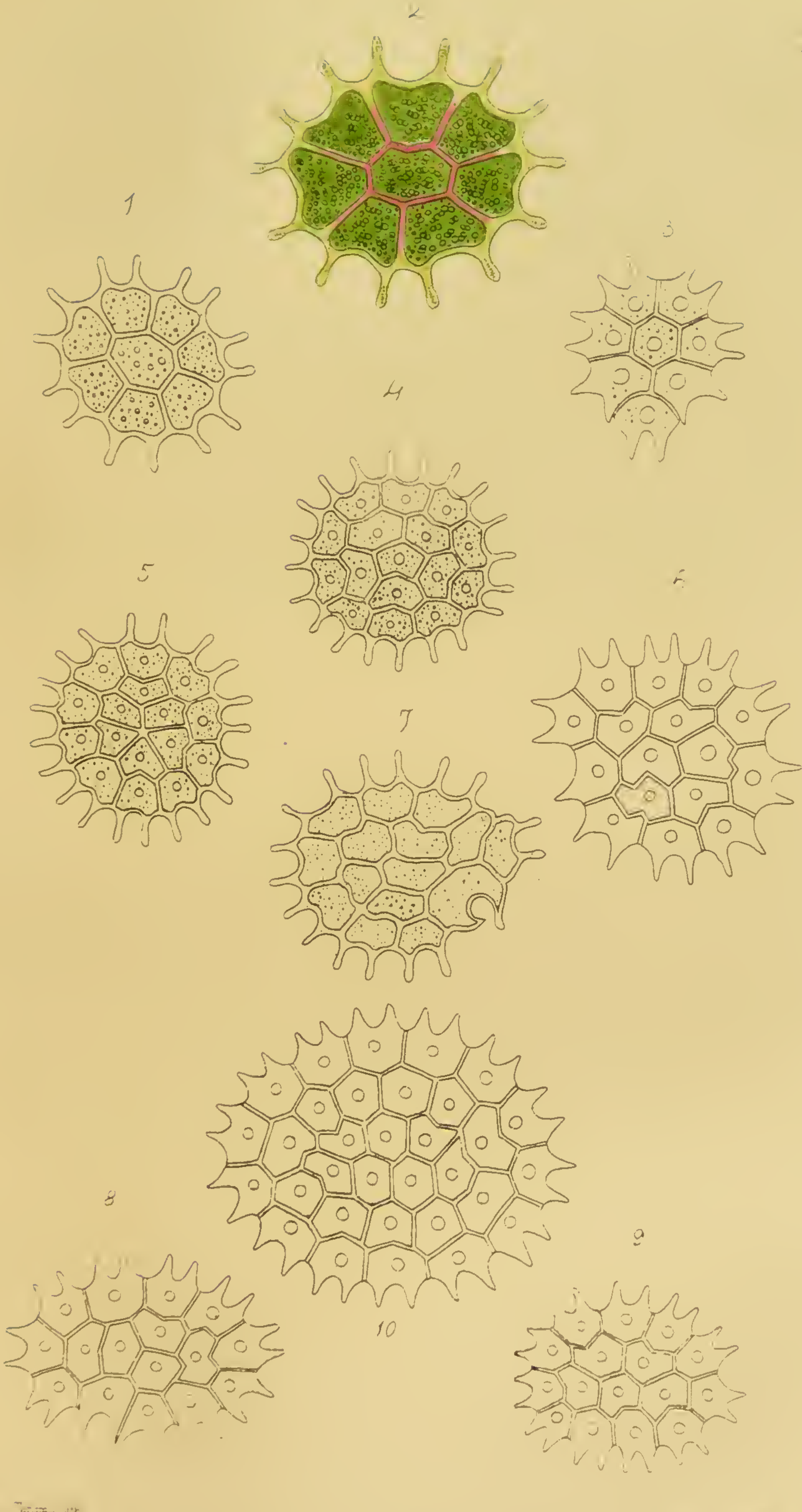
Fig. 7. Abnormal disk of fifteen cells, in which, however, one in the outer circle is larger than the rest, and doubtless stands in the place of two, from omission of the last division in the formation of gonidia. The likewise irregular arrangement may, therefore, be regarded as 5+10+1.

Fig. 8. Elliptical disk of sixteen cells, 5+10.

Fig. 9. A similar disk, but the five inner cells in a different position.

Fig. 10. Elliptical disk of thirty-two cells, 7+11+14. The colonies of thirty-two cells are rarer in this species

Pl. V



PEDIASTRUM GRANULATUM

than the sixteen-celled; I have observed in these, besides that figured, the following kinds of arrangement:

$1 + 5 + 10 + 16$
$1 + 6 + 10 + 15$
$1 + 5 + 11 + 15$
$1 + 6 + 11 + 14$ (spiral.)
$5 + 11 + 16$
$6 + 10 + 16$ (sub-spiral.)
$7 + 10 + 15$ (elliptical.)

I have never met with specimens with sixty-four cells in this species, but Nägeli, (l. c., t. v, B, 1, g,) figures a sixty-four-celled specimen, arranged $2+7+12+19+24$, in the scarcely specifically distinct *P. Boryanum*.

PLATE V.

Cytisus Adami.

Diagrams of mixed flowers, partly striking back to *Cytisus Laburnum*, on which see p. 319 in the text. The outer circle represents the calyx, the brown parts of it belong to *C. Adami*, the green to *C. Laburnum*. In the inner circle (corolla) the red colour signifies *C. Adami*, the yellow *C. Laburnum*.

Tuffen West Chromo lith

Ford & West Chromo Imp

HYBRID FLOWERS FROM CYTISUS ADAMI & C. LABURNUM

INDEX.

ON THE

ANIMAL NATURE OF DIATOMEÆ,

WITH AN

ORGANOGRAPHICAL REVISION OF THE GENERA,

ESTABLISHED BY KÜTZING.

By Professor G. MENEGHINI.

TRANSLATED FROM

THE ORIGINAL ITALIAN EDITION,

(Venice, 1845.)

NOTE.

By an oversight, the references to pages in the Annotations, p. 496 *et seq.*, are erroneous, not having been altered to adjust them to the difference of the paging in this volume and the original essay. The following corrections must be made:—4 = 346; 7 = 348; 8 = 349; 9 = 350; 10 = 351; 12 = 353; 13 = 354; 16 = 357; 20 = 360; 23 = 363; 25 = 364; 90 = 421; 106 = 445.

In reference to the discussion on the subject of measurement at p. 418, it may be worthy of attention that Kützing confesses that Ehrenberg's figures, drawn with an amplification of 300, are not smaller, but sometimes even larger than his own, which are magnified 420 times. (Note on *Epithemia ocellata*, 'Kieselschal. Bacillarien,' p. 34.)

ON THE

ANIMAL NATURE OF DIATOMEÆ.

THE Diatomeæ are microscopic beings provided with a siliceous shield or shell, on which account their form remains unchanged; they are easily subjected to observation, and easily distinguished from other minute organisms, whether belonging to the animal or the vegetable kingdom. The earlier observers considered them to be animals undoubtedly; and animals they were decidedly pronounced by Ehrenberg. On the other hand, almost every Algologist has actually taken them for plants, and in this opinion all are agreed who have more recently treated on the elementary structure of organic beings, and on the distinctions that constantly separate animals from plants, even at their first origin. In support of their animal nature, the important observations of Ehrenberg certainly possess great value, but these are insufficient; because the same arguments have induced the illustrious author to include in the same class of *Polygastric Infusoria* the Desmidieæ also, which now by universal consent are acknowledged to be true Algæ.

If a new opinion do not actually spring from between these two, there is revived under another name the ancient theory of Phytozoa and Zoophytes, the Nemoures of Gaillon, the Psychodiarian kingdom and the Arthrodieæ of Bory St. Vincent, the Green Matter of Priestley, the metamorphoses of Agardh, and we are advancing directly to the theory of spontaneous generation, and the other of defective specific limitation, in accordance with which species and genera, whether animal or vegetable, are considered to be transitory forms of the same organic type. Kützing does not admit any essential distinction between animals and vegetables. He maintains that the same being may, at various periods of its development, assume one nature or the other. The following is his theory in a few words. Every organic being is constituted of vegetable elements and animal elements, and according as the one or the other prevails, the being becomes an animal or a vegetable; in the first stages of the development of superior beings, and permanently in those of inferior rank, the two elements are equally balanced. And this is the case, in the author's opinion, with the Diatomeæ, which, on this account, cannot be absolutely referred either to one series or the other, but constitute the ring or circle which unites together all organic beings into one kingdom. Long controversies have sprung up between the supporters and the opponents of this doctrine, who, to obtain victory, mutually accuse one another of logical errors, of sophisms, and of paradoxes.

The analysis of this controversy would be tedious and of little profit; whilst on the other hand, sound logical principles may guide us to a rigorous estimate of the facts. And, in truth, the natural sciences are entitled to boast of a language that is adequate to the purpose, if we avoid the abuse of Ontology. The words *Animal* and *Plant*, like words in common use, as *Species, Genus, Order, Class, Kingdom,* do not denote any existing thing in particular. To the naturalist there exist individuals only, as to the philosopher there exist only bodies. Species is a synthetical comprehensive expression, abstracted from all the individuals so similar to each other, that they may all be considered as originating from the same parents. Genus is a still larger abstraction, comprehending all the species that resemble each other in some important characters; and so we advance to the denominations animal and plant, expressions of ideas existing only in the mind of man, and therefore entirely subordinate to impressions already received and to those which may be received hereafter. These ideas are hence more or less incomplete in every observer, nay, incomplete in all, because no one has seen every animal or every plant. On this account we not unfrequently meet with organisms of an ambiguous nature, which at first sight appear equally to belong to the animal and the vegetable kingdom. But yet with regard to this ultimate division of organic beings, we ought to proceed in the selfsame path which we find necessary to follow in respect to the first divisions of Species and Genera. When a naturalist meets with a species that appears to belong to two different genera, and to form a transition, so to speak, between one and the other, he decides according to the importance and the value of the characters, either to modify the definitions of the two genera, or to propose a new one, or to fuse both together into one. He would sin against Ontology should he assert that he found the two genera included and combined in the ambiguous species. The genus has existence only in our minds, and not in the species. In the latter we can only discover some or all the characteristics of the genus; that is, certain signs which constantly subsist in every sister species, whatever may be their diversity in other respects. Thus Kützing, when he says that in the Diatomeæ the two elements, the animal and the vegetable, are combined and in equilibrio with each other, gratuitously imagines the idea of a combination, which in reality can only take place between different substances, and hence he applies his conjecture to the expression, instead of applying the latter to the former. And he draws his conclusion from the example he uses, instituting this same comparison between the organic and inorganic kingdom, and deducing from it analogous consequences; the gradual transition from one to the other is as it were their conjunction, through the same intermediate ring or circle of Diatomeæ.

The phosphate of lime, he says, which constitutes so large a portion of the bones of animals, the silica of

Diatomeæ, and the other *mineral* elements which are found united with organic tissues both of animals and plants, represent the combination of the inorganic with the organic kingdom. According as the one or the other prevails, life or death is triumphant. The word *mineral* is in this instance so exalted, as to signify, not an intellectual abstraction, but something unknown, ideal, metaphysical. With the same right that he terms phosphate of lime or silica *mineral*, I can equally apply the word *mineral* to carbon, hydrogen, or to the triple combination of O. H. and C., or the quadruple combination O. H. C. A., since these substances also, as well as the former, do not solely of themselves manifest those general properties which we comprehend in the abstract expression *Life*. Nor ought we to allow ourselves to be deluded by the abuse with which chemists apply the word *organic* to some material elements of living beings. It is a convenient but dangerous mode of expression. The same remote elements constitute living and dead bodies; and admitting that some combinations are found in the former which are wanting in the latter, and that others can by no means be produced artificially, still what we term *life* does not reside solely in these. The same chemical combination may be alive or dead, without any knowledge of the cause on our part. It is only by comparing this with other known facts, and not by observation, that we suppose its proximate cause to be the mutual arrangements and the motion of molecules. So that, whenever any substance forms an integral portion of the tissues of a living being, it does not belong to the mineral kingdom, but to this being, and therefore to the organic kingdom. It is only when, independently of those manifestations which constitute life, this substance within a living being obeys physical and chemical laws as it would obey them out of the body, (like calculous concretions within animals, and crystals in the interior of vegetable cells, and incrustations whether internal or external,) so that they issue from the medium within which they live or the vehicles that introduce them, and environ, suffocate, and kill the animals or the plants or their tissues:—then only I should denominate this substance a mineral thus associated with an organic being. In the shields of a Diatomean, as well as in the discs of Acalephæ or Gasteropoda, in the epidermis of Crustacea, in the bones of Vertebrata, this so-called inorganic substance is, at least in part, within the same conditions as the albumen or fibrine or any other proteine combination which constitutes the rest of the tissue. In the Diatomeæ, as well as in the Mollusca, the solid shield adapts itself to the successively growing dimensions of the animal, as in the Vertebrata the bones grow *pari passu* with the other tissues. And since this growth has nothing in common with the crystallisation or successive deposition of minerals, we are forced to allow that this manifestation is of necessity comprehended in our idea of life.

Kützing, therefore, when speaking of Diatomeæ, ought to have dwelt upon the fact that in these beings silica exceeds the other material elements, and he ought only to have instituted a comparison between the proportion of this substance, and that which is elsewhere met with among the other material combinations proper to organic beings and at the same time common to them with minerals. Perhaps he would have shrunk from this comparison, for the more the second prevail over the first, the less is the manifestation of life. But we are not endeavouring in this place to learn whether a being is more or less easy to be distinguished. A serpent coiled up and an eagle circling the heavens are certainly different in their manifestation of life, but the one and the other is equally different from a stone. Where life ceases, death takes place; for these, being opposite states, admit of no transition.

The other opinion of Kützing, which, though foreign to our present subject, we feel bound to oppose, is the one which suggested to him the theory of two vitalities combined together in *equilibrio* or in *inequilibrio*. The same being, he says, may pass from the animal to the vegetable nature, or from the latter to the former, and again return to its original state. This opinion is not new, for it was previously held by Agardh, by Gaillon, and by Bory St. Vincent; but the facts which lead Kützing to adopt it are so precise and so well described, that they do not admit the easy charge of incorrect observation, by which many have hitherto been satisfied to answer arguments deduced from similar facts. He sees microscopic beings corresponding exactly with the descriptions and figures given by Ehrenberg, furnished with organic peculiarities, and presenting vital phenomena generally regarded by Ehrenberg and others as characters of animal life, assume in their successive and natural development, form, organisation, and life, such as are generally attributed to plants. And from these plants he sees reproductive bodies generated, similar to the seeds of superior and spores of inferior plants, equally endowed with characters of animality, becoming, however, subordinated to those of vegetable life. The fact is true, and may be easily verified by any one in the habit of making microscopic observations. And the explanation of this fact appears to me equally easy. If there are beings which, when they attain their perfect development, prove themselves to be decidedly vegetable, although during the first portion of their existence they presented some phenomena of animal nature, this proves that those phenomena do not exclusively belong to animals, and that we cannot draw from them absolute characters of animal nature. The imperfection, which we have already shown to be inherent in every notion we can form of the animal or vegetable kingdom, begins to diminish after such considerations, and it is under this point of view that we purpose to undertake the examination of Diatomeæ, carefully separating in the characters they present, those which they hold in common with vegetables from those in common with animals, and inquiring if they do not possess some exclusively with one or the other which may decide the question. The comparison of animals with vegetables has been treated and discussed in all its forms so many times, and by so many celebrated authors, that the mere mention of it may excite a fear that we are about to recite things antiquated or stale, or at least well known by every one. Therefore I shall abstain from the useless display of cheap erudition, and shall apply myself solely to the most recent results of scientific investigation.

The most certain manifestations of animal life are those of sensibility and motion, either of the whole body or of its various parts. It is useless to enter into minute particulars in order to prove that the word *sensibility*, like all other abstract terms, is merely a name by which we understand a class of phenomena whose cause is unknown. Hence the abstract expression has come to denote the cause itself, and by conventional agreement we say that sensibility causes the phenomena of sensation. It is *sensation* only that really exists, for that is a change that we have experienced. Analogy leads us to conjecture, according to certain indications, that similar changes occur in all other animals, and, therefore, that there is a property common in all these beings, which we call sensibility. We see that in many cases these indications become so transient that we are entitled to attribute their apparent absence to the imperfection of our means of observation.

With respect to motion, since it manifests itself objectively, and this its manifestation is always induced directly or indirectly by external causes, the distinction between vegetable and animal motion has been suggested to our minds, not by the action itself, but rather by the quality of those beings hitherto regarded as plants or animals on other grounds. And if we wish to find elements of distinction in the phenomenon itself, we look for them in the connection between external stimulants and the motion produced, as also in the instruments by which it is effected. We endeavour to prove that in plants all movements are determined by the physical or chemical influence of external agents. In animals, on the other hand, the laws of inorganic nature are not sufficient to explain the connection (otherwise more mediate and remote) between the external impression and the organic movement. Which distinction, besides being relative to the degree of our knowledge, has, moreover, a value limited entirely to the coarser phenomena, not being applicable to those of nutrition and growth; for all these are accomplished by determinate movements that cannot be explained by merely physical and chemical laws. "If nature," exclaims Humboldt, "had endowed us with microscopic powers of sight, and if the integuments of plants were transparent, the vegetable kingdom would by no means present that aspect of immobility and repose under which it appears to our senses." And the same may be said of the instruments; for the muscles of higher animals very soon disappear when we examine more simple or smaller animals, nor certainly can we deny animality to those minute Infusoria in which we are unable to distinguish either muscles or any other distinct organs.

Having then ascertained the insufficiency of these two principal characters, it became necessary to look for others, not in the simple manifestations of a supposed subjective property, but in the objective qualities themselves. And these not in their external form, for we know not the limits of *its* variety, but in the internal organisation, in the state of the more remote organic elements, in their origin and formation, or in the chemical materials of which they are constituted. This difficult inquiry is assisted by recent discoveries, through which science is now put in possession of a most important truth,—that within the superior organic type, as well in the vegetable as in the animal kingdom, there is included, so to speak, in a summary manner, the history of the lower, which present in a permanent form their various intermediate states: that the same histological and morphological facts which appear manifest in the more simple organisms, are repeated in the more complicated; that the primitive organic structure is very similar in the two kingdoms; in short, that in the first instance every plant, every animal, and every tissue in the one or the other, proceeds solely from cells. And since the primitive state, which in superior beings is only transitory, remains permanent in the inferior, we have thus, as well in plants as in animals, very simple beings, reduced indeed to the simplicity of a single cell. We do not here inquire whether we have viscera, systems, tissues, on the one hand, or roots, leaves, flowers, or even fronds or spores, on the other; the difference we are endeavouring to determine is in the primitive cell, that cell which represents the ovum or the spore as transitory beings, or the *Protococcus* and the *Gregarina* as permanent beings. The field is open, and its boundaries are well defined. The vegetable cell on one part, and the animal cell on the other, but both alike in their first origin, in their formation, in every successive change.

If a dangerous rock present itself here, and if we cannot steer entirely clear of it, we ought at least to point it out in order to prevent shipwreck. The means by which we endeavour to augment the power of our senses have a limit. The microscope reveals the presence of a corpuscle only the 100,000th of a millimetre in size; yet, since this corpuscle may be large in comparison with those which entirely elude our vision, can we ever boast that we are able to perceive the internal structure even of larger bodies than this? Hence there is always great danger of believing that to be simple which in reality only seems to be so, and which the wonderful artifice of organisation may conceal from our eyes by its transparency, or by the compact nature of its parts. Since the impossibility of penetrating deeper into structure is inherent in the means we resort to for the purpose, we may still avail ourselves of comparison as a guide, deducing nothing from observation beyond what is comparative. But the greater peril lies in the very nature of the subject; because two bodies, very different in degree of organic simplicity, may appear very similar to each other in our eyes, though armed with great magnifying powers. And since we are now strictly endeavouring to discover the characters of an element, which in respect to us is more simple than any other, it is to be feared that in some cases we may take some more complex thing for a cell.

Every organic being, if observed at the first instant of its appearance, presents itself as a simple cell. Whenever we have a cell before our eyes, this cell is either the rudiment of an ulterior organism, or it is capable of existing by itself and remaining permanently in the same condition, or it is an elementary part of some organic tissue from which it has been separated. Everything anterior to the appearance of the cell, considered in its general condition, may, in the actual state of our knowledge, be considered as still uncertain, or not fully demonstrated; and therefore it is that we take our starting point from the already beautiful and well-formed cell, because it is always identical in respect to its principal characters. Its external coating solid, quite continuous, transparent, without any indication of particular structure, viz., without a heterogeneous disposition of molecules. The contained substance liquid, solid or gaseous, different from what remains outside the cell. Nucleus adhering to the inner surface, or detached within the cavity. Nucleolus within the nucleus, distinct by a different refraction of light or by colour, or by a different appearance under chemical reagents. Another general fact, common to all living cells, is an incessant mutual interchange of materials between the fluid within and that external to the cell, through the solid tegument of the cell itself causing perpetual variations in the quantity and quality of the former.

So far the conditions are common to the two organic kingdoms. We will now compare together such elementary or primordial cells taken from beings respecting whose animal or vegetable nature there can be no doubt. If both these be subjected to the action of chemical reagents, they manifest different results; hence we are led to conclude that there exists a difference in their chemical composition.

It is useless to insist upon this mode of chemical reasoning; it may suffice here to quote the results of chemical researches. The nucleus is composed of a quarternary azotised substance (O. H. C. A.); this applies equally to an animal and a vegetable cell. The solid tegument, again, of the animal cell is always a combination of proteine with water, *i. e.* a quaternary azotised substance also. ($C.^{40}$ $H.^{62}$ $O.^{12}$ $A.^{5}$); whilst that of the vegetable cell always consists of an unazotised ternary substance, isomeric with starch ($C.^{24}$ $H.^{20}$ $O.^{10}$). The contained liquid, also, is always ternary, unazotised in the vegetable cell, quaternary and azotised in the animal. The included solid substances are promiscuously ternary or quaternary; the former prevailing more in vegetables, the latter in animals; and among the former, chlorophyll (?) starch, and gum are found exclusively in the vegetable cell. Chemical reagents, too, disclose an essential peculiarity in the vegetable cell. An extremely fine, thin membrane, granular in structure, of a quaternary azotised composition, like that of the nucleus, lines the inner wall, and hence immediately surrounds all the contents of the cell, including the nucleus, with which, in most instances, it is in direct continuity. This fine membrane is so thin, and adheres so closely to the inner wall, that, in order to perceive it, we must resort to physical or chemical agents to detach it. It exists in every cell, and precedes the formation of the wall; if it seem to be absent in any case, the reason is that in most instances it soon disappears.

These are positive facts; and in most instances the experiments by which they are confirmed admit neither contradiction nor doubt. But in the special case of a cell respeeting which we have to deeide whether it belong to one kingdom or the other, the ehemieal test is redueed to data so preearious as not to afford the same eertainty. If the wall of a eell treated with iodine be, as well as the nueleus, eoloured brown, we may pronounce it to eontain azote, and to be formed of a quaternary material. If, again, treated with sulphurie acid, and subsequently with iodine, it assumes a violet eolour, there ean be no doubt of its being isomeric with stareh, since it has been ehanged into that substanee. But if these trials fail or prove uneertain, as very often happens, we must of neeessity suspend our judgment. With respeet to the eontained substance, besides the promiseuous eharaeter of some materials already mentioned, some also which are exelusive, as, for instanee, ehlorophyll or starch, may lead to errors. The stomaehs of a Polygastrie Infusorium may be filled with these vegetable substanees, and their transpareney and minute size may eause them to appear very simple.

The suecessive ehanges in a eell furnish other very important eharaeters to distinguish the two kingdoms, but give rise, at the same time, to new and grave diffieulties. Its extension, the exeess of one diameter over the other, the variety of forms it ean assume, are frequent eonditions. The disappearanee and reabsorption of the nueleus oeeur in every eell at some period of its existenee; but in the eells of higher plants the fine inner membrane or primordial utricle soon disappears. Here is a diffieulty as to distinetion to be overeome. This remains permanent, partieularly in the Algæ, if not in all inferior plants. The enlargement of the wall, whieh in the animal eell takes plaee in a homogeneous manner, is effeeted in the plant by the deposition on its inner surfaee of sueeessive strata, eontinuously or variously formed into eireles, spiral bands, or other intermediate forms, yet of a ternary substanee, and varying little from that before mentioned $(C.^{34} H.^{24} O.^{10})$. These are produeed at a mueh later period, and then only in the eells form part of a eomplieated tissue. Then the wall is not only enlarged, but successively impregnated with various substances, as lignine ($C.^{12}$ $H.^{16}$ $O.^{8}$), with carbonate of lime, with silica, or, finally, with a quaternary azotised substance, as constantly happens in a portion of the superior wall of the epidermal cells which forms the so-called cuticle, and in the thick cellular wall of marine Confervæ. Thus the elongation effected in animal cells, on their nuclei and on their nucleole passing into distinct fibres, has only a remote counterpart in the liber cells of plants, in the hypothalline tissue of Lichens, in the so called seminal threads of Charæ and Musci, and in some modifications of Kützing's *amylide* cells. But these fibres, so distinct in the superior animals, and in many of the inferior, as in Sponges, for example, entirely elude observation when we examine microscopic beings.

In animals, as well as in plants, new cells are organised in the interior of their predecessors; but in vegetables the formation of the cells always seems to be endogenous; in animals, on the other hand, it takes place perhaps usually in the extra cellular fluid. The multiplication of vegetable cells is proved to occur in three modes.

1. Many nuclei appear floating together with granules of a different nature. Around each of these collects a minute vesicle, which successively increases, compresses the whole of them, and, along with them, terminates by filling the maternal cell, which, softening and liquefying, is finally absorbed and disappears.

2. The internal substance of the cell divides into two or four portions, which, from their origin, are seen to be surrounded by a distinct primitive fine membrane and each to be furnished with its respective nucleus, whilst the primitive nucleus and membrane of the maternal cell disappear. And, consequently, only one or two diaphragms divide the cavity among them, and, by detaching themselves, constitute the walls of the new cells.

3. In the third mode of cellular multiplication it is

the wall itself of the maternal cell that, by inflecting itself into an annular fold, constricts the fine primitive membrane, which in such a case is persistent, and divides it into two portions, so that on arriving at the centre, it completes the diaphragm.

In the animals there have hitherto only been observed with exactness the first two modes of endogenous formation of cells.

If now we descend from the comparative examination of the vegetable and animal cell, considered generally, to the special examination of the more simple organisms among vegetables, excluding all those that can be considered of an ambiguous nature, we shall find almost countless numbers which present in perfect clearness, and in their primitive as well as in their permanent state, the most simple condition of a cell and its successive changes.

Among animals, on the other hand, we certainly have, as a primordial and transitory state, the egg or *ovum*, especially in the lower animals, which are very convenient for observation; but as representatives of their permanent state reduced to its extreme simplicity, we possess solely the genus *Gregarina*, of which we know six distinct species, all of them Entozoa, all organised as simple cells, but endowed at the same time with contractility and expansibility quite sufficiently to put their animal nature beyond doubt. For, when we consider the more simple Infusoria, the Monades, the Vibriones, and *Paramecia*, we soon perceive that their simplicity is apparent only. In respect to these (Monades, &c.) we have not to take merely account of properties inherent in a simple cell, but must rather seek to estimate those which belong to tissues whose organic elements escape our sight. Chemical reagents exert only a complex action upon the entire material of the body, whence we suppose it to be principally constituted of an azotised substance. And here I dwell upon the peculiarities of such Infusoria; for if, on one hand, they denote an organisation far more complicated than what was formerly ascribed to these, they may, on the other, claim to represent the ordinary conditions of the elementary cell.

Ehrenberg has described and delineated in many so-called Polygastric Infusoria, a mouth and anus, many vesicular stomachs, secerning glands representing the masculine sex, and ovaries along with these, together with one or more eyes in very many. The existence of such organs, in certain species, seems to be a fact now placed beyond controversy and beyond doubt. But the criterion by which the organs themselves are judged by analogy to exist in other microscopic beings, are not equally certain. Thus in the *Closteria*, and generally in all the Desmidieæ, it is clear that Ehrenberg *is egregiously mistaken.*

He supposed to be a stomach the nucleus, which, in *Closteria*, as in Zygnemata, is, from the first, suspended in the middle of the cell, and is large, transparent and colourless: but in order that these might systematically be termed Polygastric Infusoria, he applied the names of stomach and spermatic glands promiscuously to grains of starch and gonidia in their different states of development. Chlorophyll and all the rest of their contents he arbitrarily represented as ovaries.

The introduction of a coloured substance, accomplished only once in a *Closterium*, and only into one of the vesicles situated at the two extremities, proves no more than this, that the supposed terminal apertures may really be found in certain species at certain periods of their existence. And we know that in vegetable cells, at certain periods, there are formed in certain parts of the plant, circumscribed and regular apertures through which the contents issue forth. The mere presence of an aperture, and the introduction of exterior solid substances through this opening, cannot, therefore, be an absolute character of animality; for this, like other characters, is only of value as it is in accordance with the general conditions of organic beings. Having observed the presence of eyes in Infusoria we forthwith proclaim as eyes every red opaque spot, not merely in Infusorial Animalcules but in all microscopic objects, and the presence of eyes is adduced as an incontestable proof of their animal nature. The observations of Kützing, already quoted, on the metamorphoses of *Microglena monadina* into *Ulothrix zonata*, and of *Cryptomonas pulvisculŭs* into *Stigeoclonium stellare*, clearly show that elementary vegetables may not only manifest an apparent movement but may also present a body similar to the so-called eye in Infusoria, and the last is probably nothing more than a cell-nucleus.

Finally the division into two equal parts, or as we term it the *deduplication*, may take place in a being of complex organisation in a mode apparently similar to that by which it is effected in a simple cell. Not only in the lower Infusoria, as Monades and Vibriones, but in Polypi also, we see a transparent area appear first, and subsequently a line of demarcation in the place where a true division is effected at a later period.

Having premised these general considerations, let us examine the Diatomeæ, availing ourselves of the special and often cited labours of Ehrenberg and Kützing, as well as of scattered observations by other authors, and adding to these the result of our own researches.

Every Diatomean is formed of a siliceous shield and a soft substance therein contained. According to Kützing, this shield consists of pure silica, or, in some cases, perhaps, of silica combined with alumina. Nägeli, further, says that the silica is deposited in the outside of an organic membrane, which he believes to be of a vegetable nature. In fact, an organic membrane ought to exist, for the silica could not become solid except by crystallising or depositing itself on some pre-existing substance. On the other hand, we cannot admit, with Nägeli, that it has been deposited externally; for in many genera, and especially in the *Achnanthidia*, the siliceous shield is covered with a very delicate dilatable membrane, itself containing silica, as is proved by its sustaining unchanged the action of fire and acids. Therefore, comparing this shield with other organic formations, whether animal or vegetable, containing, in like manner, either silica or some other so-called mineral element, we may reasonably consider it to be formed of an organic tissue permeated by silica. This permeation may occur either in the wall of a simple cell, as is seen in the epidermal cells of many plants, or within minute cells, as in various plants and animals. The action of heat or of acid, in these cases, destroying the organic matter and leaving the silica untouched, does not alter the apparent form of the organ, because the skeleton remains unaltered.

Externally to the shield, Kützing observed a thin stratum, which he denominated *cement*, which may be made visible either by desiccation or by calcination, and produces either a simple opacity, or lines, points, and maculæ, sometimes irregularly disposed, sometimes regularly. He supposes it to be a silicate of iron or of alumina. Independently of the chemical materials which it may contain, this outside integument seems to me the more important inasmuch as even without resorting to the means indicated by Kützing, I observe it to be constant, not merely in the species enumerated by him, but also in many others, and I could almost assert that it exists in all. For to me it appears to correspond with that fine membrane of the *Achnanthidia* above mentioned, which, according to Kützing's own observations, is always visible whenever the two new individuals, (into which every Diatomean is resolved in its multiplication by deduplication) (*sdoppiamento*) begin to separate. The lines and points supposed to belong to the subjacent shield belong very frequently to this kind of covering.

The shield itself is formed of at least four pieces, or valves, united together in a four-sided figure—*tetragon*.

The mode of union is unknown. But the existence of a kind of articulation which permits an opening and closing, like the valves of a shell-fish, described by Corda in a species of *Surirella*, has been denied by other observers. Be this as it may, whether spontaneous after death, or induced by external means, this separation does take place in a regular manner. Now, if we suppose an organic cell with a wall permeated by silica, and with a four-sided figure, we can easily suppose that all the sides will mechanically support each other. Moreover, we shall meet with numerous facts by a different kind of analogy, viz., that with solid animal tissues belonging either to the internal skeleton or the external tegument.

The four valves are equal in length, but in many species and genera one pair exceeds the opposite pair in breadth. In order to establish an uniform language it is convenient to term those *primary* valves or surfaces which exhibit along the middle the line of division in the act of deduplication, which, since it is formed here in a normal manner, runs parallel to the other two surfaces, denominated *lateral*. Along the *primary* surfaces we frequently see longitudinal lines, which terminate at the two extremities in small apertures. From their internal surface there project into the cavity linear marks variously formed but always longitudinal; these are termed *vittæ*.

The *lateral* surfaces have frequently a round aperture, of greater or smaller size, in the centre, and from this a fissure extends towards each extremity. This fissure either loses itself gradually, or expands into the regular terminal apertures. When this occurs, each of these surfaces is divided into two distinct valves. On these *lateral* surfaces we observe the striæ, lines, and transverse costæ, no less admirable for their beautiful appearance than for their constant regularity in number, direction, and proportion. When many individuals are united together to form one compound being, like a polyp, for instance, it is always by the *lateral* surfaces that they touch each other; and since all other characters sometimes fail, we can affix to them the denomination *lateral* from this principal one.

Besides the vittæ before mentioned, in some genera (*Biddulphia*, *Clemacosphenia*, *Terpsinoë*) there are other solid substances in their internal cavities; these are variously arranged.

These essential peculiarities of the shield may perhaps be regarded as indicating a complex structure, very different, therefore, from what would be prescribed by a simple cellular wall. Ehrenberg deduces from it an argument to compare it with the shell of Mollusca. The Arcellinæ may be cited among the Infusoria. Kützing states, in reply, that among vegetable cells there is found a peculiar conformation of the walls, with prominences, depressions, points, lines, papillæ, and perforations, disposed in a regular manner; he refers to grains of pollen, as an instance. He might have added the more appropriate instance of the Desmidieæ, which would be very closely allied to the Diatomeæ, if the latter, like the former, could be referred to the vegetable kingdom. If not equal in constancy and regularity, the Desmideæ display a greater degree of complication; and we must remember the different nature of their substance, for in the vegetable cell, when lime or silica predominates, the wall becomes uniform and regular (?) (in the text uniforme ed *ir*regolare.)

The soft internal substance is brownish yellow, or of a gold colour. It is so described by Kützing. At first it is almost always homogeneous; at a later period it becomes granular, and divides into lobes, or contracts into many spherical bodies, or only into one larger globule. The development, forms, and distribution vary in different groups, but are characteristic in the greater number of these. Usually at first there is formed a continuous membrane, which afterwards splits longitudinally, and at a later period transversely, forming four lobes, which at a later period divide into minor portions. Hence Kützing infers that this substance corresponds with the *gonimic* matter of Confervæ and Algæ in general. And he adduces, as a principal argument, that by means of alcohol he can extract from the Diatomeæ a colouring matter similar to chlorophyll.

There exist, besides, among this substance, minute, colourless, and transparent spherical globules, varying, in the same species, in number, size, and disposition, at different stages, and we may add, according to various conditions, even under the eye of the observer. Kützing describes them as oil globules, because he saw them run one into another, as well on the inside as the outside of the shield. And he adds that these oil globules, in appearance and position, exactly resemble grains of starch in other Algæ, for which they seem to be substitutes, as happens in the cotyledons of Cruciferæ. The oil globules of Kützing are regarded by Ehrenberg as glands representing the male sex, and the supposed gonimic substance he thinks belongs entirely to the ovaries.

Finally, among the various bodies which constitute the internal substance of Diatomeæ, we have to mention some globules (*globelli*), more or less numerous, which are found disposed either in transverse arches (*archi*), round the median aperture of one lateral surface, but in very few species. These Ehrenberg regarded as stomachs, being led to that opinion by seeing them coloured with indigo—an effect, however, that could only be produced by keeping the Diatomeæ a long time in water laden with this colouring matter, and often renewed. Kützing believes this circumstance sufficient to show that they are not to be deemed gastric sacs, but merely solid corpuscles, which, being situate near an opening, exerted an especial attraction upon the colouring matter. He makes no other remark on their nature.

Whilst unable to confirm or refute the opinions of Ehrenberg, we seem to have observed facts sufficient to disprove those of Kützing. First, besides the three substances or bodies of a different nature described by this author (the gonimic matter, the oil globules, and the presumed stomachs of Ehrenberg), we observe in all species when examined alive, and in many after death, a colourless substance, mostly extended in the form of a membrane, and which seems to stand in continuity with the remaining contents. Indeed Corda observed and figured it, and Ehrenberg, as well as Kützing himself, makes frequent mention of it in his descriptions. I dare not assert anything as to the nature and functions of this fine membrane; but I do assert, notwithstanding, that in its appearance, in its form, and its behaviour under the action of chemical reagents, it differs from the thin membrane or primordial utricle of the vegetable cell, to which it might be compared.

With respect to the so-called gonimic substance, its identity with the endochrome of the Algæ is not at all proved. Its colour is different, and it is differently coloured by chemical reagents. The resemblance to it in some instances, as in *Melosira*, in regard to conformation and successive alterations, is only in appearance. In the endochrome of Algæ the monogonimic substance begins by presenting a granular appearance, then it becomes distinctly granulated, and changes into the polygonimic substance so minutely described by Kützing. But these changes do not occur in the coloured substance of Diatomeæ. If we insist upon a parallel, we can only compare it to the cryptogonomic (*crittogonomica*) substance of *Byssoidia*, *Callithamnia*, *Griffithsiæ*, and *Polysiphoniæ*. It divides into parts, which successively undergo ulterior division. And in regard to these changes, we may observe that there is an essential distinction between those that occur during life and those that take place after death, the greater number happening in the latter condition. And, during life, besides the changes detected on comparing individuals of the same species, those which take place under direct observation merit particular mention. The lobes described by Kützing are seen to swell, and in some places to project and retract successively.

The identity of this substance with endochrome is contradicted by Kützing's own experiments, which will be found very exact, by any one who may repeat them. These prove it to be very rich in nitrogen; it emits ammonia copiously when decomposed by heat, and this can only proceed from a substance abounding with it, which such a decomposition compels to yield it up. Nor, on the contrary, do I believe that there is any weight in the argument from the solubility of its colouring principle in alcohol, for this is not a property peculiar to chlorophyll or to any substance of vegetable origin. Finally, I may add that if a portion of chlorophyll could be demonstrated in the interior of Diatomeæ, this would by no means invalidate their animal nature; we might still suppose that they had swallowed it for food.

As to the oil globules, I fully agree with Kützing that they have this appearance; for some of them liquefy, possess a high refractive power, and may be artificially squeezed out, so to speak. Without any discussion of the instances in which oily substances are met with in vegetable cells, I argue that they are equally present in the two kingdoms. For, I ask any one habituated to the use of the microscope and to observations on Infusoria, whether the presence of globules of an oily appearance be not a constant fact, not merely in minute animalcules, but in almost every portion of animal substance? The so-called *Sarcode* of the French microscopists assumes, in fact, the form of oil globules. I observe, too, that the number and volume of these globules increase considerably after death, and that during life they are situated upon a longitudinal line extending from one extremity to the other. And I rely upon the observation that there is some motion and successive alteration in them, as if these minute globules mixed themselves with larger ones, and separated again from them.

Finally, with reference to the supposed stomachs of Ehrenberg, hitherto no fact enables me to satisfy myself. I will only remark that, exactly in the median region of *Naviculæ*, corresponding to the large aperture, the membranous production before mentioned may be seen extended across, during life; and this, vanishing after death, leaves in its stead an ample transparent area, of circular figure, and surrounded by those granules that take colour with indigo.

We will now continue the analysis of Kützing's anatomical and physiological observations. All the Diatomeæ, he says, give out through their apertures a mucous substance, which he calls jelly, to identify it with the vegetable jelly; this either diffuses itself in water, or collects into various shapes, or contains entire and determinate simple or multiple series of Naviculæ, forming one or more gelatinous tubes, which, detached or connected into bands, assume the form of the Phycoma of true Algæ. I confess that I have no arguments to controvert the foregoing indication of the origin and formation of the peduncles in Achnantheæ, Gomphonemcæ, and Ulnariæ; but to any one who has observed these beings, the explanation will not be satisfactory at all. It would be more probable to suppose that this peduncle should represent the original cell within which the siliceous frustules were successively developed. We might again make this supposition in respect to the gelatinous tubes containing the Naviculæ of *Schizonema*, *Micromega*, and other allied genera. But be it a simple product of secretion, or of itself an organic portion, this substance may equally belong to an animal and to a vegetable. Kützing declares it to be a gelatinous substance, or isomeric with starch; but adduces no experiment to prove it. The trials I have made seem to indicate a ternary non-azotised composition; for when burned, it has not the odour of horn, but of aniseed, and the products of distillation have rather an acid than an alkaline reaction.

According to Kützing, the propagation or multiplication of Diatomeæ takes place in three modes; by development of the gonimic substance, by division, and by formations analogous to seeds or gemmules.

The first is merely suppositious, and therefore requires no further notice.

Division is always longitudinal, and takes place underneath a fine external siliceous membrane, by the formation of contiguous diaphragm-walls which divide the internal cavity. Thus the contents are longitudinally divided. And this division is *complete* if the two new individuals detach themselves, and so acquire individual liberty. It is *imperfect* if the fine siliceous persistent membrane, and the secreted gelatinous substance retain them collected together. This mode of reproduction, (which Brèbisson distinguished by the name of *duplication* and *deduplication* from the reduplication of Desmidieæ,) deserves the most attentive observation. The foregoing exposition presents the fact in its most rude and superficial general appearance, and makes us feel acutely the want of a more circumstantial description peculiar to various forms. It is only after having established facts relative at least to the principal generic types, that we can establish, on a scientific basis, the general idea of multiplication by duplication. A few observations suffice, however, to prove that this does not occur in so simple a manner as we are taught to believe by comparing it with that in vegetable cells.

In the *Achnanthidia*, for example, it is described and figured that the principal surfaces, which occupy the intermediate space between the two superior and the inferior valves, commence by presenting fine transverse lines, and next a strong longitudinal line along the middle; then there appear two new intermediate valves contiguous to each other, the superior (valve?) of the new inferior individual, and the inferior one of the superior. My observations convince me that the affair does not proceed with so much simplicity. I have often seen the two lateral valves separated, and the intermediate space thus largely amplified. In other cases there appeared only a new inferior valve complementary to the superior, the inferior individual thus remaining incomplete. Finally, in others, between the complete superior individual and the incomplete inferior valve, there appeared a new individual, with both its valves; but nearer together, smaller, finer, with lines much less distinct. The exact exposition of this and other observations relating to it, will form the subject of another Memoir. It may suffice for me to intimate here just enough to demonstrate, that in this phenomenon there is more complication than that of a simple cellular deduplication (*sdoppiamento.*)

The third mode of reproduction discovered by Kützing, and that upon which he founds his principal argument in support of the vegetable nature of Diatomeæ, is comparable, he says, to the formation of spores or of buds (*gemmæ*) in plants. The *Melosiræ* consist of globular-shaped individuals united together by means of a fine external siliceous permanent membrane, into a filiform series, in a manner perfectly similar to the articulations of a Conferva. Each of these consists of two principal valves, in form like two sections of a sphere or polyhedron, inserted upon a cylindrical wall, by means of which the two valves or principal surfaces are united together and continuous. Kützing saw some of these presumed articulations to be dilated, as also occurs in those which contain the spores of *Œdogonia*. Though he observed nothing more, this was sufficient for him to declare as a fact the propagation by spores.

The other fact has reference to those Naviculæ which have a simple or multiple sheath, constituted of what he states to be a gelatinous substance consolidated into the form of phycoma. In some species of *Schizonema* and *Micromega*, he found contained within the same substance, globular bodies, which he saw successively enveloped in new phycoma, whilst the included substance, at first minutely granular, grew into so many Naviculæ. The observation is valuable, and furnishes a very important subject for study. For, whilst in other cases the difficulty of keeping pace with the successive development of the same individual obliges us to observe comparatively, different individuals, in respect of which there may always exist a doubt whether they really belong to the same species, here we have, as it were, a whole *brood*, consisting of individuals which present, at the same time, all the phases of their development. And this expression of (covey or) brood is not here used at random; since no direct argument beyond that from external resemblance, tends to show that these reproductive bodies are true spores; whilst, in the animal kingdom we find equally numerous analogies, as well in the ovaries of Polyps and other inferior animals, as in many Ovipara of superior classes. And in fact the bag of a spider, with the thousands of small eggs that it contains, seems to me quite as like as the spore of an Alga to the organ of propagation of a *Schizonema* or a *Micromega*.

Finally, in respect to the movements of Diatomeæ, Kützing's opinion evidently accords with ours; since, after treating at some length on the question of their animal or vegetable nature, he arrives at the singular conclusion that Diatomeæ consist of three substances: 1, one inorganic, constituting the shield; 2, one organic and vegetable, constituting the internal gonimic substance, the external envelope, and the peduncles; 3, one organic and animal, from which are formed the organs of motion. We cannot admit this third opinion, inasmuch as he assigns organs of motion even to the lower vegetables and their spores, similar to those which, according to him, partake of something like animal life.

Ehrenberg discovered, in some Naviculæ, a distinct foot, similar to that of Gasteropod molluscs, projecting from the median aperture and from the fissure in the inferior valve. In some *Surirella*, again, he observed extensible and contractile cilia protruding and retracting through numerous perforations in the margin. Certainly such organs are not to be compared with the vibratile cilia recently discovered on the surface of the vegetable beings before mentioned. But (independently of the presence of these organs, which hitherto have only been seen by Ehrenberg and Corda) the motions of Diatomeæ, as admirably described by Kützing himself, are so different from the motion of Oscillatorieæ, Desmidieæ, Protococcoideæ, and the spores of other Algæ, that they must certainly be referred to a different origin. Careful experiments may exclude all exterior causes, from the mediate impulse of other bodies, from evaporation, chemical and other agency. There still remains admissible the supposition of currents produced by the continued interchange between the exterior and interior liquid. But, with equal right we may admit the other supposition, that in a being whose nature, for other reasons, we believe to be animal, the movements may be effected by the admirable vital powers through organs which escape our sight by their minuteness. I add that, even in the smallest Naviculæ, observed with high magnifying powers, there is seen, during their motions, an agitation and a kind of sparkling, or, to speak more scientifically, a rapid and indeterminate change in refraction of light at their extremities, precisely in the situation of apertures existing there in the shield. Hence I venture to infer that though we cannot draw an absolute proof in support of the animal nature of these beings from their movements, it is still right to bestow particular attention on these facts.

Resuming what has been hitherto said, and comparing the arguments which seem to indicate the vegetable nature of Diatomeæ with those which favour their animal nature we are of necessity led to the latter opinion. If we suppose them to be plants, we must admit every frustule, every Navicula, to be a cell. We must suppose this cell with walls penetrated by silica, developed within another cell of a different nature, at least in every case where there is a distinct peduncle or investing tube. In this siliceous wall we must recognise a complication certainly unequalled in the vegetable kingdom. It would still remain to be proved that the eminently nitrogenous internal substance corresponded with the gonimic substance, and that the oil globules could take the place of starch. The multiplication would be a simple cellular deduplication (*sdoppiamento*), but it would remain to be proved that it takes place, as in other vegetable cells, either by the formation of two distinct primitive utricles, or by the introflection or constriction of the wall itself. Finally, there would still remain unexplained the external motions and the internal changes, and we must prove Ehrenberg's observations on the exterior organs of motion to be false. But, again, admitting their animal nature, much would remain to be investigated, both in their organic structure and their vital functions; excepting this, so far as we know, we have only one difficulty to overcome, that of the probably ternary, non-azotised composition of the external gelatinous substance of the peduncles and investing tubes. But as the presence of nitrogen is not a positive character of *animal nature*, so the absence of it is not a proof of *vegetable*. And in order that the objection should really have some weight, it would be well to demonstrate that this substance is isomeric with starch. For then, supposing all the arguments in favour of the animal nature of Diatomeæ were proved by new and more circumstantial observations, this peculiarity, if it deserve the name of objection, might still be regarded as an important discovery. We should then have in the animal, as well as in the vegetable kingdom, a ternary substance similar to that forming the basis of the vegetable tissue.

I conclude, however, that in the actual state of science, the Diatomeæ are to be enumerated among animals, but at the same time much remains to be accomplished in order to disclose their intimate organisation and vital phenomena. In the sadness of the reflection we are consoled by the saying of the immortal author of 'Cosmos,' that there is a field open for great discoveries where at present we see only scattered and unconnected facts.

ORGANOGRAPHIC REVIEW

OF THE

GENERA OF DIATOMEÆ,

ESTABLISHED BY KÜTZING.

1. Epithemia.—*Lorica in sectione transversali trapezoidea; striæ transversales validæ interdum granulatæ v. moniliformes.*

The characteristic trapezoidal figure of the transverse section results from the circumstance that the two principal surfaces are parallel to each other, whilst the lateral ones, again, are more or less convergent.

The superior surface is convex, the inferior concave, but usually with a much less decided curve; for which reason they are not exactly parallel. In some species, again, the inferior surface is plane, and the superior strongly convex, and carried down to the lateral surface, whence the section, instead of being trapezoidal, proves semicircular. Besides, the superior surface, instead of being regularly continuous, may present prominent longitudinal costæ. At least this is the case in my *Epithemia costata,* which occurs in Dalmatia, parasitic on *Biddulphiæ.* (*E. major e latere semielliptica apicibus acutis non prominentibus, e facie elliptico elongata, dorso longitudinaliter costata, costis ad latera transverse striatis.*) This species has the form of a grain of coffee applied by its plane surface, and furrowed (*solcato*) longitudinally along its convex surface. It is 0·043‴ long, 0·034‴ broad, 0·017‴ high. And these longitudinal costæ might perhaps indicate (*accennare*) an association of individuals, such as we have in the genus *Himantidium*, inasmuch as the multiplication by bisection (*dimezzamento*) occurs precisely in that direction. In such a case we should have both in the genus *Epithemia* and the *Himantidia*, incomplete division and lateral adhesion of individuals in the family Eunotieæ, and the first example of polypariform association through adherence by one of the primary surfaces, in this respect corresponding to the *Synedræ*, with this difference only, that the latter adhere by one extremity. Ehrenberg observed four individuals thus connected in the *E. Westermanni*. The comparison is justified also by this, that in my *Epithemia* there appears a kind of foot, which projects at the two extremities, with truncated appendages.

In all *Epithemiæ* the two principal surfaces present, at each extremity, two small apertures, united to similar apertures in the opposite extremity by fine longitudinal lines. The transverse striæ of the lateral surfaces are very evident, and in some species (*E. ocellata*, *E. Argus*,) terminate on the dorsum in round apertures. They are furnished with cilia, according to Corda, in his *Navicula ciliata*, which to me appears to be an *Epithemia* rather than a *Cocconema*, as supposed by Ehrenberg (*C. gibbum*). The internal substance appears to be uniformly extended at the origin, divided subsequently into two lateral masses; it is brownish-yellow, or green. A series of minute oily drops occupies the median line. Many species live in fresh water, many in the sea, and some are found in a fossil state. Kützing enumerates twenty-one species, to which we think two others (*E. costata*, *E. ciliata*,) ought to be added.

2. Eunotia.—"*Lorica in sectione transversali trapezoidea, striæ transversales tenuissimæ.*"

Although the only character by which this genus is distinguished from the preceding be the fineness of the transverse striæ on the lateral surfaces, yet the distinction appears to be justified by the circumstance that the

Eunotiæ are never found adnate and parasitic, as is constantly the case with the *Epithemiæ*. They are all found in fresh water, the greater number are exotic, many rare. When observed laterally, they are frequently seen to be more gibbous or prominent on the dorsum, which proves that the prominences themselves are placed transversely. Thirty-six species are enumerated by Kützing. It would seem that he ought rather to refer to the *Eunotia formica* than to the *Epithemia gibba*, the *Eunotia* No. 6 (pl. 2, fig. 27 *a b*,) of Bailey, which has very well-marked transverse striæ; and this uncertainty, were there no other, renders the distinctive characters of the two genera somewhat doubtful.

3. Himantidium.—*Lorica in sectione transversali rectangula; striæ transversales tenuissimæ, densissimæ, individua in fasciam transversaliter et arcte conjuncta.*

If we could distinguish the *Himantidia* from the *Eunotiæ* by the incomplete division, from which there result associations or polyparies in the form of a band, as in *Odontidia* and *Fragillariæ*, there would still remain the character of the entire family, *i. e.* the difference between the two primary surfaces. And since these associations are not always numerous, as in the three typical species (*H. Soleirolii*, *H. Veneris*, *H. guyanense*), we find it to be justly remarked by Kützing, that this genus is not yet well established, a remark that derives increased value from the fact already stated, that there is a lateral association even in the *Epithemiæ* (*Epithemia costata*, Men.). This very resemblance, however, attracts attention to another circumstance, viz. the parallelism in the *Himantidia* of the lateral surfaces, which, in the *Epithemiæ*, are essentially convergent. Of the ten known species, four only are European; they are all inhabitants of fresh water.

Of the three genera now enumerated, Kützing constitutes his family of Eunotieæ, which only possess in common the single character of convexity in one and concavity in the other, of the two principal surfaces; a character which reappears in various genera of stomatic Diatomeæ. Abstracting this character, the *Himantidia* would be referable rather to the family of Fragillarieæ, with which they seem to have a greater affinity.

4. MERIDION.—*Individua cuneiformia, prismatico-rectangula, in corpuscula flabelliformia vel fascias spirales arcte conjuncta. Striæ transversales validæ, perviæ.*

Kützing compares the Meridieæ to the Gomphonemeæ, which they really resemble, in the cuneate form of their single frustules, when viewed in front. But Gomphonemeæ have a median aperture, and interrupted transverse striæ, on account of which they belong to another order. In the order Astomaticæ, the author himself quotes the *Odontidia* as allied to this genus; but the *Synedræ* appear to me to approach it still more nearly; from these the *Meridia* in like manner rather differ in their cuneate form—which is inconstant,—by their ovate obtuse figure at the one and their acute figure at the other extremity of the lateral surfaces. The observation of M. Zinckem on the vittæ, whose presence is inconstant, becomes very important. This fact proves, in my opinion, that there is no foundation in truly natural characters for the primary distinction which Kützing establishes between the vittated and the simply striated Diatomeæ, by which so many natural affinities are openly transgressed, and so many forced alliances are effected, as we shall soon perceive. In the scanty state of our actual knowledge respecting the true organisation of these beings, it is impossible to establish a natural classification of them. In order to deviate from this as little as possible, it would be requisite to consider all the characters collectively, as we do in all other beings, whether animal or vegetable. And every distinction based upon a single character, besides being purely systematic, loses all value as a facility for classification so soon as exceptions occur, as in the present instances. Kützing says that at first the internal substance entirely lines the inner wall of the shell, it becomes divided afterwards into minute portions, which terminate by concentrating themselves in distinct globules. I believe that these changes only occur after death. Bailey succeeded in extracting a greenish resinous substance by means of alcohol. Only two well-defined species inhabit the fresh water of all Europe; two others are doubtful.

5. EUMERIDION.—*Individua cuneiformia, prismatico-trapezoidea* (?), *in flabellum vel fasciam convolutam coalita, demum stipitata. Striæ transversales perviæ, validæ.*

As Kützing has only seen dried specimens of the *Meridion constrictum* of Ralfs, upon which he has constructed this genus, it seems that we may assert from the exact description of this author, quoted at length by Hassall, that there is no indication whatever of that gelatinous pedicel like a cushion, upon which Kützing asserts that the frustules are arranged in a fan-shape, as in the *Synedræ*. Perhaps this erroneous impression may be founded on Ralfs' figure and description of the dried specimen, compared with the living one. These are his graphic words:—"As, however, they are not arranged in a plane, as in *Meridion circulare*, but stand nearly erect, somewhat like the staves of a tub which is broader above than below, when they are dry and fall down they necessarily separate, and gaps are produced in the circular outline. In the dried specimens I find some of the frustules arranged in a circle, which however exhibits the gaps already noticed, whilst others seem to be fasciculated." Therefore there remain only the trapezoidal section from the inclination of the lateral surfaces and the constriction of these near the apex, which characters, though undoubtedly of value to discriminate species, are not sufficient to establish a genus.

The superfluous division of genera, whilst it disguises the true affinities of objects, and fruitlessly complicates the study of them, has the additional mischief of exalting, in some degree, the value conventionally attached to characters, and compels us to form a distinct family of every genus. Such is the case with this attempt of Kützing in respect to the last two genera with the name of Meridiona, though they do not really differ from the preceding genus *Eunotia*, or the following one *Fragillaria*, except by a slight modification of form. Yet a similar modification does not seem sufficient to distinguish the two genera *Meridion* and *Eumeridion*. In general, characters deduced from the form of single individuals, certainly deserve a preference in comparison with those furnished by associations of numerous individuals into polypariform bands; but inasmuch as we do not know the relation between outward figure and internal organisation, the subdivision of families founded only upon this character seems premature, to say the least.

6. Denticula.—*Individua libera singularia vel binatim conjuncta, a latere primario oblonga l. linearia, secondaria transversim striata l. costata; striæ perviæ, validæ.*

The morphological character of this genus is the predominance of the primary surfaces over the secondary, and the continuity of striæ crossing these latter. We shall have an opportunity of returning to this particular subject when treating of *Surirella*. At present it is sufficient to observe, that whilst the first five species described by Kützing, and figured in plate 17 of his work, show the greatest affinity, not merely one to another, but also with the subsequent genus, the two others, *D. constricta* and *D. undulata*, display only how vague is the artifice of this system which brings together objects so dissimilar, and separates those which are truly allied. In these two species there is not only wanting the predominance of the primary over the secondary surfaces, but instead of transverse striæ, there are elevated costæ, and in one of them (*D. undulata*) even vittæ are visible, as they are in *Surirella solea*, to which it bears so great a resemblance, and yet, notwithstanding all this, it is included in the grand division of *Diatomeæ non vittatæ*. The name of any section and the character whence it is derived, need not be constant when the section itself is founded upon an assemblage of other characters, and its true characters consequently derived from affinity. But when this character is isolated, it entirely loses all the systematic value it can possibly have, so soon as it is wanting in constancy.

7. ODONTIDIUM.—*Individua quadrangula, a latere secondario transversim striata, lanceolata, in fasciam biconvexam arcte conjuncta.*

The *Odontidia* are merely a filiform series of *Denticulæ*. Whilst among the *Himantidia* there are promiscuously enumerated species of which the individuals are concatenated, and species with individuals merely geminate (*H. Arcus*), here, on the contrary, two genera are distinguished by this character solely. And the same character—the cuneate form of the frustules—by which the genus *Meridion* is distinguished from *Himantidium*, is again met with in *Odontidium*, but inconstantly and irregularly. I do not wish to infer from this that these generic distinctions may not be appropriate, because in the paucity of our knowledge respecting the intimate organisation of these beings, there is no adequate support for this opinion or the contrary; but it seems to me a clear inference that in an organological point of view these characters possess little value. Then, the number of transverse striæ varies in the same species, probably according to age. Six species inhabit fresh waters, principally alpine, one only (*O. syriacum*) inhabits the sea, one (*O? glans*) is found fossil, and one (*Fragillaria grandis*, Ehr.) is uncertain, to which, as an uncertain species, we may add the *Syrinx annulata* of Corda, which, if the figure ('Alm. Carlsb.,' 1833, tab. iv, figs. 45, 46,) be correct, has the singular character of continuity of the transverse striæ even over the primary surfaces.

8. Fragillaria.—*Individua linearia lævissima symmetrice formata, in fascias vel rectas vel curvas, biconvexas, arcte conjuncta.*

The singular individuals which constitute the filiform aggregations of *Fragillariæ*, are so like Naviculæ that there is often a doubt whether a particular species should be referred to the *Fragillariæ* or to the genus *Diadesmis*, in which the filaments are formed of Naviculæ possessing the essential character of a median aperture in the lateral surfaces. In fact, this doubt pervades all the new species enumerated by Ehrenberg and by Kützing, with a note of interrogation, among the *Fragillariæ*. Thus the absence of transverse striæ does not seem a constant character, or at least it seems that it ought not to be considered essential, inasmuch as some of these doubtful species (*F.*? *anceps*, *F.*? *amphiceras*) are striated. And Bailey describes and figures numerous and evident striæ, even in *F. pectinalis*, merely observing that "it requires a high magnifying power and skilful management of the light to render these apparent." In this genus, too, as well as in the preceding one, and with a little more regularity, we have frequently a cuneate form of frustule, resembling that of *Meridion*. There is a highly important fact, in an organographical point of view, presented by the *Fragillariæ*, in the *variable* length of the filaments as compared with the invariable length of the frustules composing it, a variation probably induced by age. In the paucity of our positive knowledge respecting the successive development of these beings, we must take this fact into consideration. The internal substance presents great variety of distribution, as is shown by Kützing's reducing to *F. pectinalis* all the species on which Ehrenberg had founded his character deduced from this substance. The four species safely referred to this genus inhabit fresh waters.

8 (*bis*). Grammatonema, a genus hitherto ill defined, regarded by the author as intermediate between *Fragillaria* and *Diatoma*, and to which Kützing, besides the

species of Agardh (*G. striatula, G. Jurgensii*), adds, in his work on Bacillariæ, three marine species of *Fragillaria* enumerated by Harvey (*F. diatomoides*, Grev., *F. aurea*, Carm., *F. Carmichaelii*, Grev.), though with respect to the last, Harvey himself objects to its position. I am much more satisfied with the other plan suggested by Harvey, to place it in *Striatella*, for as the vittæ are well marked in this genus, the species seem to belong to it. Kützing himself, in the Phycologia Germanica, united the two species (*striatula* and *Jurgensii*) of Agardh into one corresponding with the *Arthrodesmus striatulus* of Ehrenberg, changed the named *Grammonema* into *Grammatonema*, and referred this genus to the Desmidieæ. As to the *Frag. diatomoides* of Greville, with which I was favoured by Harvey, I think this conclusion right. It is a true Desmidiean, for it has no siliceous shield. And it is to be observed, that how perfectly soever it may resemble the *Fragillariæ* in form, it wants the longitudinal canals and terminal perforations of the primary surfaces; and the internal substance is similar to that of the Desmidieæ. But as to the *Conferva striatula* (E. B.), Sowerby's figure certainly represents a Diatomean. Wallroth has favoured me with a specimen thus named, collected by Jürgens, and it proves to be a *Grammatophora*. To the same genus, too, belongs the *Diatoma striatulum*, supplied by Lenormand, whilst the *Fragillaria striatula*, which I received from the same author, really belongs to the genus *Fragillaria*, and corresponds perfectly with the *F. virescens* of Ralfs. So there remains no small doubt in respect to this genus, which can only be removed by a comparison of original specimens.

9. Diatoma.—*Individua* (*linearia*) *quadrangula, symmetrice formata, primum in fascias conjuncta, demum soluta et per isthmum gelineum molle plus minusve distinctum angulis concatenata.*

The species with striated and perfectly linear frustules (*D. vulgare, D. mesodon, D. tenue,*) are precisely similar to *Odontidia;* and those with perfectly smooth frustules (*D. pectinale, D. vitreum, D. hyalinum,*) to *Fragillariæ*. Therefore there remains no other character to distinguish them except the angular connection into flexuose chains; this character appears again in other genera (*Tabellaria, Grammatophora, Rhabdonema,*) of distant sections. We shall hereafter have occasion to resume this subject. We will only observe now, that this condition is always associated with another, that of a peduncle by which the chains are affixed to submerged objects. Perhaps it happens more frequently and more remarkably than in *Odontidia* and *Fragillariæ* that we find in *Diatoma* the cuneate form of frustules, and it is surprising to see the inconstancy of the forms which Kützing, with incomparable diligence, has been able to collect, describe, and figure, referring them to different species. Three species (*D. mesoleptum, D. elongatum, D. Ehrenbergii*) differ greatly from the others, being contracted in the centre of the principal surfaces, and two of them (*D. elongatum, D. Ehrenbergii,*) still more because they are incrassato-capitate at the extremities of their lateral surfaces. (In respect to the *D. Ehrenbergii*, Kützing cites as synonymous my *Glœonema Heufleri*, because in the specimen I sent him he saw only the *Diatoma*, which is parasitic on the *Glœonema*, which he did not notice, and so he made me appear to confound a *Diatoma* with an Hydrurea. In the arbitrary selection he makes of some characters from external form to separate genera, families, and orders, we cannot help feeling surprise in finding united in the same genus species which present differences so marked. The character of flexuose concatenation, independently of organographic condition, (which as we shall see is of little value, reappearing in other groups,) ought to have much less systematic value than those taken from the conditions of form, which may be supposed to have a direct bearing upon internal organisation. For my part I think it would be much more natural to place the smooth species (*D. pectinale,* *D. vitreum, D. hyalinum,*) in the genus *Fragillaria;* those striated with elliptico-lanceolate lateral surfaces (*Diatoma vulgare, D. mesodon, D. tenue, D. mesoleptum,*) in *Odontidium.* There would remain, as distinctly generic, the only two species which have capitate extremities on their lateral surfaces, (*D. elongatum, D. Ehrenbergii.*) These two proposed unions would be justified on both sides, for whilst the *Odontidia* have forms little different from *Diatomæ,* the *Diatomæ* are little different from *Fragillariæ.* But I wish it to be well understood, that it is not my object to propose changes in the nomenclature or systematic arrangement of Diatomeæ. I only intend to institute an organographic examination of the proposed genera and groups. And organographically we shall probably have more important distinctions than those of form between *Diatomæ* and the *Fragillariæ;* the latter have constantly two apertures at each extremity of the principal surfaces, which seem to be wanting in *Diatomæ,* without adverting to the resemblance between the *Diatomæ tenue var. dimotum* and the very singular *Bacillaria.*

The character by which the last four genera (*Denticula, Odontidium, Fragillaria, Diatoma,*) are collected together into one family, namely Fragillarieæ, is the conformity of the two primary surfaces; nor do I know how the genus *Meridion* is excluded, even by the minutest characters. Kützing, indeed, cites the affinities with *Himantidia* among Eunotieæ, with *Diadesmis* among the Naviculeæ, with the various genera of Striatelleæ and Tabellarieæ among the Vittatæ. The relation appears to us rather one of analogy than of affinity, being the polypariform association of many individuals—conditions which associate together almost every form; and by this rule *Melosira* might be allied to *Fragillaria.* As to internal substance, Kützing says it is originally uniform in the shield of all Fragillarieæ, then divided into minute particles, mixed with oily globules, or contracted into a spherical mass.

10. Cyclotella.—*Individua singularia vel binatim conjuncta, disciformia; latus primarium distinctum, annuliforme; latera secondaria plana.* (*Lorica bivalvis, valvis planis, orbicularibus, annulo interstiali conjunctis.*)

With this genus there commences a series of forms which have a type totally different from the preceding. In the former the two primary surfaces are always distinct, whilst in those under consideration they unite in a continuous cylindrical superficies. In the one the lateral surfaces have always one diameter larger than the other, so that they become more or less lengthened; whilst in the other they are flat and circular, or convex and concave, but always segments of a sphere. In the preceding series we have, indeed, among the *Odontidia*, the *Fragilariæ*, and *Diatomæ*, such a convexity of the principal surfaces as is almost round, but the extremities remain always distinct; and in the lateral surfaces the striæ or any other processes run transversely without interruption. Here, on the other hand, we have a very evident radiated arrangement. This same arrangement is presented in another family (Coscinodisceæ) of another group; and there we shall have occasion to mention it again. In the genus *Cyclotella* we find species brought together which in fact possess great similitude of external form. But those from fresh water (*C. operculata, C. Meneghiniana,*) are free from attachment, and surrounded by a gelatinous substance; whilst the marine species (*C. scotica, C. ligustica, C. maxima,*) are parasitic. But if, again, we observe that the striæ or radiating puncta of the former are wanting in the latter, we shall find, in that circumstance, reason to suspect that even in internal organisation, to us entirely unknown, there may be very remarkable differences. Hence the observations of Nägeli, on what he terms a new species of *Gallionella*, and which certainly ought to be referred to this genus, are very valuable. (See Henfrey's translation of Nägeli's 'Memoir on Vegetable Cells,' in Ray Society's Reports, 1846, Tab. VI, figs. 1, 2, 3; Tab. VII, figs. 27, 28.)

Among Kützing's species this could only be referred to *C. scotica*, to which the author assigns a diameter of $\frac{1}{80}'''$, whilst Nägeli says that his species varies from 0·014'''—0·027'''; but not being able to decide without comparing them together, it is better, to avoid confusion, that the supposed *Gallionella* should be named *Cyclotella Nägelii*. In this species, which he examined whilst living, Nägeli describes and figures a nucleus of colourless mucus attached to the wall of one of the two lateral surfaces; from this, various colourless mucous threads extend themselves, (sap currents, as in the *Spirogyræ*,) which run along the wall itself, or more rarely into the cavity, one of which, however, constantly goes across through the axis of the cell, to the central point of the opposite overlying circular surface, where it forms a nucleus so soon as there appears a diaphragm dividing the cavity itself into two. This happens as well in individuals that have no siliceous shield, as in those that possess one; for Nägeli believes the shield to be external, and referable to an extracellular substance. A similar appearance of arachnoid threads radiating from a centre was seen, too, by Kützing, in *Melosira salina*. Globules of chlorophyll, says Nägeli, are distributed in two circles near the obtuse ends of the cylinder, or are disposed in rays round the nuclei of the two circular surfaces. It cannot be denied that such observations favour the vegetable nature of this being, but certainly they cannot destroy the value of many others that support the opposite opinion. In my *Cycl. melosiroides*, named by Kützing *C. Meneghiniana*, I observe that the deduplication (*sdoppiamento*) constantly occurs in individuals of smaller diameter, which on that account attain a height proportionally and absolutely greater, that is, a larger breadth of the interstitial ring. The Euganean hills afford a new species to this genus, in their thermal springs.

Cyclotella concentrica: C. margine in lateribus secundarus concentricæ definito, radiatim striato. Diameter varying from 0·008''' to 0·02''', and the striated margin occupies about half the radius.

Taking also into account the two doubtful species (*C. minutula, C. Rotula*), which Kützing justly suspects may be frustules of *Melosira*, we have thus nine species in this genus.

11. Pyxidicula.—*Individua singularia vel binatim conjuncta, non concatenata, libera vel versilia; latus primarium obsoletum (nullum) latera secondaria convexa. (Lorica bivalvis, valvis convexis, annulo interstiali destituto.)*

It is really surprising that although Agardh, Kützing, Ehrenberg, and Brèbisson, have described and figured the *Cymbella* or *Frustulia operculata* as the type of this genus, and corresponding perfectly with the foregoing generic character—Kützing himself, without acquainting us with the mistake of others, or his own, should now form the type of the preceding genus from this same species, preserving the name at first proposed, but altering the sense; and at the same time should describe, as a new species of *Pyxidicula*, the *P. operculata* of Bailey, which seems either identical with that of Ehrenberg, or very similar to it, and to that formerly so described and figured by the authors named above. The fact is, that the specimens of Brèbisson and Lenormand, in my possession, belong to *Cyclotella*, and not to *Pyxidicula*. The other species (*P. major*) described and figured by Bailey and Kützing, seems rightly to belong to the tribe of areolated Diatomeæ. Of the species included in flints (*P. globata, P. prisca*,) we can say nothing organographically, so uncertain is their nature. The *P. adriatica* is a being equally singular, of which we know nothing in an organographical and physical point of view. The same may be said of Ehrenberg's two genera (*Goniotheciam, Rhizosolenia*), which Kützing places doubtfully at the end of *Pyxidiculæ*.

12. Pododiscus.—*Individua singularia vel concatenata, stipitata; latus primarium obsoletum (nullum) latera secondaria convexa. Stipes lateralis. (Lorica bivalvis, stipitata valvis convexis, subhemisphericis.)*

The only species (*P. jamaicensis*) is too incompletely known for anything positive to be inferred.

13. Podosira.—*Individua concatenata, distinctissime stipitata, lorica ut in præcedenti genere. Stipes centralis.*

The *Podosiræ* are merely concatenated *Pyxidiculæ*, and this concatenation results from the persistence of the fine external membrane within which the deduplication (*sdoppiamento*) takes place, precisely as in the next genus, in which examples are not wanting of an uniting isthmus and peduncle, by which the *Melosiræ* also sometimes become stipitate. To the two species of Kützing (*P. hormoides, P. Montagnei,*) both exotic, we can add one from the Adriatic:

Podosira adriatica: P. articulis sphæricis, vix depressis. Sig. Stalio found it in Dalmatia, parasitic upon *Callithamnion Borreri.* The articulations are in transverse diameter, which is the longer 0·046‴, in longitudinal diameter 0·04‴, or a little more, and frequently the two diameters are equal, and the form perfectly spherical. Though not differing from *P. hormoides,* except in the lesser depression of the articulations, I still consider it different because of the constancy of that character. Kützing, to whom I sent it, suspects it to be the same as in *P. hormoides.* For my part I hesitated a long time whether I should not refer it to a form of *Melosira monoliformis,* since in the *Melosiræ,* even, the interstitial ring is at first absent; but besides that I have found its absence in very numerous specimens to be absolute, I found nothing that I could refer to the annular channels of the *Melosiræ.* Every articulation is constituted of two valves, perfectly hemispherical, which separate on being pressed; and each pair is contained in a cylindrical sheath, which embraces and surrounds the contiguous halves of the two articulations. This sheath has a remarkable firmness, for when the articulations are broken or separated, it remains wide open and unaltered in figure. It is crossed transversely by fine striæ, eight of which are contained in 0·0075‴. They are formed of as many series of minute points, projecting like papillæ. It often happens that the two articulations are separated a little from each other, and the external tube is then contracted in the intermediate space, perhaps indicating the origin of the isthmus. I never succeeded in observing more pairs connected together. The stipes is little inferior in length to the diameter of the articulation. Longitudinal folds are always present, which I believe to be six, since there are always four (at least?) on each surface. I have never succeeded in obtaining a sight of that central aperture in the lateral surfaces, from which Kützing says he has seen the stipes to issue both in *Podosiræ* and *Melosiræ*, especially the marine species. Finally, I observe that within the articulation there appears an open space, which is entirely owing to the internal substance, for it is destroyed wholly by fire or acids.

14. Melosira.—*Individua concatenata, adnata. Lorica bivalvis, valvæ cingulo v. annulo interstitiali tenerrimo maxime hyalino conjunctæ.*

"* *Lysigonium.—Articulis globosis vel ellipticis, prope utrumque finem carina annuliformi instructis.*"

"** *Gallionella.—Articulis cylindricis, non carinatis.*"

The *Melosiræ* in general may be regarded as polypariform associations of *Cyclotellæ*, and the comparison prevails principally in the second sub-genus. The distinction of the two sub-genera is also proposed by Hassall (*Sphærophora*, *Meloseira*), but it is to Kützing we are indebted for establishing it upon the important character of the *carina*, which occurs only in the first two species (*M. salina*, *M. nummuloides*), a character on whose organographic value we cannot decide anything, but which merits some consideration in a morphological point of view. For that projecting ring bounds the lateral surfaces; whilst in the other species, with sides more or less convex, these are continuous, as it were, with the primary surfaces. In all the species we may notice the double furrow which forms a ring connecting the body of each individual laterally to the interstitial ring;

this furrow or canal presents apertures disposed in a regular manner. Kützing believes these supposed apertures to be sections of the canals themselves, that is, portions of them seen in projection. This opinion is the only one consistent with the fact, that the filament being cylindrical, and therefore presenting itself indifferently on every side, these apparent apertures are always seen arranged near the margin. Ehrenberg's assertion that they are more numerous in some species, does not seem to be confirmed. This appearance is still more complicated, inasmuch as these fine tubular canals project from the internal surface of the shield, and a slight furrow externally corresponds with them. This condition is evident in *Melosira distans,* in which, owing to the greater depth of the furrow, the apparent perforations remain separated from the margin. The interstitial ring presents peculiarities of which we have no instance in the preceding genera. Its tenuity and the great variety of its extension are important characters. But here we must add the very important one of the changes it undergoes during observation. It is not uncommon to see the two halves of the articulation separate themselves slowly, and enlarge at the same time with the ring. This fact is not decisive in respect to the great question of the animal nature of these beings; for it is not subject to a subsequent contraction, and because in plants we have the analogy of *Spirogyræ,* in which, on the rupture of the outer tube, the extremities of the articulation, which were inflected like the finger of a glove, expand themselves as if by elasticity; but many facts controvert this inference. In support of the opposite opinion, is the frequent enlargement of a particular articulation, in a manner similar to that of the *Œdogonia.* But Hassall justly observes, "for this endochrome . . . . never becomes condensed into a distinct organ or sporangium;" . . . for this reason, the resemblance is reduced to a mere appearance. As to this supposed endochrome, proofs are certainly wanting that it is an ovary, as Ehrenberg supposes; but they are also wanting to show that it consists of gum, starch, or chlorophyll, which would be necessary were it a gonimic substance, as advanced by Kützing; and analogy even is wanting, for we do not sec, in any Alga, a similar disposition of the internal substance. The often quoted resemblance to the Confervæ cannot even be deemed apparent; for in no Confervæ are distinct spherules met so regularly, or disposed so symmetrically. During desiccation it happens in the marine species, as in the *Podosiræ* already described, that the internal substance adheres to the inner wall in the form of oily globules surrounded by a distinct, transparent margin, and compressed one against another in the form of regular polygons. Ehrenberg also speaks of diaphanous vesicular spaces, which he regards as stomachs. Kützing enumerates, figures and describes nineteen species, marine, freshwater, and fossil, besides the four doubtful ones placed at the end, and the famous *ferruginea* (*M. ochracea*, Ralfs,) which he proves not to belong to the class of Diatomeæ.

We have a new species in the Euganean thermal springs; this is so different from all the others, that it might serve as the type of a separate genus, which, meanwhile, I propose as a subgenus, with the name of *Pleurosira; articulis cylindricis non carinatis isthmo laterali angulatim concatenatis.* The specific description will be as follows:—Melosira (*Pleurosira*) *thermalis: major, articulis cylindricis solitiariis, isthmo laterali angulatim concatenatis, disco laterali levissimo.* Hab. inter Cladophoras et Lyngbyas in thermis Euganeis temp. + 30 R.

The diameter varies from $\frac{5}{100}$ to $\frac{8}{100}$ of a millimetre (5 to 8 centomillimetres). The length of the articulations is so variable, that I did not think it proper to mention it in the description. The shortest scarcely exceed the diameter, but others are twice or thrice as long. In the smaller specimens the interstitial ring exceeds a little in breadth the two lateral circular bands which form part of the secondary surfaces. A distinct and large circular canal, evidently projecting into the internal cavity, and, corresponding to an external furrow, bounds the ring itself on both sides, and is easily discernible, also, from the diminished thickness of the wall. Where this ring is most dilated, it presents two fine circular striæ, which divide it into three bands, the central one being the narrowest. In the longer articulations this central band is as broad as the others, or broader, and finally there appears a third circular line, and a corresponding diaphragm, which divides it. The wall of the two bands resulting from the division of the central one, grows thicker, and these become similar in every respect to the lateral valves of the two contiguous articulations. But no sooner are the two articulations complete, than they detach themselves from one another, and nothing remains to connect them but a lateral isthmus, in appearance like a joint (*forme apparente de cerniera*) (hinge), as in *Diatomæ* and *Grammatophoræ*. The internal substance, in dried specimens, is in the form of spherules, adhering tenaciously to the internal wall of the secondary surfaces; and one row only of these spherules adheres also to the interstitial ring by the side of the canal, in a similar manner to the teeth of the *M. sulcata*. Only whilst the two articulations are being completed, these globules are found in the intermediate space. On one occasion I have seen an articulation inflated as in *M. varians*. The isthmus is indistinctly unilateral and alternate.

At first sight of this singular Diatomean, the mind instantly recurs to the figure of the *Odontellæ*; and this resemblance is more strongly suggested by the figure given by Bailey of his *Gallionella*, (pl. 11, fig. 8,) which Kützing refers to *Odontella polymorpha*, a figure which, except for the contraction corresponding with the circular canals, coincides perfectly with our species. Were it only that Bailey, when comparing his *Gallionella* with *Diatoma auritum*, insists upon its cylindrical form, its want of appendages, and the mode of connecting the articulations by a "flexible hinge-like ligament," I believe that Bailey might with justice regard his species as belonging to *Gallionella* or *Melosira,* and I propose to name it *Melosira* (*Pleurosira*) *Baileyi.*

The celebrated Kützing, to whom I communicated these remarks, replies, "your *Melosira* (*Pleurosira*) *thermalis* is in no respect different from the *Odontella polymorpha.* I have compared your specimen with that of Montagne. There are even found the delicate (*zarten*) points upon the shield, as in the other which I have inadvertently omitted in my figure. Your specimen is certainly an *Odontella,* although the articulations are cylindrical (*teretes*), for it is the same also in the *O. aurita.* I think of uniting, in future, the Biddulphieæ with the Tripodiscieæ."

Although I have had an opportunity of examining fragments only of Montagne's *Isthmea polymorpha,* adhering to an imperfect specimen of *Polysiphonia subtilissima* from Cayenne, with which the celebrated author favoured me, I am still positive in treating the matter differently. It is admirably figured by Kützing; the articulations are not cylindrical, and though obtuse and slightly prominent, the lateral processes are very evident. Whether this belongs to the same genus as other *Odontellæ,* and whether that genus belongs to the family of Biddulphieæ, and to the order Areolatæ, is a question to which we shall return.

Now, resuming all that has reference to the family of Melosireæ, we shall find, as a character common to them all, the circular figure of the vertical section parallel to the lateral surfaces ; a character which, as well as the other, of a radiated disposition of the striæ upon the lateral surfaces, we shall find repeated in the family of Coscinodisceæ, which, having the shield of a cellular structure, belong to the tribe of Areolatæ. Perhaps we may suspect some *Melosiræ* (*sulcata, decussata, lirata,*) to be furnished with the same organic condition, and hence arises a fresh doubt respecting the systematic value that has been ascribed to it.

In general we may also say, that in the Melosireæ the development of the lateral surfaces prevails over that of the primary ones, which we find finally to disappear in certain genera (*Pyxidicula, Podosira,*) as well as in some species of *Melosira* (*varians, orichalcea*), the increased length of the articulations involving the corresponding development of the primary surfaces. And it is to be observed, that although in this family the primary surfaces differ precisely as much in form as they do in the three preceding ones, yet we find in these the same organic character as in the greater number of the other genera, viz., the presence of longitudinal furrows or canals. The separation of one lateral surface or valve from the other, with the consequent dilatation of superficies, which the primary surfaces exhibit before the duplication takes place (though verified to some degree in other genera, yet in the *Melosiræ* better than elsewhere), presents an undeniable analogy with the *reduplication* of Desmidieæ, which Brébisson distinguishes from the *deduplication* of Diatomeæ. The particular disposition of the internal substance, the currents or mucous threads radiating from a centre, the enlargement of some articulations, and the dilatation of the interstitial ring, are isolated facts, which however merit particular attention in the paucity of our knowledge.

15. Campylodiscus.—*Individua singularia, disciformia; discus curvatus vel tortuosus, rotundato-ellipticus radiatus.*

Although I have hitherto only been able to examine that one species of this genus (*C. clypeus,*) which is found in the fossil flour of Santa Fiore, in the kieselguhr of Franzensbad, and constitutes the entire substance of the tripoli of Eger, I think I can add something to what Kützing says of it. He indicates, indeed, in fig. 5, the thickness of the margin, which, in this instance, represents the primary surfaces uniting together into a continuous superficies, but neither in the other figures nor in the description does he notice it any more. Now, this superficies merits the more consideration because, referring it, as analogy requires, to the primary surfaces, it offers an exception to the general law that the transverse striæ are wanting. For these are very evidently continuous, and therefore may be compared to those upon the lateral or secondary surfaces of *Denticula*, of *Odontidium*, and *Diatoma*. We noticed the same condition before, treating of *Odontidium*, in the *Syrinx annulata* of Corda. But there remains that other character of the primary surfaces which seems to have the more organic importance,—the longitudinal division.

I have not seen the intermediate gradations, but I have certainly seen two individuals, one superimposed upon the other, and adhering closely, which might fairly be regarded as proceeding from the deduplication (*sdoppiamento*) of one individual. This brings new support to the affinity of this genus with the *Melosiræ* suggested by Kützing. That microscopical observations are to be interpreted with the severe scrupulosity of critical logic is well known to those who habitually use that valuable instrument; and the prudent caution will be more requisite when we have before us a fact at variance with many others. I ought not, therefore, to suppress a doubt that occurred to me relative to the continuity of these transverse striæ over the primary surfaces. In hundreds of individuals I have succeeded in obtaining a front view of the margin, and in seeing it crossed by those thick striæ which correspond to the radii of the lateral surfaces. These are among the microscopic objects which may be regarded as gigantic, and in respect to which we may banish all suspicion of illusion. But it may be supposed that in all such cases I have had before me only one of the lateral valves, and that the interstitial ring was wanting. Individuals geminate through an antecedent deduplication might have removed that doubt. But these are rare, and owing to the complication produced by the superposition of four similar transparent valves, I could not safely decide whether the striæ were continued through the entire depth of a cylinder which I could only see obliquely or in front.

As to the interruption of the radii, which is regarded as a specific character, this is not at all constant, and may, perhaps, depend upon the imperfect state of the specimens. The dotted appearance of the central disc always presents that regularity which Kützing only represented in the fig. 5 before mentioned. Similar puncta may also be seen in the spaces between the radii. The central aperture described by Ehrenberg is rightly denied by Kützing. A sort of analogy in form connects this genus with some species of the next; the only distinction I believe to be a repetition of that very important character of transverse striæ on the primary surfaces.

16. SURIRELLA.—*Individua singularia navicularia, margine striata; latus secundarium primario majus, linea media longitudinali lævi percursum.*

This genus is divided into four distinct sections. The first comprises the flexuose species, (*S. clypeus, S. Campilodiscus, S. flexuosa, S. elegans, S. spiralis, S. Myodon*); and really one is at a loss to find the motive that could induce Kützing to separate these generically from *Campylodisci*. In fact there only remains, in my opinion, the above-mentioned character of striæ continued over the primary surfaces in *Campylodiscus clypeus* to distinguish that genus. But the doubt already expressed as to this character, acquires still greater weight when we compare these *Campylodisci* with the flexuose *Surirellæ*.

In the *S. Campylodiscus* Kützing represents (Pl. xxviii, fig. 26, *c, d*,) the lateral valves detached, which give a perfect figure of a *Campylodiscus*, and their inclined margins viewed in front (*a, b*,) resemble transverse striæ on the primary surfaces.

The species (*S. didyma, S. solea, S. regula, S. multifasciata, S. thermalis*,) narrower in the centre than at the extremities of their lateral surfaces (*medio plerumque constrictæ*) are, in the opinion of Kützing himself, so allied to the *Synedræ,* that there remains no character to distinguish them except that they are free, whilst the latter are parasitic and affixed.

I confess that I cannot comprehend by what motive Kützing divides the numerous species that follow into two sections, (oblongæ, ellipticæ et ovatæ.) Were there a difference, how small soever, but constant, this might have a systematic value as rendering the distinction of species more easy; but we have only to compare together the two species *craticula* and *bifrons,* which figure in the two sections, to convince ourselves that the distinction proposed is not based on a constant character. And it causes real surprise to find enumerated in the second of these sections a species (*S. angusta*), which it is true has not the median contraction, but, from similitude of form, would by any one be supposed to belong to the section preceding, which we say is allied to the *Synedræ,* and in which section we have the *S. regula* and *S. multifasciata* both equally wanting in that character. Comprising, then, in a single group, both these sections, we assert that here exists that important character of the secondary surfaces exceeding the primary, which, as before stated, forms the contrast with the *Denticulæ.* But even among the latter there is not wanting an instance of the opposite condition (*D. undulata.*) The new *Surirella Jenneri,* of Hassall, as well as *Denticula constricta,* has the primary surfaces perfectly equal in dimension and form to the secondary. After all I believe that affinities and distinctions are rather to be sought in internal organisation than in external form, the latter having no organographical value except as an indication of the former. With regard to structure, though we are still far from having sufficient data whereon to establish any principle of classification, yet we find in *Surirella,* more, perhaps, than in any other genus of Diatomeæ, a multiplicity of organs and a complex organisation. The *S. striatula,* of which Turpin and Corda have given figures of little accuracy and in a great degree imaginary, supplied to Ehrenberg materials for numerous and valuable observations. It would appear that Kützing, anxious to establish the vegetable nature of Diatomeæ, designedly passed over this argument, and sought to distract attention by creating new species out of the various forms assumed by *S. striatula* at successive periods of age and degrees of development. Such we may suspect to be his *S. Pala* and *S. ovata,* as well as the *S. ovalis* of Brèbisson, who, as early as 1835, and not in 1838, had made public his *S. biseriata,* a name, therefore, which ought to be retained in preference to the later one (*S. bifrons*) of Ehrenberg. Bailey, too, noted the quick and lively movements of *S. striatula,* and I had frequent opportunities of observing it in our Euganean warm springs. I could compare together living individuals, among which there occurs an indescribable complication of internal structure, and dead skeletons, such as are represented by Kützing. Nor can I omit here the *S. gemma,* in which Ehrenberg discovered numerous extensible and contractile cirrhi which appeared to serve as organs of motion. It appears that Kützing had seen something similar in *S. solea,* (Pl. iii, fig. 61, 2*a*.) And in regard to *S. gemma* we must remember the lateral openings from which, according to Ehrenberg these cirrhi are protruded; openings which it would seem must exist also in *S. fastuosa,* and which remind us, also, of those before mentioned in some species of *Epithemia,* as the cirrhi remind us of the cilia of *E. ciliata* (*Navicula*) of Corda. It appears to me that it is now with Diatomeæ as it was with Mollusca down to the time of Cuvier, and that anatomy has to effect the same beneficial revolution in their natural classification, which it produced in the system and nomenclature of Conchylia.

Kützing finally ascribes to the same genus *Surirella,* as the last section or sub-genus (*Podocystis*), that species which I found to be so common in our sea, and which he therefore names *adriatica;* this association is truly singular, for whilst we see that the second sections are merely distinguished from *Synedræ* because they are not affixed, we find the *Podocystidæ* stipitate and affixed. Yet do I intend to maintain that it is not allied to the other *Surirellæ*. I only notice how vacillating are the principles of the proposed classification. The *Podosphenia* of Hassall, excluding the synonyms, seems to belong to this sub-genus.

17. Bacillaria.—*Individua bacilliformia prismatico-rectangula, linearia, primum in seriem rectam tabulatam transversim conjuncta, dein in series obliquas dimota.*

The singular appearances assumed by the only species of this genus (*B. paradoxa*) and the liveliness of its motions have long been celebrated (Müller). The principal organographical character that distinguishes it from the *Fragillariæ* is the same that allies it to a different group of the family, viz., the interruption of the transverse striæ in the median line of the secondary surfaces, to which is added the parallelism of the primary surfaces. Hassall overlooked the former of these characters in the figure he gave of this species. The physiological character of mobility of the frustules, and the symmetrical disposition which they assume, becomes the more important, inasmuch as they do not recur in any other Diatomeæ; and therefore we believe that they merit this particular mention.

18. Synedra.—*Individua bacillaria, prismatico-rectangula, demum uno vel altero fine adnata: latus secundarium primario æquale, vel angustius, linea lævissima media longitudinali percursum.*

* *Scaphularia.—Minutæ, rarissime adnatæ, lævissimæ; (non transversim striatæ.)*

The eleven species enumerated in this sub-genus are only classed together by negative characters, viz., the want of the characters of other genera more or less allied. In general it is only required that they should have their secondary surfaces marked with transverse striæ, either continued or interrupted, to be placed among the *Denticulæ* or the *Surirellæ*. In one (*S. quadrangula*) we have the character of *Denticulæ*, the excess of the primary surface over the secondary; in others (*S. virginalis, S. constricta*,) we have the median contraction of the primary surfaces characteristic of the second section of *Surirellæ*. Thus, indeed, all these species only want the central aperture to belong to the *Naviculæ* or *Achnanthidia* (*S. Biasollettiana*). Certainly we cannot say that the presence or absence of these characters is of little importance; we have only to remark that with the highest powers of the microscope it is often impossible to decide with certainty whether they have the transverse striæ and the median aperture or not.

** *Echinaria: lævissimæ, demum affixæ et plerumque radiatim aggregatæ.*

The seventeen species contained in this section do not differ materially from those in the former, except in being affixed. Many of them are attenuated at the extremities of their primary surfaces; but those destitute of that character (*S. amphicephala, S. tenuissima, S. tenuis*,) have great analogy in form with the *Ulnariæ*. We have also species in this section that are curved in their secondary surfaces (*S. curvula, S. Arcus*,) and in their primary ones, (*S. lunaris, S. bilunaris*,) which resemble the *Eunotiæ* and *Achnanthidia*. The *S. amphicephala* is distinguished from all by its dilated extremities.

*** *Ulnaria: affixæ, flabellatim disruptæ, in latere secundario, excepto spatio medio longitudinali lævi, transversim striatæ.*

Although the twenty-four species of this section have nothing in common but the general character of all the *Synedræ* (their bacillary form and the absence of a median aperture), still we find enumerated among them species that are unattached, (*armoricana, sigmoidea, vermicularis*,) and even destitute of the characteristic striæ (*vermicularis*); and this because the spirit of system (*spirito* *systematico*) has not gone the length of separating them from the other species with which in all other respects they have superior affinity. And as to the transverse striæ, this character of their interruption at the median line, which is not only stated in the definition of the section and of the genus, but is even taken for the basis of classification in the primary division of *Diatomeæ non vittatæ astomaticæ*, clearly fails in very many species, (*præmorsa, aequalis, mesolepta, Ulna, danica, splendens, armoricana, sigmoidea, scalaris,*) in which these striæ are continuous, as in *Denticulæ*. The *D. oblonga* may be compared with the above-named species. And it is also to be remarked, that though the transverse striæ are continuous in these species, as Kützing has accurately delineated them, still the characteristic transparent median line remains visible when the object is withdrawn to the remotest extremity of the microscope, which proves that there must be a longitudinal furrow traversing all the striæ; and to ascertain its depth it would require that the screw regulating the movement of the stage or of the microscope should be micrometric. This slight furrow is also visible in a fragment that accidentally presents the transverse section of such a *Synedra*. The type of this section is *S. Ulna*, and many other species as well as this (*acuta, oxyrhyncus, amphirhynchus, valens, armoricana, sigmoidea, vermicularis,*) have the primary surfaces perfectly linear; but others, again, have the extremities of these surfaces attenuated (*debilis*), like the greater part of those of the preceding section; others only rotundate, (*premorsa, spectabilis, scalaris;*) in reverse of these many are contracted in the middle, and cuneate and truncate at the extremities, (*lanceolata, mesolepta, aequalis, vitrea, danica, splendens, biceps, capitata.*) Among the latter we have three, (*danica, biceps, capitata,*) which, in the important character of capitate extremities of the secondary surfaces, resemble the *amphicephala* of the preceding section. And in the greater number of species in this section, as well as in some comprised in the former, (*notata, Martensiana, Vaucheriæ,*) the form is so similar to that of *Naviculæ* as to leave nothing but the want of central aperture to distinguish them. Finally, there are not wanting in this section species more or less curved. Those that are curved in the secondary surfaces (*mesolepta, biceps,*) might be regarded as similar to *Eunotiæ,* but they differ essentially in being attached. Those again which are curved in the primary surfaces (*Ulna, tergestina, armoricana, sigmoidea, vermiculans,*) have analogy only with the Achnantheæ. As to the *Sigma,* Kützing himself avows his suspicion that it may belong to the *Raphidogloeæ.*

**** *Tabularia; bacillis in stipite brevi, horizontaliter crescente, tabulatim disruptis.*

Exclusive of two (*S. Gallionii, S. Arcus,*) all the species (9) of this section want the transverse striæ; and all have that linear form, slightly attenuated at the extremities of the primary surfaces, which we have noticed in many species of the preceding section. The distinctive character of this section, the stipes on which the frustules grow side by side contiguous to each other, is very important in an organographical point of view. And by this character the species described and figured by Hassall under the name of *S. lunaris* would seem to be related to the *S. Arcus,* if it be really distinct.

***** *Grallatoria; stipite elongato sæpe ramoso, bacillis plerumque geminatis lævibus.*

Among the six species of this section, which in their aspect call strongly to mind the family of Licmophoreæ, two are perfectly linear on the primary surfaces, (*S. crystallina, S. gigantea,*) and one of them (*gigantea*) has the extremities of the secondary surfaces capitate. The rest have the primary surfaces attenuato-truncate at the extremities. All are smooth, wanting striæ.

****** *Rimaria; bacillis in tabulam connatis, demum modo Diatomatis disruptis et angulis alternis cohærentibus.*

Besides the sectional character which intimates an analogy with *Diatoma,* the only species that figures here (*S. rumpens*) differs from all the other *Synedræ* by the tumid and rounded extremities of the primary surfaces.

From this rapid examination of the sections into which the seventy species of *Synedræ* are divided, and to which Kützing adds seven more as uncertain, it appears that very different relations might be established among them; and that if in the greater portion an evident similitude in form would seem to indicate a very distinct genus, in many there appear indications of resemblance to genera and families totally different. We must therefore repeat, in this instance, that in the want of data whereby to judge of the organic importance of character, and in the arbitrary nature of the selection, of necessity resulting, Kützing has achieved a supremely laborious and diligent task, by discriminating, describing, figuring with wonderful accuracy, and distributing with some sort (*quacunque*) of systematic order so immense a number of species. As to the organographical considerations which can be instituted in this genus, they reduce themselves to the single one of length predominating over breadth, and the eminently bacillary form derived from it. Thus Kützing observed the opposite characters of *Synedræ* and *Surirellæ;* that the lateral surfaces exceeded in one, the primary surfaces again in the other. But it is not in this that the opposition really exists. For even among the *Surirellæ* we have some (*medio plerumque constrictæ*) of those which do not exhibit the boasted prevalence of the lateral surfaces, and which, therefore, we might with equal propriety enumerate among the *Synedræ;* whilst almost all *Synedræ* of the first section (*Scaphularia*), and some of the second (*Echinaria*) want even the last distinctive character that would remain,—of being affixed. The surfaces, which in all *Synedræ* are really reduced to the smallest dimensions, are the two which in *Surirellæ* of the last two sections, (*oblongæ, ovatæ, ellipticæ,*) and in the sub-genus *Podocystis,* still remain very evident, viz., the terminal surfaces. Kützing observes, that in conformity with the flattened form of the *Surirellæ,* and the lengthened form of the *Synedræ,* the intermediate spaces are placed laterally on the median line of the first, and are accumulated at the extremities of the second. But this accumulation never occurs until after death. Whilst they are alive the internal colouring substance is mostly situated along the median line of the lateral surfaces, or sometimes along the sides of these, and then in four to eight distinct lobes. In some species it is disposed in symmetrical and equidistant transverse fasciæ. In the central region there is often a transparent space, and many other varieties are met with; these are quite sufficient to indicate a complicated organisation, but we do not know how to interpret them rightly. Finally, we ought not to pass over in silence the important organic condition of two very distinct longitudinal lines on each of the primary surfaces, terminated at both extremities in minute perforations; a condition clearly delineated by Kützing in seventeen species, and which, in the smaller ones, we may suppose to have been obscure, or even unobserved.

Comparing together the four genera (*Campylodiscus, Surirella, Bacillaria, Synedra,*) which constitute the family of Surirelleæ, it is easily perceived that the last two only deviate from the Fragillarieæ by the character of interrupted striæ; and the first two deviating sensibly in the succession of species from the circular shape of the lateral surfaces, or of the transverse section, establish a transition between the Melosireæ, and the group formed of these two genera, along with the Fragillarieæ and the Meridieæ. Hence it is impossible to establish an organographical character that shall embrace the entire family and strictly represent its type. For even restricting the organographical data we possess to the predominance of the vertical surfaces (primary and secondary), with the greatest reduction of the terminal ones (inferior and superior), such as we have in the Fragillarieæ and the Meridieæ, but without the predominance of the primary over the lateral, as in the former,—what value these characters have, in what relation they may stand to internal organisation, I do not believe that we can decide in the actual state of science.

The five families (*Eunotieæ, Meridieæ, Fragillarieæ, Melosireæ, Surirelleæ,*) united together and arranged in two groups, as they have the striæ continuous (the first three), or interrupted (the last two), constitute the order Astomatica, or those wanting a character that is regarded as essential to the following order.

19. Cocconeis.—*Individua singularia elliptica, depressa, latere secundario foraminifero adnata, nunquam stipitata, latere superiori medio longitudinaliter impresso-sulcato.*

The general form of *Cocconeis* is that of a disk of an ellipsoidal figure, with surfaces more or less exactly parallel, plane, or slightly curved. It corresponds, therefore, to the figure of *Campylodiscus* and the flexuose *Surirellæ;* for in this genus, as in those, the secondary surfaces prevail so much that the primary are reduced to a simple margin. We know these to be the secondary surfaces by the transverse or radiating striæ with which the superior surface in many species is marked, and by the central perforation of the inferior surface; and because the division which is effected parallel to these corresponds to the marginal fascia which represents the primary surfaces. Contrary to all the genera hitherto examined, it is precisely by one of these secondary surfaces that the *Cocconeis* adheres to those filiform algæ, on which it lives parasitically. Hence their resemblance to the *Epithemiæ* is only in appearance. The individuals multiplied by duplication become quickly free, for it is rare to find them geminate; but they soon adhere parasitically to Algæ, and collect together in great multitudes. Most of the freshwater species are perfectly smooth. It is remarkable that the form of *C. Pediculus* (*C. Kützingæ*, Breb.) is conico-truncate; this is not noticed by Kützing in his definition, much less in the figure, on which account, before asking for his opinion of my own specimens, I thought he was describing a different species. Hence, in the duplication, the superior individual becomes smaller than the inferior; and from the same condition it results, that the margin appears bilineate when it is simple, as Kützing figures it, and trilineate as the same Kützing describes it in the specific definition, when it is merely in the course of duplication. The marine species display on their superior surface very elegant transverse granulated striæ, which either extend across the entire breadth without interruption, or radiate either from a median line or a central space. In only a few species the striæ are longitudinal, or concentric and waved (flexuose). The ulterior characters by which the thirty-four species of this most elegant genus are distinguished one from another, are still very slight.

20. Doryphora.—*Lorica simplex bivalvis quadrangula navicularis non concatenata, apertura in latere secundario nulla; linea suturali media longitudinali; stipitata.*

The principal characters of the family are wanting in the single species of this genus (*D. amphiceros.*) Fixed at one of its extremities by a stipes, and wanting the central aperture in the secondary surfaces, it differs from the *Surirellæ* only by the continuity of the transverse striæ. In respect to the central aperture, Kützing observes, that it may even be wanting in the *Naviculæ* themselves, and may be wanting in some individuals though present in others of the same species. On a character like this is based the difference of the orders. With more right, and supported by numerous facts, I can assert that there is a continuity of the striæ in many *Surirellæ*. Hence I regard the *Doryphora* as allied to these, and particularly to the *Podocystidæ*.

Now with regard to the family of Cocconideæ I can only repeat what has been said of the genus *Cocconeis*, that it presents a new type of organisation, differing from the preceding, summarily, in this, that the temnogenesis is effected transversely in the direction of the body, though vertically in respect to the point of attachment; in other words, that in these the surfaces become superior and inferior, which in the others were lateral.

21. ACHNANTHIDIUM.—*Individua simplicia, singularia vel binata, libera; a latere primario linearia genuflexa.*

Admitting it to be proved that in the species of this genus (*A. microcephalum, A. delicatulum*) there positively exists a median aperture in one of the lateral surfaces and not in the other, and that two perforations exist at the extremities of the primary surfaces, as stated in the definition of the order and in that of the family: admitting this, we should still have to decide whether the uncertain relations of these characters to other families, and their inconstancy, will give us any right to erect a distinct genus on principles so slight and precarious. This is, indeed, a systematic experiment that is not sufficiently established on an organographical basis.

22. ACHNANTHES.—*Individua solitaria vel binata vel numerosa in fascias plus minusve elongatas transversaliter conjuncta, stipite laterali adnata.*

In the want of striæ three species (*minutissima, exilis, parvula*,) present great analogy of form with the preceding. In one of these (*parvula*) there is wanting the characteristic angular bending, for which reason it becomes very similar to *Odontidium* and *Diadesmis*. The other ten species (*striatæ*) differ only by very slight characters from each other. Besides the organic difference between the two secondary surfaces, the constant median aperture of the inferior or ventral, (Ehrenberg,) and besides the process of duplication, which may be studied, in all its details, in the *Achnanthides* better than in any other Diatomeæ, the stipes truly merits particular consideration. Its constant collocation proves that the *Achnanthides* are, like the *Surirellæ*, adherent by one extremity, and the insertion of the stipes becomes oblique only because the duplication always takes place on the side of the dorsum; that is, in other words, from the two individuals which are formed at the expense of the first one, only the one corresponding to the dorsal surface is ultimately separated; and the same thing occurs with those that follow. As to the internal substance, Ehrenberg says it is divided into many rounded portions, which in *A. longipes* collect in the middle, like rays, around the median aperture. In the *A. salina* (*A. brevipes*, Ehr.) the same Ehrenberg describes this substance as separated, from the first, into four lobes, which finally divide and resolve themselves into moveable corpuscles.

23. Cymbosira.—*Individua vel solitaria vel binata, stipitata; in series isthmo gelineo concatenato.*

The essential character by which the single species (*C. Agardhii*) generally differs from the *Achnanthides* seems to indicate that in this the duplication happens promiscuously either in the inferior individual or the superior. The series consisting of solitary individuals may be considered as originating from the successive duplication of only one superior or dorsal individual. The same may be supposed of the series of geminate individuals alternately conjoined; but when the conjunction is unilateral the supposition is admissible that after the first duplication is accomplished the second is effected in an inferior individual, and repeated in the inferior one through the successive links of the chain. We may notice that the dimensions vary greatly in different individuals, but are constantly the same through all of one series. The specimens from Cayenne, parasitic on *Polysiphonia subtilissima*, (along with *Podosyra Montagnei* and *Odontella polymorpha*,) differ from the

Adriatic specimens by their larger curvature and more decided transverse striæ.

The family of Achnantheæ is also distinguished from all others by the complicated structure of the shield. The primary surfaces, Kützing says, are formed of three pieces, two lateral, transversely striated, and one median traversed by two longitudinal striæ with terminal perforations corresponding to their extremities. Hence every individual will appear to be formed of eight valves. To me it appears, on the contrary, that these transversely striated lateral portions can by no means be distinguished from the secondary surfaces; there being neither angle nor joint to indicate the supposed distinction. I do indeed find that the two halves of each lateral surface are inclined to each other like a roof, and they easily become detached one from the other, thus constituting, together with the two primary surfaces, at least in appearance, six valves. The internal funnel-shaped appendage which accompanies the central perforation of the inferior valve, is really very remarkable.

24. CYMBELLA.—*Individua solitaria vel geminata, libera (nec adnata nec inclusa), curvata inæquilatera; latere primario uno (interiori ventrali) angustiore, altero (exteriore, dorsali,) latiore; lateribus secundariis æqualibus (transversim striatis); aperturis mediis marginalibus approximatis.*

In general form, in the parellelism of the curved primary surfaces, in the inclination of the secondary surfaces, in the trapezoidal transverse section, and in the mode of attachment when parasitic, (*C. Pediculus,*) the *Cymbellæ* are very similar to the *Epithemiæ*. They differ essentially from these by the two perforations placed in the border of the inferior side of the lateral surfaces, and therefore sufficiently near each other to seem united into one when placed obliquely. They have, moreover, a distinct aperture at each extremity. The difficulty of making out these characteristic perforations in the minuter species renders uncertain the generic arrangement of some among the fifteen species enumerated by Kützing.

25. COCCONEMA.—*Individua ut in genere præcedenti sed stipitata, stipite ex uno apice cymbellarum crescente.*

Without concerning ourselves with the generic value of the character which is wanting in six of the eleven species ascribed to *Cocconemæ*, it is most interesting to consider that whilst some *Cymbellæ* adhere parasitically to submerged bodies by their ventral surfaces, like *Epithemiæ*, the *Cocconemæ*, again, adhere with a stipes by one of their extremities. Are we hence to infer that the adhering side may be either one of the primary surfaces or one of the secondary (Cocconoideæ) or finally one of the extremities? Or must we regard adhesion as a primary character in judging of the organographical correspondence of the various surfaces and different types, and make other characters subordinate to it, such as the one derived from the division which sometimes takes place in the direction of that surface, sometimes transversely to it? Again, admitting the first case, ought we not, at least, to ascribe to this character a value superior to that of the presence or absence (at least when they are doubtful,) of the central and terminal apertures? Or, finally, that adhesion of the only species of *Cymbella* which is said to be parasitic (*C. pediculus*), is it not merely ventral in appearance, as seems sometimes to be the case in certain *Achnanthides?*

26. SYNCYCLIA.—*Individua cymbelliformia transversim in fascias circulariter in curvas connata, in substantia gelinea molli amorpha nidulantibus.*

The genus *Syncyclia* (*S. salpa, S. quarternaria*) represents, among the Cymbelleæ, the genus *Eumeridion* in the order Astomaticæ, the *Epithemia costata* in the family of Eunoticæ. Whenever the lateral surfaces are inclined to each other, by the different extension of the two primary surfaces, the associated series must be formed circularly, as it is effected in a circular or at least a curved manner in the plane of the associated series, whenever the primary surfaces are cuneate, and the convergence of the lateral surfaces is in the direction of one extremity (*Meridion, Odontidium, Diatoma.*)

27. Encyonema.—*Cymbellæ longitudinaliter seriatæ tubo gelineo simplici tenerrimo molli inclusæ.*

The gelatinous tube within which the Cymbellæ referred to this genus are included (*E. paradoxum, E. prostratum,*) might perhaps be compared to the stipes of *Cocconema,* and thus serve to explain its origin. We must, in that case, suppose the stipes to represent the gelatinous sac within which the Cymbellæ is developed.

In all the family of Cymbelleæ (*Cymbella, Cocconema, Syncyclia, Encyonema,*) we may repeat what has been said before of the genus *Cymbella,* since the distinction of genera is based upon characters merely accessory. We may here refer to what Kützing says of the internal substance. This is disposed in two laminæ extended upon the lateral surfaces, which present a median notch (*emarginatura*) corresponding to the convex side, and are collected together into a very fine transverse membrane.

28. Sphenella.—*Individua solitaria, cuneata, libera, nec affixa, nec stipitata, involuta.*

The *Sphenellæ* only differ from *Naviculæ* in their cuneate form, perfectly similar to that of *Meridion,* by which, too, the associations (*S. angustata*) become flabelliform and quasi circular; but they differ from *Meridion* by the central perforation of both secondary surfaces, and by the interruption of the transverse striæ of the same surfaces, (*S. glacialis, S. vulgaris.*) Hence there remains a greater similitude to the *Naviculæ,* and the distinctive characters are so slight, that the generic arrangement of at least two species (*S.*? *parvula*, *S.*? *Lenormandii*,) out of the seven remains uncertain.

29. GOMPHONEMA.—*Corpuscula silicea a latere primario cuneata, basi affixi vel stipitata, stipite gelineo.*

As *Cocconemæ* from *Cymbellæ*, so *Gomphonemæ* only differ from *Sphenellæ* by the stipes; on which account species are now referred to *Gomphonema* which formerly belonged to *Sphenella* (*G. olivaceum*). And with respect to the whole thirty-three species of *Gomphonema*, it is still doubtful whether they ought not rather to be placed among the *Sphenellæ*. Independently, therefore, of the value which the presence of the stipes may have as a generic character, it is important to consider it in an organographical point of view. Kützing supposes the *Gomphonemæ* to be at first free, like *Sphenellæ*, and that afterwards they affix themselves by means of the (gelatinous) substance of the stipes, which in his opinion they secrete from the inferior extremity. No direct observation confirms this hypothesis, and it is at least as just to admit the other, that the *Sphenellæ* are at first attached, like the *Gomphonemæ*, and afterwards become free. Ehrenberg says, that the *Gomphonemæ* can become free and again adhere. The circumstance of a tubular cavity through which this stipes runs, according to Kützing, and the laceration that is produced in this tube, when in the act of duplication the two new individuals separate from each other, effecting a dichotomy, if by any means it could be reconciled with the idea of a simple secretion, certainly agrees better with the supposition that the stipes in *Gomphonema*, like that of *Cocconema*, may be compared with the tube of *Encyonema*, and, like that, capable of its own proper growth, and therefore endued with life. But it remains to be proved that the stipes can divide itself from above downwards, to produce the dichotomy, as maintained by Kützing. There is little to be remarked on the form of *Gomphonema*. The primary surfaces are constantly cuneiform-truncate. In one only (*curvatum*) they are curved. The secondary are obovato-acute in the first eleven species; elliptico-lanceolate in four, (*dichotomum, affine, intricatum, lanceolatum;*) in all the rest they are distinctly capitate or more or less panduriform.

30. SPHENOSIRA.—*Individua in filum complanatum anceps rectum arcte conjuncta, a latere secundario apicibus inæqualibus; apertura media distincta.*

Kützing himself observes, that the single species of this genus (*S. catena*) belongs rather to the genus *Diadesmis* of the following family, because, although the apices of the secondary surfaces are unequal, it wants the constant character of all Gomphonemeæ, the cuneiform primary surfaces; whilst we see represented the associated form of *Sphenella angustata.*

The Gomphonemeæ, according to Kützing, (*Sphenella, Gomphonema, Sphenosira,*) are related to the Licmophoreæ in form and development. They differ by the absence of the vittæ, and the presence of a central perforation in the lateral surfaces. The internal substance is disposed in two laminæ extended over the primary surfaces; in opposition, therefore, to what takes place in the preceding family of Cymbelleæ. Ehrenberg notices, also, colourless vesicular spaces. We must not omit, that even in Gomphonemeæ the primary surfaces are traversed by the usual two longitudinal striæ, terminating, superiorly at least, in distinct apertures.

31. NAVICULA.—*Individua singularia libera, regularia, rectangula, prismatica; apertura media rotunda.*

In this genus, the richest of all in species, and the type of a family the richest of all in genera, from which some have adopted the name Naviculeæ rather than that of Diatomeæ for the entire class, the constant character is the symmetry of each pair of surfaces as well as of both extremities. We have seen this character, with a few exceptions, in the family of Fragillarieæ, and still more in the Surirelleæ. Hence it follows, that in some genera

(*Denticula*, *Synedra*,) or in some species (*Surirella*) of these we must resort to other characters to establish the distinction, more especially as the forms are frequently very similar. This essential character—that of the entire family—is the presence of a central aperture in both the secondary surfaces. But this character is wanting in some species of *Navicula* (*Oxyphyllum*, *vulpina*, &c.) and in one of the subsequent genera; and Kützing observes that it is often very difficult to discover the aperture on account of its minuteness, and that it is absent in some, though evident in others of the same species. Therefore, without attempting from this to argue in opposition to the organographical importance of the character itself, it is certainly of diminished value systematically considered; and Kützing acted prudently, in doubtful cases, by regarding evident affinities of figure, so as not to separate similar objects from one another. Kützing divides the large number of species (137) into six groups, according to their shape;—*lanceolatæ*, *oblongæ l. ellipticæ*, *gibbæ*, *constrictæ s. nodosæ*, *lunatæ*, *sigmoideæ*. The greater number of species belonging to the first section (*lanceolatæ*) have precisely the form termed navicular, the primary surfaces linear, and the secondary longato-elliptical, with their apices more or less acute. We have seen above that the first section of *Synedræ* (*Scaphulariæ*) have this same form; and after the admission of Kützing himself and his example in respect to one species, it is truly surprising to see the *Scaphulariæ* and *Naviculæ lanceolatæ* generically separated from each other. Some of the species referred to this first section show a gradual transition to the different forms of the succeeding sections. But in all these we find species described and figured in Kützing's work so similar to one another, that there occurs a well-grounded suspicion respecting the propriety of the distinction. And here it is proper to observe, that in Diatomeæ, more perhaps than in any other class of organised beings, it is difficult to pronounce a certain decision on the value of characters. In animals, as well as in plants, the multiplication by reproduction is accompanied frequently by alterations more or less important in size and external form. When, again, the multiplication is effected by simple division, both the forms and dimensions remain constant. Nor will we here enter upon the difficult question that relates to reproduction; neither do we intend to define in what this differs from simple division, though a division it certainly is. In the Diatomeæ the distinction is easy. In these a reproduction certainly takes place, since mixed among the larger individuals of every species we often see some smaller, some very small, and others of every intermediate size. But their enormous abundance seems to proceed from division (*divisione*) rather than doubling (*dimezzamento*). Now, in doubling (*dimezzamento*), the forms and dimensions (of the secondary surfaces) continue perfectly equal. Hence that wonderful uniformity in myriads of individuals which present themselves to our observation, all of which, perhaps, were derived by successive partition from a single one. Hence the natural tendency that must be felt by every observer to distinguish more species when, among these individuals mathematically equal to one another, he sees some rather different in form and dimension; or when he sees other thousands of individuals differing only by slight conditions from the former, but all precisely equal one to another. If, again, he then happen to meet with forms mingled among them, different but in degree, and which successive observation proves to belong to the same species, he reflects upon the difference that prevails among them, as well in proportion as in dimension, and he easily believes, again, that these differences are really greater than those frequently proposed to distinguish species. Kützing, for example, gives us four figures of *Navicula viridula*, (Pl. iii, fig. 44; 1, 2, 3, 5, 6: Pl. iv, fig. 10, 15: Pl. xxx, fig. 37.) These he properly refers to the same species, although the proportion between the breadth and length, the degree of convergence of the sides, and the ventral prominence, are certainly unequal. If we compare the three figures of *Navicula nodosa* (Pl. iii, fig. 57; 1, 2, 3,) we shall see in one of these (2) a median enlargement that is wanting in the others. Certainly we find minor differences when comparing species with species. If we look to dimensions, it is only in some species that Kützing observes and figures the two extremes in size, as, for example, in *N. amphisbaena*, (Pl. iii, fig. 42.) For the rest he contents himself with noting the largest size. But Ehrenberg observes also the smallest extreme that he meets with, and delineating exactly the intermediate forms, puts in evidence the specific characters that remain independently of age and degrees of development. Treating of the dimensions of these microscopic beings, I cannot avoid making a few observations. Mohl has discussed the methods of micrometry in a profound manner, showing the comparative degree of accuracy to be attained by them. From that inquiry it appears that the camera lucida is the most exact and safest of all; I have found it more convenient than any other. Taking a glass micrometer (by Plössl) in which a millimetre is divided into 100 parts, I copy the image of it by the camera lucida, repeating the operation many times to ensure the exactness of my copy. Though executed with an excellent machine, the diamond-marks are never perfectly equidistant, and are always too broad to exclude slight inaccuracies. On this account many trials are required to obtain a sufficient approximation. From this copy I can ascertain with precision the amplification obtained, which is always relative to the vision of the individual. Whenever I wish to determine the size of an object, I copy the image with the same combination of eye-glass and object-glass, with the same camera lucida, at the same distance; and measuring that upon a graduated scale, I obtain the dimensions sought for by an easy reduction. To abridge and facilitate the inquiry, I construct a decimal scale on a copy of the micrometer; upon this I can draw the divisions, if the magnifying power do not exceed 600 diameters, and by causing the image from the camera lucida to fall upon it, I have its measurement immediately taken. I have constructed one of these scales for every combination of my microscope, and thus by a simple application of the camera lucida, I can measure every object without at all changing the conditions of the observation. I dwell upon the method I pursue in my microscopical researches, to prove that I devote to it scrupulous accuracy. The screw micrometer also gives millimillimetres, and by the addition of a nonius even decimillimillimetres; but besides that it is inconvenient to keep it applied to the plate of the stage, and that there is great loss of time and interruption of the observation in applying it when its use is required, it has always the great inconvenience of waste of trouble. In ten observations with the screw micrometer, we scarcely find two that perfectly agree. With the camera lucida one only is sufficient. I think it unnecessary to bring arguments against the method of applying a glass micrometer over every object we wish to measure. Still the plan of a micrometer fixed in the eye-glass, and previously corrected by examining another micrometer as the object of observation, possesses great convenience, though not perhaps scrupulous accuracy. But we have not merely to measure the objects we are about to describe; we must also define that measurement. It would seem so simple a thing for all to use the same standard, and there is so much convenience in the metrical measure and decimal notation, that it excites real wonder to see how prevalent among men of science is the habit of preferring the duodecimal measurement peculiar to every country, and expressing that in vulgar, not decimal fractions. The evil would be less were any one (standard) adopted, constantly used, and defined. But the matter is worse than this. Ehrenberg speaks perpetually of a line, without stating the standard; at the same time he gives its equivalent in metrical admeasurement, and from this it appears that his line is equal to two millimetres. This line is one peculiar to himself; for the line of English measure, which is the smallest of all, exceeds two millimetres in measurement. Kützing makes use of a linear measure with the same notation as that used by Ehrenberg,—three small marks, which usually indicate the millimetre, to the right of the cipher. It would appear that he intends to speak of the same conventional line; at least I arrive at this conclusion from the following comparative table of the extreme length of some species of *Navicula*, deduced from direct observation, from the cipher of Ehrenberg and that of Kützing, on the double supposition of the line being conventionally equivalent to two millimetres, and to the line of the Parisian inch = 2·707 centim., and from Kützing's figures.*

Navicula amphisbæna	0·070 millim.
Ehrenberg, $\frac{1}{20}'''$	0·100
Kützing, $\frac{1}{26}'''$	0·076—0·104
Kützing's figure, 0·021 ($\frac{420}{1}$) . . .	0·050
Navicula cuspidata	0·070
Ehrenberg, $\frac{1}{5}'''$	0·133
Kützing, $\frac{1}{23}'''$	0·087—0·117
Kützing's figure, 0·0242° ($\frac{420}{1}$) . .	0·0576
Navicula appendiculata	0·027
Kützing, $\frac{1}{54}$	0·037—0·050
Kützing's figure, 0·0093° ($\frac{420}{91}$) . .	0·022
Navicula viridula	0·047
Kützing, $\frac{1}{32}'''$	0·062—0·084
Kützing's figure, 0·0192 ($\frac{420}{1}$) . . .	0·0457
Navicula gracilis	0·054
Kützing, $\frac{1}{26}'''$	0·076—0·104
Kützing's figure, 0·0207 ($\frac{420}{1}$) . .	0·049
Navicula major	0·235
Ehrenberg, $\frac{1}{6}'''$	0·333
Kützing, $\frac{1}{9}'''$	0·222—0·300
Kützing's figure, 0·058 ($\frac{420}{1}$) . . .	0·130
Navicula oblonga	0·135
Ehrenberg, $\frac{1}{12}'''$	0·166
Kützing, $\frac{1}{11}'''$	0·180—0·246
Kützing's figure, 0·0466 ($\frac{420}{1}$) . . .	0·110

It results from this table that the ciphers of Kützing express, in fractions of a line (equal two millimetres),

* In the present translation the decimal numbers indicate millimeters or parts when not otherwise marked, and parts of a line are given in common fractions with the sign '''.—Ed.

measurements in general a little exaggerated; not so much, however, as those of Ehrenberg; and the figures (in Kützing's plates) are rather below the truth, which we may explain on the supposition that for the sake of economising space—a bad economy—he has not chosen to figure the larger individuals. I may add, by way of confirmation, the measurement of the striæ which mark the shields of every species in constant proportion. In the *N. viridis,* (the *viridula* of Ehrenberg, not of Kützing,) Ehrenberg states that 13—15 striæ are comprised in $\frac{1}{100}$ of a line, and Kützing 12—14. I find seven of these striæ constantly in a centimillimetre, 70 in a decimillimetre, and then with a power of 686 I always find 0·00098 met. between one stria and another, with the utmost exactness. Having directly inquired of Kützing himself, he politely told me, in reply, that he made use of a micrometer by Plössl, marked upon glass, in which the Paris line is divided into thirty parts, and that he placed his object upon this micrometer whenever he wished to measure it. At the same time he favoured me with a copy of his micrometer magnified 100 diameters. Now in this copy every division, said to equal $\frac{1}{30}$ of a line, is 0·00498 met.; hence such a line would be = 0·00149 met., or something more than half the measure of the line of Vienna, which is 0·002638 met. Finally, I cannot quit the subject of dimensions without making another observation. When we examine many individuals of the same species, we find both large and small in the process of deduplication. And we find many of the same size collected together whenever this is the case. Hence it seems that deduplication may occur at any age. And it seems to me that the greater the dimensions, the less frequent is this process; and I never saw the largest species doubled. It is a question, when does this process cease? Is it only the larger individuals, in which no division takes place, that propagate their species by true reproduction? or are some individuals destined from their earliest origin to multiply by deduplication and others by reproduction? This is an inquiry that refers as well to *Naviculæ* as to all the other Diatomeæ, and we have noticed it already when treating of *Cyclotella.*

The forms of *Naviculæ* of the three following sections (*ellipticæ, gibbæ, nodosæ,*) greatly resemble those of the *Surirellæ,* differing only by the median aperture. Instances of vittæ occur in *N. paradoxa.*

The two species referred to the section *lunatæ* belong to two types entirely different. The one (*N.* ? *genuflexa*) has the two primary surfaces curved, and is a true *Achnanthidea* without a stipes; the other, again (*N. lunata*), has the secondary surfaces curved, and hence has analogy only to those *Synedræ* which, exactly under this point of view, we have compared to the *Eunotiæ.*

The *sigmatellæ,* or sigmoid *Naviculæ,* to the curvature of the secondary surfaces which we see in some *Synedræ,* unite the habitual lanceolate form of the *Naviculæ,* in which all the eleven are very like each other. The greatest difference is that presented by the primary surfaces, which are either lanceolate also, or linear.

Now, considering the *Naviculæ* collectively in an organological view, we find, especially in the larger forms, very important conditions. Along the primary surfaces run two lines or small canals, terminating at their extremities in distinct foramina, as we have already found in all the preceding families. And it is around these foramina that the valuable observations of Ehrenberg on *N. major* (*viridis,* Ehr., not Kützing) demonstrate the currents produced in the ambient liquids, flowing as if they issued by one extremity and entered by the other. In each of the secondary surfaces are three ample perforations, one in the centre and two at the extremities; and, projecting from the latter, soft bodies, which Ehrenberg supposes analogous to feet, and subservient to motion. And it is also in the before-mentioned species that Ehrenberg saw clearly the ingestion of indigo, and indisputable movements in the internal organs "connected (with the body) by an irritable hyaline jelly, hence often exhibiting a tremulous motion." Whoever has observed many living *Naviculæ* may yet, even after long study and persevering laborious examination, find himself obliged to confess, as I do confess, inability to decipher the complex organisation; but he may also declare, conscientiously, that he has seen, in these, numerous phenomena perfectly analogous to those presented by animals, and to which no vegetable ever presents any similar.

32. AMPHIPLEURA.—*Individua singularia navicularia prismatica longitudinaliter sulcata, apertura media nulla.*

Kützing observes that mere regard to similarity of form caused this genus to follow the *Naviculæ*, though the want of a median aperture excludes it from the Naviculeæ. He might have said the same of some *Synedræ.* It is a circumstance worthy of remark, that on account of the two projecting lines of the secondary surfaces, the division cannot take place without a species of reduplication. The one of the three species which is sigmoid (*A. rigida*) is curved on the primary surfaces, and under a double aspect manifests an analogy (not an affinity) with the Achnantheæ. Although the central perforations are absent, the terminal ones seem to remain in the *Amphipleuræ.*

33. CERATONEIS.—*Individua navicularia libera singularia rostrata, prismatica, quadrangula; apertura media distincta, terminalibus nullis.*

The rostrum only, Kützing says, distinguishes this genus essentially from *Navicula.* The first species (*C. laminaris*) differs but very slightly in form from some *Naviculæ,* (*N. cuspidata, N. rostrata,*) but if the terminal apertures be really absent in this and present in the others, the organographic difference is great. Of the other four species, one is sigmoid, (*C. Fasciola,*) one contorted and spiral, (*C. spiralis,*) and two merely arched, (*C. Closterium, C. Arcus*). But in the last the symmetry of the primary surfaces is remarkable, whence there results a decided analogy to the *Epithemiæ*, whilst the resemblance to the Achnantheæ, observed by Ehrenberg, is not apparent; and I said to the *Epithemiæ* rather than the Cymbelleæ because neither Ehrenberg nor Kützing take any notice of a median aperture on the lateral surfaces; with this we are not to confound the umbilicus projecting from the ventral surface.

34. Stauroneis.—*Individua libera, singularia, navicularia; apertura media transversali.*

The numerous species (34) of this genus, divided into three sections *læves*, (*genuinæ*,) *punctatæ* (*Sticloneis*) *striatæ* (*Stauroptera*) do not differ from *Navicula* except by the transverse direction of the aperture, a condition on whose organographical value we cannot pronounce any judgment, not knowing the office of this aperture, nor its relation to internal structure. Still it is right to observe that in many species it does not seem to be the aperture itself that is placed transversely, but rather the depression, at the bottom of which is found a round perforation, as in *Navicula*, and, as in these, there is a sort of funnel stretching into the cavity, which becomes visible when we look in front of the primary surface.

35. Amphiprora.—*Individua libera, singularia, aperturis terminalibus binis mediis, nec marginalibus.*

From the figures of two out of three species, which Kützing describes in this genus, it appears to me that we may believe the two terminal apertures constituting the essential character of this genus, to be nothing more than the usual minute foramina which serve to terminate the two longitudinal lines or canals that traverse the primary surfaces of almost all *Naviculæ*. Nor perhaps are central apertures wanting in the lateral surfaces; but these are seen in profile in the figures referred to. The so-called wings, (*alæ*) or projections, belong, therefore, to the secondary surfaces, and constitute the only distinctive character of the *Amphiproræ*.

36. AMPHORA.—*Individua libera, singularia, aperturis mediis binis lateralibus, terminalibus nullis l. obsoletis.*

The *Amphoræ* are *Cymbellæ* with primary surfaces equal, and secondary surfaces symmetrically convex, instead of plane and inclined. We have yet to learn whether the two median lateral perforations exist on one part only or both. In the first case the analogy would be complete; in the second, every *Amphora* might be called a double *Cymbella*. And indeed the two individuals into which every *Amphora* divides itself, by deduplication greatly resemble two *Cymbellæ*. Yet perhaps this resemblance is only apparent. In the *Cymbellæ* there is one primary surface, the dorsal, which forms the convexity. Again, in the middle of the *Amphoræ* the convexity is itself referable to that one of the secondary surfaces which remains. The *Cymbellæ*, in subdividing, give origin to two complete individuals. The two individuals proceeding from the division of the *Amphoræ* are wanting in one of the two lateral convexities; their lateral surface, of new origin, ought to become convex, like the other. In the *Cymbellæ* there occurs a simple division or deduplication; in the *Amphoræ* the division or deduplication is succeeded by a species of reduplication. It results, from this conformation, that in the *Amphoræ* the navicular figure is only apparently similar to that of the *Naviculæ*. The one is navicular in the secondary surfaces, the other in the primary, because of the prominence of the secondary. The division of *Naviculæ* is parallel to the elliptical or rhomboidal surfaces; in the *Amphoræ* it is vertical to these (surfaces). I therefore absolutely exclude the *A. atomus* from this genus, as it is a *Navicula* or a *Synedra*. The doubt raised by Kützing as to the *A. ellipticæ* appears a certainty to me; no central aperture in the primary surfaces being admissible. On the same motive I assert that if the *A. acutiuscula* do truly belong to this genus, the figure 1 (Pl. V, fig. 32) is incorrect, for it represents a median aperture; and equally so is the third figure (Pl. XX, fig. 18) of the

A. hyalina, by the same author. In respect to the median lateral perforations, besides the already expressed doubt whether they exist on both the primary surfaces or only on one, it is also to be observed that they are wanting in six, (*A. veneta, A. aponina, A. coffeæformis B. Fischeri, A. acutiuscula, A. borealis*,) out of the eighteen species assigned by Kützing to this genus.

37. Diadesmis.—*Individua navicularia in fascias elongatas (biconvexas) arcta conjuncta; aperturæ mediæ singulares et terminales binæ distinctæ.*

In 1836, Kützing published (Dec. xvi, n. 153) the new genus *Brachysira*: "*frons minutissima constituta e frustulis paralleliter et irregulariter coadunatis.*" Now, in his Monograph of Diatomeæ, he makes no mention either of the genus or the species (*B. aponina*) which was nothing more than *N. appendiculata*. Nay more, there is enumerated among the Naviculeæ the *Brachysira serians* of Brebisson, and Bailey's fine observation on *N. major* (*N. viridis*, Ehr.) is suppressed, "that it is not rare to meet with four, sometimes even eight, united laterally." The genus *Diadesmis* is established, however, in which the Naviculæ are arranged in rows exactly as in the species just described, only perhaps with more constancy and regularity. Yet the foundation of this genus is justified by analogy with other families, and by that similarity of genus in the parallel series which perhaps is supremely attractive in systematic classification. But independently of the value of the genus, which I do not controvert, the organic condition of this concatenation in the *Diadesmæ* and *Sphenosiræ* seems to furnish important considerations. If the central aperture of the secondary surfaces were really stomatic, serving to the ingestion of aliment, we might suppose that, in respect to the individuals contained in the midst of these fasciæ, that, unlike the terminal ones, they took their nutriment mediately. Although such a condition occurs in other classes of animals, yet in our case it is purely hypothetical. Now in opposition to this hypothesis stands the fact of all the Diatomeæ destitute of this aperture. Instead of it, we find in almost all of them the presence of two terminal perforations of the primary surfaces, always so situated, even in associations of numerous individuals, that they can perform their functions freely. The minuteness of these apertures would be adapted to the tenuity of the food they were intended to receive, and might, in some degree, explain why nothing can be discerned as to the nature of this food or the conformation of the digestive organs, whilst in other Infusoria, even of smaller dimensions, the substances received can be clearly distinguished. And although the terminal apertures of the secondary surfaces may seem to belong to organs of motion, (as Ehrenberg has described, in some of the larger species, and as appears indicated also by the nature and direction of the movements themselves,) still it is a reasonable supposition for any one to believe that the median aperture is subservient rather to the generative function.

38. Frustulia.—*Individua navicularia, in substantia gelinea amorpha nidulantia.*

The only character that distinguishes this genus from the *Naviculæ* is the presence of a mucous envelope. In one of the two species (*F. maritima*) the Naviculæ are included in various numbers within a distinct cell. Again, in another, (*F. salina*) the enveloping mucus is amorphous. By the same character Ehrenberg comprehended also in this genus that *N. appendiculata* of which Kützing had constructed his genus *Brachysira.* Organographically, the *Frustuliæ* show the transition of the free to the included Naviculeæ.

39. Berkeleya.—*Phycoma gelineum molle basi globosum, ramos filiformes naviculis dense aggregatis repletos emittens.*

In this and the two succeeding genera (*Raphidogloea, Homœocladia,*) there is not merely wanting the primary character of Naviculeæ, the central aperture, but even the form of the shields corresponds to that of many *Synedræ* of the sections *Scaphularia* and *Echinaria;* hence they seem rather to belong to the family of Surirelleæ in the preceding order.

40. Raphidoglœa.—*Phycoma globosum gelineum molle, intus fasciculis naviculuarum in fila radiantia dispositis farctum.*

The principal character of this genus is taken from the amorphous disposition of the gelatinous substance, in which the Naviculæ, or rather the Synedræ are immersed. Under this point of view the genus *Berkeleya* is intermediate between the *Raphidoglœa* and the *Homœocladia*. But it is the characteristic disposition of these Synedræ, that whilst they are mixed together in a disorderly manner in the preceding genus, and fasciculated almost in a parallel manner in the following one, in this they are arranged in fusiform fasciæ, confluent by the pointed extremities. Whether we consider the first or the second of these characters, I doubt whether we can regard them as sufficient to distinguish the three genera. In one of the four species enumerated by Kützing (*R. manipulata*) the great variety in the size of the Synedræ is remarkable; he says they vary from $\frac{1}{23}$rd to $\frac{1}{60}$th of a line, but with an amplification of 420 diameters he delineates them from 7 to 25 millimetres, corresponding therefore to 0·0166 millim.—0·0595 millim.

41. Homœocladia.—*Phycoma filiforme ramosum, ex tubo gelineo intus fasciculis navicularum linearium elongatarum bacillariarium farcto compositum.*

In confirmation of what has been already stated of the difficulties attending the distinction of these genera, I have subjoined the description of a new *Homœocladia*, which in external figure bears a striking resemblance to the *Raphidoglœæ*, and in its association of filaments might perhaps be referred to the *Berkeleyæ*.

H. heloides pumila, parasitica, adnata, filis tenuibus e centro radiantibus, dichotomis sensim attenuatis; synedris, continue fasciculatis, mediocribus, e facie linearibus, e latere oblongo ellipticis, obtusis.

Schizonema helioides, Zanard, in litt. *Ad Ulvam latissimam legit Dalmatiæ Sandri. Frons.* 3 *mill. vix attingens Rivulariæ adspectum omnino præsefert. Fila ad basim* 0·02 *mill. vix crassa et, ut in Rivulariis, rotundata. Longitudo Synedrarum* 0·039 *mill., latitudo* 0·0043 *mill.*

In this genus, too, we may notice the greatest variety of dimensions. Thus, for example, Kützing gives the length of the Synedra of *H. pumila* $\frac{1}{34}'''$, which, referred as he states to the Paris line, corresponds to 0·079 millim. But in the figure with an amplification of 420 linear, it only equals 0·016 met., and therefore corresponds to 0·0383 millim. Now I find the length to vary in my specimens from 0·0457 millim. to 0·078 millim., and therefore not far from the extremes above described. This same species also presents in its thick inferior trunk, and in the fasciculato-fusiform disposition of its Synedræ, rather more relation to the two preceding genera. Kützing refers my *Schizonema ruorum* to this genus *Homœocladia;* and justly, for it certainly does not belong to the *Schizonemæ.* But I think he might just as properly refer it to the *Berkleyæ,* on account of the thickness of the walls of the mucous threads, and the uniform confusion (*affastelmento*) of the Synedræ. As to the dimensions of these last, Kützing says they correspond to those of the *Raphidoglœa interrupta;* but this accords little with Kützing's figure magnified 420 linear; this is 0·023 metr., and therefore corresponds to 0·054 millim.; it accords much less with the measurement indicated ($\frac{1}{25}'''$), which is = 0·108 millim., though the greatest length of these Synedræ in my *H. lubrica* is = 0·04 millim. Of the seven species yet known in this genus, two only (*anglica, Martiana,*) present marginal striæ on the lateral surfaces; this makes them far more similar to the *Synedræ.*

42. SCHIZONEMA.—*Phycoma filiforme tenue luxum, ex tubo gelineo* (*cœloma*) *ramoso naviculas abbreviatas longitudinaliter seriatas fovente compositum. Spermatia externa simplicia tubo adnata sessilia.*

The characteristic differences between this genus and the following one (*Micromega*) assigned by Kützing, correspond with those proposed by Agardh (Conspect. crit. Diatom. 1830), in which, after rejecting the division, previously suggested by Greville, of the two genera *Monema* and *Schizonema*, he is induced by observation to admit it in fact, obstinately insisting on rejecting it in name. It is a lamentable thing, and the primary source of the confusion that all deplore in the synonyms of botany and zoology, that a mistaken vanity frequently induces authors to maintain their own errors with pertinacity, and blindly to reject the opinions of others. Greville divides the *Schizonemæ* of Agardh into two, *Monema* and *Schizonema*; Agardh maintains that the difference between them rests solely on a different degree of organic development, which it is often difficult to discover; therefore he recasts the two genera into one. Somewhat later Agardh finds certain species in which the character defined by Greville, as distinctive of the genus *Schizonema*, is evident. When he discovered his own error he ought to have restored to Greville both the genus *Monema*, and the species taken from it. But it was too hard a case; so he turned round to establish a new genus (*Micromega*), and refer to it the true *Schizonemæ* of Greville; thus taking away from that author all the species that he had judiciously divided into two genera. The scholars blindly follow their master. The same story, changing the names, may be applied to many questions of synonyms. If the two genera be really distinct, their names ought to be *Monema* (*Schizonema*, Ag. and Kütz.) and *Schizonema* (*Micromega*, Ag. and Kütz.); nor can we adopt the opinion of Ehrenberg, who, disapproving of the elision in the word *Monema* (*Mononema*), as if there were no legitimate examples, rejects it as erroneous, and substitutes in its stead a new name (*Naunema*) applicable to the two genera which he reunites. It is doubtful whether the right of priority ought to be assigned to the *Hydrolinum* of Link, which along with a *Monema*, comprised an Alga (*Conferva Hermanni*), and therefore cannot be considered sufficiently definite. The name *Monema*, which on account of its elision should be written *Monnema*, applied to the species constituted of a single tube including the Naviculæ, and placed in comparison with the rest, (*Schizonema*), referable to the species where the single series of Naviculæ have a proper tube, and the union of these threads (fili) constitutes the frond, is so much the more exact since the second, *Schizonema*, both by etymology and generic character of Agardh himself, as mentioned already, (*Systema Algarum*, 1824,) denotes this condition in a graphical manner. There is still an important character described by Kützing in reference to the position of the organs which he terms *spermatia*. These are external in *Monnema* (*Schizonema*), immersed again in the *Schizonemæ* (*Micromega*), as if intimately allied to the simple or compound structure of the external tube. Now after the consideration of such characters, the result of an attentive examination is my conviction that some species referred by Kützing to the first of these genera belong really to the second; and, for the reasons just stated, these will be all entitled to the name assigned by Kützing, whilst all the other species of *Schizonema* should become *Monnema*, and those for which the name *Micromega* was uselessly created, should become *Schizonema*.

This discordance of opinion as to the arrangement of some species in one or other of the two genera, which, independently of their names, appear so distinct and so clearly defined, arises from the great difficulty of discerning the parallel tubes, including the particular (*singole*) series of Naviculæ. In some species the wall of the external tube is clearly distinct, and the Naviculæ are confused within; but in some others it seems as if instead of a tube there is a mucous mass in which the Naviculæ are immersed. Then there remains a doubt whether the series of these Naviculæ are included in distinct tubes or in simple canals hollowed out of the common mucous mass. It may perhaps be suspected that the tubes visible in specimens that have been moistened, do not really exist during life, and originate in a change that has taken place after death. And it is quite certain that the partial tubes waste away sometimes, as well during life as by some alteration happening after death, so that they appear evident in some but not in other parts of the same specimen. The character indicated by Kützing of the so-called spermatia, external in *Monnemæ* (*Schizonema*, Kütz.), and internal in *Schizonemæ* (*Micromega*, Kütz.), would therefore assist us very much, were it constant and capable of being verified. But Kützing himself only found these spermatia external in a single species (*S. tenue*). Therefore there only remains the sole negative character of the absence of partial tubes, and whenever we succeed in observing these, the species must undoubtedly be referred to the succeeding genus. The absence of partial tubes, and consequently confused disposition of the Naviculæ, is evident in the following species.

Monnema quadripunctatum, Grev.

Kützing changed Lyngbye's specific name (*Bangia quadripunctata*) as erroneous, and substituted that of *Schizonema tenellum;* establishing the length of the Naviculæ, from Lyngbye's original specimens, to be $\frac{1}{115}'''$, which, in the Paris line, would equal 0·0235 millim. But, with an amplifying power of 420, he represents it no more than 5·5 millim., which is equal to 0·0131 millim. Estimating this line conventionally at 2 millim., $\frac{1}{115}$th of this would be 0·017 millim., and there would be more agreement. But upon an original specimen with the same name he establishes another species (*S. Ehrenbergii*) which he pronounces synonymous with the *Naunema Dillwynii* of Ehrenberg. In this he says the Naviculæ are $\frac{1}{110}'''$ long, or 0·0246 millim.; but he represents them 5 millim. with a power of 420, corresponding therefore to 0·012 millim. Here again there is ground for the same consideration, as to the slight difference we should meet with between the size of the figures and the admeasurement, were the latter understood as expressed conventionally in lines equal to two millimetres. It seems to be so from the figures of Lyngbye and Greville, but not from either of the two species of Kützing. We are led to this supposition by an observation of Harvey, who says, that in the *M. quadripunctatum* the Naviculæ are larger than in any other English species, whilst by Kützing's description, and still more by his figures, there would seem to be only two of these in which the Naviculæ are of smaller dimensions. Harvey says, that specimens from Carmichael differ in external appearance from those of Mrs. Griffiths, though agreeing as to internal structure.

I received from Lenormand a specimen from Calvados, with the name *Schizonema quadripunctatum*, in which the length of the Naviculæ was 0·024'''.

Here it seems right to mention some different species, all belonging to the genus *Monnema*.

Monnema tenuissimum, Kütz., (Schizonema.)

Having been favoured by Kützing with an authentic specimen of this his species, I could with certainty compare it with specimens from Venice sent to me by Kellner. I have ascertained that the length of the Naviculæ = 0·022 millim. This would agree sufficiently with that indicated by Kützing in the description, where he says it is $\frac{1}{110}$th of a Paris line, or = 0·0246 millim. But he figures these Naviculæ with an amplification of 420, no more than 4·5 millim. which corresponds to 0·0107 millim. Here it seems, then, that the measurement expressed in the description ought really to be understood in relation to the Paris line, or still better, to the smaller one of Vienna, whilst, on the other hand, the figure would disagree less with the admeasurement interpreted by the conventional value of 2 millim., although $\frac{1}{110}$th of such a line would be equal to 0·0184 millim.

Monnema tenue, Kütz., (Schizonema.)

As in the preceding species, I also find in the authentic specimen of Kützing, as well as in others which I have examined, that the size of the Naviculæ corresponds to the measure described in the definition in the line of Paris ($\frac{1}{110}$ = 0·027 millim.) whilst the figure given with an amplification of 420 diameters is only 5 millim., and therefore corresponds to 0·012 millim.

In this species Kützing observed the presence and development of the spermatia.

Kützing observes that his *S. tenue* does not correspond with the *S. tenue* of Agardh, therefore he ought to have changed the name.

Except for the figure of Agardh there is reason to suspect that it belongs to a true *Schizonema*, though published together with *Micromegæ*, which combine a coriaceous consistence with the essential character of partial tubes ('Icon. Algar. Europ.,' fasc. i, tab. 3.) I find, on the other hand, that the *Schizonema* frequent in the Lagunes of Venice, by me denominated *S. adriaticum*, is referable to this species, and not to the preceding one, where Kützing would place it, and I persist in regarding it as corresponding to the definition and description which Agardh gives of this his own species.

Under the name of *Schizonema comoides*, to which it certainly does not belong, I received from Lenormand a beautiful species allied to the preceding, but in which the Naviculæ are constantly smaller, scarcely measuring 0·018 millim. in length. In these, the so-called external spermatia are very abundant. This is an important species, because the Naviculæ, being very stipitate, and many times seriate, it becomes extremely difficult to convince one's self that the partial tubes are absent, and the presence of external spermatia is really in accordance with that absence.

From the Lenormand I also received, under the name of *Schizonema Grevillei*, inapplicable to it, another very beautiful species, with very fine short threads, in which the Naviculæ are not only still shorter (0·017 millim.) but also narrower (0·0045 millim.) and very acute.

Monnema rutilans, Ag., (Schizonema.)

In authentic specimens from Kützing and Jürgens, I find the length of the Naviculæ 0·025 millim., and their breadth only 0·004. Kützing says their length is $\frac{1}{100}'''$ or 0·027, with the usual contradiction of a much smaller figure. In this the Naviculæ are only 7·7 millim., which, with a power of 420 corresponds to 0·018.

I have no specimens of the two forms which Kützing considers to be varieties of the preceding, with the names *S. parvulum*, *S. lubricum*.

Monnema Hoffmanni, Ag., (Schizonema.)

In a specimen with which I was favoured by Kützing, I find the Naviculæ 0·03 millim. long, and 0·0064 broad, corresponding to the description of Kützing, and larger than his figure (9·5 millim. $\frac{1}{420}$ = 0·0226).

I cannot understand why Kützing gives this form as a variety of the preceding, whilst in external characters, in the dimensions and the shape of the Naviculæ, there are distinctive appearances sufficient and comparable to those by which other species are distinguished.

Monnema ectocarpoides, Mgh.
Schizonema viride, Ktz.

The enforcement of the law of priority is, without offence to modesty, or culpable charge of vain glory, as applicable to matters of our own as to those of another. Kützing, in quoting the name given to this species by me, of necessity condemns the one proposed by himself, since I had previously established, though I had not published it. He might have spared me one of the two names, but he would not. In the description, he gives the size of the Naviculæ $\frac{1}{100}$ of a Paris line or 0·027 millim. But in the figure, with the same power of 420 diameters, he delineates the Naviculæ 8 and 15 millimetres long = 0·019—0·038 millim. On the other hand, I have never found the Naviculæ shorter than 0·02, or longer than 0·031, either in the authentic specimen of Kützing, or in the numerous ones from the Adriatic. The breadth is constantly a fifth of the length.

This form, too, is regarded by Kützing as a variety of the *S. rutilans*, I know not on what motive.

As to Ehrenberg's synonym (*Naunema balticum*), quoted by Kützing; that author determines the length of the Naviculæ $\frac{1}{72}$ of his conventional line; equivalent to $\frac{1}{144}$ of a millimetre, or 0·0069 millim., he draws it no less than 16 millim., and speaks of transverse striæ, 18 to 20 of which are included in $\frac{1}{96}$ of a line, which, notwithstanding the amplification of 2300 diameters and upwards, are not to be discerned in the figure.

Monnema Dillwynii, Grev.

Kützing states the length of the Naviculæ to be $\frac{1}{25}$th of a Paris line, or 0·0318, but he figures the length as 6 millim., with an amplification of 420, which corresponds to 0·0142. In authentic specimens received from Berkeley, and corresponding perfectly with Kützing's description and figure, I find the length of the Naviculæ 0·022 millim., the breadth of the primary surfaces 0·007, that of the secondary 0·005.

Monnema Lenormandi, Ktz. *in litt*, (Sehizonema.)

Under the name of *Schizonema Dillwynii*, Lenormand favoured me with a *Monnema* from Calvados, differing greatly from the preceding. I wrote to Kützing, who replied that he had already ereated a speeies with the name *S. Lenormandi*, sending me in confirmation a fragment of his specimen. The Naviculæ are 0·0255 millim. in length, and attain a breadth of 0·04 in the primary surfaces, when they are near the state of duplication.

Monnema sordidum, Kütz., (Sehizonema.)

Kützing establishes the length of the Naviculæ $\frac{1}{100}$, $\frac{1}{120}$th of the Paris line, or 0·0270—0·0225 millim., and moreover refers to this species speeimens from the lagunes of Venice, corresponding in all other characters, the Naviculæ being 0·0245 millim. in length, and 0·0064 in breadth, both on the primary surfaces, whieh are lineari-rotundate, and on the elliptieo-linear, obtuse secondary. In a specimen with which I was favoured by Kützing, I was not able to see the Navieulæ clearly, but they seemed to me somewhat smaller, not, however, so much so as in this author's figure (5 millim. $\frac{1}{420}$ = 0·0119).

Monnema Grevillei, Harv.

This is one of the most instruetive speeies, for the Naviculæ are frequently placed transversely, in such a way as to demonstrate the total absence of partial tubes. It is interesting also from the large size of the Navieulæ, which exhibit the proeess of duplication very clearly. In these, too, Kützing saw the central aperture. In the specimen with which I was favoured by Berkeley, under the name of *S. Grevillei* (Alg. Danm.) and *S. quadripunctatum*, Ag, I find the greatest dimension of the Naviculæ to be 0·034 millim. in length, and 0·016 in breadth, as well on the primary surfaces, which are a sort of parallelogram with the angles slightly rounded, as on the secondary, that are broadly elliptico-obtuse. This differs little from the figure given by Kützing, magnified as usual, 420 diameters, which, being 13 millim. long, corresponds to 0·0309. But the dimensions given in the definition ($\frac{1}{48}$ = 0·564 millim.), are much greater.

Monnema subinconspicuum, Mgh.

I found it at Trieste, parasitic upon *Ectocarpus arctus*, along with other Diatomeæ.

The threads, or *filaments*, are scarcely a millimetre long, and are 0·085 broad. The Naviculæ are 0·02 long, and 0·005 broad, as well on the primary surfaces as on the secondary.

The simplicity of the filaments had led me to believe that the species corresponded to *Naumena simplex* of Ehrenberg, excluding the synonym of *S. tenue* of Agardh. But the dimensions stated in the description ($\frac{1}{96}$—$\frac{1}{48}$th of a line, or 0·0052—0·0104 millim.), and the paucity of the Naviculæ included in the gigantic figure, seem to contradict that association.

Among the species ascribed by Harvey to the genus *Monnema* (regarded by him as a simple sub-genus), the four following are unknown to me; *spadiceum*, Grev.; *virescens*, Harv.; *dubium*, Harv.; *crinoideum*, Harv. Three others (*implicatum*, *parasiticum*, *comoides*), belong to the subsequent genus. The last (*prostratum*) is an *Encyonema*.

Of the remaining species described by Kützing as *Schizonema*, and, therefore, wanting in partial tubes, I infer from direct observation of authentic specimens, that some belong to the following genus; *araneosum; trichocephalum; Smithii; helminthosum; scoparium; sirospermum.* Of others I believe the same, from the figures of Kützing, which disclose either partial tubes or so regular a linear arrangement of Naviculæ as is never met with in *Monnemæ; minutum, humile, floccosum, crispum, plumosum, capitatum, Bryopsis, Arbuscula, hydruroides, mucosum.* But the two species *lutescens* and *striolatum*, which I do not possess, appear to be true *Monnemæ*.

Finally, with respect to *Schizonema illyricum*, in which

Kützing describes and figures the Naviculæ as disfigured by desiccation, I ought to state that I have observed such Naviculæ and thought them specifically characteristic of a *Schizonema*, which, for this reason, I denominated *S. Cercaria*. I have ascertained subsequently that the Naviculæ of many species undergo a similar alteration. It takes place more frequently in the *Micromegæ* or true *Schizonemæ* of that genus than in *Monnemæ*. It appears that sometimes, perhaps in certain physiological or abnormal conditions, the solid substance of the shield is redissolved. The appendages, too, with which the disfigured Naviculæ seem, in such cases, to be furnished, are due to the partial tube, which closes upon them (*vi si addossa*), grows thin, and bursts.

43. Micromega.—"*Phycoma filiforme ramosum, tubo communi externo cinctum, ex naviculis serialis compositum. Series navicularum singulares tubulis internis minoribus propriis* (*secundariis*) *vel fibris tenerrimis curvatis bicrispis cinctæ. Spermatia immersa, ex dilatatione navicularum oriunda.*"

From what has previously been stated, it would seem to be proved that, by the laws of nomenclature, we ought to maintain the name of *Schizonema* for this genus: 1st. Because Agardh established this genus (Systema, 1824) with a definition indicating an essential generic character which distinguishes it from the preceding, "*fila fasciæformia e filis angustioribus coadunatis composita, granula elliptica includentibus, in quæ iterum secedunt.*" 2d. Because, in the very description succeeding the definition, he insists upon this organic condition "*Compositæ* (*plantæ*) *sunt e pluribus individuis licet filiformibus, iterum includentibus eadem fere corpuscula quæ in Frustulia et Meridione invenimus.*" And he adds this excellent character of the mode of branching, "*Ramosa apparent, et ab auctoribus ita describuntur, quod tantum ex fissione filorum oritur.*" 3d. Of the ten species ascribed in this work, for the first time, and all contemporaneously, to the genus *Schizonema*, four (*Smithii, corymbosum, apiculatum, ramosissimum*) really belong to it in the sense we have assigned; three, again, belong to the genus *Monnema* (*rutilans, quadripunctatum, Dillwynii*); two are uncertain (*lacustre, Grateloupii*); and one (*micans*) must be referred to another genus (*Raphidoglœa*). 4th. The distinction established by Greville is well expressed in the character of the genus *Monnema*, of which he takes *M. quadripunctatum* as a type, establishing, at the same time, as the type of *Schizonemæ*, the *S. Smithii*. 5th. When Agardh (1828) discovered the structure of *Micromega*, he found that many species, which he had formerly ascribed to the genus *Schizonema*, presented the same appearances, and he referred some of them to his new genus in his 'Conspectus criticus' (1830). A greater or less rigidity of cartilage is not a sufficient character for the distinction of genera; and, in fact, we find that it lends little aid in the determination of species, when employed, as it is by Kützing, in his subdivision of the genus *Micromega* into two sections. It varies, moreover, exceedingly in the same species.

In respect to Kützing's definition, we have only to notice the fine crisped fibres which he seems to have seen encircling the series of Naviculæ sometimes, instead of the characteristic partial tubes. I have never happened to see these fibres. In every species I have been able to examine, I always saw, with greater or smaller degree of difficulty, but always distinctly, the partial tubes. Sometimes, certainly, I have seen these tubes so fine, so transparent, so colourless, that, at first sight, they only seemed to be fine margins. By the aid of some reagent, especially of a solution of iodine more or less concentrated, with or without the addition of sulphuric acid, moderating or interrupting its previous or subsequent reaction, I have succeeded in clearly perceiving the partial tubes. I cannot suppose that the action of these reagents would produce such a coagulation of the surrounding amorphous mucous substance, as to simulate the tubes themselves; for the coagulation could not produce regular tubes, and moreover the presence of these tubes is always accompanied by a regularly seriated disposition of the Naviculæ. There can only remain the supposition already mentioned, that besides the presence of a single enclosing tube, as in *Monnemæ*, and that of partial tubes, characteristic of the *Schizonemæ*, there may be a third condition, that of a continuous mucous substance in which single Naviculæ or the entire series of them may be imbedded. And this third condition according to the changes induced, and especially in consequence of desiccation and perhaps of the use of chemical reagents, may simulate either one or both these opposite conditions. Finally, in respect to the partial tubes, I perceive that frequently, where they remain empty of Naviculæ, they are so contracted and contorted as to appear like nothing but the finest threads, which often unite the remaining Naviculæ together by their apices. And the condition I have before described, when treating of the filiform appendages with which Naviculæ sometimes appeared to be furnished (v. *S. Illyricum*,) is the same which is seen also in the figure given by Ehrenberg of his *Naunema Agardhii*. Therefore, without pronouncing any judgment on the fibres indicated by Kützing, I express merely my own supposition that their apparent presence may be produced by the partial tubes themselves.

To the organic condition of the so-called internal spermatia, prudently noticed by Kützing, I think we ought to refer the circumstance of the great variety of dimensions presented by Naviculæ, not only in the same species, but very frequently in the same specimen. Varieties are often met with in different individuals which an attentive examination compels us to recognise as belonging to the same species, while within the same thread all are found to be equal. In the *Schizonemæ*, on the other hand, we find, mixed amongst the larger Naviculæ, others that are less, and some very small, scarcely visible with the highest powers of the microscope. It seems as if the so-called external spermatia of the *Monnemæ* become detached before development, as Kützing observed, in one species; and that in the *Schizonemæ*, on the contrary, these spermatia, if we regard their internal collocation, become developed within the cavity of the generating frond.

This is one of the principal reasons why the determination of species becomes extremely difficult. Others may be mentioned: the immense number of species; the excessive variations of external form; the want of agreement between the measurements indicated by Kützing in his descriptions and those of his figures, and those also deduced by direct observation from authentic specimens; finally, the very intricate synonymy, impossible to disentangle when we have not before the eye, authentic specimens of all the species, to institute a comparison.

Kützing describes and figures twenty-four with wonderful accuracy. To these I think that eighteen, ascribed by him to the preceding genus, ought to be added; and not a few still remain to be denominated and described. We will be as concise as possible.

Schizonema implicatum, Harv.
Micromega intricatum, Kütz.

Kützing does not give any reason for changing the name.

Schizonema parisiticum, Griffiths.

Kützing says the Naviculæ are $\frac{1}{115}$th of a Paris line, or 0·0235 millim. He figures the largest of them 4 millim., corresponding to 0·0095. In an authentic specimen received from Berkeley, as well as in those from Lenormand and Brebisson, under the name of *S. rutilans*, and corresponding exactly with the first, I find the greatest length of the Naviculæ 0·02 millim., and the greatest breadth 0·005.

Schizonema bombycinum, Kütz., (Micromega.)
Schizonema patens, Kütz., (Micromega.)
Schizonema flagelliferum, Kütz., (Micromega.)
Schizonema lineatum, Kütz., (Micromega.)

Kützing says the Naviculæ are $\frac{1}{110}$ to $\frac{1}{100}$th of a line in length, or 0·0246 to 0·027 millim. The largest of his figures is 6·5, corresponding to 0·0155. In an authentic specimen from Spalato, with which Kützing obliged me, and in the corresponding ones from Zara, collected by Sandri, the extreme length of the Naviculæ is 0·02, and the greatest breadth of the primary surfaces is 0·0047 millim.

Schizonema floccosum, Rudolph, (not Kütz.)

The length of the Naviculæ indicated by Kützing is $\frac{1}{60}$th of his line, or 0·045 millim. In specimens collected in Dalmatia by Vidovich, which correspond with the description, the greatest length of the Naviculæ is 0·046, the breadth of the primary surfaces 0·005 millim., in single individuals; the breadth of individuals very near a state of duplication was almost double, and that of the secondary surfaces, which are elliptico-rhomboidal, 0·009. In this very distinct species the extraordinary thickness of the partial tubes is remarkable; they are often more than double the breadth of the Naviculæ.

Schizonema hyalinum, Kütz., (Micromega.)

The length assigned by Kützing is $\frac{1}{65}$ to $\frac{1}{80}$th of a line = 0·0416 to 0·0338 millim. The greatest length, in plate xxiv, is represented ($\frac{120}{1}$) 7·5, or 0·0179‴, and the greatest breadth, in plate xxv, 1·5, or 0·0036 millim. In numerous specimens from Dalmatia, transmitted to me by Vidovich, and corresponding perfectly to the descriptions and the figures, I find the greatest length 0·034, and the greatest breadth of primary, as well as of the linear-lanceolate secondary surfaces, 0·004 millim.

Schizonema tenellum, Kütz., (Micromega.)
Schizonema Hyalopus, Kütz., (Micromega.)
Schizonema ramosissimum, Agardh.

Kützing says that the Naviculæ are $\frac{1}{80}$th of a line long, or 0·045 millim., but he figures them only as 7·7 = 0·0183, and the very small 0·0024. In a specimen from Lenormand, and in some from Dalmatia, collected by Vidovich, corresponding in external appearance, and other characters, with Kützing's figures and description, I also find the greatest length 0·028, the breadth of the primary surfaces 0·005, and that of the elliptico-elongate obtuse secondary surfaces 0·0064 millim.

In an authentic specimen from Chauvin, obligingly sent to me by Desmazières, with the name of *Schizonema apiculatum*, which is cited by Agardh himself as belonging to *S. ramosissimum*, and which differs a little from the preceding, the Naviculæ attain 0·054 in length; more frequently they are only 0·042. The primary surfaces are linear; the secondary, elliptico-elongate, rather larger, are a quarter of the length in breadth. Many smaller ones (0·02) are mingled with the others.

Under the same name of *S. ramosissimum* I received from Harvey and Berkeley a species entirely different from Kützing's, and corresponding perfectly with the description and figure given by Kützing of his *S. striolatum*. In this the transverse striæ upon the external surface are very evident. Although Kützing does not state the dimensions of the Naviculæ in his definition, those represented in his plate, and calculated by the usual rule as equalling half the indicated amplification, would be twice as large. In our own, the greatest length is 0·018 millim., and is not quite three times the breadth of the primary surfaces. In the figure of *S. striolatum*, the greatest length is 7·5 millim. ($\frac{420}{1}$) = 0·18, and is almost four times the breadth.

Schizonema setaceum, Kütz., (Micromega.)

The length assigned by the author $\frac{1}{58}$ to $\frac{1}{60}$ of a line = 0·0467 to 0·045 millim., delineated 8·2 millim. ($\frac{420}{1}$) = 0·0195.

In an authentic specimen from Kützing, and in those that I refer to this species, I find the Naviculæ 0·02 millim. long, but considerably broader than the figures of this author; the primary surfaces being 0·004, and the secondary 0·07, whence the shape becomes manifestly elliptical.

Schizonema aureum, Kütz., (Micromega.)

Although Kützing has indicated no other locality than Sidmouth, I refer to this species some specimens that I collected at Zava, which correspond perfectly with this author's description and figure. The Naviculæ are 0·032 millim. long, (Kützing says they are $\frac{1}{80}$ line = 0·0338 millim.; and represents them 7 millim. $\frac{420}{1}$ = 0·0166,) and are 0·006 in breadth of primary surface, and a millimilli-metre more in the secondary. In this species I have seen single Naviculæ with swollen internal spermatia, as Kützing delineates in his *M. polyclados*, to which at first I thought it must belong.

Schizonema corymbosum, Ag.
Schizonema myxacanthum, Kütz., (Micromega.)

The greatest length of the Naviculæ, according to the author, $\frac{1}{55}$th of a line = 0·0492 millim. (according to the figure only 0·022). To this I believe I ought to refer a specimen I collected at Trieste, the Naviculæ of which attained 0·05 in length, and 0·009 in breadth, as well in the primary linear, as in the secondary elliptico-acute surfaces.

The partial tubes are very evident, and so is their confluence at the apex, from which is derived the digitato-multifid ramification.

Schizonema apiculatum, Ag.

The $\frac{1}{55}$th of a line, which Kützing assigns as the length of the Naviculæ, corresponds to 0·0492 millim. As usual, the figure gives a measurement of half the size. In specimens from Lenormand and Brèbisson, I find the length of the Naviculæ 0·04 millim., the breadth of the primary surfaces 0·01, of the secondary 0·012, and the figure of both perfectly corresponding with the description and the delineation of Kützing.

Schizonema medusinum, Kütz., (Micromega.)

In specimens so denominated by the author, I find the Naviculæ 0·036 millim. long, 0·0047 broad in the primary surfaces, and a millimillimetre more in the secondary. Kützing does not state the dimensions; from his figure, I infer the length only to be 0·0262, and the breadth in proportion.

Schizonema chondroides, Kütz., (Micromega.)

I regret that I have been unable to study this species, on account of the peculiar mode of prolification at the extremities.

Schizonema spinescens, Kütz., (Micromega.)

Found in Venice, by Zanardini. The Naviculæ (0·042 millim. long, and 0·0062 broad,) differ little from the dimensions indicated by Kützing ($\frac{1}{60}$th of a line), being about twice the size of the figure (9·6 millim. $\frac{420}{1}$ = 0·022).

Schizonema albicans, Kütz., (Micromega.)

If the specimens from Dalmatia, which I think ought to be referred to it, really belong to this species, the name is not well chosen; indeed it indicates a condition which the author confesses not to be constant, (*vel olivaceo-virescens*) and which is common to many species in a state of decay. Length of Naviculæ 0·036, (Kützing says $\frac{1}{90}$th of a line = 0·03 millim., and figures them 6 millim. = 0·0142), the breadth of the primary surfaces 0·0061, of the secondary, which are broadly elliptical, it is a millimillimetre more.

Schizonema torquatum, Harv.
(Micromega polyclados, Kütz.)

It is on Kützing's authority that I refer to his species the authentic specimen which I received from Berkeley with the name above mentioned. In this I find the length of the Naviculæ 0·03 millim., and the breadth 0·005 in the lateral surfaces, which exceed the primary by a millimillimetre. The dimensions, therefore, (not described by Kützing,) are something less than twice those of his figure. Kützing is right in remarking that my *Schizonema nebulosum*, which I erroneously considered belonging to the genus *Frustulia*, corresponds to this species in the form and dimensions of the Naviculæ. Although when dried upon paper it only forms a light cloud, yet, when diligently examined, it proves similar in ramification to Harvey's species.

Schizonema pallidum, Ag., (Micromega.)

In a specimen gathered by me at Trieste, and corresponding perfectly with the description and figures, I find the greatest length of the Naviculæ to be 0·04, whilst Kützing says it is $\frac{1}{58}$th of a line = 0·049 millim. The breadth, both of the perfectly linear primary, and the elliptico-elongate secondary surfaces is about 0·008. We shall find a perfect agreement with Kützing's figure by supposing, as usual, that it represents one half of the indicated amplification of 420 diameters, the Naviculæ being here 8·5 millim. long.

I believe that some specimens, also collected at Trieste, by Zanardini, (which are perfectly similar to the preceding in external appearance, but of which the Naviculæ are shorter and more slender,) belong to a different species, not described by Kützing. In the one, the length is five times the breadth; in the other it is six times in respect to the secondary surfaces, and more than eleven times in respect to the primary. Length 0·036; breadth of the primary surfaces 0·006, of the secondary, 0·0035 millim.

Schizonema corniculatum, Ag., (Micromega.)

Although I might be supported by Kützing in the determination of this species, and though my specimens perfectly agree in external appearance with the figure given by this author, still I cannot but confess some doubts as to the species itself. And, in the first place, Kützing attributes a larger size to the Naviculæ than to those of the preceding species. He says they are no less than $\frac{1}{50}$th of a line, therefore 0·054 millim., and in conformity to this he represents them 1·1 millim., with an amplification one half less than what he assigns to his figure. On the other hand, I find the greatest length 0·03, and the greatest breadth, whether of the exactly linear primary surfaces, or of the elliptico-elongate secondary, 0·007. The length being rather more than four times the breadth, the form of these Naviculæ corresponds with that represented by Agardh (*Icon. Alg. Europ.*, tab. 4.) I find that the figure given by Agardh himself does not correspond with it in external appearance; the figure agrees much better with the preceding species.

It is true that we can find this form more or less rich in penicillate branches, which would seem to justify the opinion of Kützing, who regards the *Micromega penicillatum* of Agardh as a variety of the same species, but without noticing whether the *Schizonema penicillatum*, Chauvin, should also be placed there; but the same specimens more denuded have no resemblance to Agardh's figure. For this reason, before I consulted Kützing, and before he published his work, I had given the name of *Micromega divaricatum* to the one I had collected very abundantly at Zava.

Schizonema Blyttii, Ag., (Micromega.)

The following species are ascribed by Kützing to the preceding genus.

Schizonema minutum, Kütz.
Schizonema humile, Kütz.
Schizonema araneosum, Kütz.
Schizonema comoides, Ag.

I am indebted to the celebrated Berkeley for an opportunity of studying this species, and of convincing myself of the existence of special tubes, which easily escape observation, owing to their own tenuity and the size of the Naviculæ, whose uninterrupted series are narrowly stipate. It is by these characters, and by the form and proportion of the Naviculæ themselves, that I was led to the exact determination of the species, though the dimensions are very different from those indicated by Kützing. He says the Naviculæ are as much as $\frac{1}{55}$th of a line in length, or 0·049 millim., (and he represents it, with a power of 400 diameters, 8·9 millim., which would be about half the size indicated,) and I, again, found it no more than 0·024 in length, 0·005 in breadth of the secondary (*qu.* primary?) surfaces, and very variable in the always broad secondary surfaces, which attain to 0·012 millim.

Schizonema floccosum, Kütz.

If, as seems probable, there exist partial tubes in this species, and we ought therefore to retain it in this genus, it is necessary to change the specific name, for there is already a *Schizonema floccosum* of Rudolphi. By the customary laws, we ought to name it *S. Kützingii.*

Schizonema crispum, Montag.
Schizonema plumosum, Kütz.
Schizonema capitatum, Kütz.
Schizonema trichocephalum, Kütz.

I find a *Schizonema*, from Marseilles, with which I was favoured by Solier, and in which the Naviculæ are 0·025 in length, to correspond exactly with the definition and the figure of Kützing. He says they are as much as $\frac{1}{120}$ of a line = 0·0225 millim. There are evidently partial tubes, and the figure of Kützing leads us to suspect their existence.

Schizonema Bryopsis, Kütz.
Schizonema Arbuscula, Ehrenb. (Naunema.)

Although Ehrenberg asserts that there are no partial tubes, still he admits that this species forms a transition to the genus *Micromega*. Kützing's figure, by analogy with other species, induces us to admit their presence.

Schizonema hydruroides, Kütz.

I cannot help observing that Kützing, the most acute observer and most faithful painter of nature, has in this species also clearly delineated the special tubes, though he has placed it in the genus *Schizonema*.

Schizonema Smithii, Agardh.

The testimony of Kützing, and a comparison with an authentic English specimen, obligingly supplied by Berkeley, convince me that the *Schizonema* which we have most abundantly of all in the Lagunes of Venice, belongs to this species. I was led away before from this conclusion by the exclusive locality of Sidmouth, indicated by Kützing, and the comparison of specimens with which I was favoured by Harvey, of which we shall speak by and by, by the difference of measurement, and the evident presence of partial tubes. Kützing says the length of the Naviculæ is $\frac{1}{50}$th of a line, or 0·054, and, as usual, gives a figure less than half the size he mentions, (— 1·1 millim. ($\frac{420}{1}$) = 0·026.) I find the greatest length to be constantly 0·044, the breadth of the secondary elliptico-elongate surfaces 0·012, and that of the primary slightly elliptico-truncate 0·012. As to its generic position, I observe that Harvey places this species in his section *Schizonema*, corresponding to the *Micromegæ* of Agardh and Kützing.

Finally, though incidentally, it is right to make a remark here on the practice, with even the most conscientious authors, of copying references without verification. Both Harvey and Kützing copy from Agardh the reference to *Ulva fœtida* of *English Botany* (pl. 2101), whilst in that classical work there is only the *Conferva fœtida*, and the *Ulva fœtida* of Vaucher is merely cited, by mistake, as synonymous.

Schizonema sirospermum, Kütz., (Micromega.)

Though not appertaining to this series, I here advert to this species, because the specimens just mentioned, with which I was favoured by the celebrated Harvey under the name of *S. Smithii*, belong to it. Kützing informed me that he had received them, without a name, from Ralfs, and that he had named them as above. To him, therefore, I leave the description. Length of Naviculæ 0·0337 millim.; breadth of the elliptico-elongate secondary surfaces as much as 0·007; that of exactly linear primary surfaces 0·01. In this species I clearly saw the so-called internal spermatia, in form at first ellipsoidal, afterwards globose, varying in diameter from 0·028 to 0·05, furnished with a double envelope, within which the internal granules grew gradually in size. Similar in external appearance to Kützing's figure of the following species.

Schizonema helmintosum, Chauv.

The specimen with which I was favoured by Berkeley corresponds perfectly with the figure and description of this species given by Kützing, varying a little in the assigned dimensions of the Naviculæ. Length 0·052 millim., (Kützing says $\frac{1}{10}$th of a line = 0·54; he figures it 1·1 $\frac{420}{1}'''$ = 0·26 millim.,) breadth of the elliptico-truncate primary surfaces as much as 0·008, and of the elliptico-rotundate secondary 0·012; less, therefore, than one third of the length, which is the proportion indicated by Kützing. In this species I have never been able to see the central perforation with distinctness. As to the delicately crisped fibres, described and figured by this author, I have assured myself that they are nothing more than the margins of thick partial tubes.

Under the same name of *Schizonema helmintosum*, and with the indication of Chauvin (*Alg. de la Norm.*, *Fasc.* IV, *No.* 77), I received from Lenormand a *Schizonema* from Calvados which differs very much from the preceding in the dimension of the Naviculæ, though very similar to it in external appearance and in the forms of the Naviculæ. These are 0·32 long, and 0·007 broad. As in other species, there are mixed among the larger Naviculæ, others smaller, some very small. Hence we may suspect that the English species do not exactly correspond with the French. We are induced to form this opinion by the observation of Harvey, "The frustules are larger than in *S. Smithii*, longer and blunter, double, and rather densely set." This is applicable to the specimen from Berkeley, but not to this one of Chauvin, which ought to be authentic.

Very different, both in external appearance and in the extreme tenuity of the threads (*fili*), is another *Schizonema*, also from the Coast of Calvados, obligingly supplied by Lenormand, with the name *Schizonema helmintosum var.* Chauv., in which the Naviculæ are 0·0185 in length, and 0·006 in breadth, as well of the exactly linear primary surfaces, as of the elliptical secondary. The partial tubes embrace the navicular series closely, and frequently after, when the Naviculæ have escaped, contract into fine threads or become deformed and wasted.

Schizonema laciniatum, Harv.

I received specimens of this beautiful species from Harvey himself, and found the Naviculæ 0·027 long, and 0·007 broad, in the primary surfaces, which are almost exactly linear, and in the elliptico-rotundate secondary 0·0065. This agrees with Harvey's observation "*Frustules very minute and exceedingly numerous.*" This would seem to refer to a species different from that described and figured by Kützing, with the name *S. scoparium*, in which he says the Naviculæ are $\frac{1}{50}$th of a line in length = 0·054 millim., and to which he assigns as an uncertain synonym this of Harvey, and the *S. Smithii* of Mrs. Wyatt, (*Alg. Danm.* No. 151), which, according to the indication of Harvey, would rather seem to belong to the one before mentioned as *S. sirospermum*.

Schizonema mucosum, Kütz.

From Kützing's figure we should be induced to suspect the presence of partial tubes in this species also. As to the synonym of Agardh (*S. tenue*), it seems more easy to suppose that some mistake may have occurred in the denomination of a specimen, though received from the author himself, than to suspect so incorrect an observation as would result from the description and figure of this his own species given by Agardh, (*Icon.* tab. 3.)

Among the species ascribed to this genus or sub-genus by Harvey, two remain still to be mentioned.

Schizonema obtusum, Greville.
Schizonema Wyattiæ, Han.

We ought, finally, to add some species which we could not possibly include in any of the preceding.

Schizonema Stalianum, Mgh.

S. parasiticum, lubricum, viride vel viridi-rufescens, filis setaceis, longe productis, apice attenuatis, irregulariter ramosis, ramis divergentibus brevibus ; naviculis arcte seriatis mediocribus (0·03), *longitudine latitudinem sextuplo superante, e facie exacte linearibus, e latere elongato ellipticis ; parum angustioribus obtusiusculis.*

Sig. Stalio sent me specimens of this species, found at Lesina, in Dalmatia.

It attains the length of three or four centimetres, is very mucous, and adheres strongly to paper. The threads (*fili*) attain almost a decimillimetre in thickness near the base. It resembles none of the before-mentioned species in external appearance, except the *S. helmintosum var.* of Chauvin. The partial tubes are very slender, but distinct. Kützing, to whom I sent it, acknowledged that it was new.

Schizonema papillosum, Mgh.

S. parasiticum, pumilum, mucosissimum, viride, filis ultra setaceis subsimplicibus vel ramulis spiniformibus *acutis ornatis, papillis minutissimis regulariter dispositis omnino tectis; naviculis arcte seriatis mediocribus* (0·0264) *longitudine latitudinem fere quadruplo superante, e facie leviter elliptico truncatis, e latere anguste ellipticis, obtusiusculis.*

Sig. Botteri sent it from Lesina to his friend Zanardini, by whom it was communicated to me.

It scarcely attains two centimetres in length; the threads are about two decimillimetres in thickness, the colour dark green. The greatest breadth of the primary surfaces is rather less 0·007; that of the secondary 0·0043; the papillæ appear hemispherical or slightly conical; they are 0·0007 in height, and are arranged in a quincunx.

Schizonema Corinaldi, Mgh.

S. parasiticum, pumilum, viride, filis subsimplicibus setaceis, naviculis seriatis, minutis (0·016) *longitudine latitudinem fere quintuplo superante, e facie exacte linearibus, e latera anguste ellipticis.*

Corinaldi found it at Genoa, and Solier sent it to me, without a name, from Marseilles.

It is parasitic, like the preceding, growing on *Scaphularia scoparia*, or upon *Polysiphoniæ*, and in like manner is about two centimetres long. The threads, slightly mucous, are a decimillimetre and a half in thickness. They are usually simple; the few ramifications are short and divaricate.

Schizonema Zanardinii, Mgh.

S. tenuissimum, pallide virens, filis capillaribus in ramos arachnoideos corymbosos monosiros sensim solutis, naviculis laxe seriatis mediocribus (0·025), *longitudine latitudinem quadruplo superante, e facie exacte linearibus, e latere ellipticis.*

(*Schizonema*, Sp. nov. Zan. in lit.)

Zanardini found it plentifully in the Lagunes of Venice. Form: globular tufts, of three or four centimetres in diameter, which, dried upon paper, form an uniform spot, in which, by a lens only, the separate threads can be distinguished. Though Kützing assured me that this was a new species, yet by its mode of ramification it resembles *S. flagelliferum*.

This long speciological discussion may to some appear misplaced, or at least at variance with the proposed plan of this essay, intended as an organographical and physiological examination of the genera. The principal ground of my defence is the great importance of Kützing's most valuable work, and the respect that is due to so great an author. Who would dare to subject so immense a collection of most delicate observations to critical examination, unless he were able to counterpoise them with a series of his own observations, if not equally numerous, at least sufficient to prove the critic in possession of means and practice, and diligence and honesty of observation? Such has been my object, and if I have erred in any respect, for I must admit that it is easy to err in such minute researches, I hope, notwithstanding, to have demonstrated both the excellence of the instrument expressly made for me by Amici, of which I am sure that no one possesses its equal, Mohl only excepted, and the good intentions by which I endeavour to prove my gratitude to the most gracious Prince who bestowed upon me so munificent a gift. I believe, too, that an examination of various specific forms is necessary, that we may deduce from them some considerations as to the organology of the genus.

The presence of minute Naviculæ among the larger, to which we have adverted in many species, seems to me to prove—what might easily be deduced from the observations of Kützing—that the so-called Spermatia are developed within the fronds, if we may use an expression taken from the vegetable kingdom. I could never perceive that these smaller Naviculæ were included in distinct tubes, or that they constituted an uniform series in the order of their size. It seemed, rather, to be constantly the case that they were dispersed through the tubes of the larger ones. From this it seems that we may conclude that when the spermatium is mature, when its envelopes are broken up and about to be reabsorbed, the young Naviculæ, passing from tube to tube, are finally dispersed. And continuing to supply the want of sufficient observations by induction, we may suppose that these do not begin to divide until they have attained their greatest dimensions. It then becomes intelligible how the partial tubes originate, through the persistence of the thin external membrane, which we know, by preceding observations, manifests itself distinctly whenever the deduplication takes place. Only we must suppose that the silica is reabsorbed, while the membrane remains in *Monnemæ*, on the contrary, it disappears. It is most important to observe how these series of Naviculæ are formed within the proper tubes. It is, in fact, the result of observation that their disengagement is always effected in the plane of the primary surfaces. The series may present either the primary or the secondary surfaces. In either case the Naviculæ may be found arranged one behind another, either contiguous or more or less apart. They are sometimes imbricated with the primary, never with the secondary surfaces; and when the imbricated series is viewed on one side, the Naviculæ present themselves with their secondary surfaces entirely free and inclined obliquely. Therefore we must suppose, so soon as the deduplication (*sdoppiamento*) has taken place, the two new individuals, rotating upon one of the sides of their surface of contact, as upon a hinge, represent, in some manner, a box which opens, and the two primary surfaces coming into contact, the disengagement or separation becomes more or less complete. If these deductions be legitimate, as to me they appear to be, the result is that the successive growth of the entire frond is due to a double element; the elongation of each series by incessant deduplication, and the *intercalation* of new series between those that pre-existed. The comparative examination of the extremities is important in respect to the elongation. In various species the single partial tubes tend to detach themselves from their reciprocal union, either uniformly from the base (*flagelliforme, medusinum, Zanardinii*), or merely towards the summit, in a sort of fan-shape (*helmintosum, lacinatum*). Again, we find the multiplication of the series principally effected near the apices, and accomplished more quickly from the elongation of the pre-existing ones, on which account the extremities are clavate (*Arbuscula, clavatum.*) Where these two processes advance, *pari passu*, the resulting extremities are obtuse (*patens, Bryopsis, intricatum*). Where the elongation of the first series always precedes the appearance and formation of the new ones, the apices are acute (*floccosum*, Kütz. *ramosissimum, Hyalopus, araneosum, Smithii, torquatum*). It is characteristic, too, of some species (*chondroides, trichocephalum, capitatum, corymbosum, spinescens*), to have the prolification terminal, which manifests a succession of distinct periods of vegetation. Finally, the particular condition of the *S. myxacanthum* demonstrates a contemporaneous elongation of the series, which the resistance of the external envelope compels to flow towards the apex, until, that resistance being overcome, a palmate disposition of the branches is produced.

As to the Naviculæ, we know still less of them than in the preceding genera. Ehrenberg says that some of them are striated, but this is not confirmed by Kützing, nor have I seen striæ in any species. Yet in some I have seen the two longitudinal lines of the primary surfaces *dog-*

which are considered to be canals. I have not been able to see the median aperture, which Kützing describes and figures in some species (*helmintosum*). As to the distribution of the internal substance, though nothing positive can be deduced from the observation of specimens dried and softened, or even preserved in alcohol, it is yet remarkable that even in such a state it presents different conditions that are constant in each species. In most instances it is collected along the central part of the lateral surfaces, so that it exposes a colourless longitudinal area in the centre of the secondary surfaces, and only the two extremities of the primary surfaces are colourless. Sometimes, too, the median line of these last is colourless, because the colouring matter is lodged (*nicchiata*) in the four inner angles. It is not unusual to find it condensed in a single central globe. In a few species only I have seen it constantly divided into two portions corresponding to the extremities, whilst the median area of the entire body of the Naviculæ remained uncoloured.

44. Dickieia.—*Phycoma foliaceum* (*phylloma*) *basi substipitatum. Naviculæ in membrana gelinea irregulariter sparsæ.*

Kützing does not describe the structure of the so-called membrane of the only species (*D. ulvacea*) of this genus, and I am sorry that I cannot consult Berkeley's description. This membrane may be formed of cells including the Naviculæ, as in *Frustuliæ*, or of elongated cells or tubes, as in *Schizonemæ*, or of a single capacious flattened cell comparable to that in *Monnemæ;* or, finally, this so-called gelatinous substance may be a mass entirely continuous, in which the Naviculæ may be immersed, as indicated by Kützing " in der gallertartigen Haut eingebettete," as we have suspected of some species regarding which there seems to be a doubt whether they belong to the *Monnemæ* or the *Schizonema*.

The last seven genera, (*Frustulia, Berkeleya, Raphi-*

lœa, Homeocladia, Schizonema, Micromega, and Dickiea) constitute the group of Schizonemeæ. The substance which surrounds and includes the Naviculæ in these genera, which seems to be the same as the peduncle in *Achnanthides, Podosiræ,* and many other genera, is termed jelly (gelinea), by Kützing, who, under this denomination, compares it to that of the true Algæ. The observations adduced in the preceding memoir confirm the absence of nitrogen, and its ternary composition. Now we know, from the observations of Schmidt, Lœwig, and Kölliker, that a similar substance, destitute of nitrogen, ternary, insoluble in caustic potash, and isomeric with starch, constitutes the external coriaceous stratum in the Ascidia, simple and aggregate, and forms the gelatinous mass in which groups of individuals of compound Ascidia are lodged. These authors found that the presence of this substance is a character common to all the Tunicata, and it is supposed that the *Doliolum mediterraneum* ought to be placed in the same family from this character. This discovery, which I before supposed possible, has therefore now entered the domain of science. As the presence of a quaternary azotised substance is no exclusive character of animal nature, so the presence of a ternary non-azotised substance, isomeric with starch, is no more an exclusive character of a vegetable nature.

With respect to origin and formation of this substance, it is undecided whether, as Kützing asserts, we are to regard it as a product of secretion, or rather as existing *per se.* All animal secretions are formed in the same manner. The theory of Goodsir, Bowman, Henle and Mandl has recently received confirmation from the labours of Lereboullet on the biliary vessels of the *Aselli* and those of Gros on the production of butyraceous vesicles on the internal surface of the mammary utricles. It is now proved that whatsoever the animal secretions may be, they are effectuated by a production of new cells on the secreting surface, and the accumulation of liquid which penetrates within them by endosmosis through the double wall dividing their cavity from that of the producing cell. When these vesicles become detached, they either maintain a life of their own, as in the epidermis and its productions, or they burst and pour out their contents. If such be the origin of the gelatinous substance enveloping the Schizonemeæ, we must allow that the secerning surface is either external or internal to some particular organ. And these little cells, invisible from their minuteness or tenuity, may continue to live, or at least to pour out their contents, before or after they issue from the secerning organ. But all this is hypothetical, and wanting in any support of observed facts. Again, considering the history of the successive development of Diatomaceæ, it is more probable to suppose the possible permanence, extensibility, and progressive growth of one of the embryonal tunics, of which we have numerous examples, were there no other, in all animals that undergo metamorphoses.

The Schizonemeæ and the other seven genera (*Navicula, Amphipleura, Ceratoneis, Stauroneis, Amphiphora, Amphora, Diadesmis*), before mentioned, constitute the great family of Naviculeæ. The Naviculeæ, says Kützing, when treating of their affinities, very much resemble individuals of the preceding families, with which they were formerly confounded ; but they are to be distinguished as well by the central aperture of the two lateral surfaces as by the regularity and symmetry both of these and the primary surfaces. He says, on the other hand, that this aperture is frequently absent, especially in the Schizonemeæ, or at least escapes observation by its minuteness. Now I add that we have this same regularity and symmetry of form in the *Synedræ*, and, with few exceptions, in all the family of Surirelleæ. So that there is good reason for inquiring what essential character remains to distinguish the Naviculeæ? The consideration before adduced with regard to the origin and nature of the investing substance in *Schizonema* would seem to me to furnish some reason for bringing hither the affixed *Synedræ*, in a physiological point of view, only that this union would be one of analogy rather than affinity, inasmuch as we find corresponding conditions in almost all the families. It is still true, as Kützing observes, that here the included are the prevalent forms, occurring with the free and naked forms, whilst the linear association is only represented by one genus *Diadesmis*, and the stipitate forms and cateniform associations are entirely absent. But, with respect to the morphological signification of this predominant inclusion, I am far from agreeing with Agardh and Kützing in regarding it as indicating a higher organisation. In the theory of Agardh, where every inferior being represents an elementary organ of superior beings, the mere aggregation of many individuals, which, taken together, form one collective individual, is sufficient to mark a step towards organic superiority or perfection. But we have too many examples of similar aggregations even in the lowest members of both organic kingdoms to satisfy ourselves with this character of complication. It is not the mere aggregation of organs, but rather their mutual concurrence in the formation of new organic assemblages (congegni) that establishes the superiority in plants, as well as in animals. For this reason the Annelidæ are the lowest among the Articulata, even whilst the number of joints, all equal to one another, of which they are constituted, is indeterminate. For this reason I believe that the opinion is well founded which regards Synpetalous flowers as superior in organic complication to the Dialypetalous, as the flower in general is the most complicated apparatus of the plant, like the head of an animal. And without wandering from the question into extraneous digression, I shall content myself with recalling to memory what I have intimated before in relation to the involving substance, to sustain the opinion that the included forms are to be regarded as inferior to all the others; and the affixed, stipitate, and concatenated, as intermediate between these and those that are free; which last, conditions being equal, are superior to all the rest.

Regularity, then, and symmetry of form appear to me characteristic of inferiority, nor do I consider new arguments necessary to maintain a principle which is universally adopted in all natural classifications.

I am sorry to repeat here what I have said so often already, that we are entirely wanting in true data to judge of the affinities of Diatomeæ, among themselves as well as with other beings, and of the degree of their organic complication; for we are completely ignorant, as it were, of what this organisation is. And as to this, Kützing only informs us that the internal substance, which he terms gonimic, extends itself in a thin strip (*fettuccia*) along the secondary surfaces, then divides itself transversely in the middle, and finally contracts itself into one, two, or rarely more globular portions (*grumi*). We have already found contrary to the opinions of Ehrenberg, some more important particulars respecting the Naviculæ. Nor have we anything different to add, generally, as to all the family.

The Naviculeæ, together with the two preceding families (Cymbelleæ and Gomphonemeæ), constitute the group of Distomaticæ, a group characterised solely by the organic condition indicated by the name, and which we have so often found to be wanting.

The other two families (Cocconoideæ and Achnantheæ) which, comprehended under the name of Monostomaticæ, constitute, in union with the preceding, the grand division of Stomaticæ—appear to be much more nearly allied. The entire system, I am obliged to repeat, is constructed upon isolated and inconstant characters, and on that account cannot fail to be vacillating. But it is equally necessary to allow that, in the actual state of science it would have been difficult to do better; and we must also regard it as a principle suggested by sound reasoning, to attribute great importance to the presence or absence of the central aperture in one or both of the secondary surfaces, for that condition ought to be referred, of necessity, to important peculiarities of internal structure. And therefore it becomes difficult to conceive how the exceptions can be so numerous as to render this character so insufficient for classification.

The Stomaticeæ, together with the Astomaticeæ, of which we have already spoken, constitute the great order of Striated Diatomeæ, which is proportionally, much more extensive than the two following.

45. Podosphenia.—*Bacilli a latere primario cuneati a latere secundario obovato-lanceolati, affixi. Stipite nullo* (*vel obsoleto*).

With this genus commences the order of Diatomeæ furnished with Vittæ, or internal prominences, which divide the cavity of the shield more or less incompletely into distinct chambers; and here, too, commences the family of Licmophoreæ, in which is reproduced the cuneate form of the Gomphonemeæ. This genus represents, in the Licmophoreæ, the genus *Sphenella* of the Gomphonemeæ, for, like that, it is distinguished from other genera of the same family by the more or less complete absence of the stipes. The obovato-lanceolate figure of the secondary surfaces is precisely that of the *Sphenellæ* and of the Gomphonemeæ in general. The cuneate form of the primary surfaces is, in *Podosphenia*, always more dilated at the summit and acute at the base, so that they resemble a triangle more than a trapezium. Of the nine species described and figured by Kützing, only one (*P. Ehrenbergii*) presents transverse striæ on the secondary surfaces. The essential character of Gomphonemeæ, the median aperture in both secondary surfaces, is absent.

They present also the character of Vittæ. But if we carefully examine these vittæ, they are merely the same longitudinal lines which run along the primary surfaces of almost all the preceding Diatomeæ, the same lines which in many cases are produced by distinct canals furnished with terminal perforations. And here let us not forget how these canals evidently project into the cavity of the Melosireæ, forming more distinct vittæ than others ever do; on which account, if we ought really to found on this character the distinction of orders, the family of Melosireæ or the genus *Melosira* at the least, ought undoubtedly to be referred to the order Vittatæ.

46. Rhipidophora.—*Bacilli a latere primario cuneati, altero latere obovato-lanceolati, stipitati.*

We encounter the same difficulty in distinguishing *Rhipidophora* from *Podosphenia* that is experienced when practically applying the generic distinction established between *Sphenella* and *Gomphonema,* and in all other similar cases (*Cymbella* and *Cocconema*, &c.); these differ only in the stipes, which is very variable in length, and not always entirely wanting in the first of these two genera.

The large size of some among the fourteen species enumerated by Kützing permits us to observe clearly the conformation of the shield. Let us suppose a cylindrical articulation of *Melosira,* and so compress it unequally on one of its sides, and in the direction of both pairs of opposite surfaces, that the resulting form shall be cuneate, and the two incomplete diaphragms formed by the internal prominence of the longitudinal canals shall extend, like these, and lose themselves towards the pointed extremity which forms the base. Such is the structure of *Podosphenia* and *Rhipidophora.* Viewed on one side, that is on the lateral surfaces, they present an obvate arch (*fornice*) marked on the periphery of the surfaces themselves. And the margin of this arch is thickened by the presence of the canal, which, seen in front, presents in the curve its brightness, with an appearance of perforation.

It would be important to ascertain how the deduplication takes place. Whenever one of the frustules, (Bacilli) separates into two, one of the vittæ previously existing remains, and a new one appears in the internal side. Does the formation of the new vitta precede or follow the median deduplication? I have not made such observations as enable me to decide, but it seems to me that the former is the case.

And the distribution of the internal coloured substance bears a great resemblance to that of *Melosiræ*, especially in a state of desiccation.

As to the stipes, as well in this genus as the next one, I have to repeat what has been said of *Cocconema*.

47. LICMOPHORA. — *Bacilli flabellati a latere primario anguste cuneati, altero latere lineares basi et apice rotundati. Stipes crassus rigidus.*

The resemblance of this to the preceding genus is only apparent. But a true affinity connects *Licmophora* to *Synedra*, from which it only differs by that character which, though regarded as essential to the Meridieæ is found very inconstant in Fragillarieæ and reappears in many species of *Surirella*. The vittæ, in *Licmophora*, are not to be compared with those in *Rhipidophora*. They are nothing more than the usual longitudinal canals projecting into the cavity, by which the apparent perforations or sections of their cavities appear very near the margin of the summit. The distribution of the internal coloured substance is different from that in the two preceding genera, and greatly resembles that of *Synedra*.

If we compare these with the sections *Tabularia* and *Grallatoria*, we cannot at all recognise the alleged affinity.

For this reason, I think we ought to exclude the *Licmophora divisa* from this genus, and place it in the preceding one.

The four species that remain, (*fulgens, radians, flabellata, Meneghiniana,*) though described and figured by Kützing with so much diligence, are very difficult to distinguish, owing to their great variability in size and proportion, on which account, too, their form is very inconstant.

48. Climacosphenia.—*Bacilli a latere primario cuneati, vittis longitudinalibus moniliformibus, altero latere obovato-lanceolati, disseptis transversalibus in loculos divisa.*

The two species contained in this genus (*C. australis, C. moniligera*), have nothing in common except the moniliform vittæ. But in what these really consist we cannot ascertain from the figures. In the first, Kützing does not delineate the secondary surfaces, and from the figure any one would say that he had drawn a *Synedra*. The second, again, resembles a *Podosphenia*.

After this analysis of the family of Licmophoreæ (*Podosphenia, Rhipidophora, Licmophora, Climacosphenia*), we can only repeat what has been said of the first two genera. And as, in our opinion, we ought to exclude from it the genus *Licmophora* and unite this to the Surirelleæ, it will also be right to change the name of the family. Thus limited, it will remain allied to the Gomphonemeæ more than to any other. As to the so-called *interanea*, we have already recorded their arrangement in distinct globular masses as in *Melosira*. Ehrenberg, treating of *Podosphenia*, says that this organic condition is peculiar to young individuals; and he says he can distinguish, in the midst of the others, two of these globules, which he regards as representing the male organs. He asserts that, in some species, he has also seen the gastric cells. But when they grow old, Ehrenberg himself says that this internal substance accumulates in a central mass, which is frequently radiated. Kützing, again, describes the internal substance as disposed in two strips (*fettucce*), applied to the primary surfaces, which divide themselves transversely into two or more parts, and finally resolve themselves into globules. But he certainly must have taken these particulars from the genus *Licmophora*.

50. Striatella.—*Bacilli tabulati longitudinaliter vittati; vittæ perviæ numerosæ densæ striæformes, stipes lateralis.*

Though the only species of this genus (*S. unipunctata*), is common in the Adriatic, I confess myself unable to form a clear idea of its structure. The complication it presents in external appearance, and which is reproduced in the figures of Kützing, seems to proceed from vittæ of the surface opposite to the one observed shining through; there result from this, vittæ, strongly and faintly marked, alternating with each other. Does each one of these vittæ include a canal? And how far do they project into the cavity? The singular condition described and figured by Kützing of smaller tablets (*tavolette*) attached to larger ones, indicates a peculiarity of development, which has no analogy in the remainder of the class.

51. Tessella.—*Bacilli late tabulati, non concatenati, dense longitudinaliter vittati; vittæ medio interruptæ alternantes, stipes nullus?*

This genus, too, is reduced to a single species (*T. interrupta*), and, therefore, it is impossible to judge of the value of the characters that distinguish it from the preceding or the succeeding, whilst we do not know the organic importance or the true structure of the vittæ. The breadth of the tablets is remarkable, being five times more than the length. There is frequently an absence of a few vittæ, accompanied at the same time by a deformity or derangement of those contiguous. It appears that this condition precedes the deduplication, but we have no observation in point. It still remains, also, to determine the figure of the lateral surfaces.

52. Hyalosira.—*Bacilli tabulati quadrati, concatenati lateraliter stipitati, interrupte vittati; vittæ alternantes medio lineolis subtilissimis conjunctæ.*

At first I was afraid that I was led, by want of skill in observing, to believe that I could see in the two longer (*rectangula*, *obtusangula*) of the four species of this genus a continuation of the vittæ from one margin to the other, instead of their being interrupted and alternating, as they are figured and described by Kützing. Continuing my observations, I succeeded at last in finding one individual exhibiting to my sight the alternations described. Hence I became convinced that the latter condition is not merely inconstant but even the least frequent. The secondary surfaces, neither described nor figured by Kützing, are elliptico-acute, and on these are inscribed the smaller concentric ellipses, which mark the margin of the incomplete diaphragm formed by the nearest vittæ.

53. RHABDONEMA.—*Bacilli tabulati concatenati lateraliter stipitati, interrupte vittati et transversaliter striati; vittæ capitatæ. Striæ transversæ sinis longitudinales numerosas formantes.*

I have only had an opportunity of observing one (*R. adriaticum*) of the three species of this genus; and it is because I must therefore limit myself to this that I cannot agree to what Kützing represents in his description and figure. He omits to indicate the form of the tablets, which can only be obtained by observation of the secondary surfaces, or by a longitudinal section; and it is entirely from this form that the appearances are derived, on which the specific distinctions are supported. In the Adriatic species, the figure of the secondary surfaces is linear in the centre, and cuneato-attenuated (*assottigliata*) at the extremities. The frustules (*bacilli*), therefore, are thick in the middle, have laterally the two primary surfaces strongly inclined together towards the outside, and are much attenuated in the extreme margin. The vittæ are nothing more than canals projecting into the internal cavity, and projecting slightly, indeed, at the surface, in the middle, and continuous from one extremity to the other. In specimens dried and softened again, the canals themselves include air collected irregularly into bubbles more or less extended. Hence the appearance of interrupted and capitate vittæ. The appearance of four transverse series is produced by the form of the frustules (*bacilli*). The transverse striæ are continuous even across the vittæ and canals; and it is only by attention to the slight projection of these, that, in withdrawing the object by slow degrees from the microscope to bring different parts into focus, we can see first the striæ of the intermediate spaces and not those of the canals, then the latter and not the former, and *vice versâ* if the object be brought near again. They then appear always in interrupted longitudinal series, but sometimes in the intermediate spaces, and sometimes on the vittæ; and we can never see them on both at once. Near the margins, the difference of surface diminishes, and therefore the striæ appear continuous.

In the figure which Ehrenberg gives of *R. arcuatum*, (pl. xx, fig. 8,) the secondary surface is represented simply elliptico-acute, and the vittæ appear entirely confined to the extremity. I suspect this figure to be taken from the external aspect rather than from direct observation; and from analogy with our species, I should be induced to believe that the primary surfaces remain parallel to each other quite to the attenuation of the extremities, and, therefore, that the series of the apparent vittæ becomes double rather than quadruple.

The four genera, (*Striatella, Tessella, Hyalosira, Rhabdomena,*) which constitute the family of Striatelleæ, are certainly connected by a great affinity. Still it is difficult to determine their mutual relations, or the connexion of the entire family with others. Kützing places the Striatelleæ in comparison with the genera *Fragillaria, Diatoma,* and *Achnanthes,* as they do not specially differ from the two former except in the abundance of vittæ, to which, I believe, the two usual longitudinal canals are correspondent. From *Achnanthes* they differ as well in form as in the absence of a central aperture. We will compare them with the next family when we have treated of it, contenting ourselves at present with intimating that they are more closely allied to the Fragillarieæ than to any other preceding family.

Kützing rightly observes, that the Striatelleæ are found indifferently, sometimes free, sometimes affixed. It seems, however, that they were all originally in the second of these conditions. Still, in the association of individuals resulting from deduplication the Striatelleæ repeat all the forms of the Fragillarieæ. Finally, as to the *interanea*, Kützing says they are at first disposed uniformly, then collected into small spherules, which become condensed into a central globe. This last condition is characteristic of the single species of the genus *Striatella*. But with regard to *Hyalosira* and *Rhabdomena*, I think it important to mention the wasting away of the coloured internal substance into longitudinal strips parallel and intermediate to the vittæ.

54. Tetracyclus.—*Bacilli late tabulatia infilum arcte connati, longitudinaliter continuo et arcte vittati; a latere secundario utroque apice late rotundati, ventro medio maxime inflato, stipes nullus.*

The presence of vittæ solely distinguishes the single species (*T. lacustris*) from *Odontidium*. The lateral surfaces are convex, and traversed by transverse and arcuate costæ. I have not seen the straight median costa figured by Hassall, nor the absence of these costæ in the space in the centre, as figured by Kützing. But because the median lobe is strongly convex, its plane is different from that of the lateral lobes; hence, when the costæ of one can be seen, those of the other cannot, and *vice versâ*. I can in no way comprehend Kützing's reason for enumerating this genus among the *Diatomeæ stomaticæ*, except by supposing that he regarded as a large central aperture the entire median cavity, which seems to be open when, observing the lateral surface too nearly, the corresponding convexity escapes from the field of view. Fragments of organisms, similar to *Tetracyclus*, are very common in the fossil flour of Santa Fiore.

55. Tabellaria.—*Bacilli adnati obsolete stipitati, demum semivoluti, concatenati, interrupte longitudinaliter vittati; a latere secundario ventre et apicibus inflati.*

The variation of form in the frustules (*bacilli*) of this genus is very remarkable. On this account it becomes so very difficult to distinguish between the two principal species (*T. flocculosa, T. fenestrata*) of this genus, common in fresh water throughout Europe; and the synonyms become so complicated and obscure.

Hence Kützing rightly sought the limits between the two species in the fine character of alternate vittæ in *T. flocculosa*, and opposite vittæ in *T. fenestrata*. With regard to these vittæ, I observe that they are alike arranged in fine striæ, which continue without interruption even where the vittæ are alternate. Their alternation in *T. flocculosa* is not at all constant, and Hassall, too, makes this remark.

After a long and attentive observation, I believe I have convinced myself that the structure of the *Tabellarieæ* is something different from that described and figured by our author. The primary surfaces have a rectangular figure; the secondary are linear, or rounded merely at the extremities (as I find in authentic specimens of *T. fenestrata*, from Jurgens), or swollen circularly in the middle, or at the ends, as seems constant in *T. flocculosa*. It follows that the form is that of a cylindroid, strongly compressed, or of three smaller cylinders, the central one larger than the others, united together by parallel walls, and placed at a distance less than the diameter even of the lateral cylinders; I never obtained a sight of any aperture. The internal cavity is variously divided by incomplete diaphragms. When one only exists, as is frequent in *T. fenestrata*, it is clearly seen to be furnished with a large central perforation, and to contain a canal, which, running along the internal wall of the primary surfaces to where the diaphragm detaches itself, comes to communicate with another similar canal, hollowed in the free margin of the diaphragm itself. When we observe such a frustule (*bacillus*) on one of its secondary surfaces, the large central aperture eludes the eye; still it may be seen, but only across the transparent surface itself.

In this species we may frequently see two similar diaphragms. In the *T. flocculosa*, as many as nine may be met with (Hassall). They are not all equally easy to be seen in specimens that have been dried and softened. A green substance seems to be coagulated within them; and where this is wanting, the transparency prevents our distinctly seeing either the canals or the diaphragms.

It is a frequent condition of the *T. flocculosa* that this coloured substance is found in one lateral half, and not in the other, of the same canal; hence the alternating character of the so-called vittæ. So there does not exist a canal continuous to open extremities, which traverses the frustules (*bacilli*), as authors describe and delineate, but many apertures (*fenestræ*), arranged in a series, in which bubbles of air remain imprisoned, unable to make their escape without rupture of the shield.

In the *T. fenestrata*, every individual has two diaphragms when the development is complete. When deduplication takes place, two individuals are produced, each having one diaphragm.

The second diaphragm afterwards appears, and, at a later period, another deduplication. It is still a question whether both the new individuals equally divide; whether a new diaphragm appears in both or in one only; whether on the inner or outer side; and whether among the four individuals resulting from the second deduplication, those are equally prolific which retain the primitive diaphragms, or those which have new ones only,—or both together? In the *T. flocculosa* it is rare to see one diaphragm only; and, again, it often happens that two contiguous frustules (*bacilli*) possess different numbers of them. Therefore, besides the inquiries indicated above, another might be instituted on this species, —whether or not the deduplication is always subsequent to the formation of a diaphragm? a circumstance in which the essential difference between this and the preceding species seems to reside.

In the fossil flour of Santa Fiore, besides the *T. amphicephala*, we find many fragments which cannot all be referred to the two preceding species. The vittæ seem to have disappeared in all, owing to the absence of colouring matter, and the under-mentioned conditions of the shield are clearly seen in all.

It is justly observed, by Hassall, that there is a difference, in the mode of connection, between the two common species (*flocculosa, fenestrata*). In the second, there is a distinct cushion (cussinetto), in the form of a hinge, connecting one frustule to another. In the first, the angles are nearer together, the hinge is wanting, and there remains in its stead a sort of detached border, showing that the very fine external membrane has been lacerated, yielding to the excessive distension, but persisting partially to maintain the union, and without retracting itself, as it must do, in the other species, to originate the hinge.

This diversity of condition appears to me in accordance with the different period of development at which the deduplication occurs in the two species, as well as with the other considerations already mentioned. I think that we ought to take this fact into account, as also serving to support my opinion, as to the nature of this external membrane.

Besides the two living species, and the fossil one just mentioned, Kützing describes another, discovered by Lenormand; and enumerates three from America, the discovery of which is due to Ehrenberg.

56. Terpsinoe.—*Bacilli tabulati adnati, obsolete stipitati, demum semisoluti et isthmo concatenati, vittis transversalibus abbreviatis marginalibus* (*non perviis*) *capitatis in latere secundario nodosi.*

If we imagine a series of frustules of *Tabellaria* joined together, not laterally, but the head of one to that of another; or, in the direction of breadth instead of length, we shall form the most just idea of the only species of this genus, (*T. musica*). And though I could not study it in the very small fragment with which Kützing favoured me, I still think I can assert that here also, as well as in the preceding genus, the canals run without interruption along the attachment and the free margin of the diaphragms; and the apparently capitate vittæ are produced either by animal matter, or an open space in those imprisoned canals.

Fragments, similar in appearance to what is seen laterally in the margins of the frustules of Terpsinöe, are met with in the fossil flour of Santa Fiore.

57. Grammatophora.—*Bacilli oblongato tabulati, adnati demum semisoluti et isthmo concatenati; vittæ longitudinales semper binæ, medio interruptæ, plus minusvæ curvatæ.*

Kützing, treating of *G. marina*, the most common, remarks that by calcination the exterior inflexions of the vittæ disappear, and that, on this account, a greater distinctness is acquired by the canals, in which these vittæ are situated, and which extend uninterruptedly the entire length of the frustules. He represents these canals, by two delicate lines, one external, the other internal, to each vitta, as well in this species as in all the others. I see the external line clearly, and to me it seems to indicate the conjunction of the secondary valves with the primary. The striated margins, seen in many species (*tropica, gibba, gibberula, serpentina*) belong to the lateral surfaces; and when, as in *G. marina*, they are smooth, they turn yellow by the action of heat, like the remainder of these secondary surfaces. On account of this colouring, it is difficult to see the external arches of the vittæ, for these lines run at a tangent to them. I suspect that along this suture there runs a fine canal, hollowed out in the thickness of the wall, the cavity of which appears as a furrow, or rather as a perforation, at the extremities. The oval aperture (*fenestra*), which is visible in the middle of the secondary surfaces, belongs to them in appearance only, as in the preceding genera. It is only seen because of the transparency. In *Grammatophora*, also, the appearance of interrupted vittæ, is produced by the presence of diaphragms pierced by an ample central elliptical perforation, and containing a distinct canal along their attachment to the wall. Ehrenberg, too, describes these diaphragms, which divide the internal cavity regularly into three distinct compartments. This arrangement is also shewn by heat, and by acids; and the various portions separate themselves so neatly, that we may, in a certain manner, effect a most accurate dissection. In this genus, these diaphragms have the characteristic condition of very various degrees of flexature, which are constant in each species, and impart to them the most elegant appearances. In the deduplication, the line of division between the new individuals, and the fine lines which form the boundaries of the two new lateral surfaces, precede the appearance of the corresponding diaphragms. These are the fine lines delineated by Kützing within the vittæ, and regarded by him as the internal margins of the canals, in which he believes the vittæ themselves to meet together. The deduplication of *Grammatophora* greatly resembles that of *Achnanthidium.*

Ehrenberg describes the internal substance as consisting of a central transparent and colourless body, containing small gastric vesicles, and terminated at each extremity by three-lobed dark-green appendages, which project into the three corresponding cavities. The cushions (cuscinctti) or hinges that retain the frustules in connection are very evident, in all the thirteen species of this genus, as in the *Tabellaria fenestrata;* and this remark goes to confirm what we have said of that species.

The family of Tabellarieæ (*Tetracyclus*, *Tabellaria*, *Terpsinöe*, and *Grammatophora*) constitute by themselves alone the order Stomaticæ. The two preceding families (*Licmophoreæ* and *Striatelleæ*) are comprised in the order Astomaticæ. These two orders constitute the tribe of Diatomeæ vittatæ.

Any one examining these beings with diligence will entirely convince himself that the distinction of the two orders is altogether insufficient. No Tabellaria has a central perforation in the secondary surface, at all to be compared with that of the Diatomeæ, constituting the order Stomaticæ in the preceding tribe. Nor have I succeeded, moreover, in discerning the other four perforations, described by Ehrenberg as existing in the middle of the terminal surfaces. As to the four genera comprised in this family, since the sole character by which they were united together, and which was brought to establish the principal distinction between the Fragillarieæ and Striatelleæ, has been proved to be erroneous, it will remain to be inquired whether there be other distinctive characters. I firmly believe that Tabellarieæ and Striatelleæ ought to constitute one family, since the diaphragms, which Ehrenberg considers characteristic of the second exclusively, are not wanting in the first. The only doubt that I could rationally entertain would arise in respect to the genus *Terpsinöe*. The figure of the lateral surfaces, the total form of the frustules, the arrangement of the vittæ, the direction of the apparent transverse canal, finally, the similarity to the other allied genera in external aspect, would induce us to regard the frustules as connected to the head of each other, rather than laterally; as we have already stated, to give a clearer idea of the subject. But then, how can we reconcile the transverse deduplication with all the other instances in which, on the contrary, it is longitudinal? For if we would attribute a greater degree of generality to this law than to any other; setting out from the direction of the deduplication, always parallel to the secondary surfaces, to decide upon the correspondence of all the other parts with each other, we must then withdraw the title of general from the other law (which is laid down as general), that the direction of the vittæ is always longitudinal. In either case, the genus *Terpsinöe* varies entirely from its allies, so that I think it must be regarded as the type of a distinct family.

Owing to the mere presence of vittæ, Kützing has elevated the group of three families just examined, no less than to a degree superior to that of an order, and which he denominates a tribe. The analysis we have instituted appears to me sufficient to prove that this characteristic condition is solely due to the larger development of an organ which really exists, or is in some degree represented, in the various families of the preceding tribe. And though, systematically, we might wish to assign it a great importance, yet in a natural classification it must certainly be subordinate to the assemblage of characters. Therefore, abstracting this character, and looking solely to natural affinities, I believe that the Licmophoreæ ought to be placed near the Gomphonemeæ, with the exception that the genus *Licmophora* is to be placed by the side of *Synedra*, and therefore in the family of Surirelleæ; and all the other vittated Diatomeæ must be ranged in the order Fragillarieæ.

58. Coscinodiscus.—*Individua solitaria, libera, lorica bivalvis silicea, in latere secundario disciformis, cribrata.* The only essential character that distinguishes this genus from the *Cyclotellæ*, is the areolation of the secondary surfaces. And it is entirely on this account, that, whilst belonging to the first tribe, it is placed in the last. We ought to repeat here, that when treating of *Cyclotella*, we noticed the points and radiated lines in the lateral surfaces of the freshwater species (*operculata*, *Meneghiniana*) and the fossil ones, (*minutula*, *Rotula*,) a circumstance that imperiously requires an union of the two genera. In what relates to this areolation, the expression *cribrata*, of Kützing, includes a false idea, inasmuch as these cells are not perforations at all, as this author

states (*lorica perforata*). The observation that, by placing the object alternately nearer to, or more distant from, the microscope, the cells and their intermediate spaces appear successively in light and shade, is sufficient to prove that the appearance is produced either by simple depression or elevation, causing a difference in the surface, or perhaps by minute cavities in the thickness of the wall itself.

Kützing takes no notice of the marginal perforations described by Ehrenberg, who enumerates as many as twenty-five in *C. lineatus*.

Ehrenberg describes the internal substance, either collected into a globular mass in the centre, or radiating irregularly all round from the centre towards the circumference, or more frequently arranged in small distinct globules, like those of *Melosira*. He sees, also (*C. patina*), a globular gland, and a contractile diaphanous area which he believes to belong to the male sex.

59. Actinocyclus.—*Individua solitaria, libera; lorica bivalvis silicea, disciformis* (*breviter cylindrica*) *cellulosa; cellulæ radiis pluribus lævibus interruptæ. Septa interna nulla.*

In a specimen of chalk marl, from Oran, in my possession, which consists almost entirely of *Coscinodisci*, *Dictyochæ*, *Melosiræ*, and spiculæ of sponges, I could not possibly find a single *Actinocyclus*, although seven out of twenty-four species of this genus are indicated in this substance. This proves only one circumstance, which, for other reasons, can easily be imagined, that in the same formations the species and genera appear to be different at different points. I think, also, that I ought to introduce two observations equally applicable to this genus and both the preceding and subsequent genera.

Among the innumerable valves of most species of *Coscinodiscus*, more or less regularly curved, many are found to be flexuose or curved in various ways; there is this variety of curvature in valves perfectly similar to each other in every other character. Considering, then, that in *A. undulatus* the six apparent rays are produced by a similar flexuosity, a doubt necessarily arises, either that the two genera are not sufficiently distinct, or that the characters deduced from this flexuosity are not sufficient to distinguish the species. There occurs, also, naturally to the mind, a comparison under this aspect of the *Coscinodisci* with *Campylodisci* and the flexuose *Surirellæ.*

In some individuals exactly referable to *Coscinodiscus eccentricus,* and which preserves both the valves, there are seen five incomplete radii, which vanish entirely when the object is withdrawn so far from the microscope that the surface only is visible. I conclude from this that these radii are so many internal partitions (*setti*). On this supposition, the species would not belong to any one of the three genera. Besides Ehrenberg having also found it alive near Cuxhaven, in the North Sea, it would seem improbable that such an organic condition could have escaped so expert an observer; and we must, therefore, suppose that a different thing is referred to.

Kützing describes and represents the radii to be perfectly smooth; Ehrenberg, again, though he does not express it in his figures, says that they are finely punctated. In almost all the species there are indicated marginal apertures corresponding to the radii. In many, which Ehrenberg observed alive, the coloured internal substance was variously grouped into many lobes near the centre.

60. Actinoptychus.—*Individua solitaria libera, lorica bivalvis silicea disciformis* (*breviter cylindrica*), *cellulosa; cellulæ radiis septisque internis radiantibus pluribus interruptæ.*

The beautiful observations of Ehrenberg are fruitful in very important particulars relative to some species of this genus, (*duodenarius, sedenarius, octodenarius.*) Of these particulars, Kützing takes no notice. The triangles into which the disc is divided by the radii, appear alternately clear and dark, precisely as happens in *Actinocyclus undulatus,* where that appearance is evidently produced by the flexuose state of the surface. A line traverses the middle of these triangular spaces. The marginal perforations correspond to the lines which border the triangular spaces in *A. sedenarius*, to which again they run in the middle of those of *A. duodenarius* and of *A. octodenarius;* and the internal septa (*setti*), according to Ehrenberg, always correspond to those radii which do not terminate in an aperture. We learn, too, from the figures, that the areolation of the surface is continued without interruption even over the radii, and that, besides the indicated apertures, there are visible also those of the opposite surface, which alternate with the former. And Ehrenberg observes, that on this account there occurs an optical illusion not easy to explain. Hence arises a suspicion that an equal number of septa (*setti*), but alternating with each other, project from the inner superficies of both surfaces without reaching the opposite surface, and so the marginal apertures belong sometimes to one, sometimes to the other.

All the species do not seem to have the same structure. In some, at least, (*ternarius*, *senarius*, *octodenarius*,) the radii are figured smooth, as in *Actinocyclus;* it is not said that the triangular spaces are alternately clear and obscure, nor that they are traversed by a longitudinal line; and there remain doubts as to the marginal apertures.

As to the internal organisation, little can be collected from the observations of Ehrenberg.

Finally, it deserves attention, that the fourteen species enumerated in this genus differ almost exclusively in the number of radii. Two only, (*senarius*, *hexapterus*,) having the same number, are much different from each other. Three have unequal numbers.

The family of Coscinodisceæ (*Coscinodiscus*, *Actinocyclus*, *Actinoptychus*) is, even in the opinion of Kützing, more nearly allied to that of the Melosireæ than to any other. I believe that both the *Campylodisci* and flexuose *Surirellæ* are to be regarded as allied to this family.

61. LITHODESMIUM.—*Individua a latere secundario triangula in corpus prismaticum articulatum conjuncta.*

The several frustules are united together by a shorter intermediate body, in which Ehrenberg observed a granulated surface; this, he says, appears in young individuals only, which are, therefore, pliable when dried. He regards this granulation as indicating the process of siliceous ossification.

The only species of this genus (*L. undulatium*) inhabiting the North Seas, is too little known to exclude all doubt as to its nature.

62. AMPHITETRAS.—*Individua a latere secundario quadrangula (depressa) ad angula isthmo molli concatenata. Catenæ breviter stipitatæ adnatæ.*

Kützing himself observes, that the species of this genus may easily be thought to belong to the *Isthmiæ.* The only difference is that upon which the distinction of the entire family is founded, that is, the angular figure of the lateral surfaces. This character is, indeed, extremely conspicuous, and in want of other data may serve very well to distinguish genera. But that this is of itself sufficient to separate, not families merely, but even orders, will be conceded with difficulty in a natural classification.

I found the very beautiful *A. antediluviana* among some specimens of *Biddulphia quinquelocularis,* from Calvados, obligingly supplied by Brébisson. The smooth fascia deserves attention; it traverses the frustule in the direction of its length. It is sometimes absent, sometimes double, or even triple. The appearance of the areolation is different from that of the allied genera. It seems produced by minute projecting papillæ. The ample round apertures are very evident, corresponding with each of the four angles of the secondary surfaces, as described by Ehrenberg, but omitted by Kützing from his description as well as his figure.

Kützing does not acquaint us with his authority for referring as a doubtful synonym of this species to the *Isthmia vesiculosa* of Agardh, which, from that author's description, would rather appear to be a Desmidiea. In my monograph of the Desmidieæ (1840), I had regarded this species as the type of a genus, which at that time was by Kützing denominated *Isthmosira*.

I have not happened to meet with the *A. adriatica* recently published by Kützing, (*Phycologia Germanica*, p. 115,) which, by the strong prominence of its angles, is much more allied to the *Isthmiæ*.

It is to be observed, that this projection varies very much in the preceding species, as stated by Ehrenberg, and as I have observed in the specimens before mentioned. The other species, *A. parallela*, which hitherto has only been found in a fossil state, seems to be very distinct.

63. Amphipentas.—*Individua pentagona.*

Both species of this genus are of a doubtful nature. Collecting here together all that is referable to the family of Anguliferæ, (*Lithodesmium*, *Amphitetras*, *Amphipentas*,) I can only repeat what was before said of the second of these genera. The first is uncertain in its nature, but, at all events, can have no affinity with the second. The last has some resemblance, at least in external appearance.

The two families, Coscidonisceæ and Anguliferæ, constitute the order Disciformes. I know not what character can have led Kützing into this union, for the very name of the second family contradicts that of the order. I believe that the Coscinodisceæ cannot be separated from the Melosireæ, and that the Anguliferæ, excluding the genus *Lithodesmium*, ought to be united to the Biddulphieæ.

64. Tripodiscus. — *Individua singularia? libera?*

lorica bivalvis discoidea circularis, in utroque latere (secundario) tribus processibus appendiculata.

The only species of this genus, which of itself constitutes the family of Tripodisceæ, does not essentially differ from the *Coscinodisci*, except by three short appendices projecting from each of the lateral surfaces, which are tubular, and terminate in an aperture. Ehrenberg, also, suspects the presence of other smaller marginal apertures. The areolation of the surface is so confusedly represented in the figure, as to lead to the belief that even the organic condition is complicated, which gives that appearance.

65. Isthmia.—*Individua trapezoidea vel rhomboidea, compressa, cellulosa, zona transversali ex cellulis minoribus formata, notata, stipitata, isthmis majoribus in catenas subramosas irregulares conjuncta. Divisio oblique transversa.*

The complicated synonymy of the two species of this genus (*enervis, nervosa*) justifies the new name given by Kützing to the second. The *Conferva obliquata* of Smith belongs to the first, and therefore Ehrenberg was in error when he bestowed upon it a new specific name (*enervis*). The other required to be named, and Kützing was fully entitled to call it *I. nervosa.* By the laws of synonymy, therefore, the two names *obliquata* and *nervosa* ought to remain. The longitudinal costæ of this latter are quite extraneous to the surface; they project slightly into the interior cavity. Both in the one and the other the siliceous cellular membrane of the median portion persists, whilst within it a formation of two lateral valves takes place, which complete the two individuals proceeding from the deduplication. This process reminds us of that of the Achnantheæ, and approaches the reduplication of Desmidieæ.

The transverse zone, represented by Kützing in the median portion, is neither constant nor regular. I believe it to be produced by the permanence of some portion of the cellular siliceous external membrane, which is lacerated in the deduplication. A portion of it may remain in the middle, whilst its lateral extremities are denuded, or *vice versá*, the former may remain denuded, and the latter covered. It still remains to be explained how the formation of the new valves takes place, whether they are organised *in situ*, or project by degrees from the companion valves, to which they are contiguous from the beginning, the intermediate ring only developing itself subsequently (*consequentemente*), as in *Melosira*.

The gelatinous isthmus, which connects the individuals together, and the stipes by which the entire chain is affixed, seem to prove the presence of an exterior gelatinous membrane.

66. ODONTELLA.—*Individua lævia, compresso teretiuscula medio fasciata utroque apice cornibus binis lateralibus instructa et concatenata, adnata.*

I am compelled, by the want of specimens, to confine my examination to that one only of the five species of this genus which I have already treated upon in reference to my *Pleurosira thermalis;* and I can only insist upon what I have stated on that occasion. The individuals of *Odontella polymorpha*, have an elliptic cavity in the middle, and at the extremities are compressed in the direction of the greater diameter of that ellipse; but viewed laterally, they present an obtuse, but linear edge (*canto*). The lateral processes, by which the individuals are connected together, are very evident. The difference, therefore, between this form and that of *Pleurosira thermalis*, and of *P. Baileyi*, is very great. Another important difference exists in the conjunction of the median ring with the two lateral valves. In my *Pleurosira* there is on both sides a large, distinct, circular canal (*canaletto*), evidently projecting into the inner cavity, and corresponding to an external furrow. But in the *Odontellæ* there exists neither furrow nor projection; and I really doubt whether there be a fine canal. A like condition exists in both with respect to the delicate points on the shield, which Kützing says he has omitted in his figure of *Odontella;* these being absolutely referable to the internal substance, as in the *Melosiræ.*

67. Biddulphia.—*Individua concatenata, punctato-cellulosa* (*cellulis in lineas rectas transversales ordinatis*), *utroque latere obtuse dentata* (*dentibus marginalibus majoribus*) *septis transversalibus internis loculosa.*

The inner cavity is not divided into distinct transverse cells, because the septa, far from being complete, only project in a very little way. Their greatest prominence corresponds with the extremities of the frustule, and thence they proceed, growing more slender, towards the margins of the lateral valves, to which they exclusively belong. A similar elevated rim (*orlo*) in the internal cavity limits, also, the lateral processes by which the frustules are connected together. Each of these processes terminates in an acute corner (*spigolo*), and has therefore a three-sided figure, and is situated obliquely.

The terminal surfaces (lateral in respect to the chain) are smooth, or they present an elliptico-elongate figure, traversed, parallel to the smaller axis, by two lines which mark the conjunction of the two lateral valves with the median body. Corresponding externally to these lines, is a deep furrow, which is clearly seen in the projecting corners (*spigoli*); internally there is a projecting fold (*cercine*), like an incomplete diaphragm of the areolar border. Hence the form of the frustules is very different from that indicated by Kützing, who represents them as flattened cylindroids. For they are almost parallelopipeds, and when they are united together by an external siliceous cellular membrane, more or less incompletely persistent, they constitute a prismatico-quadrangular filament. When they are free, the extremities are thinned, rounded, and lobed, according to the number of incomplete cells. The two primary surfaces are smooth; they present transverse elevations and depressions in correspondence with the cells above mentioned. The lateral processes are more or less completely denuded of the fine cellular membrane, and are united in concatenation with each other by a cushion (*cuscinetto*), bounded externally by a precise line, but internally irregular.

The deduplication takes place in this genus as in those preceding. The double ligament merits observation, which remains to unite the median lobe of both surfaces of each extremity with the corresponding (ligament) of the adjoining frustule. This ligament, from the gradual elongation, breaks across in the middle, maintaining its rigidity.

In the Adriatic we have the two species, *quinquelocularis* and *trilocularis*. To the second I refer a form with smaller and less elongated frustules, which at first I thought a new species, and as such communicated it to Kützing, who, on the other hand, believed that it belonged to the *quinquelocularis*. I note this circumstance to indicate an important organic condition. When the frustules are empty and diaphanous, we can easily see, owing to the transparency, the costæ of the surface opposite to the one observed, and especially the two extreme ones, which correspond to the least thickness, and can therefore be seen along with those of the anterior surface. The number of the so-called cells is then apparently increased by two. It happens in this way that the *quinquelocularis* sometimes resembles the *septemlocularis*.

Kützing ascribes to this genus, as a doubtful species, the *Denticella Fragillaria*, of Ehrenberg.

In the *quinquelocularis*, I once saw a frustule broken in the direction of the conjunction of the lateral valves with a median cincture, and surrounded by 4—6 polyhedral corpuscules, of a diameter equal to one fourth that of the frustule, and of a cellular structure, adhering to the margin of the fracture.

Finally, we cannot but remember the *Isthmia nervosa*, which seems to differ from *Biddulphia* in no other respect than the trapezoidal figure of its primary surfaees.

68. Zygoceros. — *Individua libera* (?) *compressa utrinque corniculis doubus perforatis instructa, non concatenata.*

The two speeies of this genus, (*Z. Surirella, Z. Rhombus*) were observed in a living state by Ehrenberg, who saw that they were always free, and thenee established, prineipally on the want of stipes and of eateniform eonjunetion, their generie distinetion from *Biddulphia.*

He observed, also, the smooth median faseia whieh he compared to that of the *Melosiræ.* Having regard to the rhomboidal figure of the seetion, and the large terminal perforations of the two lateral processes, the eomparison with the genus *Amphitetras* is mueh eloser.

In the ehalk marl of Oran, I saw a fragment whieh I eould not better refer to any other genus of Diatomeæ. It was an oblong body, with three lobes on eaeh side, and two lobes with a large eireular perforation at the two extremities. The spaee eorresponding to the two median and more prominent lobes, was divided from the two others by means of two very distinet lines, and the whole surfaee was regularly areolated.

The family of Biddulphiæ (*Isthmia, Odontella, Biddulphia, Zygoceros,*) has affinity, aecording to Kützing, with none but the following one (Angulatæ); and in the letter before referred to, he intimated to me his thoughts of reuniting them to the Tripodiseieæ. Here I remind the reader of what I have said on the genus *Amphitetras,* and of the family of Anguliferæ, whieh, perhaps, exeluding the genus *Lithodesmium,* seems strictly to eonneet itself with the Biddulphieæ. If there really exist also an affinity with the Tripodiseeæ, as Kützing maintains, that affinity may suggest the transition to the Coseinodiseeæ and thenee to the Melosireæ.

In respeet to the internal organisation of the Biddulphieæ, we learn, from the fine observations of Ehrenberg, that there is always a coloured substance disposed in lobes, which he supposes to represent the ovaries, in the midst of a transparent and colourless body.

69. Triceratium.—*Individua libera, lorica bivalvis triangula, in utroque latere tridentata vel corniculata, non concatenata.*

The perfect resemblance of the primary surfaces, and the large apertures of the three processes in the secondary, render this genus precisely intermediate between *Amphitetras* and *Zygoceros*; nor, indeed, can I comprehend how Kützing could place them in three separate families, and even in two distinct orders. As to the minute apertures, which Ehrenberg states to be uncertain, in the conjunction of the lateral valves with the median fascia, we may suppose that they are only apparent as in the *Biddulphiæ*, where they certainly do not exist. Of the four species hitherto described, two (*Favus, striolatum*) were observed by Ehrenberg and by Sonder in a living state, in the North Sea.

Like *Zygoceros*, the *Triceratia* become detached completely in deduplication, and, therefore, do not, like *Amphitetras*, form cateniform chains. They possess, also, a more decided motion. This character, however, does not appear to me of so much importance as of itself to fix the limits of distinct families; and Kützing himself, who proposes a separate family (Angulatæ) for the genus *Triceratium*, comprises *Zygoceros* in that of Biddulphieæ, where the catenæform association is so preponderant.

70. Actiniscus.—*Individua solida radiata, stellam æmulantia.*

Although, besides a species exclusively fossil (*A. Stella*), omitted by Kützing, one of the other two has been observed alive by Ehrenberg (*A. Pentasterias*), and the other exclusively in this state, (*A. Sirius*,) still we have no positive data as to the internal organisation of the genus.

71. Mesocena.—*Individua libera solitaria, annulum circularem aut angulosum sæpe spinescentem referentia.*

On the five species of this genus we can only repeat what has been said of *Actiniscus.*

72. Dictyocha.—*Individua reticulata spinosa, libera, solitaria.*

Independently of the distinctive characters of the ten species (one, the *D. gracilis,* being added by Kützing) which merit attention by the variety of form, size, proportion, disposition, and even number (*D. aculeata, D. trifenestrata*) of the (*maglie*) cavities, as well as the presence and length of the spines, already noticed by Ehrenberg, this author's observations on some of these species that may be studied in a living state (*aculeata, Speculum, Fibula*) are very valuable. From these it appears that the animal is soft, and quite external to the siliceous body which it bears on the surface, like a dorsal shield (*scudo*), as the *Arcellæ* bear their calcareous shell.

Though observations are wanting to show that the organisation proved only in some species of this last genus (*Dictyocha*), is common to the whole family of Actinisceæ, yet we may infer by analogy that it is so. In fact, we cannot interpret the structure of those beings in any other way than by supposing the body of the animal to be external.

And how slight soever, may be our knowledge of the *Dictyocha,* it is still more than sufficient to prove an organic type not merely quite different from that of the other families comprised in the same order (Appendiculatæ), and in the same tribe (Areolatæ), but even from the type of all the other Diatomeæ.

I believe that whatever be the rank assigned to the group of Diatomeæ in the Zoological series, the first division ought to be that of true Diatomeæ and Actiniseeæ. Yet, in the actual state of science, we may eharacterise the first as completely lorieated, the second reduced, in the dermal skeleton (*dermoscheletio*), to the presence of a simple dorsal shield. It is indeed true, that, in other classes of animals (Mollusca), the characters derived solely from the dermal skeleton have not so high a taxonomie value. It is possible that we may come to establish the basis of classification, even in Diatomeæ, upon the particulars of their intimate organic structure; but since this may never be realised, I believe that, provisionally at least, this character should be considered the principal one.

The order, therefore, of Appendiculatæ (Tripodiseieæ Biddulphieæ, Angulatæ, Actinisceæ) is the most artificial of all, and even in that respect inconsistent. By the same title that *Zygoceros* and *Triceratium* are inserted, we ought also to insert *Amphitetras* and *Amphipentas* (if they be true Diatomeæ). The Biddulphieæ constitute a very natural group, when we unite the Anguliferæ and exclude *Lithodesmium* and the Angulatæ. There would remain some doubt as to the genus *Odontella*, in respect to the want of areolation in the shield. *Tripodiscus* would remain intermediate between this group, and the Coscinodisceæ. Finally, the Actinisceæ, in my opinion, ought to be entirely excluded.

Thus the entire tribe of Areolata (Disciformes, Appendiculata,) would be reduced to three groups only, (Coscinodisceæ, Tripodisceæ, Biddulphieæ,) to which, this denomination really belongs. And here, we cannot but adduce some considerations on the organie condition that gives origin to it. In the Biddulphieæ, the structure of the shield seems evidently cellular. In the Coscinodisceæ we have supposed it to be such on account of the optical phenomena it presents, and examination eonfirms this supposition. Comparing, then, the tribe of Areolatæ with the preeeding, under this point of view, and independently of the animal or vegetable nature of Diatomeæ, considered as organised beings, we find ourselves of necessity, reduced to a dilemma. Either the shield of the Areolatæ has a structure entirely different from that of the other Diatomeæ, or the shield of the latter has a compound structure, which escapes the eye, though armed with the highest magnifying powers, owing to the tenuity, and minuteness of its elementary parts. Perhaps some one may attempt to elude the question, by admitting that this shield can be no other than a product of secretion. But, besides that, the products of secretion are living beings, organised and susceptible of their own ulterior organic modifications, as we have previously demonstrated: in either mode it is necessary to admit a particular organisation in the secreting organ, because its products assume a particular configuration and texture. If, therefore, the vital and organic power be understood as limited solely to the soft substance, and extended afterwards to the solid, it always comes to be the same thing—the peculiarity of organisation. The difference is reduced to the soft or solid constitution; nor does this isolated condition prove, in my opinion, the mineral condition of a tissue which does not present any character either of crystallization or inorganic deposition.

Of the two discordant opinions, I believe we ought to admit that which supposes by analogy the usual elementary structure to prevail in the shields of all Diatomeæ. And, in truth, the presence of striæ, points, depressions, elevations, manifests, in many even of those not areolated, a structure neither uniform nor continuous. We find, too, that independently of this condition, many degrees of correlation connect the genera of the last tribe to some of those of the two preceding. The *Odontellæ* are rightly placed near the *Biddulphiæ* and *Isthmiæ*, though they do not possess an areolated shield. And if a decided organic affinity be undeniable in the entire organisation of such beings, it is reasonable to suppose, that even in the structure of an organ common to them all, the differences may be produced only by a slight modification in form, and principally in the dimensions, of the organic elements.

It remains to be decided what this structure is. The shield of the Biddulphieæ seems to be a very simple cellular tissue. It is true, sufficient observations on its origin, formation, and successive growth, are wanting; but although we have no direct observations (which may deceive), we ought necessarily to admit it to be such. It will then be the same as that of other Diatomeæ, which often appears to be a very simple, uniform, and continuous vitreous lamina, but this appearance, perhaps, arises from the minuteness of the cells of which it is constituted, or from their complete obstruction and perfect continuity.

Whatever be the structure of the Areolatæ, it can never be regarded as belonging to the walls of a cell. Indeed, on the supposition of the vegetable nature, and of the inferior rank that the Diatomeæ would occupy in the class Algæ, we must assert for these, as for all the others, the same condition of a simple cell. For in a system where the distinction of monogonimic, polygonimic, and cœlogonimic cells is adduced as of high taxonomic value, a character of so much higher importance cannot be lightly neglected.

The study of microscopic beings presents much greater difficulties than that of the microscopic parts of larger organisms. The ideas that we habitually form to ourselves of the great and the small, are relative to the capacity of our senses, and he who sharpens thôse senses the most by the aid of physical instruments, most extends the relations of those ideas, to distant confines. In this way we come to persuade ourselves, that in nature there exists no absolutely great nor absolutely small. The minutest organisms are not, therefore, the most simple in construction, and their organisation frequently baffles all means of observation. It follows, from these reflections, that in the study of beings of a given family or class, it assists us greatly if we select those that present the greatest complication of structure, because the comparison of these may reveal the organisation which others disguise under an assumed simplicity.

In the three tribes we have examined (Striatæ, Vittatæ, Areolatæ), Kützing arranges all the Diatomeæ which he believes to form a section of the first of the two classes into which he divides all the Algæ. No one who considers that even the Charæ are comprised in the same class, will feel any wonder at this assemblage. But without calculating either the degree or the position attributed to the group of Diatomeæ in the Organic Kingdom, and attending only to the examination of their ulterior division, I believe that the observations adduced may serve to demonstrate that in the three proposed tribes we have unnatural dismemberments and associations. The same conclusion prevails also in respect to the six orders (Striatæ, astomaticeæ and stomaticeæ; Vittatæ, astomaticeæ and stomaticeæ; Areolatæ, disciformes and appendiculatæ,) as well as to the ulterior divisions in the first two, taken from the continuity or interruption of the striæ and the presence of one or two stomatic apertures. Much more naturally established do we find the nineteen families, (Eunoticeæ, Meridieæ, Fragillarieæ, Melosireæ, Surirelleæ, Cocconoideæ, Achnantheæ, Cymbelleæ, Gomphonemeæ, Naviculeæ, Licmophoreæ, Striatelleæ, Tabellarieæ, Cosconidisceæ, Anguliferæ, Tripodisceæ, Biddulphieæ, Angulatæ, Actinisceæ;) respecting these we have seen that, in the actual state of science, few changes would be fully justified. Such changes appear to me to be the following:—the union of Meridieæ with Fragillarieæ; the separation of the genus *Licmophora* from the family that bears its name, to join it with *Bacillariæ* and *Synedræ* in the family of Surirelleæ; to examine it again comparatively with that of Naviculeæ, to decide upon the presence, constancy, and value of the character of a median aperture, which alone serves to separate them; the comparison, under this point of view, of the Licmophoreæ (excluding the genus *Licmophora*) with the Gomphonemeæ; the necessary fusion into one only, of the two families Striatelleæ and Tabellarieæ, the character of median aperture given as distinctive of the second being absolutely false, with the separation of the genus *Terpsinöe* as a distinct type; the removal of the Coscinodisceæ, and probably of the Tripodisceæ, among the Melosireæ; the grouping together of the three families, Anguliferæ, Biddulphieæ, and Angulatæ, excluding *Lithodesmium* as uncertain; and leaving there the genus *Odontella*, which demonstrates the affinity of the entire group with the Melosireæ; finally, the decided separation of the Actinisceæ from all the other Diatomeæ.

These changes being admitted, and the principle being conceded, to its full extent, not to allow absolute value to any character taken separately, the Diatomeæ would be divided into two sections; the Actinisceæ, and all others that could be comprised under the name *loricatæ*, unless we should refuse to acknowledge that the first (section) have really any bond of alliance with the second, except the siliceous nature of the dermo-skeleton. In the *loricatæ* it would be hasty to separate the genus *Terpsinöe* from all the others, which might be reduced to eight families only:—1, Eunotieæ; 2, Fragillarieæ, (uniting with them the Meridiceæ, the Striatelleæ, and the Tabellarieæ;) 3, Melosireæ, (comprising the Coscinodisceæ, Tripodisceæ, Anguliferæ, Biddulphieæ, and Angulatæ;) 4, Cocconoideæ; 5, Achnantheæ; 6, Cymbelleæ; 7, Naviculeæ (with all the Surirelleæ;) 8, Gomphonemeæ (with all the Licmophoreæ, except the genus *Licmophora*.) These families, too, might be separated into two groups, according as the temnogenesis takes place by simple *deduplication*, (Eunotieæ, Fragillarieæ, Naviculeæ, Gomphonemeæ, Cymbelleæ, and Cocconoideæ,) or by *reduplication*, (Melosireæ, Achnantheæ.) I do not believe, however, that this distinction is so essential as it may seem; for even in this case it appears to me that the evident complication of the process in the second group, proves the like of the apparently simple process of the first. In fact, it is indeed always necessary that the two new lateral valves of the two individuals be organised, even in simple Naviculeæ, and the separation of the two pre-existing always precedes the deduplication. It does not, therefore, appear to me that we can entirely agree with Ehrenberg in what he adduces to distinguish the process of deduplication (*sdoppiamento*) from regeneration and reproduction. We cannot say that anything gives way, where the formation of new valves appears, and that the division is effectuated by that. The division is merely the last stage of the process, and the persistence of the two exterior valves does not seem to me sufficient to prove that a total regeneration of the two new individuals has not occurred. Nor can any one prove that a reabsorption of organic substance and a local renewal (*ripristinamento*) of organisation has not taken place. And since the new parts which make their appearance change the individual essentially, and do not belong at all to its individual growth, as Ehrenberg sagaciously observes, from this it clearly follows that it had previously ceased to enjoy individual life. If I were not afraid of appearing too transcendental, I would compare the progressive deduplication (*sdoppiamento*) in the Diatomeæ, with the successive development of the terminal bud (*gemma*) of the Sertularieæ. This unfolds itself (*si sdoppia*) into two organisms, which, in smaller dimensions, might appear almost equal; but one of these enjoys an individual life, the other, again, becomes halved (*si sdoppia*), and so on indefinitely.

As respects the rank and position to be allowed the Diatomeæ in zoological classification, it results from the observations hitherto collected, that nothing positive can be asserted. No one, henceforth, will have a right to contradict the authoritative opinion of Ehrenberg, who ascribes them to the class of Polygastric Infusoria.

[Kützing has recently published (' Botanische Zeitung,' 3d of April, 1846, No. 14, p. 249) some new Diatomeæ, discovered by Brèbisson, at Falaise. An *Achnanthidium*, a *Gomphonema*, two *Naviculæ*, a *Ceratoneis*, two *Synedræ*, and a new genus belonging to the family Striatelleæ.

73. Pleurodesmium.—"*Trichoma articulatum fasciæforme, articuli plani sæpe geminati, fascia transversali media hyalina notati, ex sulcis longitudinalibus obsolete punctatis* (*perforatis?*) *costati; costis rugulosis.*

And thus is completed the number of seventy-two genera proposed (in the preceding enumeration Kützing omitted number 49 by mistake); and the number of species is brought up to more than eight hundred.]

(For further information in regard to these genera, and additional ones since proposed by Kützing, see his ' Species Algarum,' 1849.—Ed.)

ANNOTATIONS.

Page 4.—Without engaging in controversy, rather to show our high esteem for Kützing, we deem it necessary to subjoin a few words, lest we should seem desirous of eluding the question, or not duly weighing the reasons of this excellent author. "There do not exist in nature definite (*scharfe*) boundaries between species, classes, and kingdoms, and our having admitted these theoretically, leads us to regard some inferior animal forms as plants, and some vegetable forms as animals. The limiting of the boundaries between the two organic kingdoms is always a problem. All metaphysics should be excluded from the study of nature, in which we can only proceed by the empirical way, and therefore we ought to restrict ourselves to what we see, observe, and understand." These thoughts, expressed by Kützing, ('*Ueber die Verwandlung der Infusorien in niedere Algenformen:*' Preface,) are strictly logical. But the conclusion deduced by the author is not legitimate, that we ought to admit a common point of departure for the two kingdoms. If it be absurd to admit the problem to be solved positively, it is equally so to admit that it is decided negatively. The contradictions to which he alludes, as produced by the false supposition of the existence of a limit between the two kingdoms, belong to authors or books, and not to the science. The very examples, the *vibratile ciliæ* of *Surirella Gemma* (Ehrenberg), and of the spores of *Vaucheria clavata* (Unger), have an answer in the observation of Siebold. All the observations on the mobility of the sporidia of the inferior Algæ, of the spores of *Vaucheria*, of the Zoosperms, of *Sphagna*, *Charæ*, *Marchantieæ*, Filices, and, lastly, of Fucaceæ, prove nothing more than this, that vegetable beings, in certain stages of their development, and in certain conditions, possess a mobility that simulates animal mobility. It is a positive fact, that the complicated animal organisation discovered by Ehrenberg in many of his polygastric Infusoria, cannot be recognised in some that are referred by analogy to the same class; but it does not at all follow, from this, that we ought to regard these sporidia and the spores of Algæ as animals; for, besides their want of this organisation, they manifest an evidently vegetable nature by their subsequent development. Neither ought we to deny an animal nature to other beings in which this complicated organisation exists. The multiplication by division, or, in other words, temnogenesis, is not, as Ehrenberg believed, exclusively animal. By good right we admit it in vegetables also. But is the organic process by which it is accomplished the same in the two kingdoms? If the character, in its generality, cannot serve for the distinction, it only follows that there is a necessity for further researches in order to discover the peculiarities.

The *Closteria*, and Desmidieæ, in general are plants, and not animals. In the actual state of science, we are compelled to admit this proposition. The organic structure, the physiological phenomena, the history of their development, the chemical materials they contain, manifest, in these beings, a perfect correspondence with others, which, in every point of view, correspond with the abstract idea of a plant. But what they present in common with other beings, evidently animal, is merely an appearance, or, at the most, a resemblance, in external form. Ehrenberg was misled by this appearance, and guided by this fallacious similitude, thought that he discovered in the Desmidieæ, the same organic peculiarities which proved the animality of other beings. Ought he to have reasoned thus? However, the most accurate observer, and the man of genius, is liable to error. Nor by this can his merit ever be impaired, or the benefits he has conferred on science be diminished. The loss will accrue only to those who, disdaining the fatigue of observation, content themselves with the authority of a master, and accept indifferently his real discoveries and his errors. Heaven be praised, the day of authority has passed away, and he who bends to the yoke, may wander in peace, but science will not proceed the less, and may even derive advantage from these errors. From the study of the Desmidieæ, and comparing them with animals, valuable knowledge on the intimate structure of vegetables has been derived.

The very beautiful observations of Flotow, upon what he terms *Hæmatococcus pluvialis,* seem to prove its animal nature. Nor does the appearance of some Algæ (determined by Kützing from the figures as *Ulothrix tenerrima*, *U. tenuissima*, *Gloiodictyon viride, &c.*) in the vessel where the supposed *Hæmatococcus* had remained immersed in water for some time, after having been previously dried for fourteen months, certainly demonstrate that these represent a different stage in the existence of the same being. If such were the case, we must infer from it, that in despite of all appearances of animal nature, this *Hæmatococcus* was really nothing but the germs of some Algæ, and therefore vegetable.*

We are led precisely to this conclusion by the still more accurate and valuable observations of Kützing, on the metamorphoses of *Microglena monadina* into *Ulothrix zonata*, and of *Chlamidomonas Pulvisculus* into *Stygeoclonium stellare*. Some may raise a doubt whether the globules, from which the filaments of *Stygeoclonium* are developed, were precisely the same as those that moved at first, and were furnished with a red spot and a ciliary appendage; and again, whether they were previously mixed together, and confounded with the others, owing to their resemblance in external aspect, or only made their appearance (*comparsi*) subsequently. But

* See the following paper in this volume. Also on *Chlamidococcus* and *Chlamidomonas* in 'Braun on Rejuvenescence.'—Ed.

still, admitting that we are treating absolutely of the being that is regarded as an animal by the author, and denominated *Chlamidomonas*, and that the *Stygeoclonium* actually derives its origin from it, the conclusions from this fact may be reduced to the following; that the germs of *Stygeoclonium* possess motions similar to animals; that they are provided with a red spot similar to the eyes of Infusoria; that they even sometimes possess a terminal cilia; sometimes a transparent space or an aperture by which they fix themselves, to vegetate; and the supposed *Chlamidomonas Pulvisculus* is nothing more than the germ of *Stygeoclonium*. As to the other organisms, as well animal as vegetable (*Tetraspora, Palmella botryoides, Protococcus, Gyges, Pandorina, Monas, Gloeocapsa, &c*) which seem to have an origin similar to that of *Chlamidomonas*, Kützing merely intimates their similarity of form.

Our author rightly distinguishes the two methods pursued in the study of organic beings; to consider them either with Linnæus, completely developed, or with Goethe, in their successive development. The definitions of the former are derived from an empirical synthesis; I do not allow that such can only be arbitrary, because no empirical idea can be defined; for it appears to me that we can know nothing more than we learn by our senses, and therefore I rather believe all those definitions to be arbitrary which are not logically empirical. The history of the successive development of a being, approaches more nearly to the true idea that we ought to form of it, not because that idea is absolute, for there can be nothing in nature absolute to us who form part of nature herself, but because the notion or conception of a thing is so much the less incomplete, the more numerous the points of view are from which we consider it. And thus, in examining the successive stages of development, we always fall into arbitrary error, for time has no interruption, and in this respect there is an imperfection inherent in our nature; for we want a measure for the fraction into which time, as well as space, is naturally divided.

It is true that, in the study of nature, we ought to proceed independently and abstractedly of any preconceived idea, attending to phenomena only; but still it is necessary to select these phenomena one from another, to compare them, to separate those they possess in common, and those in which they differ, thus gradually ascending to synthesis. Every metaphysical idea, assumed *à priori* as the basis of a doctrine, is of necessity arbitrary. But synthesis, logically executed and preceded by the analysis of individual facts, leads us securely to the attainment of knowledge. There may be error in the observation, or in the deduction, but never in the method.

When Kützing, combating the principle of the existence of a precise limit between the animal and the plant, concludes that there exists no such limit, he only substitutes one metaphysical principle for another, and therefore wanders from the maxims laid down by himself just before.

When he demonstrates that movements, and the organs by which these are performed, are not exclusively those of animals, and that there may be an appearance of an eye, a stomach, and a mouth, in vegetables, he controverts his own theory of a double nature, animal and vegetable, in the same being.

The observed facts are valuable. They prove the insufficiency of the characteristics given by authors to distinguish animals from plants. And, even if it should remain impossible for our most remote posterity to decide, whether given beings can, or ought to be included in the abstract idea of a plant, or in that of animal, this will not suffice to confound the two ideas, because their empirical nature is relative, indeed, but not arbitrary.

Perhaps the most important observation of Kützing, on this subject, is that of the different vital phenomena presented by the most simple vegetables, according to the prevalence in them of the external gelatinous (cellulose) membrane, or of that internal one which he terms amylaceous, and which is the primordial utricle (of azotised quaternary substance) of Mohl. In this second case, there are movements, and ciliæ by which they are effected. The sporidia of the lower Algæ, the spores of the *Vaucheriæ,* the spirilla of antheridia, the filaments of Oscillarieæ, are either destitute of a gelatinous sheath, or it is softened and almost dissolved. The air promotes the development of the gelatinous substance, light and heat that of the amylaceous.

Inseparable from the preceding question is that of speciological and generic limitations. It is a demonstrated and very important fact, that many organisms described as species and genera of the inferior Algæ, are merely transitory forms of more complicated beings. The consequence to be logically deduced, is the exclusion of these supposed species and genera from the catalogue of beings. He who desires to continue the enumeration of them as such, ought, to be consistent with himself, to establish species and genera even of the transitory forms of all other beings in nature, unless he maintain that the transitory forms of inferior organisms differ in this respect from those of the superior, inasmuch as they can persist as such, live, and multiply. I believe that this position cannot be impugned even as respects the most elevated organisms, since Teratology furnishes a sufficient number of examples to prove the possible permanence of every transitory form; and in the inferior organisms, multiplication is confounded with simple increase. It would remain to be decided whether we could always clearly distinguish reproduction from multiplication, and if so, whether we possess positive data to determine the attainable point of organic perfection of which every being is capable. But, since we are oftentimes destitute of this secure criterion, we ought to obtain data by observation, and to consider that development to be the highest which is the highest we are able to observe. Nor can any one assert that if development be arrested at some intermediate form, this has not occurred from the want of favorable circumstances, and ought not to be considered transitory. As Monstrosities are classified, to facilitate study, or lead to the attainment of general notions (*concetti*), so I allow that the transitory forms of the inferior organisms should be classified, compared and, if you please, named systematically; but that they ought to figure in the same rank with forms permanently attained, and truly specific, I can never logically allow.

Page 7.—Some regard the epidermis as a product of secretion, and therefore destitute of organisation and life. Recent inquiries as to secretions, prove that they are accomplished by a process exactly similar to that of nutrition and growth. The question is now reduced to decide whether the product of epidermal secretion ceases to live whilst it still forms part of the animal structure, and when this change takes place. I am glad it is in my power here to introduce a note I have received from the learned Moses Benvenisto.

"The epidermis, as well as the more complicated parts, which derive their formation from it, and possess characters and functions in common with it, is certainly organised. But this organisation is of an inferior grade to that of many other tissues, because it is simply cellular and not vascular or fibrous. It is similar to the products of secretion which abound in nucleate cellules, not elongated into fibres, nor developed in canals; but with the difference, derived in part from the contact of air, in part from the action of absorbent vessels, that this external secretion possesses no elementary liquid to maintain the cells disaggregated, floating, and inflated; hence result only cells that are closely united, compressed, and disposed in numerous superimposed layers. But I hold a middle course between those who say that the epidermic substance is inorganic and dead, and those who will have it to be existing *per se*, and living by a life of its own. In my opinion it has an organisation, and therefore a life, but of a low degree, and is also the product of secretion from another more noble and complex element of the body over which it is extended. What is this generating element? This is a necessary inquiry, and not less important than interesting to the physiologist and medical practitioner. This element certainly forms part of the tegumentary membrane, in which the epidermis constitutes the ultimate layer and most superficial covering. I do not believe that it can be the follicles or crypta, because these minute organs afford mucus, oil, or cerumen, a liquid adapted to lubricate, but not to organise, capable of accumulation, but not of concretion; for when once covered with epidermis, we cannot conceive how their apertures can still secrete oil (*sego*) or any other liquid whatever; so that if the cutis be considered as the same with the mucous follicles, the epidermis is thin where these are abundant, and, again, it presents the greatest thickness where these are rare, or absent, as in the palm of the hand, or the sole of the foot; finally, because very often in morbid thickening of the epidermis, we do not find the follicles varying from their natural condition. But I believe that the organs producing the epidermis, at least in most places, and in most instances, are the papillæ which possess so many vessels of every kind, that we cannot suppose them wanting in the function of secretion. And indeed we observe that wherever the papillæ are most numerous, most developed, and most vascular, there the epidermis is the most manifest. It is thickest on the palms of the hands and the soles of the feet, where, to serve the office of touch, the papillæ are most numerous, and are organised and arranged in a particular manner. It is thickest on the tongue, where the sense of taste requires an abundance and prominence, of the papillary organs. And speaking of mucous membranes, wherever they exist there also exist sensitive papillæ, animated by nerves of sense, that is in the vicinity of the natural orifices of the body. According to the most recent teachers of pathological anatomy, and especially Professor Rokitansky, hypertrophy of the papillæ is detected beneath the condensed epidermis, in inveterate ichthyosis, and in common warts. All accumulations of epidermis which assume the form of scales, spring from papillæ developed in the form of cylinders, villi, and rami. According to Cruveilhier, accidental horn is a morbid product of papillæ of the skin, crowded together, and twisted into a papillary substance. But with regard to hairs growing physiologically and pathologically, as well as to horn, which seems always to be formed by an agglutination of the skin, we must remember that, as they are composed of two different elements, one an external envelope of epidermic nature, and the other, an oily medulla, varying in colour, so both the papillæ and the follicles concur in their formation. Both the one and the other are altered in different ways, precisely according to their accidental, or pathological production."

As to the organisation of bone, there still remains a doubt with respect to the presence of saline particles mineralogically deposited in the parietes of the bone-corpuscles; yet it is proved, that in the numerous concentric laminæ that constitute the walls of bone canals, in the radiating tubes that traverse them, and in the bone-corpuscles themselves, the calcareons substance is in the same condition as the proteine, with which it is found intimately united.

Recent observations have proved, what might reasonably be supposed, as to the shells of Mollusea, that they have a decidedly cellular structure, the lime, together with proteine, constituting the walls of the cells.

We know that the same is true of the silex in the epidermis of Gramineæ and Equisetaceæ, and of the lime in Corallines and other marine Algæ.

Page 8.—" A cosmical history of the universe, resting upon facts as its basis, has, from the nature and limitations of its sphere, necessarily no connection with the obscure domain embraced by a history of organisms, if we understand the word history in its broadest sense. It must, however, be remembered, that the inorganic crust of the earth contains within it the same elements that enter into the structure of animal and vegetable organs. A physical cosmography would, therefore, be incomplete if it were to omit a consideration of those forms, and of the substances which enter into solid and fluid combinations in organic tissues, under conditions which, from our ignorance of their actual nature, we designate by the vague term of *vital forces*, and group into various systems in accordance with more or less perfectly conceived analogies. The natural tendency of the human mind, involuntarily prompts us to follow the physical phenomena of the earth through all their varied series until we reach the final stage of the morphological evolution of vegetable forms, and the self-determining power of motion in animal organisms." (Humboldt Cosmos, vol. 1, p. 348. Otte's translation.)

Page 9.—Nägeli appears to me to have treated more profoundly than any other modern author on the limits of the two organic kingdoms, (*Ueber die gegenwärtige Aufgabe der Naturgeschichte, inbesondere ,der Botanik. II, Th. Zeitschr. für wissenschaftliche*, Botanik. II Heft., 1845.) But yet objection may be made as to the differential character established by him, of a cellular membrane, ternary in the vegetable, quaternary in the animal: the primordial utricle of the permanent vegetable cell in the Algæ (*amylid-cell* of Kützing), which, like the nucleus to which it is always connected, consists of a quaternary azotised substance, is sometimes, perhaps, not even accompanied by a ternary membrane (*gelin-cell* of Kützing); the cellulose itself becomes permeated by nitrogenated matter (Payen, Kützing); and finally, an abundant ternary substance, isomeric with starch, is present in the organisation of animal beings, (Schmidt, Loewig, Kölliker.) The suggestion of Nägeli that the chief cause of animal sensibility and mobility, resides in that characteristic (quaternary, azotised) quality of the cell-wall, seems confirmed by the valuable observations of Kützing, already referred to, respecting the mobility of the inferior Algæ, of sporidia, of spores, and spirilla. But even if we admit this idea, we can deduce no other than the following principle from the facts hitherto known. The primordial vegetable cells (internal or naked primordial utricle), have, like animal cells, the wall constituted of a quaternary azotised substance, and possess a mobility similar to animal mobility. Yet there remain material differences in the contents. But, if this were not so, if observation failed to detect a material difference between the rudiments (*primordia*) of the two kingdoms, no one, from that circumstance, would have a right to maintain that the difference does not exist. When we compare together the rudiments of plants, or those of animals, do we find material differences corresponding to the almost infinite varieties of form and organisation which ensue with successive development? It is necessary to repeat, that our senses are limited, and that if we desire to pass beyond those boundaries by powers of reasoning, we may do this by no other means than reliance upon other facts exactly observed. Taking advantage of instances in which the power of our senses is improved, we reason upon others where that power is more limited. Thus, in respect to the rudiments of organic beings, the observation of their successive development proves that even when those rudiments do not manifest material differences to our senses, these still exist.

Still we ought, in every way, to be extremely cautious in deducing anything from these observations which may seem to prove the animal nature of vegetable germs, even when they are made with great accuracy; inasmuch as we can controvert them by others equally exact of a contradictory nature. Such are those made by Nägeli upon his *Conferva glomerata*, var. *marina*, and upon the *Achlya prolifera*. In the former, especially, he could trace the entophytic development of the *Bodo viridis*, which, at a certain period, almost exactly resembles sporidia, but does not at all participate in the successive changes that these undergo in germination.

Page 10.—Nägeli has digested in an able manner all the facts relating to vegetable movements. The first series of movements is intimately connected with growth, and in regard to this we do not possess sufficient data to establish a general difference between the two organic kingdoms. The second is referable to the different positions assumed by various organs of plants under the influence of external agents; and those movements are explained by an accumulation of juices in determinate tissues, excited by these agents, or by the elasticity of the cellular membrane. The movements of individual parts of certain organs are mechanically produced by the desiccation or intumescence of various tissues. But still the question remains almost untouched in respect to the locomotion of the inferior Algæ, sporidia, spores, and spirilla. The impulse communicated by endosmosis and exosmosis, has certainly a large share in the phenomena; but, after all, there remains the fact of vibratile ciliæ, which seem to take part in these movements.

Page 12.—The *Protococcus* and *Gregarina* are beings that present the greatest degree of simplicity in their permanent state. Though, down to 1842, I had limited the genus *Protococcus* to those vegetable beings only which really present the greatest possible simplicity, other authors, and Kützing in particular, continue to insert species of more complicated organisation; hence some confusion is created whenever we refer to this example of organic simplicity.

I admit into the genus *Protococcus* only those vegetables which, according to our means of observation, are reduced to a simple cell. When the period of reproduction arrives, the wall of this cell is either reabsorbed, or is lacerated, and its contents are poured out; the rudiments of new individuals make their appearance, which are never visible in the cavity of the maternal cell. The development of new individuals occurs, on the other hand, inside the maternal cell of *Chlorococcus* and *Hæmatococcus*.

The genus *Gregarina* was proposed by Dufour, and very well described by Siebold. Kölliker examined six species (*Die Lehre von der thierischen Zelle. Zeitschr. für wissenschaft. Botan.* II Heft, p. 40.) They are simple cells, containing very minute granules (*granelli*), small drops of oil, and a central vesicle filled with a transparent liquid, with a few oily drops, and a dark round nucleus. They move by the expansion and contraction of the cellular wall. Their reproduction is effected by an endogenous cell-formation. The contents separate into two globular portions, which accumulate around two nuclear vesicles newly produced; the membranes form round the two globules, and thus arise two filial cells, which, after the redissolution of the maternal cell, separate from each other and begin to enjoy their individual life. The same author supposes that some species of *Bodo*, *Monas*, *Spirillum*, *Vibrio*, &c., equally belong to this new family of *Unicellular Infusoria*, but we have no direct observations to prove this.

Page 13.—Collecting together all that has hitherto been observed as to the first origin of cells, the supposition we are able to form is the following. The first elements we are able to perceive are the so-called elementary granules (*granelli*) in animals, and the mucous granules in plants. These are very minute solid corpuscules, of a quaternary azotised substance, capable of growth, but not of multiplication, nor of ulterior development. In the midst of these appear the nucleoli in plants. Around every nucleolus, mucous granules collect together, forming a species of crust. The body resulting from this is a nucleus or cytoblast. Around this appears a membrane of a quaternary azotised substance, which is the so-called primordial utricle. Upon the external surface of this, a membrane of ternary composition, not azotised, is organised; this is the true cell-wall, which alone remains after the primordial utricle and the nucleus have disappeared. Whatever may be the mode in which the new cells appear, we may assert, on good foundation, that the previous formation of a nucleus is constantly followed by the primordial utricle, and in consequence by the cellular wall. The uncertainty and variety are referable to the first formation of the nucleus, to the contents which remain confined, or are successively formed between the nucleus and the primordial utricle, and to the mechanism forming the cell wall. It is not yet decided whether this origin of the cells is exclusively endogenous, or may not even be exogenous. Recent inquiries as to the nature of yeast, (*Hygrocrocis*, *Leptomitus*, &c.,) seem to prove that nuclei alone, or, perhaps nucleoli, may separately give origin to cells. In such a case the mucous granules would be foreign to the new plant, and would contribute immediately to its formation; the nucleoli would be its germs. Every one sees the difficulties that are to be encountered in this research, the cautions that are to be used in drawing conclusions from every fact observed, and the necessity of advancing always from the known to the unknown. Hence, in denominating the organic elements which are before our eyes, we are not to commence with what appears the most simple, but rather with that which is decidedly organised and clearly characterised.

In animals, besides the solid elementary granules already referred to, there are small vesicles incapable of ulterior growth and reproduction. They are simple drops of oil enveloped in a stratum of coagulated albumen, and may be imitated artificially. Other vesicles are capable of growth, but not of multiplication. They contain liquid albumen, and one or more oily drops, as, for example, the vitelline vesicles. Perhaps they are analogous to globules of chlorophyll in plants, or those of starch.

The nucleoli are vesicles similar to the preceding; they consist of a contained fatty substance, and an envelope of proteine. They are susceptible of growth and multiplication, which takes place by division. Their original formation is as yet unknown. The nuclei are vesicles formed of albumen or fibrine, or perhaps of caseine, containing, besides the nucleolus, an albuminous liquid, oily drops, and elementary granules. The formation of nuclei is entirely obscure; but it seems proved that it cannot take place without the persistence of the nucleoli. The nuclei are multiplied endogenously, and in consequence of the multiplication of the nucleoli. The contents of the nucleus collect round the nucleoli originating from the division of the primitive nucleolus, constitute their partial integument, and set them free by the reabsorption of the maternal vesicles. The nuclei are not only capable of uniform growth, and of multiplication, but also undergo numerous modifications, especially conversion into fibre. The cells have walls soluble in acetic acid, and are, therefore, composed of a combination of proteine, either simple, or penetrated with horn, gelatine, chondrine, calcareous salts, &c.; and they contain, besides the nucleus, water, albumen, fat, extractive matter, salts, and other compounds peculiar to the various organs.

Whether the formation of the animal cell be endogenous or exogenous, it requires the pre-existence of the nucleus, upon which the membrane begins to appear, which by degrees separates and dilates, surrounding it, and holding it adherent to a point within its wall.

More rarely, the formation of a cell takes place within a collection of granules having a nucleus in its centre. The gelatinous substance which superficially surrounds or unites and amalgamates the granules, becomes coagulated, so to speak, and is consolidated into a cellular membrane.

These particulars are mostly taken from the work of Kölliker, in which there may be found a critical analysis of the physical and chemical theories proposed by authors to explain the facts adduced.

Page 16.—Nägeli gives an ingenious explanation why the multiplication of cells is always endogenous in plants, and exogenous in animals. He supposes that the quaternary azotised substance acts catalytically on the circumjacent materials to produce organisation. In animals, therefore, the cellular wall acts upon the extra-cellular materials; whilst in vegetables, the ternary gelatinous envelope being once formed, the catalytical action of the nitrogenous portion is limited to the interior of the cell itself. We are indebted to Mohl for the discovery of cells that remain permanently limited to this membrane alone, (so called amylid-cell,) and thus we find an explanation consistent with this theory, and also with the facts recently observed in the development of yeast.

Though it be true that systematic distinctions are always baffled by nature when they are based upon the materiality of characters taken absolutely, it is yet true that general laws admit of no exception, and that a single one would suffice to destroy their generality. The appearance of exceptions proceeds from the complication in which natural facts occur, a complication that frequently disappears, when, instead of characters taken absolutely, we obtain a view of the organic and vital conditions which give rise to them.

Page 20.—The Tabasheer of the Bamboo, which consists almost entirely of pure silex, seems to be a product of simple excretion, and therefore in its nature inorganic. But in all other cases in which the presence of silex is manifest in plants, as in the epidermis of Gramineæ, Palms, and *Equiseta*, the part which it takes in the formation of the cell-wall is undeniable.

The stomatic cells of *Equiseta* merit particular attention, both from the silex they contain, and the transverse striæ they present on the internal surface. This resemblance to the shield of Diatomeæ might lead us to believe that we ought to regard it as an argument for maintaining the vegetability of the latter. I do not think that I ought to dwell upon such an objection; I only notice it because I would not appear to be, or pretend to be, unacquainted with it. Yet it seems to me important in another point of view, the apparent complication that the simple cell-wall may assume when penetrated by silex.

Page 22.—In the description of Diatomeæ it often happens that the valves are confounded with the surfaces. The surfaces are remarkably distinguished by established characters into primary and secondary. In descriptions, it appears to me right to admit; for the sake of brevity, the denomination *surface* (*faccia*) for the primary, and *side* (*lato*) for the secondary. But the valves do not exactly correspond to the surfaces. The lateral valves are never absent; they sometimes exist solely, as in *Pyxidicula* and *Podosira*. In many cases, principally in Achnantheæ and Melosireæ, the lateral valves are so bent or curved as to form parts of the primary surfaces.

But the valves, which exactly correspond with the primary surfaces, are seldom distinct; and perhaps even where there is an acute angle for a boundary, as in *Navicula*, we cannot say that there is a complete disjunction. In most cases, the two primary surfaces, and therefore the corresponding valves, unite into a continuous plane, with a re-entering curve. The distinction of terminal surfaces, very evident, especially in the Surirelleæ, is most important. When there are distinct terminal surfaces, the primary surfaces are very limited. But these terminal surfaces may belong to the primary valves, or the secondary, or lateral. If we take the Eunotieæ, it seems evident that the more or less acute or obtuse extremities belong to the lateral valves, and therefore the two primary remain entirely separated. But in the Surirelleæ, these seem again to belong to the primaries, and to participate with them in the process of deduplication.

Page 23.—The solid products which, under the form of incomplete diaphragms, project into the inner cavities of *Biddulphia* and *Terpsinöe*, belong to the lateral valves. I can say nothing of *Climacosphænia*, but in the *Isthmia nervosa* we have something similar, though less developed. I think we may also refer the septa of *Actinoptychus* to the same. Perhaps *Terpsinöe* may be placed by the side of *Biddulphia* in the Family of Melosireæ, by the same character. Their principal difference from Vittæ, is in their transverse as well as longitudinal direction. The Vittæ belong to the primary valves as well as to the surfaces. These peculiarities of structure are certainly very important, because we must reasonably suppose that they bear a direct relation to the internal organisation of these beings.

But if we consider that in the same genus (*Isthmia*), we have two species very similar to each other, one of which always presents those incomplete diaphragms, whilst the other is always devoid of them, we are of necessity led to exclude this character from the basis of classification.

Page 25.—The colourless membrane, which connects all the internal organs of Diatomeæ together, constitutes the principal portion of their body, as Ehrenberg has well observed in many places. Its transparency impedes our view of its organisation. It seems that the vesicles observed by Ehrenberg in some species, and supposed to belong to the male organs, were directly hollowed out of this substance. Their dilatation and contraction seem rather to indicate a respiratory function. I believe the tube that runs longitudinally from one extremity of the Naviculæ to the other, and perhaps represents their organ of digestion, to be hollowed out, in like manner, from this substance, and void of a proper membrane.

Page 90.—In the *Ceratoneis Fasciola*, Ehrenberg describes and figures a distinct median aperture in the centre of the lateral surfaces.

Page 106.—Kützing, in the *Phycologia Germanica*, assigns to the Naviculæ of *Micromega pallidum*, instead of $\frac{1}{32}$d of a line, $\frac{1}{80}$th = 0·034‴.

ON THE

NATURAL HISTORY

OF

PROTOCOCCUS PLUVIALIS.

By FERDINAND COHN.

[Abstracted from the 'Nova Acta Acad. Cæs. Leop. Carolin. Naturæ, Curios. Bonn,' tom. xxii, pp. 605—764, 1850.]

By GEORGE BUSK, F.R.S.

ON THE

NATURAL HISTORY

OF

PROTOCOCCUS PLUVIALIS, Kutz.

Hæmatococcus pluvialis, Flotow.
Chlamidococcus versatilis, A. Braun.
Chlamidococcus pluvialis, Flotow and A. Braun.

The author commences his paper by referring to the observations of Flotow, on the same subject, under the name of *Hæmatococcus pluvialis,* ('Nova Acta Ac. C. L. C. N. C.,' vol. xx, p. 11,) and to which he assigns the highest merit. He proceeds to give an abstract of Flotow's observations as an introduction to his own.

However various the metamorphoses undergone by the *Hæmatococcus* in the course of its development, they may, nevertheless, be referred to two principal forms,—the *still* and the *motile.* The former, *H. pluvialis quiescens,* forms a sort of crust on the margin and bottom of the vessel in which it is kept; the other, *H. pluvialis,* swims about in the water.

The motile form is from 0·0003 to 0·0012 of a Paris inch in diameter, and consists of a colourless mucous envelope, probably open in front, within which is contained the true mother-cell, and which is either centric or excentric. The contents of the latter are grumous and vesicular, and either altogether of a carmine red colour, or of one inclining to blood red or green, with a central, multiform, red nucleus; seldom altogether green. The mucous envelope is frequently wanting, or is so closely applied to the cell as to be scarcely apparent. The red nucleus appears to have a special coat, which, however, probably does not exist; it appears as a hollow vesicle, placed on or near to the inner surface of the wall, and presents on one side an opening, or, only half or two thirds of it may exist. The nucleus is detached by pressure, and in the spot where it was situated appears a colourless vacuity. The anterior extremity of the mother-cell exhibits either none, or cobweb-like processes, which are but seldom apparent, particularly in the globular or ellipsoidal forms which represent *H. pluv. rotundatus*. Or there exists, at the anterior extremity, a wart-like transparent process, from which arise simple or bifurcate, filamentous elongations or tentacles, as in the form *H. pluv. papillatus*. When this process is conical and attenuated we have *H. pluv. rostellatus*. Not unfrequently short setose hairs spring from the periphery of the mother-cell, stretching across the space between this and the mucous envelope, and which characterise *H. pluv. setiger*.

These motile forms, which may be comprehended under the common name of *H. pluv. versatilis*, are transformed into the still form, becoming round, and retracting the various processes above noticed; whilst the mucous envelope is condensed into a papyracous membrane.

This still *Hæmatococcus pluvialis, quiescens, aquaticus, genuinus*, from 0·0001 to 0·0029 Paris inch in diameter, forms loose masses without its being retained, however, by any special mucous hypothallus. It sometimes has, and sometimes has not a mucous envelope; the mother-cell is either entirely filled by the sometimes grumose-granular, sometimes grumose, or even gelatinous contents, so that the boundary line is reduced to capillary thickness or is completely obliterated; or it is only partially filled, and the contents then form a smaller and, most usually, central globular mass, which is probably contained in a second cell. This was evident, however, in only one case.

As more intimate constituents of the contents, both in the still and in the motile form, numerous more minute spherules are to be considered. The *red* formative material is to be referred to the sphere of fructification, the green to that of vegetation. Consequently the green spherules in *Hæmatococcus* must be regarded as *germ granules*, or *gonidia*, which, when larger and internally organised by a cell nucleus, become green gemmules. When these gemmules, in the form just described, escape from the mother-cell, they resemble the innumerable dependent forms commonly associated under *Protococcus Monas;* they exhibit an instance of retrograde metamorphosis, producing a succession of similar organisms, which, shooting out in succession in a longitudinal direction, constitute confervoid filamentous forms, or, sprouting out, expand into Ulva-like growths. Amongst the latter, one is very remarkable, foliaceous, of a quadrangular figure, consisting of many cells, which, like a simple *Hæmatococcus* cell, is carmine red in the centre and green towards the margin.

The green gemmules, however, are capable of progressive development, destined to reproduce the *Hæmatococcus* at once, when, for instance, the individual to which they belong possesses sufficient red formative mucus for its penetration and fructification. This is apparent from the circumstance that the two-coloured, still forms which are entirely filled with red and green gemmules, in process of time become altogether red. And in this case the red coloration gradually extends from the central nucleus, as its original seat, towards the periphery, whilst in the retrograde metamorphosis the red coloration of the globules proceeds from without to within.

In whatever way the spores formed of this red substance escape, they develop themselves, and at an unfavorable time of year and dormant condition of vitality, float, in flocculent aggregations, on the surface of the water. They then increase in size, become organised internally, and surrounded with a membrane derived from a thickening of the peripheric layer of the spores. They are thus transformed into *H. pluv. atomarius*, which, in the course of further development, becomes of a rose-red colour and gelatinous, surrounded with a mucous envelope, and constitutes the form of *H. pluv. mucosus;* which is finally transformed again into the normal form. The dispersion, therefore, of the red spores is not a proceeding without object, or a morbid process, but subservient, in an incredible degree, to the multiplication of the plant.

In a favorable season, and when the vegetative powers are in full activity, the spores, after their expulsion, remain adherent to each other, connected by a mucous material, afterwards becoming free, and successively transformed into the motile form of *Hæmatococcus*.

Another motile form is of a smaller size, distinguished by its active motion, and characterised as *H. pluv. porphyrocephalus*. It has a flask-like or obovate form, 0·0002—0·0004 Paris inch in length, with a red capitate projection at the anterior extremity, and ventricose posteriorly.

In general, from the motile condition all these forms pass immediately into the still form. But the alternation between the still and motile forms depends altogether upon external conditions, and is by no means capricious. Whether the still form, upon its division, develop motile individuals, depends upon the light and temperature.

Multiplication by division (*status viviparus*) occurs both in the still and in the motile forms. The contents of the mother-cell, surrounded by a mucous envelope, divide into four (frequently more) portions, each of which includes a central particle of red matter, and surrounds itself with a gelatinous membrane.

The division frequently commences in the motile condition, and continues in the still. The younger individuals, with red mucous globules, spores, buds, and green gonidia, and consequently furnished with all the requisites for existence, burst the mother-cell, and become free. Should they belong to the second generation, and consequently arise from the division of already motile cells, the young individuals frequently remain in connexion, and revolve together until at last they become detached from each other. From this circumstance arise aggregations of 4, 5, 6 minute globules; even 8 individuals occur together in a mucous envelope. Some cells divide even into 12 or more, and revolve in common like a *Volvox*.

Other forms of division are noticed. Besides this mode, multiplication by gemmation takes place, both in the still and motile forms (*innovatio*). Within the mucous envelope there is formed a parietal, colourless vesicle, into which the red atoms pass from the mother-cell, and thus gradually colour the young individual.

The author proceeds to describe the effects of desiccation, &c., upon the appearance and colour of the varieties of *Hæmatococcus*, and notices the extraordinary power of vitality after desiccation for many months, when the *Hæmatococcus* has been slowly dried; and even after quick drying, it would seem that development is possible by means of spores and gemmules from the form named *H. atomarius*. And even in some cases after such individuals had been swallowed and evacuated by Infusoria, for instance, by *Philodina roseola*. Even momentary exposure to a boiling temperature does not destroy their vitality altogether, though it does so partially.

A summer temperature, however, very much promotes the development of the *Hæmatococcus*, so much so, in fact, that occasionally all the stages are gone through within eight days. Commonly, the motile forms retain that condition only for a few days or hours. When some in the motile form are placed in a glass of water, within twenty-four hours a red border appears at the margin of the water as it evaporates, consisting of still vesicles undergoing division, whilst beneath it is a broader, greener, reddish band containing the motile individuals. The motions of the various forms of *Hæmatococcus* are then described, (p. 623,) and, from the description, appear to be very like those of *Euglena viridis*. In fact so much so that Flotow himself compares them with those of *Astasia pluvialis*, deeming, however, that species, which is either identical with, or closely allied to *Euglena*, as an animal Infusorium. He goes on to say, however, "that there is no appearance, in the *Hæmatococcus*, of animal organisation, particularly of a mouth, intestine, or stomach; nor is the admission of indigo into the interior ever observed."

Flotow considers that the source of the motion of the globules of *Hæmatococcus* is quite problematical.

Having thus premised an abstract of the more important points in Flotow's researches, from which the above are extracts, the author proceeds to detail his own observations, which he says are to be considered only as supplementary, in a great measure, to those of Flotow, which he regards as of the highest value.

On the 2d January, 1850, some particles of sand containing *Protococcus pluvialis* which had been collected by A. Braun, were placed in a deep glass vessel and covered with snow-water. The first moving forms were noticed on the 8th of January. The *Protococcus* had been in a dry state in the herbarium for two years. Other experiments showed that this retention of vitality endured through many years.

In his experiments the author found great convenience in the employment of little glass vessels in the form of a truncated cone, about two inches deep and one inch and a quarter in diameter, with a flat bottom polished on both sides. These little vessels were filled with water to the height of two to three lines. It was only in vessels of this kind that he was able to follow the development of a number of various cells throughout its whole course. Although he agrees in the main with the views expressed by Flotow, the author differs from him, at the commencement, in one important particular. Flotow looked upon *Protococcus pluvialis* as a multicellular plant, the individual cells of which are held together by a common parent vesicle. Although he does not express himself particularly with respect to the kind and mode of this connexion, it may be taken that he regarded it something like that which obtains in *Nostoc*, or rather, perhaps, like the structure of *Polycoccus punctiformis*, Kutz., in which numerous cells are said to be surrounded by a thin, common cell-membrane. (Kütz., 'Phycol. Germ.,' p. 148.)

This view, however, is undoubtedly erroneous. The *P. pluvialis* is in all its phases a *unicellular plant.*

The idea of a unicellular plant, as first propounded by Nägeli, as a systematic principle ('Gattung. einzelliger. Algen.' Zurich, 1849,) does not apply throughout to the extent in which he employs it. He certainly includes under the term a number of genera, having a certain degree of internal relationship, as indicated by the fact that previous phycologists had united them in large natural orders, (*Chamæphyceæ*, Kg.; *Ulvaceæ*, Harvey; *Palmelleæ*, Decaisne, Endlicher, &c.) On the other hand, the definition of a unicellular Alga, "that in it the individual is a single cell," is too wide or too narrow, (l. c., p. 1.) Too wide, because this definition may be applied with equal right to other Algæ, which must be reckoned among the multicellular, such as *Œdogonium*, which is a Conferva, or *Prasiola*, one of the Ulvaceæ, as *Desmidium* and *Gallionella*, or as *Tetraspora*, all of which are declared to be unicellular Algæ. Too narrow, because it is only by straining the definition that such things as *Pediastrum*, *Sphærastrum*, which form definitely bounded bodies, and many *Palmelleæ*, can be included under it. Just as little do the characters assigned to a unicellular plant bear a comparative scrutiny. The unicellular Algæ are said—1. to present merely a reproductive, and, normally, only a double kind of cell-formation; this is, however, contradictory to the doctrine of Alternation of Generations, which is extensively applicable among the organisms in question. For it is only after a series of divisions that the true reproductive formation of spores takes place. And *Closterium*, or *Eunotia*, which, after numerous divisions, produce true spores by conjugation, differ from *Spirogyra* and *Ulothrix* solely in this, that in the latter the parent-cell, which connects each pair of divisional individuals, being converted into a cuticular substance, is persistent, whilst in the former it is soon dissolved. Whence it is also incorrect to say—2. that unicellular Algæ are normally separate and without organic connection, because the containing and interstitial gelatinous substance should not be regarded as such. At all events I have been unable to perceive any essential distinction between the enveloping substance in *Fragillaria* and *Mougeotia*, genera which are equally readily separable into distinct cells, and in *Nostoc* and *Apiocystis*.

As far as this, therefore, I agree with the reviewer of Nägeli's observations, (in Mohl and Schlechtendal's 'Botan. Zeit.,' 1849, Nos. 41-45,) but when he goes on to assert "that there are no such things at all as unicellular Algæ, and that each cell is only part of a system of cells contained one within the other, (l. c., p. 801,) it is impossible for me to coincide with him.

There are, undoubtedly, unicellular Algæ, that is to say, Algæ, the fluid contents of which, sometimes containing already organised particles, are enclosed in a single, semifluid, nitrogenous envelope, and this again in a cell-membrane, often consisting of several layers of different kinds; and which, moreover, possess the faculty of dividing themselves into several secondary cells, for the most part equivalent to the primary cell. To *these unicellular Algæ* belongs *Protococcus pluvialis*.

That this is the case is most clearly seen in the still form, which is most distinctly characterised by its cell membrane, a more or less thick, though always colourless, envelope. In some cases it is gelatinous, and then surrounds the contents with a broad, peculiarly refractive ring, (Fig. 33.) In cases where this tunic does not exhibit a double contour line, it is manifested by the dark and sharp border surrounding the contents, and which, especially on the transition of the motile into the still form, is the first and most certain criterion of the incipient change. Thus it resembles the membrane of many Protococcaceæ and other Algæ. It never secretes true thickening layers on the surface. Although this cell-membrane exhibits all the optical characters of one composed of cellulose, I have found it impossible to demonstrate the presence of that principle by means of iodine and sulphuric acid; it is not coloured by those reagents even after the contents of the cell have been expressed. But this does not show that the membrane is not of a vegetable nature, because other Protococcaceæ behave in the same way; nor can cellulose, by those reagents, be shown to exist in *Oscillatoria*, *Nostoc*, *Merismopædia* and other unicellular Algæ.

The still cell always assumes a deep, almost black colour, upon the application of a watery solution of iodine; but this does not depend upon the coloration of the cell-membrane itself, but upon the circumstance that the nitrogenous contents, coloured by the iodine, are seen through the transparent tunic.

The contractility of the contents when exposed to the action of acids or alcohol, proves that they are endowed with the same properties as the *primordial utricle* of Mohl, the *amylid-cell* of Kützing. But there is no evidence of the existence of any special layer of the contents, which could be exclusively designated as a "primordial sac;" it would much rather appear as if the entire contents of the cell (*endochrome* of authors), in most cases, were to be regarded as essentially homogeneous, and that it is only the outermost, for the most part densest peripheral portion of them which possesses the faculties, which in other plants, particularly in the large-celled Algæ, appertain to an also optically distinct layer. (*Vide* 'Ueber die Rotation des

Zellsaftes,' in *Nitella flexilis;* by Göppert and Cohn, Botanische Zeitung, 1849, No. 37—40.)

There are, however, phases of development in which the colourless or almost aqueous cell-contents can be distinctly defined from the denser, coloured, gelatinous, peripheral substance. Whilst, therefore, in most cases, the still form, according to Kützing's terminology, would have to be regarded as *hologonimic* full-cells, in which the solid contents completely fill the cell, so, when the primordial sac and cell-juice are separated, they would necessarily come under the denomination of *cœlogonimic*, hollow cells.

The contents vary very much in consistence, colour, and solid constituents.

The red and green portions of the contents appear to be of equal physiological importance.

The green colour is removed by ether, on the evaporation of which solvent there remain green, afterwards colourless drops. Dilute sulphuric acid at first renders the colour paler; but its prolonged action produces a bright verdigris hue, which gradually becomes more and more intense, and often almost a blue green. Hydrochloric acid has a similar effect; a tinge of brown is produced by nitric acid. Carbonate of potass scarcely affects the green colour; it is gradually but totally destroyed by caustic potass, the contents at the same time swelling and becoming transparent.

The red colour is also to some extent soluble in ether, but is less affected, or scarcely at all by any of the other reagents above enumerated. It differs, therefore, from the erythrophyll or the acidified anthocyanine of chemists, as well as from the colouring matter of litmus and phycoerythrin, which, according to Kützing, is peculiar to the Florideæ. In its chemical relations it seems most nearly allied to the phycohæmatin of *Rytiphlæa tinctoria,* but the latter is insoluble in ether. It also seems to be related to the orange coloured oil, which, according to Nägeli, is formed, under morbid conditions, in many unicellular Algæ.

The contents of cells which have been long dried, generally assume an oily appearance. The oily material, then resembles in every respect the red globules which have been described as being oil, in various species of *Chroolepus*, such as *C. oleiferum*, *hercynicum*, *velutinum*, *aureum*, and *Jolithus*. Like the latter, also, it is capable of becoming green.

The change of colour from green to red in *Euglena* appears to be a process very nearly allied to that which takes place in *Protococcus*, if it be not identical with it. Great confusion and much contradiction is evident in nearly all writers who have referred to the subject of the colouring matter in plants, and accurate researches on the subject would appear to be of the greatest moment.

The red substance of *Prot. pluvialis* is not always of an oily aspect; it only becomes so in more advanced age. Whether it really be oil, the author does not venture to decide, although the relation of the material towards light, alcohol, and ether (and he might have added, water), are in favour of its being oil. And according to his researches, oil is much more generally distributed than has been supposed, among the lower Algæ; occurring in many true brown spores, such as of *Œdogonium*, *Spirogyra*, *Vaucheria*, &c.

When still or motile cells are brought in contact with a very weak watery solution of iodine, they become internally, in most parts, of an intense violet or blue colour. The author, however, does not believe that this colour actually, in all cases, depends upon starch, as in the present state of chemistry it would appear necessary to conclude that it did. He was satisfied that the red substance was invariably and entirely coloured blue. When some of the cells were ruptured, all the previously red globules had become entirely dark blue, so that the red colour was wholly removed, whilst the green substance of the cell with its granules was not so much altered, though also bluish. The larger drops also appeared blue, so that there was no difference whatever, in this respect, between their reaction and that of starch, which also frequently occurs in similar small globules. But that the red, oil-like, or at all events, fluid substance, should be actually identical with the colourless, solid starch, which always presents a definite structure, can scarcely be asserted. May there not, however, in the Vegetable kingdom, be a coloured fluid, exhibiting the same reaction with iodine, in all respects as starch? If this be the case, the infallibility of the blue reaction with iodine, as a criterion of the presence of starch, would become questionable; and, particularly in the case of the unicellular Algæ, in which large-grained starch does not occur, would this observation be of importance. Nägeli had noticed the blue colour assumed by this orange-coloured oil on the addition of iodine, especially when it was collected into large blue-green drops by means of alcohol.*

Of great importance, moreover, is the relation of the green and red colouring matters to each other. For, notwithstanding their different chemical and physical conditions, the one passes into the other, and *vice versâ.* The observations hitherto made on this subject, indicate that the red colour which normally is always formed as the cells become drier, particularly in moist air, depends upon a less saturation of the cells with moisture; is the attribute in fact of a lower hydrate of chlorophyll. But that a deficiency of water is not the sole cause of the change of colour, is proved by longer observations of the vegetation of *Protococcus.* Nor does light either appear to be the exclusive cause of this phenomenon, which remains still in considerable obscurity.

With respect to the solid constituents of the *Protococcus* cell-contents, they may be distinguished into chlorophyll vesicles, colourless or green granules, the above-mentioned amylaceous granules, and the nucleus.

* The yellow oil, of which there is a considerable quantity, in the winter spores of *Volvox*, (the so-called *V. aureus*, Ehr.,) is coloured blue-green by iodine.—Ed.

The term chlorophyll-vesicle (chlorophyll-blaschen) was first introduced into the anatomy of the Algæ by Nägeli, although Meyen had previously expressed a similar view respecting the structure of the chlorophyll. Nägeli regards them as minute membranous vesicles, containing a mucus coloured with chlorophyll, only apparently presenting the aspect of nuclei or hollow spaces, frequently forming starch in their interior, and which are found in the Palmellaceæ, Desmidieæ, Vaucheriaceæ, and multicellular Algæ. In *Prot. pluvialis*, they present the appearance of minute green rings, about 0·002‴ in diameter, the interior being sometimes darker, sometimes more clear, and frequently almost opaque. They occur principally in the green cells, to the number of one, two, three, four, or more. Rarely observed in the red cells. They are coloured dark brown or violet, by iodine. The author supposed that in *Protococcus* they stood in connexion with the division of the cell; but could not determine with certainty that their number corresponded with that of the secondary cells. Kützing looked upon them as gonidia or cell-nuclei, assigning to them the function of propagation of the individual; but Cohn does not coincide in this view, though ignorant of their true nature with respect to the life of the cell.

The sometimes colourless, sometimes green granules, are very minute, none being more than 0·001‴ in size. The colourless may be regarded as protoplasma- (mucus, schleim-) granules, the green as chlorophyll granules, which latter must not be confounded with the chlorophyll vesicles.

Whether there be a true cell-nucleus in *Protococcus*, Cohn has not ascertained with complete certainty. It is known, moreover, that in most of the other Algæ, and particularly the unicellular, it has not yet been made out satisfactorily, whether, in the first place, a nucleus does occur, and if it does, what its function may be.

The presence of starch has above been stated to be doubtful.

Microscopical analysis, therefore, demonstrates, in the still cells of *Protococcus*, whatever aspect they may present, the following elements:

1. A closed cell-membrane; 2. contractile, sometimes colourless, sometimes green, sometimes red, cell-contents: the latter in innumerable droplets, the two former frequently condensed or separated into more solid granules; 3. lastly, one or more chlorophyll vesicles, and in certain stages a cytoblast. All these elementary parts occur also in the cells of other plants, and there is, consequently, no difficulty in the referring of all such forms, when in the state of rest (the special value of which is only shown by the history of their after-development) to the simple vegetable cell.

This inquiry, however, is far more difficult in the case of the much more variously constructed motile form.

This form was considered by Flotow to consist of a larger parent vesicle, surrounding numerous smaller red and green cellules, and itself again surrounded by a mucous envelope, within which were two tentacula, often placed upon a beak-like projection.

The first thing ascertained by Cohn was the non-existence of the mucous envelope. The optical appearances distinctly showed the existence of, not an enveloping, at all events fluid mucus, but of a solid membrane.

Although this statement does not accord with the notions hitherto entertained with respect to similar appearances of an enveloping mucous layer in other Algæ—which has been regarded by Kützing as a gelatinous or mucous envelope, consisting of jelly (gelin), and termed by him a gelatinous cell (gelin-zelle) or tube, or sometimes amorphous gelatine; and which has been designated by Nägeli as an "enveloping membrane (hüll-membran), who supposes its outer layer to consist of a homogeneous, semifluid gelatinous substance,—Cohn states, that at all events, in the case of *Protococcus*, a structure so abnormal and different to what exists in all other plants, does not occur. The central coloured globule, lying in the colourless envelope, is certainly sharply defined, but not as in the still cells, surrounded with a strong double contour line, but with a delicate simple one, which gives it a peculiar soft appearance. Either by mechanical means, or by chemical reagents, the internal globular mass may suddenly be made to lose its contour, and to spread so as entirely to fill the cavity of the colourless envelope. From which it would appear that the internal globular body is not surrounded by any special cellulose-membrane, but only by one readily destroyed by chemical or physical agency, probably nothing more than a dense layer of protoplasm. Whilst, on the other hand, the external membrane represents a true cell-membrane, enclosing between itself and the coloured substance a colourless, aqueous fluid, probably pure or nearly pure water.

The motile form of *Protococcus*, therefore, consists, as it were, of two cells, one within the other, both of which, however, differ essentially from the common vegetable cell: the external having a true cell-membrane and aqueous contents; the other, or internal one, with denser, muco-gelatinous, coloured contents, but without a true, rigid (starre) cell wall. Cohn proposes to call the external transparent vesicle the "enveloping cell" (hüllzelle), and the internal coloured one, the "primordial cell." The term "primordial sac, or utricle," which nearest corresponds to this organism, can only be applied to its peripheral layer, and not to that together with the contents; and the term "amylid-cell" of Kützing involves a chemical error.

Neither of these bodies are true, perfect cells, inasmuch as the former wants the primordial utricle, and the second is without the true cell-membrane. The two together would represent the perfect cell; and the entire aspect corresponds, externally perhaps, to a plant-cell in which the primordial utricle has become detached from the cell-membrane and contracted itself into a globular mass in the interior. But in the present case the course of development is completely opposed to this view.

On the other side, again, the primordial cell corresponds to the cytoblast of the common plant-cell, not only because, like that, it is free, and for the most part excentric, floating in the interior of the cell, but also in its relation to the development of the cell-membrane, in which it agrees in its function with that assigned by the theory of Schleiden and Schwann, to the nucleus, in the formation of the cell-membrane.

The form of *Protococcus,* named by Flotow *Hæm. pluv. versatilis setiger* (fig. 15), presents a perfect analogy between the primordial cell and the nucleus of the common plant-cell. He states that the filaments which proceed from the central mass to the peripheric cell-wall, are tubular, giving passage to the red molecules from the central mass. These filaments, however, which proceed from the outer wall of the primordial cell towards the inner surface of the enveloping cell, correspond morphologically to the so termed mucous filaments (sap-streams) by which the cytoblasts are commonly retained in the centre of their cells. That they also correspond chemically with these, is proved by the fact that they are rendered more distinct by iodine, and that they can be made to retract by means of reagents; and, in fact, they exhibit, in the course of development, peculiarities which characterise them as consisting of protoplasm.

The existence of these delicate threads passing from the central mass to the enveloping cell, and the appearance occasionally of little particles having molecular motion, serve to show that the contents of the enveloping cell are not of a gelatinous consistence, but of an aqueous nature. And the continuity of the primordial cell-wall with the filaments shows that it is surrounded only with a denser layer of protoplasm, and is not enclosed in a rigid membrane of cellulose.

The form *versatilis,* therefore, of *Prot. pluvialis* is to be regarded as a cell with clear aqueous contents, in which a central, also cellular, mass of protoplasm, or a primordial-sac-like organism, performs the part of a nucleus.

The most distinctive characteristic of the primordial cell, and what appears to constitute its most essential importance in the life of the cell in general, but particularly in that of the Zoospore (schwärm-zelle), consists in its being the contractile element of the vegetable organism, that is to say, that from an intrinsic activity it possesses the faculty of altering its figure, without any corresponding change in volume.

It was Ehrenberg who first asserted that there was an absolute boundary between animals and plants; finding even, as he fancied he did, in the smallest of the former, —the Infusoria,—which had previously been regarded as mere unorganised masses of mucus, the same systems of organs as those by which the most highly-developed animal is characterised, that is to say, distinct nutritive, motile, vascular, sexual, and sensitive systems. Siebold called the existence of these organs in question, regarding the organisation of the Infusoria as a homogeneous parenchyma, in which he recognised only a nucleus, and in one division a mouth and œsophagus. Nevertheless he asserted that plants and animals were essentially distinct, and that there was no transition from one to the other, the nature of the plant being always immotile and rigid, whilst the animal possessed the faculty of contracting and expanding its body. This contractility, he observes in another place, is the only certain diagnostic character, all others being invalid.

It is not, however, the animal organism itself which is contractile, but only a single tissue in it; all the rest, skin, bones, and connective tissue, are as rigid or passive as the vegetable membrane, or at most elastic; in the higher animals the muscles only are contractile, and only in the lowest, viz. the Infusoria, the entire body.

Whence Ecker assumed the existence of a special contractile substance, which sometimes occurs in a formed state, as a contractile cell or as muscular substance, sometimes amorphous, as in the bodies of the Infusoria, Rhizopoda, and Hydroida. Kölliker confirmed this view, and carried it out particularly in the case of the Infusoria, which he declared to be unicellular animals with a contractile cell-membrane and contents.

The contractile substance is characterised by the following attributes :—it is homogeneous, or finely granular, transparent, of the consistence of albumen, gelatiniform, soft, more refractive than water, but less so than oil; insoluble in water, but gradually decomposed; destroyed by caustic potass ; coagulated and contracted by carbonate of potass, as well as by alcohol and nitric acid; having the power of forming aqueous cavities, which originate either by the separation of the water contained in it, or by its reception from without; owing to which the remainder becomes denser and more granular; and, lastly, it presents the appearance, in water, of contractile drops, which move like an *Amœba*.

All these properties had already been observed by Dujardin, in a substance of which the Infusoria and Rhizopoda are principally composed, and which he termed "Sarcode;" the aqueous spaces or hollows he named "Vacuoles," regarding them as the most characteristic feature of the substance; these spaces had been erroneously regarded by Ehrenberg as stomachs.

All these properties, however, are possessed by that substance in the plant-cell, which must be regarded as the prime seat of almost all vital activity, but especially of all the motile phenomena in its interior—the protoplasm. Not only do its optical, chemical, and physical relations coincide with those of the "Sarcode," or contractile substance, but it also possesses the faculty of forming "vacuoles," at all times, and even externally to the cell; a property, it is true, which has for the most part been hitherto overlooked or misinterpreted.*

* Sometimes, as in the zoospores of Volvox, these vacuoles exhibit rhythmical contractions.—[Ed.]

These clear, aqueous spaces, the so termed vesicular contents, are presented in all young cells, and play a considerable part in cell-division, and the sap-currents; they are in all respects analogous to the vacuoles of the sarcode, as already supposed by Meyen.

From these considerations it would therefore appear as certain as it can be made by an empirical deduction from the premises in such a subject, that the *protoplasm* of Botanists, and the contractile substance and *sarcode* of Zoologists, if not identical, are at all events in the highest degree analogous formations.

Whence, the distinction between animals and plants, viewed in the above light, must be thus understood; that in the latter, the contractile substance, as the primordial utricle, is enclosed within a rigid, ligneous membrane, which permits only an internal motion, evidenced in the phenomena of circulation and rotation; while in the former it is not thus enclosed. The protoplasm, in the form of the primordial sac, is, as it were, the animal element in the plant, in which it is *confined*, being *free* only in the Animal kingdom. Or, to express the thought broadly, the energy of the organic vital activity, realised in motion, is especially connected with a nitrogenous, contractile substance, which, however, in the plant, is "cribbed, cabined, and confined" by a rigid, inert membrane, absent in the animal.

The above motile attributes belong eminently to that form of the primordial sac to which the author has given the name of primordial cell, under which term he means generally to designate that form of the primordial sac which in itself assumes the figure of a cell, and is either entirely without any rigid cell-membrane, or at least may exist independent and isolated from it. Such is the case, particularly in the Zoospores (Schwärm-sporen) of the Algæ.

This is exactly the condition presented in the primordial cell within the enveloping cell, in the motile form of *Protococcus pluvialis*.

The colourless protoplasm often constitutes by far the greater part of the primordial cell, which then appears as an almost entirely colourless, sharply-defined globule, owing to the fact that the protoplasm is invariably surrounded, where it is free, by a sharp border, as if by a membrane. It is only in the middle or at one end of the globule that there generally remains a deposit of the green substance in the form of a ring or lateral mass, (Fig. 26.)

The same colourless protoplasm occurs in all cells, even where the other coloured substances are much developed; especially does it always appear as a delicate, almost imperceptible layer constituting the outer boundary of the coloured primordial cell, the periphery of which then becomes sharply defined, and as it were surrounded by a delicate, transparent, membrane. (Fig. 16.) Besides this, the colourless protoplasm seems to occur exclusively at the anterior extremity of the primordial cell, where it is produced into a conical elongation or beak. (Figs. 18, 36.)

The *green* substance appears sometimes as a thin and fluid, sometimes gelatinous, sometimes more solid mucus, and is perhaps more abundant and better developed in the motile than in the still form.

The red substance generally forms only a central mass of greater or less size; more rarely it constitutes exclusively the contents of the primordial cell. It is interesting to trace all the stages of the transition from the green into the red substance, and one stage or phase especially has long been regarded with great interest, in which the red pigment is reduced to a single minute granule, attached to the interior or to one side of the primordial cell, then representing what is described by Ehrenberg as the "red eye spot" of the Infusoria, and which was discovered by Kützing, Fresenius, and Thuret, in the spores of Algæ.

The three substances just considered present themselves in the *form* of colourless, red, and green globules, granules, and drops; but besides these, the primordial cells contain, at times, vacuoles, chlorophyll-vesicles, starch, and larger colourless granules of unknown material.

The so termed "vacuoles" occur, in greater or less number, in the interior of the primordial cells; they must be regarded as clear aqueous secretions from the colourless or coloured protoplasm, which is consequently forced from the centre of the cell towards the periphery. They are formed, and change, both in number and figure, under the eye of the observer, and present the aspect of large, hollow, clear vesicles, which have the effect of causing the coloured contents to appear frothy (Figs. 21, 27); and they are frequently developed in such number, that the coloured protoplasm seems only like a green deposit on the wall, and even there to be wanting in parts. By them it is that the internal watery cell-contents, as in the common plant-cell, become definitely separated from the more dense peripheric protoplasm (the primordial utricle). The chlorophyll-vesicles resemble, in all respects, those already described in speaking of the still form. They are occasionally wanting in every form of cell, but generally so in the more minute, one or two-coloured primordial cells. (Fig. 41.)

By starch granules are meant, in this case as in the still cells, very minute, colourless, strongly refractive particles or granules, rendered blue by iodine, and which, on the first appearance of the contents, are present in great abundance in certain stages.

The colourless granules, which were met with only on one occasion, in almost all the cells in the vessel, especially in the smallest, were highly refractive, spherical, transparent corpuscles, visible through the coloured contents. They were neither coloured nor changed by iodine, acids, or alkalies. They resemble similar corpuscles which occur in *Euglena viridis* at certain times.

The author then proceeds to describe the infinite variety in appearance of different individual cells, owing to the varying quantities or arrangement of the elements above described; almost the only part of a motile *Pro-*

tococcus cell which is alike in any two individuals being the enveloping cell.

The anterior projection, beak or rostellum, is always an immediate prolongation of the colourless protoplasm, forming the outermost boundary of the primordial cell, but into which, speaking generally, the coloured substance is not continued.

The contractile movements of the primordial cells is usually very slow, but occasionally more rapid, in that case very closely resembling those of *Euglena viridis.* These more rapid changes of figure and appearance, take place particularly upon the partial evaporation of the water in which the cells are contained. But if this evaporation proceed further, and fresh water be not added, further and more important changes take place in the primordial cells of *Protococcus pluvialis,* which may be comprehended under the term of "*deliquescence.*" This process is exclusively characteristic of the vegetable primordial cell, particularly in all zoospores on the one side, and also in the Infusoria on the other.

The phenomena in question present two stages or phases. In the first, the outlines appear less sharply defined, because the coloured substance is somewhat retracted from the border of the primordial cell. It is then clearly evident that the colourless protoplasm constitutes the special smooth boundary membrane of the primordial cell. The cells become flattened, and at the same time wider. The contents also are now altered; previously more homogeneous and transparent, they now become throughout granular, and the red substance runs together into large drops. At this time commences the formation of vacuoles, the number of which continues to increase. In this way the interior of the primordial cell again becomes colourless, clear as water, and the granular, coloured contents, compressed against the walls. The figure of the cell, in the meanwhile, is so much expanded that it comes to be applied upon the wall of the enveloping cell, ultimately filling it altogether, (Figs. 27, 28,) so that the entire zoospore appears to consist of only a single, coloured, granular, vesicular disc, corresponding in size with the original enveloping cell.

The *Protococcus pluvialis* has true motile organs, namely, two long vibratile cilia arising from the primordial cell, and which, passing through two openings in the enveloping cell, move about in the water. These organs, during the life of the cell, move so rapidly that it is then difficult to perceive them; they are only recognisable by the currents they produce in the water. But when the motion is slackened they are evident enough. They are also rendered very distinct by iodine.

They are always placed upon the extreme point of the conical elongation, on the anterior end of the primordial cell, and in such a manner as to appear to be immediate continuations of its substance, and as that process itself consists of protoplasm, it is evident that the cilia must be regarded also as composed of the same substance. They appear in some cases to possess an adhesive property. They resemble, in fact, in all respects, the so-called proboscis of certain Infusoria, such as *Euglena* and the *Monades,* and not to differ organologically from the non-vibratile but retractile filaments of *Aconita* and *Actinophrys.*

It is only that portion of the vibratile filaments beyond the enveloping cell that exhibits any motion, the portion within the outer cell is always motionless, and in that part of their course the filaments appear to be surrounded with a sheath. This seems to be the case, not only from the greater thickness at that part, but also from the circumstance, that when, from the passage of the cell into the still condition, the cilia disappear, the V-shaped, or forked internal portions remain visible. And it is then, also, that the openings through the enveloping cell become, for the first time, visible (Fig. 46.) Such are the "encysted zoospores" (umhüllte Schwärm-zellen.)

There are, however, forms in which the enveloping membrane cannot be distinguished at all, and in general does not exist: these forms are designated "naked zoospores" (nackte Schwärmzelle.) They are true primordial cells; that is to say, their external boundary is formed of nothing but the contractile cell-contents, or protoplasm; a true, solid, and rigid vegetable cell-membrane is wholly wanting. They thus correspond in their structure with the zoospores of most of the other Algæ (*Vaucheria*, *Œdogonium*, &c.) These naked zoospores originate in various ways, and belong to various stages of development. The following varieties of this kind of primordial cell may be distinguished.

1. Those which differ from the encysted only in the absence of the enveloping cell. This form corresponds with the younger condition of the encysted zoospore, arising from the division of the cell, around which the enveloping cell is not yet formed.

2. Another form arises immediately from the still cell, distinguished by its verrucose figure, and its, for the most part, cinnabar red colour. It is of small size, and, narrow in shape (Fig. 32.) On "deliquescence" taking place, the primordial cell becomes expanded, and at the same time flatter and of a lighter colour, the coagulated red droplets exhibiting a lively molecular motion in the interior. In this case, also, large colourless vesicles are then developed in the interior.

In certain conditions, this form of primordial cell resembles, in its form and aspect, the genus *Astasia* of Ehrenberg.

3. Are very minute naked zoospores, not more than 0·002‴ to 0·005‴ in size, mostly globular. They contain chlorophyll granules and red droplets, more rarely chlorophyll-vesicles, and colourless granules of unknown nature, as described above (Fig. 41.)

4. Perhaps the most remarkable of all the numerous aspects presented by *Protococcus pluvialis*, is the form of naked zoospore named by Flotow *Hæmatococcus porphy-*

rocephalus. It is in the form of extraordinarily minute (from 0·0015‴ to 0·004‴) globules, consisting of a green, red, and colourless substance (protoplasm) in unequal proportions. The colourless protoplasm, in these, as in all primordial cells, constitutes the outermost delicate boundary; the red substance is for the most part agglomerated towards the anterior end in minute spherules, the granular green substance occupies more the under part, whilst the middle is most usually colourless. The shape varies extremely.

Hence it is apparent that the naked zoospores, although as regards their development not of equal value, are all constructed in an analogous manner, varying only in their mutable form, size, and colour. But they are all true primordial cells, which before desiccation undergo deliquescence, having no rigid, solid, ligneous membrane, being enveloped only in a mutable layer of protoplasm, and with colourless green and red contents, in part organised into granules and droplets, rarely containing colourless granules of unknown nature, and chlorophyll vesicles, and always moved by means of two longer or shorter vibratile filaments.

Having thus gone over the anatomical description of the various forms of *Protococcus*, the author proceeds to the history of its development.

1. The *Protococcus pluvialis* is a unicellular Alga, a simple cell, or at least the individual represents an organism which exhibits the conditions of a simple cell; each multiplication of the cell reproduces the species, and is at the same time an act of propagation; each dissolution of the parent-cell into secondary ones constitutes a new generation; each secondary cell is an independent individual of the same species.

2. The *Protococcus pluvialis* is a plant subject to an "alternation of generations;" that is to say, the complete idea of the species is not exhibited in it until after a series of generations. The forms of development which can be possibly comprehended in the idea of the species, do not

in reality make themselves apparent until a series of independent successive generations has been gone through.

3. The individuals of each such generation are capable of propagating themselves in new generations. The individuals of the second generation, are among themselves, speaking generally, of equal value; as respects the individuals of the parent generation, they are sometimes of equal value with them, sometimes not.

4. If the secondary cells are not of equal value to their parent-cells, a series of successive generations must precede the last generation, the individuals of which are again equivalent to the first mother-cell. The number of these generations does not appear to be determinate.

Let us assume that a parent-cell (A) has produced a number of secondary cells (B) which are of unequal value to their parent. The individuals of this second generation propagate a third generation equivalent to their parent-cells (B) or not equivalent (C.)

In the first case there may also be a fourth generation (B″), a fifth (B‴), and more, which are all equal among themselves, and to their parents, but not equal to the parent-cell of the first generation (A); until at last a generation is produced which is not equivalent to its own parent. Now this is either equivalent (A′) to the first generation, and the cycle closes with it, or it is still not equivalent to it (E). In that case, it either propagates again a number of equivalent generations, (C′. C″. . .) or non-equivalent (D, E . . .) until at last one appears, A′, which is equivalent to the first generation, and thus the cycle closes. By equivalent, the author means such individuals or generations as correspond with each other in their essential, physiological, and organological relations, although they may differ in unessential properties, such as colour, size, internal consistence, &c. Non-equivalent, are those generations which in their structure and vital relations exhibit essential differences, such as "still" and "motile" cells, and among these, again, their various forms; but particularly those which are derived from a different mode of propagation.

There is a large number of different modes of propagation in *Protococcus pluvialis*, which, indeed, are all fundamentally analogous, but produce very different forms. The main distinction depends upon the number of divisional individuals produced from a parent-cell. Their number appears always to be a sub-multiple of 2. A cell may produce 2, 4, 8, 16, 32, 64 individuals.

The propagation depends upon a division of the cell-contents, particularly of the colourless or coloured protoplasm, or of the primordial sac. This body, without any demonstrable influence of a nucleus, is capable of subdividing into a determinate number of portions, in the ratio just stated. Each of these portions acquires a globular figure, in the next place surrounds itself with an envelope of protoplasm, and then represents a visible organism, which, after the resorption of the parent cell-membrane, is capable of existence as an independent reproductive individual.

The protoplasm which constitutes the external boundary of this body, like all organised protoplasm, is capable of secreting a rigid vegetable cell-membrane. Two conditions now may present themselves.

1. *Either*, such a rigid, ligneous membrane is formed within the mother-cell, around the portions of protoplasm separated by division as above, that is the primordial sacs: in which case there are produced only still secondary cells, usually different in their structure from the parent-cell. This process takes place only when the parent-cell itself belongs to the still form, that is to say, when the cell-contents or the primordial sac are closely surrounded by a rigid, tough, ligneous membrane:

2. *Or*, the secondary individual, surrounded only by a tunic of protoplasm, is liberated in this condition as a *primordial cell*, and developes two vibratile filaments; it then has the faculty of motion, and represents a naked zoospore. This process may take place as well in the segmentation of still, as of motile primary cells. Here, also, two conditions are possible.

a. Either, the zoospore does not develop, during the period of its motility, any rigid, tough, ligneous membrane, but only when the motility has ceased, whereupon the zoospore passes into the still form. This is the case in the peculiar naked zoospores, of minute size, which are produced in greater number than 2, that is to say, to the number of 8, 16, 32, 64, from the parent-cell. They cannot multiply until they have assumed the still form:

b. Or, the zoospore, during the period of its motility, acquires a delicate but rigid membrane, which, however, is separated from the primordial cell by an aqueous fluid; it then represents the *encysted zoospore*. These are capable of propagation by segmentation, reproducing, however, only motile forms, although sometimes non-equivalent ones.

Besides this, the primordial cell in the encysted zoospore may produce a second, rigid, tough, ligneous membrane, around its whole periphery, by which it is closely surrounded, whilst the delicate, outer enveloping cell is removed. In this way the encysted zoospores pass into the still form, and the cycle of possible developmental forms is closed.

These appear to be the essential laws to which all the phenomena attending the development of *Protococcus pluvialis* may be referred; and the author then proceeds to particular instances.

It is difficult, from the numerous uninterrupted links of a chain of phenomena, to select that which should be regarded as the representative of the normal condition, and to which all the rest might be referred; but, on the other hand, it is indifferent where the commencement is made, and the author therefore commences with the still form, which, within a rigid, tolerably thick, ligneous membrane, indicated by a double contour line, contains uniformly red, opaque, granular contents, contractile in alcohol, and presenting in the centre a cytoblast (?) in the form of a lighter coloured vesicle

(Fig. 2). This form arises from the metamorphosis of the encysted zoospore into the still.

It may undergo changes, which may be distinguished as essential and non-essential. The latter have reference to the change in form and colouring of the contents; the former, to propagation.

The latter process takes place by the division or segmentation of the contents, at first as above stated, into two, then into four, eight, or sixteen, when the division usually terminates, and the segments pass into the motile form; although further *still* generations may arise in the same way. The segmentation takes place in the following mode. In the first place the cell becomes elongated, so that its diameter in one direction is twice as great as in the other (Fig. 5). Then a constriction of the contents is perceptible about the middle of the length of the cell, which gradually deepens, and the cell contents or primordial sac are divided into two halves (Fig. 6). These are separated by a line which forms between them; and finally each is organised into a distinct globule (Fig. 7), which becomes surrounded with a ligneous membrane. The membrane of the parent-cell is passive during this process—continuing, for a time, to surround (sometimes in a gelatinous form) the secondary cells; it is finally dissipated, and they thus become free. The part played by the supposed cytoblast in the process of segmentation is very doubtful.

During their dissolution, the cell-membrane of the defunct parent-cells is gradually converted into a mucoid substance, retaining the secondary cells more or less in connected masses. In this way arises the *Prot. pluvialis, leprosus*, of Flotow. It is known also that other unicellular Algæ and Infusoria (*Chlamidomonas*, *Euglena*, *Monas*, *Vibrio*, Zoospores, Diatomaceæ, &c.), under certain circumstances, form similar envelopes, either by the secretion of a mucoid substance, or the transformation of their cell-membrane into such.

After a certain number of such divisions, all in the still form—usually after the third or fourth—the ultimate segments, instead of surrounding themselves with a ligneous membrane, become free, in the naked condition, and developing the two motile filaments, represent a motile primordial cell. (Fig. 12.)

The way in which the vibratile cilia are produced is quite obscure.

The production of motile zöospores may take place on the first segmentation of the contents of the primary, still form, or after the intervention of an uncertain number of such divisions as said before; but it is clear that the segments of the contents of a still cell may at any time assume the motile condition, and that their prolonged retention of the still form depends upon various external conditions. But with division, on the other hand, it does not appear possible for the still form to be changed into the motile, whilst the contrary may undoubtedly take place.

The production of the enveloping cell around the primordial cell is then described, as in a former part of the paper; and the analogy between this process and that of cell-formation, given by Mohl, Nägeli, Schleiden, &c., pointed out. (Figs. 16, 17, 20, 21.)

The encysted zoospores, thus constituted, grow for a time very considerably, and after a certain time exhibit a tendency to propagate, that is to say to divide.

The contents of the primordial cell (which alone is potential in this act) exhibit lines of division into four symmetrical portions, most distinctly shown by the chlorophyll vesicles. Then, in directions corresponding to these lines, the cell-contents are divided into four contiguous portions, which gradually become isolated, and assume a globular form, afterwards develope the two vibratile cilia, and upon rupture of the parent-cell, become free, and swim away. (Figs. 12, 13.)

A new enveloping cell is afterwards developed, and these secondary motile cells become a second generation of encysted spores, which, though in some respects unlike, yet must be regarded as equivalent to their parent.

Sometimes the enveloping cell is developed around each secondary primordial cell, whilst still within the parent-cell.

After a certain number of generations of this kind, their course is interrupted. A delicate double line is perceptible around the primordial cell, which is the first indication of the new, rigid, ligneous membrane, which is formed around it (Fig. 46). The motile zoospore, in other words, is again transformed into the still form. The *primordial cell* is converted into a *primordial sac*, and the cycle is closed.

Besides these, which are the most usual modes of propagation, viz. that of the *still* cells into two, and of the motile, into four secondary cells; there are a number of others which may be considered as irregular, and in which forms are produced, which do not re-enter the usual cycle until they have gone through a series of generations.

The cell-contents, for instance, of the still form, instead of dividing first into two, and then these again each into two secondary cells, and so on, may at once be subdivided into four segments, as takes place in the motile form. (Fig. 8.)

More frequently and regularly, under certain circumstances, the cell-contents of the still form divide at once into eight portions, which become naked zoospores of small size (Figs. 31, 32). It is not quite clear what becomes of this form of motile zoospore, but there seems reason for believing that they occasionally develope an enveloping cyst, and thus become encysted zoospores, and occasionally secrete a cellulose tissue and become *still* cells; but most of them probably perish without any further change. They would thus correspond with the smaller motile spores observed by Thuret and A. Braun in other Algæ (*Hydrodictyon*, *Achlya*, the Fucoideæ, &c.) associated with the larger germinating spores, and which themselves were deprived of the germinative faculty.

In the same way that the "still" parent-cell may produce, instead of two, eight secondary cells, so, on the other hand, may the motile encysted zoospore, which normally produces four secondary cells, divide into only two. (Figs. 22, 23, 35.)

It appears that both longitudinal and transverse division of the primordial cell may take place; but that the vibratile cilia of the parent-cell retain almost to the last moment their function and their motion, after the primordial cell enclosed by it has long been detached as a whole, and become transformed into the independent secondary cells. (Fig. 38.)

The individuals of the secondary generation, when the encysted parent-cell divides into two, are for the most part equivalent to their parent; but should the latter divide into more than two, its progeny then is very dissimilar to it. For the encysted zoospores may also divide into a generation of eight, sixteen, thirty-two, according as the primordial cell has been partitioned into eight, sixteen, or thirty-two portions, which become organised into as many independent primordial cells. The individuals of the secondary generation are of course smaller, in proportion to the greater number of parts into which the primordial parent-cell was subdivided, and they are also the more dissimilar to it in proportion to the less quantity of its substance that they may contain.

These minute zoospores, however they may originate, are always true primordial cells, and, under unfavorable circumstances, perish as such. What becomes of them under other circumstances is not very easy to determine. It is certain, however, that they can pass into the still form, assuming a globular shape, losing the vibratile cilia, and secreting a ligneous membrane. They sometimes undergo this change while still within the parent-cell. They thus constitute a mulberry-like mass, which gradually increases in size as the individual cells grow (Fig. 40). They are also, after their liberation from the mother-cell, sometimes seen to form an enveloping cell around them, thus becoming encysted zoospores, differing from the larger form of that kind only in size (Fig. 41).

The author once observed four cells arranged as it were in a cross, and connected to each other by the *anterior* end (Fig. 25), and which, from their structure, appeared to be referable to the encysted motile zoospore. It is a very remarkable circumstance, and one difficult of explanation, that in this case each of the four larger primordial cells was connected with each of the two contiguous cells by two transverse processes, which passed through the enveloping cell-membrane. In this respect there was a resemblance to *Chlamidomonas pulvisculus* and *Trachelomonas volvocina*, Morren, which remain connected by the beak or vibratile cilia. ('Recherch. sur la Rubefact.,' Tab. II, fig. iii *b*, Tab. V, figs. 9, 8.) I think, however, that this condition is to be explained upon the supposition that four primordial cells have been formed within a parent cell by the usual mode of segmentation, but that instead of their being completely separated from each other, they remain connected, and that then, after resorption of their common, parent enveloping-cell, also develope in the usual way special enveloping-cells, which are of course in contact in the centre, and necessarily assume a cruciate figure. A smaller portion, which in the organisation of the segments was not taken into any of them, has become an independent but more minute primordial cell, lying between the arms of two of the primordial cells constituting the cross. The above process seems to be analogous to what takes place in *Gonium* or *Volvox*, in which the individual segments, after division, are retained in connexion.

Having thus gone over the various morphological and developmental conditions of the *Protococcus*, the author proceeds to its biology.

The most striking of the vital phenomena presented by this organism is that of periodicity. Certain forms, for instance encysted zoospores, or certain colours, appear in a given infusion, at first exclusively, then principally; they gradually diminish, become more and more rare, and finally disappear altogether. After some time their number again increases, and reaches, as before, an incredible amount; and this proceeding may be repeated several times. Thus a glass which at one time presented only still forms, contained some weeks before nothing but motile ones, and would again in a few weeks contain nothing else.

The same thing may be observed with respect to the segmentation. If a number of motile cells are transferred from a larger glass into a small capsule, it will be found, after the lapse of a few hours, that most of them have subsided to the bottom, and in the course of the day, they will all be observed to be on the point of subdivision. On the following morning the divisional generation will have become free; and on the next, the bottom of the vessel will be found covered with a new generation of self-dividing cells, which again proceed to the formation of a new generation, and so on. This regularity, however, is not always observed.

The influence of every change in the external conditions of life, upon the propagation, is highly remarkable. It is only necessary to pour water, from a smaller into a larger, shallower vessel, or one of a different kind, at once to induce the commencement of segmentation in numerous cells. The same thing occurs in other Algæ; thus the *Vaucheriæ* almost always develope zoospores, at whatever time of year they may be brought from their natural habitat into a room.

Light is conducive to the manifestation of vital action in the motile zoospores, and they always seek after it, collecting themselves at the surface of the water, and at the edges of the vessel.

But, in the propagative act, on the contrary, and when they are about to pass into the still condition, the motile *Protococcus-cells* seem to shun the light; at all events they then seek the bottom of the vessel, or that part of the drop of water in which they may be placed, furthest from the light.

Too strong sunlight, as when it is concentrated by a lens, at once kills the zoospores. A temperature of undue elevation is injurious to the development of the more active vital activity, that is to say, for the formation of the zoospores; whilst a more moderate warmth, particularly that of the vernal sun, is extraordinarily favorable to it. Frost destroys the motile, but not the still zoospores.

When kept in the dark, the zoospores become blanched, that is to say they acquire a pale green colour, almost without granules or red substance; the chlorophyll-vesicles, moreover, are not visible, so that the contents of the primordial cell appear as a soft, homogeneous, substance. The membrane is of a soft gelatinous consistence; the motile zoospores continue their movement uninterruptedly, without, as is usual, sinking to the bottom, or passing into the still form, or into the stage of segmentation.

Under the influence of light, the cells give out a large quantity of oxygen. It is perhaps the continued greater evolution of gas by the motile spores, as compared with those in the still condition, that causes them by preference to rise to the surface, and the latter to sink.

Strychnine and morphine, even in the proportion of 1 part to 150 parts of water, had no immediate influence on the motion and life of the cells, whilst a solution of iodine so weak as not to render starch anywhere visible, acts at once as an active poison. Cohn observed that when he had starch granules together with motile zoospores on the object glass, and added a very dilute solution of iodine, the *motile cells*, by their death, shew themselves to be much more sensitive reagents with respect to iodine, even than starch. Rapid evaporation of the water in which the motile forms of *Protococcus* may be contained, kills them at once, but a more gradual, such as takes place in deep glasses, causes them merely to pass into the still form, in which they retain their vitality for years.

Cohn observed very frequently that the contact of metal with the water in which the *Protococcus-cells* were, was destructive to their life.

In the still form, the phenomena attendant upon the cessation of life, are somewhat different from those in the motile cells. In certain circumstances, the contents, particularly in the red zoospores, dissolve, from the periphery, into innumerable minute droplets. Or a peculiar dissolution of the coloured contents takes place, in such a way that they lose their colour, also from without to within, so that at last the cell appears dense and opaque, but altogether colourless, and is deprived of all vitality. (Fig. 43.)

The paper then concludes with some general considerations.

1. The question arises, whether the *Protococcus* is necessarily to be regarded in all its stages of development as a Plant; or whether it should not rather be referred to the Animal kingdom.

To any one who reads the writings of the most distinguished observers on this subject, it appears almost incomprehensible, that any doubt could exist whether any organism, when sufficiently investigated, should be an animal or a plant. For all, nearly without an exception, agree in this, that an animal and a plant are essentially and typically of distinct structure, and that this essential diversity must also be expressed in the most minute and lowest organisms; and that, therefore, there can be no question of any real analogy between an animal and a plant, to say nothing of a relationship or a transition from one into the other.

It appears, however, to Cohn, that the question of *animal* or *plant* has been stated too generally, and requires to be defined with greater precision. As the question is generally put, it would include the inquiry as to whether the *Protococcus pluvialis* were allied to the Lion or to the Oak. All our common notions of the two kingdoms being derived from such higher organisms as those, and not from those of the invisible world.

But the *Protococcus* is as far from the Lion as it is from the Oak; there are observable in it, properties which would appear to find their analogies only in *certain* animals or *certain* plants, viz., among the Infusoria or the Algæ.

Of the *latter*, again, the more highly organised, multicellular forms must be excluded, these belonging manifestly to the Vegetable Kingdom. A *Fucus*, for instance, is incontestably differently constructed from a *Protococcus* cell. It is only the so-called unicellular Algæ of Nägeli, the Palmelleæ and Diatomaceæ, about whose proper position there can exist any possible doubt.

In the same way, of Infusoria, next to the Rotifera, all those among the *Polygastrica* of Ehr. must be excluded, which have distinctly a mouth and anus, as well as an intestinal canal, or at least an œsophagus. With respect to these, also, no doubt can arise as to their proper position in the scale of animated nature.

Besides these, however, there are Infusoria, having neither intestine nor anus, which do not take in any solid nutriment, and in which the existence of a mouth is not demonstrable by direct observation, and can only be surmised from analogy. These constitute the division of the *Anentera*, Ehr., *Astoma*, v. Siebold. With respect to these, it may certainly be reasonably questioned, whether an organism should be more properly referred to this division of the Infusoria, or to the Algæ just mentioned. It cannot but be doubtful whether a given creature is to be regarded as belonging to the *Monadina*, *Cryptomonadina*, *Volvocina*, *Astasiecæ*, *Bacillariæ*, *Amœbæ*, *Arcellinæ*, &c., or whether it should not be referred to the *Cryptococcaceæ*, *Protococcaceæ*, *Palmelleæ*, *Desmidieæ*, and *Diatomaceæ*. It may even be questioned, whether some of these natural families be not more nearly related with some families in the other kingdom, than with their neighbours in the kingdom to which they themselves belong, or whether even certain divisions from both natural kingdoms might not properly be associated. It is only with this limitation that the question, as here considered, must be understood,—whether *Protococcus pluvialis* is to be regarded as animal or plant; or, since of the above-mentioned genera of Infusoria some only present any similarity with it, whether it is to be considered as an animal belonging to the *Monadina*, *Cryptomonadina*, *Volvocina*, or *Englenæ*, or whether it should not be referred, as an Alga, to the family of the Palmelleæ.

Although Flotow, after much consideration, comes to the conclusion that *Protococcus pluvialis* must be regarded as a plant, the reasons upon which he is induced to come to this conclusion do not appear to be well chosen. They are,—1. its capability of revival after having been dried for months and years; 2. the viability of separate portions of its substance; 3. the occurrence of gemmation which, moreover, in the proper sense of the word, is more than doubtful. All of which circumstances may be observed occasionally in the Animal Kingdom.

By Morren, on the other hand, this organism, under the name of *Discenæa purpurea*, is arranged among the Infusoria in the family of the *Cryptomonadina*, Ehr., and has assigned to it a place close to *Trachelomonas volvocina*, Morren, (non Ehr.) Focke also conceives that the reasons above assigned by Flotow for the vegetable nature of *Protococcus*, are the rather calculated to prove its animal nature.

According to Ehrenberg, for an organism to be characterised distinctly as an Infusorium, it is requisite that it should possess a complete organisation analogous in all respects to that of the higher animals; on the other hand, however, Dujardin, Siebold, Kölliker, &c., contest this, considering spontaneity and contractility alone, as indispensable criteria.

Now to consider *Protococcus pluvialis* in both these points of view.

First, as regards Ehrenberg's doctrine. The organisation of *Protococcus* may very plausibly be referred to that of the anenterate Infusoria, as understood by that observer; in this case the enveloping cell might perhaps be explained as the shield; the primordial cell as the proper body of the animal; the chlorophyll-vesicles, colourless granules, and cytoblasts, as the testes; the red and green globules as ova; the frequently existing red pigment spots as eyes; the vibratile cilia as a proboscis; the hyaline spot as mouth; and the vacuoles as stomachs. At all events the organs which Ehrenberg has figured and described as of such nature in *Trachelomonas*, *Volvox*, *Euglena*, *Chlamidomonas*, *Closterium*, *Euastrum*, &c., present such appearances that, although they are in reality organised in an essentially different way, they cannot be optically distinguished from what they are represented to be.

On the other side, these bodies correspond in all respects with the organisms which are found either absolutely in indubitable plants, or in the spores of such plants.

Whence it is apparent that the proof of an animal organisation offered by Ehrenberg, does not suffice in doubtful cases incontestably to prove the animal nature of a doubtful creature when alive, because formations are presented even in plants which cannot be directly shown to be distinct by optical or chemical means, but only indirectly, with the aid of analogy.

If, on the contrary, that view of the structure of the Infusoria be the more correct, which regards them only as simple contractile cells, and all the above elementary parts as parallel, not with animal but with vegetable organisms, we arrive at more comprehensive conclusions.

One of the characteristics of *Protococcus* is this, that it affords analogies, at different periods of its growth, not with one only, but with many genera hitherto considered distinct. Thus the motile, or "swarming," form agrees with the genus *Pandorina*, Ehr., or more closely still with *Chlamidomonas*, from which, indeed, it is scarcely to be distinguished. But the latter, according to Cohn, has not yet been observed in the "still" condition.

But *Pandorina* and *Chlamidomonas* have long enjoyed only a very doubtful character as animals; Kützing having arranged the former among the Palmellaceæ, as *Botryocystis morum;* and Siebold the latter among the Algæ, in spite of the only certain character admitted by him as distinctive of an animal nature, viz., the contractility of the body.

Protococcus pluvialis, however, presents the most striking analogies with genera in which this property is exhibited in the highest degree, the genera *Euglena* and *Astasia*, which, according to our present knowledge, must be regarded as indubitable animals, their claim to be so considered having even never yet been called in question by any careful observer.*

Among the points in which the closest resemblance exists between *Protococcus* and *Euglena*, may be enumerated the following :—

1. The red matter in the latter presents precisely the same characters, and, like that of *Protococcus*, is coloured blue by iodine, and contains corpuscles not to be distinguished from the chlorophyll-vesicles.

2. The colourless extremities of *Euglena* manifestly correspond with the colourless elongation of protoplasma at the two ends of the *Protococcus* cell; the beak also of *Euglena*, with its single cilium, precisely corresponds with the biciliated extremity of *Protococcus*.

3. The eye-spot of *Euglena* appears to be chemically analogous with the red pigment spot in certain stages of the zoospores of *Protococcus;* it is equally coloured blue by iodine.

If to the above it be added that *Euglena*, at least according to Dujardin, Siebold, and Kölliker, equally presents the characters of a simple closed cell, it will be

* This is now, by no means, the case.—[Ed.]

apparent that the motile form of *Euglena* is constituted on the same type as the primordial cell of the motile form of *Protococcus*.

The author then details some observations on the development of *Euglena viridis*.

Euglena is not always motile; at certain times it passes into a state of rest. To this end, it assumes a globular form, developes more opaque, denser contents, and forms around itself, a rigid, colourless membrane; in this state it cannot be distinguished from the still form of *Protococcus pluvialis*, and as in that plant, the cells are often united into floating expansions. In this form, and particularly when aggregated into these expansions, it has already been occasionally placed among the Algæ; *Microcystis Noltii*, Kg. appears to be the still form of *Euglena sanguinea*, and *M. olivacea*, Kg. is probably to be referred to *Euglena viridis*.

This stage, however, of the so-called process of becoming encysted, is not, as commonly supposed, connected with the decease of the organism, but within the membrane, segmentation goes on; the coloured, enclosed globular body subdividing exactly as in *Protococcus* into two, four, eight, sixteen, thirty-two, or more portions. These isolated, primordial cells, as they may be called, become free, by rupture of the rigid wall enclosing them; and either resemble their parent, or when much smaller, are very dissimilar to it, assuming more the appearance of green, eyeless Monads.

On the other hand, the motile form of *Euglena*, also, just like the motile zoospore of *Protococcus* may subdivide into two, or it may be into more, also motile secondary individuals. Whence it is manifest that the development of *Euglena viridis*, proceeds on precisely the same type as that of *Protococcus pluvialis*.

With respect to the motion of the *Protococcus* cells; it is to be noticed that Ehrenberg, and with him all later observers, agree that animal motion is voluntary, arising from internal psychical causes, that it is conscious and directed to some object; whilst that of plants would appear to depend upon external physical causes or stimuli; that it is not voluntary, nor directed to any object, but automatic (vide Ehr., Abh. d. Berl. Ak. 1830). Cohn, however, from numerous observations expressly directed to this point, is disposed to call in question, the existence of this essential distinction between the motions of the Infusoria, and that of the vegetable zoospore.

Leaving out of the question the more highly organised Infusoria furnished with the manifest mouth and œsophagus, the motion of a large part of the *Anentera*, Ehr. *Astoma*, Siebold, is not essentially different from that of the zoospores of certain Algæ.

Towards the end of the paper, Cohn observes, that in the course of its preparation he had only been able upon optical and physiological grounds, to render it probable, that the rigid cell membrane of the still form and the tender enveloping cell of the motile zoospores, consist of the same non-nitrogenous material, of which the rigid membrane of all plant-cells is composed—viz.: cellulose; he had, however, since succeeded, by chemical means, in placing this fact beyond doubt. If a drop of water containing some still and motile zoospores, be brought in contact simultaneously with a very dilute watery solution of iodine, and moderately diluted sulphuric acid, the "enveloping" cells of the motile and the cell-membrane of the still form, immediately assume a beautiful blue colour (Fig. 47). In performing this experiment, it is necessary to employ neither a too concentrated, nor a too much diluted sulphuric acid.

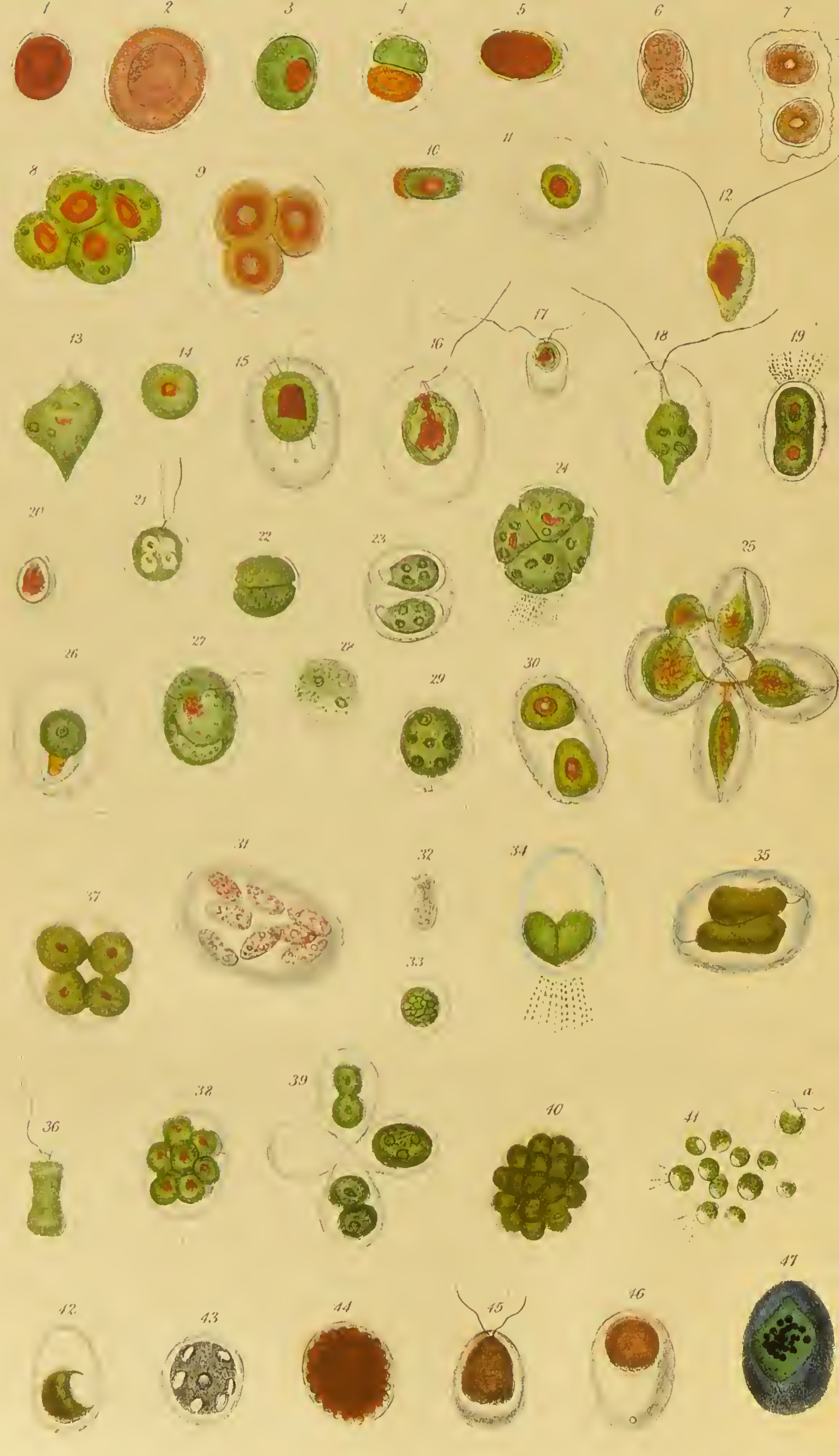
The author concludes by some general observations on the subject of the "Alternation of Generations," exhibited in such instances as *Protococcus pluvialis*, and on the importance of the history of its development, with relation to a systematic arrangement of the Algæ. Most of our *species* and *genera*, are based merely upon differences in size, form, and thickness of the cell-wall, and the colour, consistence, and intimate organisation of the contents. But the history of the development of *Protococcus pluvialis*, shews how very uncertain such characters are. It cannot be doubted, moreover, that the great diversities exhibited in the above respects, at different stages of its growth, by *Protococcus pluvialis*, exist also in other Algæ, if they were duly sought after, and that researches in other species, from the same points of view as those embraced in the present memoir, would probably reduce very materially the large number of genera and species of Algæ.

Thus we see that a single species, owing to its numerous modes of propagation, can pass through a number of very various forms of development, which have been either erroneously arranged as distinct genera, or at least as remaining stationary in those genera, although, in fact, only transitionary stages. Thus the still *Protococcus* cell, (Fig. 2,) corresponds to the common *Protococcus coccoma*, Kg. When the border becomes gelatinous, it resembles *P. pulcher* (Fig. 70); and the small cells, *P. minor*. The encysted motile zoospore is the genus *Gyges granulum* among the Infusoria, resembling also, on the other side, *P. turgides*, Kg. and perhaps, *P. versatilis*, Braun. The zoospores divided into two (Figs. 23, 30), must be regarded as a form of *Gyges bipartitus*, or of *P. dimidiatus*. In the quadripartite zoospores, with the secondary cells arranged in one plane, we have a *Gonium* (Fig. 37). That with eight segments (Fig. 38,) corresponds to *Pandorina Morum*, and that with sixteen, to *Botryocystis Volvox* (Fig. 44). When the zoospore is divided into thirty-two segments, it is a *Uvella* or *Syncrypta* (Fig. 40). When this form enters the "still" stage, it may be regarded as a form analogous to *Microhaloa protogenita*; this Algal genus is probably, speaking generally, only the product of the *Uvella* division in the *Euglenæ* or other green forms. The naked zoospores (Fig. 32), finally, would represent the form of a *Monad*, or of an *Astasia*; the caudate variety, approaches that of a *Bodo*.

A critical and comparative consideration of the foregoing facts would therefore appear to render untenable almost all the principles which modern systematists have hitherto adopted as the basis for the construction of their Natural Kingdoms, Families, Genera, and Species.

But it must not hence be concluded, that the result of these investigations implies the existence of a state of complete anarchy in the domain of microscopic organisms; or that any one form among them, may assume any other form indifferently; that, in fact, there are no real *species* in the invisible world. Such is by no means the case.

Critical enquiries such as the present, have for their result—like the spear of Telephus—the healing of the wound they inflict. It is manifestly better,—although at the expense of erroneous notions, long admitted as infallible—to substitute, by the aid of a complete and continuous history of development, a much more defined, because natural idea, of *Genus* and *Species*, for that hitherto set up, in artificial, but, at the same time, unnatural Systems.



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DESCRIPTION OF FIGURES.

Fig.

1.—A small "still" cell of *Protococcus pluvialis*, revived after desiccation. The contents grumous, almost filling the cell-membrane.

2.—A very large cell, in which the red, finely granular contents, fill up the membrane, and have in the centre a clearer space. (cytoblast?)

3.—A green cell with chlorophyll-vesicles, containing an excentric, reddish, lighter-coloured vesicle (nucleus?) surrounded by an opaque red ring.

4.—A cell which had been dry for six years, undergoing segmentation after its revival; one half is green and granular; the other red, presenting an oil-like substance.

5.—A cell which has assumed an elliptical figure preparatory to its dividing.

6.—Division further advanced.

7.—Completed division. The secondary cells appear to have a cellulose coat, and are surrounded by the mother-cell, which has become gelatinous.

8.—Division into four.

9.—The same, still surrounded by the parent-cell.

10.—Commencement of division; a green, small cell, with a red zone at the border, and red central substance, as well as a lighter coloured nucleus.

11.—A "still" cell, containing, within a distant, dense, colourless coat, a coloured globule also surrounded with a membrane.

12.—A large naked zoospore, green, with red central substance, and a colourless spot at the anterior end, with two vibratile cilia, originating, either in the division of an encysted zoospore or from a "still" cell.

13.—An irregular-shaped, quadrangular, flat, *Euglena*-like zoospore, with chlorophyll-vesicles, colourless anterior end, and two cilia.

Fig.

14.—A green cell with red central substance, on the point of assuming the motile form.

15.—An encysted zoospore, with filaments of protoplasm, (*P. setiger*, Flotow), a distant "enveloping cell," two cilia, chlorophyll-vesicles, &c.

16.—An encysted zoospore, with distant "enveloping cell," green, gelatinous, primordial cell; red, granular, disseminated central substance, and a colourless point, (*P. papillatus*, Flot.)

17.—A very small, globular, encysted zoospore, (*P. rotundatus*, Flotow.)

18.—An encysted zoospore, pointed at both ends, altogether green, (*P. rostellatus*, Flot.)

19.—Commencing division of the primordial cell into two.

20.—A young pyriform primordial cell, around which the "enveloping cell" is just beginning to show itself distinct from the primordial cell.

21.—An older cell, with colourless vacuoles.

22.—Commencing division into two; the wholly green, primordial cell, closely surrounded by the enveloping cell, shows a constriction in the middle.

23.—Commencing division into two; each secondary primordial cell has developed an enveloping cell around itself, whilst still within the parent cell.

24.—Commencing division into four.

25.—An unusual and incomplete division into five; four pointed, encysted zoospores, not completely parted after the resorption of the common "enveloping cell," remaining connected by processes arising from the point where the cilia are placed; a smaller portion has become organized into a naked primordial cell, also connected with the others. (Vide fig. 39.)

26.—Only half of the primordial cell consists of the green globular substance; the other half is a colourless granular protoplasm, enclosing in the centre a red substance resembling a nucleus.

27.—An encysted zoospore in the commencement of

Fig.

deliquescence. The primordial cell is resolved into green and red granules, forms clear vacuoles, and is on the point of filling up the enveloping cell.

28.—An encysted zoospore which has deliquesced; the primordial cell has entirely filled the "enveloping cell," and become resolved into green and red granules.

29.—An encysted zoospore, which has passed into the "still" condition; the spherical, wholly green, primordial cell, has acquired a closely investing cellulose coat, whilst the "enveloping cell," has become resolved into a mucid substance, on which the cilia are no longer visible.

30.—Division of a "still" cell into two elliptical secondary cells, which present a nucleus in the centre, and remain enclosed by the parent cell, become gelatinous. (Vide fig. 7.)

31.—Division of a "still" cell into eight: the parent cell is resolved into a gelatinous substance, and encloses eight small, cylindrical, red zoospores.

32.—Two of these zoospores after their escape.

33.—Yellow-green "still" cell, with gelatinous envelope.

34.—An encysted zoospore, the primordial cell of which is on the point of division into two. The remote, enveloping cell supports the two cilia, whose presence is only indicated by the current they produce.

35.—An elliptical encysted zoospore, the primordial cell of which is already divided into two secondary cells. The vibratile cilia and transparent projections upon which they are placed, are visible within the parent-cell.

36.—One of the secondary cells after its liberation.

37.—Division of an encysted cell into four; the globular, green, granular, secondary cells, almost fill the parent-cell; arranged something like the cells in *Gonium pectorale*.

38.—Division of an encysted zoospore into eight globular,

Fig.

secondary, primordial cells, which almost fill the parent-cell. Their disposition resembles that of *Botryocystis morum*, Kg.

39.—Incomplete division of an encysted zoospore into four, also encysted secondary cells, which remain connected in the centre after the removal of their common enveloping cell. This seems to represent a further development of that given in figure 25.

40.—Division of an encysted cell into thirty-two minute, spherical, entirely green, primordial cells, which completely fill their delicate parent-cell. This arrangement corresponds to the genus *Sphærastrum tesserale*, Kg., or to *Uvella virescens*, Ehr., or to *Syncrypta volvox*, Ehr.

41.—Zoospores from the last-described form escaped from the parent-cell. One of them (*a*) shows the formation of a membrane around it.

42.—An encysted zoospore with a spherical primordial cell, the green, non-granular contents of which, are retracted to one side, in a crescentic form, whilst a colourless vesicle occupies the other half. This modification appears to depend upon a deficient supply of water.

43.—A red cell, which, by desiccation, has become colourless, showing grumous contents with oil-globules.

44.—A large red "still" cell, the contents of which are divided into numerous (64?) segments.

45.—A red encysted cell.

46.—A red "still" cell, originating in the transition of the cell represented in fig. 45 into the "still" condition.

47.—An encysted zoospore, treated with iodine and sulphuric acid.

*** All the figures are magnified under a power of 500 linear.

INDEX OF GENERA OF MICROSCOPIC ALGÆ TREATED IN THIS VOLUME.

C. AND J. ADLARD, PRINTERS, BARTHOLOMEW CLOSE.

REPORT

OF THE

COUNCIL OF THE RAY SOCIETY,

Read at the Tenth Anniversary Meeting, held at HULL, *Sept. 12th*, 1853;

W. SPENCE, Esq., F.R.S., in the Chair.

The Ray Society was established in the year 1844, for the purpose of publishing and supplying to its Members, original works, translations, and reprints of works, that were not likely, on account of their expense, to be published in the transactions of existing societies, or to be undertaken by publishers, in consequence of the improbability of their meeting with a remunerative sale. The Council of the Ray Society feel it necessary to remind the Members of this fact, as it will explain, on the one hand, why their works cannot be of a highly popular character, and on the other hand, why they feel that they have a claim on the support of all those who are anxious to promote the study of Natural History Science. As to how the Society has fulfilled its mission, they would appeal to the twenty-two volumes which have already been issued to the Members. Many of them are standard works on the subjects to which they have been devoted, and all have contributed to advance a knowledge of the principles and facts involved in the study of the sciences of Zoology and Botany.

Since the last Anniversary Meeting of the Society, which was held at Belfast, in September, 1852, the following works have been distributed to the Members:

1. Vol. I of Mr. C. Darwin's Monograph of the family of Cirripedes; including the Sea-acorns (*Balani*).
2. Vol. III of the Bibliographia Zoologiæ et Geologiæ, by Professor Agassiz; edited by H. E. Strickland, Esq., F.R.S.

The Council had hoped that they should have been able to have announced at the present Meeting the distribution of two other works, but circumstances over which they have had no control have prevented their being able to do so. One of these works, the sixth and last part of Messrs. Alder and Hancock's work on the Nudibranchiate Mollusca, has been deferred on account of the wish of the authors to use all the materials in their possession up to the present time, and thus to render the work as complete as possible.

The publication of the second volume of Mr. Darwin's work on the Cirripedes has also been delayed, in order to enable the author to include in it his researches upon collections of animals belonging to this family which have been recently made.

Instead of a mixed volume of papers by foreign authors on subjects in Zoology and Botany, the Council have resolved, at the request of many of their botanical Members, to publish a translation of Dr. A. Braun's work on the Rejuvenescence of Plants. This work will be edited by Mr. Henfrey; and Meneghini's paper on the Animal Nature of the *Diatomaceæ*, and an abstract of Cohn's paper on the Natural History of *Protococcus pluvialis*, will be added. This book is nearly completed, and will be speedily issued, with the sixth part of Messrs. Alder and Hancock's Monograph. The publication of Hoffmeister's work on the Reproduction of the Cryptogamia, which the Council had thought of translating, they are glad to state has been undertaken by Mr. Highley, and they hope will shortly appear, so as to be accessible to the English student.

For the year 1854, the Council propose, if no unforeseen circumstance arise, to publish the fourth volume of the Bibliography of Zoology and Geology. They have also great pleasure in announcing that they have received the plates of Professor Allman's work on the British Fresh-water Zoophytes, and that this work, with thirteen coloured plates, in imperial 4to, will be one of the publications for 1854.

The Council would especially call the attention of the Members to their financial condition. Last year they had to report that £657 were due on that and the past years. They have now to report that £707 are due. Of this sum:

£336	18*s*.	is	due for	1853,
£144	13*s*.	„	„	1852,
£91	6*s*.	„	„	1851,
£84	12*s*.	„	„	1850,
£50	8*s*.	„		1847-8-9.

During the past year the number of Members who have withdrawn or died amounts to 45, and 8 Members have been added; so that there are now 709 on the list.

The Council would again urge that the only limits they have to their labours are the funds derived from their subscriptions, and that just in proportion as these are increased, are they enabled to publish a larger amount of matter to present to the Members for their subscription of one guinea per annum.

The Council appointed, last year, J. S. Bowerbank, Esq., Treasurer; and Dr. G. Johnston, of Berwick-on-Tweed, and Dr. Lankester, London, Secretaries.

Abstract of Treasurer's Account from June, 1852, *to May*, 1853.

RECEIVED.	£	s.	d.	EXPENDED.	£	s.	d.
Cash in hand at last audit	86	11	6	Bookbinding	29	15	0
By subscriptions	542	17	0	Engraving, printing, &c.	76	15	10
				Printing letter-press	226	0	3
				Editing	54	6	0
				Collector	24	10	7
				Books	2	13	6
				Secretary	125	0	0
				Advertising	8	3	3
				Local Secretaries' Expenses	9	10	0
				Postage, Stationery, &c.	9	6	11
					566	1	4
				Cash in hand	63	7	2
	£629	8	6		£629	8	6

Auditors:

GEORGE SHADBOLT.
JAMES TENNANT.

Moved by PROFESSOR BALFOUR; seconded by R. M'ANDREWS, Esq.:

That the Report now read be adopted, and printed for circulation amongst the Members of the Society.

Moved by J. HOGG, Esq.; seconded by R. J. BELL, Esq.:

That the thanks of this Meeting be given to the President, Council, Treasurer Secretaries, Local Secretaries, and Auditors, for their services during the past year.

Moved by Dr. LEE; seconded by A. STRICKLAND, Esq.:

That the following Gentlemen be requested to act as a Council for the following year.

PROFESSOR D. T. ANSTED M.A. F.R.S. F.L.S.
CHARLES C. BABINGTON, Esq., M.A. F.R.S. F.L.S.
ROBERT BALL, Esq., LL.D. M.R.I.A., Sec. R.Z.S.I.
PROFESSOR BELL, Sec. R.S., F.L.S.
J. S. BOWERBANK, Esq., F.R.S. F.L.S.
GEORGE BUSK, Esq., F.R.S. F.L.S.
W. B. CARPENTER, M.D. F.R.S.
PROFESSOR DAUBENY, M.D. F.R.S.
SIR P. de M. G. EGERTON, Bart., M.P. F.R.S.
PROFESSOR EDWARD FORBES, F.R.S. F.L.S.
PROFESSOR GOODSIR, M.D. F.R.S. L. and E.
A. HENFREY, Esq., F.R.S. F.L.S.
SIR W. JARDINE, Bart., F.R.S.E. L.S.
REV. LEONARD JENYNS, M.A. F.L.S.
G. JOHNSTON, M.D. LL.D. F.R.C.S.E.
E. LANKESTER, M.D. LL.D. F.R.S. F.L.S.
PROFESSOR OWEN, D.C.L. F.R.S. F.L.S.
ROBERT PATTERSON, Esq., Pres. Nat. Hist. Soc. Bel.
PROFESSOR JOHN PHILLIPS, F.R.S.
PRIDEAUX J. SELBY, Esq., F.L.S.
W. SPENCE, Esq., F.R.S. F.L.S.
HUGH E. STRICKLAND, Esq. M.A. F.R.S. F.G.S.
G. WATERHOUSE, Esq., F.Z.S.
W. YARRELL, Esq., F.L.S.