BOOK I.

GENERAL MORPHOLOGY.

CHAPTER I.

MORPHOLOGY OF THE CELL.

SECT. 1. **Preliminary Inquiry into the Nature of the Cell.**—The substance of plants is not homogeneous, but is composed of small structures, generally indistinguishable by the naked eye; and each of these, at least for a time, is a whole complete in itself, being composed of solid, soft, and fluid layers, different in their chemical nature, and disposed concentrically from without inwards. These structures are termed Cells. For the most part, a group of them are in close contact and firmly united; they then form a Cell-tissue. But every plant which completes its term of life has at least one period in which certain cells separate themselves at definite points from the union, and, after isolation, each begins for itself a separate course of life (spores, pollen-grains, ovum-cells, gemmæ).

The shape and size of the whole plant, the form, structure, and volume of the cells are subject to regular changes, and their nature cannot therefore be inferred from the knowledge of one single phase, but rather from the sum of changes which may be called the life-history of the cell. And as, moreover, each cell fulfils its own definite part in the economy of the plant, *i. e.* is specially intended for certain chemical or mechanical purposes, so also cells show a variety in form, which corresponds to the different functions. These differences, however, do not usually arise until the cells have passed through their earlier stages; the youngest cells of a plant are only slightly distinguishable from one another.

The law of configuration that prevails in all cells is also more clearly evident in the young state; the more the developing cells assume the special purposes for which they exist, the more difficult it becomes to recognise this law. The morphological law of cells, thus briefly pointed out, we will now endeavour to expound more in detail.

By far the largest proportion of cells in the living succulent parts of plants, *e. g.* young roots, leaves, internodes, fruits, are seen to be made up of three concentrically-disposed layers: firstly, an outer skin, firm and elastic, the Cell-membrane or Cell-wall, consisting of a substance peculiar to itself, which we call Cellulose (Fig. 1, *B*, *C*, *h*). Close up to the inner side of this entirely closed membrane is a second layer, also entirely closed, the substance of which is soft and inelastic, and always contains albuminous matter; H. v. Mohl, who first discovered this substance, has given it the very distinctive appellation of Protoplasm [1]. In the condition of cells now under consideration it forms a sac enclosed by the cell-wall, in which usually also other portions of protoplasm are present in the form of plates and threads (Fig. 1, *B*, *C*, *p*). Absent from some of the lowest organisms, but present in all the higher plants without exception, there lies imbedded in the protoplasm a roundish body, the substance of which is very similar to that of the protoplasm, the Nucleus (Fig. 1, *A*, *C*, *k*). The cavity enclosed by the protoplasm-sac is filled with a watery fluid, the Cell-sap (Fig. 1, *B*, *C*, *s*). And besides this, there are also very commonly found in the interior of the cell granular bodies, which however may be passed over for the moment.

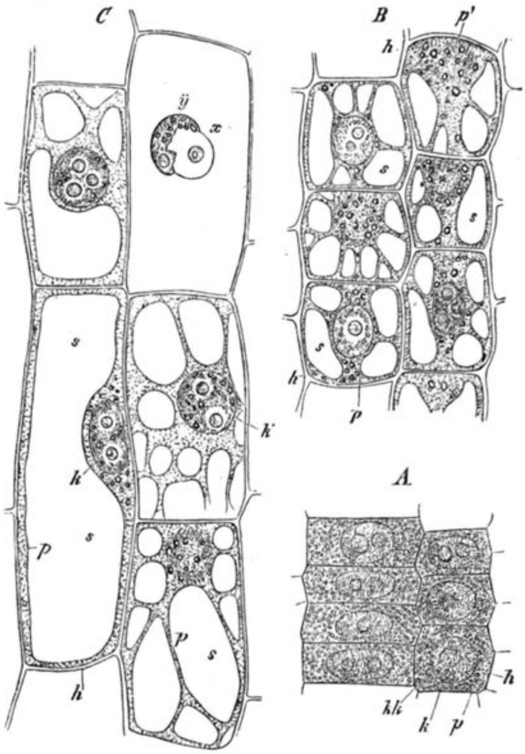

FIG. 1.—Parenchyma-cells from the central cortical layer of the root of *Fritillaria imperialis*; longitudinal sections (×550). *A* very young cells lying close above the apex of the root, still without cell-sap. *B* cells of the same description about 2 mm. above the apex of the root; the cell-sap *s* forms separate drops in the protoplasm *p*, behind which lie walls of protoplasm; *C* cells of the same description about 7—8 mm. above the apex of the root; the two cells to the right below are seen in a front view; the large cell to the left below is in section; the cell to the right above is opened by the section; the nucleus shows, under the influence of the penetrating water, a peculiar appearance of swelling (*x*, *y*).

Thus, then, cells in the stage of development now described consist of a firm membrane, soft protoplasm (including the nucleus), and fluid cell-sap. At first, however, the sap is wanting; if the same cells be examined in a very early state of their development they are smaller (Fig. 1, *A*), their cell-wall thinner, and the protoplasm forms a solid body in the middle of which lies the nucleus, at this time relatively very large (*k*). The cell-sap first appears when the whole cell is increasing quickly in volume (Fig. 1, *B*); it presents itself originally in the form of drops (vacuoli) in the interior of the protoplasmic body (Fig. 1, *B*, *s*); at a later period these usually coalesce, and form a single sap-cavity (Fig. 1, *C*, *s*) which is enclosed by the now sac-like hollow substance of the protoplasm.

[1] H v. Mohl, Ueber die Saftbewegungen im Inneren der Zellen.—Bot. Zeitg. 1846, p. 73.

In their earliest state the cells of the wood and cork of trees show also conditions of development which correspond essentially to those represented in Fig. 1. In these cells, however, a new condition follows very soon after the appearance of the cell-sap; the protoplasm containing the nucleus disappears, leaving the cell-wall filled either with air or with water. Older wood and cork when completely formed thus consist of a mere framework of cell-walls.

But now arises an important difference between the behaviour of those cells which enclose a protoplasmic body, and of those from which it has already disappeared. The former only can grow, develop new chemical combinations, and, under certain conditions, form new cells. The latter are never capable of further development; if they are wood, they are of service to the plant only from their firmness, power of absorbing water, and from their peculiar form; if cork, they form protecting envelopes which surround the living succulent cellular tissue.

Since then no further process of development can take place in the cells which no longer contain protoplasm, it may be concluded that the latter is the proximate cause of growth. We shall see in a future paragraph that the development of each cell begins with the formation of a protoplasmic body, and that

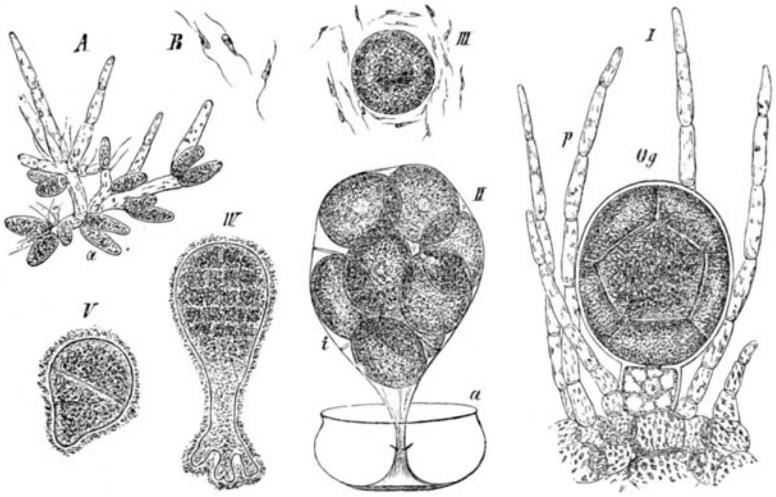

FIG. 2.—Sexual reproduction of *Fucus vesiculosus*; *A* cellular filaments bearing antheridia; *B* spermatozoids; *I* Oögonium, *Og* with paraphyses *p*; *II* the exterior membrane *a* of the oögonium is split, the inner *i* protrudes, containing the ova; *III* an escaped ovum, with spermatozoids swarming round it; *V* first division of the fertilised ovum: *IV* a young Fucus resulting from the growth of the fertilised ovum (after Thuret, Ann. des Sci. Nat. 1854, vol. ii). (*B* × 330; all the rest × 160.)

the cell-wall is also generated from it; but the relation of the protoplasm to cell-formation is still more strikingly conspicuous in those cases in which it continues its life for some time as a naked sharply-defined solid body, and only at a later period clothes itself again with a fresh cell-wall, and again takes up cell-sap within itself. We have an excellent example of this in the reproduction of the Fucaceæ. On the fertile branches of these great marine Algæ, of which we may take *Fucus vesiculosus* as an example, large cells are formed in peculiar receptacles, the Oögonia (Fig. 2, *I*, *Og*); the space enclosed by the cell-wall is densely filled with fine-grained protoplasm, which at first presents a homogeneous mass, but at last falls into eight portions, and these, completely filling up the cell-cavity of the oögonium, press against one another, and become polygonal. The wall of the oögonium consists of two layers; the outer one splits, and the inner one protrudes in the form of a sac, which distends by absorption of water; in this enlarged sac the portions of protoplasm become globular (Fig. 2, *II*); then this also bursts, and the protoplasmic bodies, now completely spherical, escape. By the fertilising action of other smaller protoplasmic structures, the spermatozoids, these spherical bodies are excited to further development; out of the interior of the ball of protoplasm (the fertilised ovum) a colourless substance next makes its appearance, which hardens into a closed cell-wall. The newly-formed cell now grows in two different directions in different modes, and produces after further transformations (Fig. 2, *V* and *IV*) a young Fucus-plant.

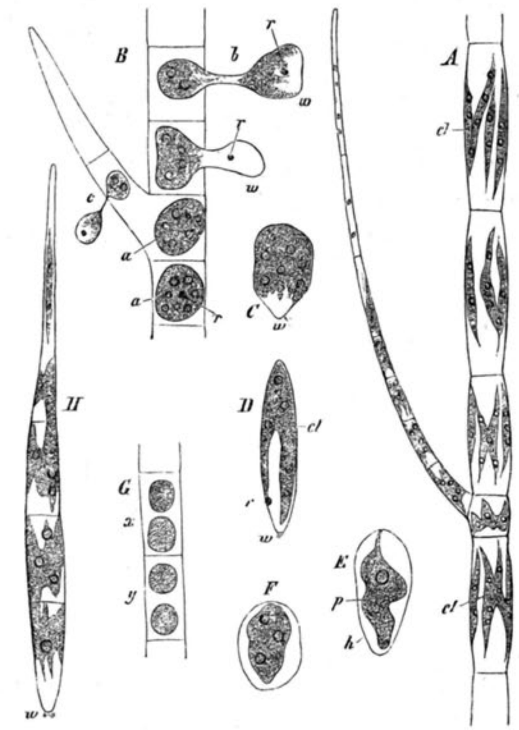

FIG. 3.—*Stigeoclonium insigne* (after Nägeli, Pflanzenphysiol. Untersuchungen, Heft 1); *A* a branch of the Alga consisting of one row of cells, with a lateral branch; *cl* green-coloured protoplasmic structures (chlorophyll), imbedded in the colourless sac of protoplasm of each cell not shown in the drawing; *B* the protoplasmic bodies of the cells contracting and protruding through openings in the cell-wall; *C* swarm-spores still without cell-wall; *D* one come to rest; at *E* and *F* killed; the protoplasm *p* contracts and allows the newly-formed cell-wall *h* to be recognised; *H* a young plant grown from the swarm-spore; *G* two cells of a filament in the act of dividing; the protoplasmic body of each cell (*x*, *y*) has temporarily split into two equal parts, and contracted by addition of a re-agent.

Still more clearly than in these cases does the independence of the protoplasmic body of a cell show itself in the formation of the swarm-spores (zoospores) of Algæ and of several Fungi. Here in many cases, as in *Stigeoclonium insigne* (Fig. 3; *B*, *a*), the protoplasm-sac of a cell filled with cell-sap contracts, lets the water of the cell-sap pass out, and forms a solid roundish lump, which, escaping through an opening in the cell-wall, and impelled by an internal force, swims about in the water (*C*). While it is passing out of the cell-wall, the protoplasmic body shows, by its motions and changes of form, that it is soft and extensible; but, once freed, it assumes a definite specific form, conditioned by an internal force. At last, usually after some hours, the swarm-spore comes to rest; if killed by the proper means, the protoplasmic body contracts (*E*, *F*, *p*), and a fine cell-wall may now be recognised, which it did not possess at the time of its exit, and at the beginning of its swarming. When once at rest, it also changes its form, and increases in volume, while fluid cell-sap collects in the interior. The cell formed in this way now grows in a manner dependent on the specific nature of the plant;—in our example it specially elongates itself (Fig. 3, *D* and *H*),—whereon new changes (in this case, *e.g.*, cell-divisions) begin.

These examples, and many more might be added, show us that the protoplasmic body forms the cell; the cell, in the sense defined above, is evidently only a further form of development of it; the formative forces proceed from it. It has hence become usual even to consider a protoplasmic body of this kind as a cell, and to designate it as a naked membraneless cell or Primordial Cell; its relationship to a cell provided with membrane and cell-sap is somewhat like that of a larva to the perfect insect, which is developed from the larva into the more perfectly matured form.

The development of a swarm-spore, like that of a Fucus-ovum, shows,—as may also be proved in the case of every other cell,—that the substance out of which the cell-wall is formed was already contained in the protoplasm in some form or other which could not be recognised; and so the formation of the cell-wall must be regarded as a separation of matter hitherto contained in the protoplasm. In the same manner the water of the cell-sap, although taken up from without, must nevertheless pass in through the protoplasm; and, while it gathers inside as cell-sap, it takes up from it soluble substances; and so far the formation of the cell-sap also appears as a separation of matter hitherto contained in the protoplasm. We shall see, further on, that the substance of the nucleus also, where it is present, was originally distributed in the protoplasm, and that the nucleus is formed by the collection of certain particles of protoplasm at the centre of the growing cell. Thus the cell provided (by development) with membrane, nucleus, and cell-sap appears as the result of a differentiation of particles of matter hitherto contained in the protoplasm. The essential point is this,—that this differentiation always leads to the formation of concentrically disposed layers, the outermost of which, the cell-wall, is firm and elastic, the middle one, the protoplasm-sac, soft and inelastic. If the cell, as is usually the case, is at first without any sap-cavity, the protoplasm is the less firm and more watery in the middle, or a nucleus in this case is formed, which, at least in young cells, is always more watery than the surrounding protoplasm. When at last the cell-sap makes its appearance, the inner cavity of the cell is always filled with actual fluid, in which the nucleus often takes up a central position surrounded by protoplasm, or, more usually, it approaches, together with the protoplasm, the circumference of the sap-cavity, and becomes parietal. So long as that condition of cell-development in which the cell appears as a sap-cavity bounded by a membrane—certainly the one most commonly seen—had alone been observed, it was correct enough to define the cell as a vesicle; it is obvious, however, that this view does not apply to many true cells, *e.g.* to young tissue-cells (as Fig. 1, *A*), of the true nature of which we should get but a very ill-defined conception were we to regard them as vesicles. The term applies still less to the structure of swarm-spores and of the ova of Fuci.

Sect. 2. **Difference in the Forms of Cells.**—In the conformations described in the previous paragraphs, the development of the cells seldom remains stationary. Still further changes of form usually take place in the separate parts of the cell. The collective volume of the whole cell generally increases for a considerable time with corresponding increase of the cell-sap ; not unfrequently it mounts up to a hundred or even a thousandfold the volume of the cell at the time of its formation. During this increase, the contour—the collective form—of the whole cell, commonly undergoes a change ; if it was at first roundish or polyhedral, it may afterwards become elongated, filiform, bag-like, prism-shaped in length or tabular in breadth, many-armed, or branched. The cell-wall may increase very considerably in thickness, and this thickening is usually not uniform; single spots remain thin, in others the thickened membrane becomes prominent without or within ; strap-shaped prominences, spines, knobs, &c. appear. In the substance of the cell-wall itself, differences also manifest themselves, which result in imparting to it greater firmness, elasticity, or hardness, or, on the other hand, greater softness or pliancy. The protoplasm may, in these processes, decrease more and more in quantity, until at last it forms an extremely thin membrane, which lies so close to the cell-wall that it does not become visible till contraction takes place; after the completion of the growth of the cell-wall it may even entirely disappear. But in many other cases the protoplasm increases with the increase in volume of the cell; it forms a thick-walled sac, the substance of which is endowed with constant motion, while filiform or strap-shaped strings of protoplasm often pass through the sap-cavity of the cell. In those cells which appear externally green, certain portions of the protoplasm become separated, and assume a green colouring; these particles of chlorophyll may appear in the form of bands, stars, or irregular masses; but they usually form numerous roundish granules, and the particles of chlorophyll always appear as parts of the collective protoplasmic substance of a cell. Sometimes, mixed with the green colouring matter which tinges these portions of the protoplasm, are pigments of other colours, red, blue, or yellow (as in Florideæ, Oscillatorieæ, and Diatomaceæ); or the particles of chlorophyll assume, through changes in their colouring matter, other tints, mostly yellow or red. Colouring matters may also appear as dissolved in the cell-sap. The other chemical compounds which are formed in extremely large numbers in the cell, are mostly dissolved in the cell-sap ; but many of them assume definite forms; thus arise granules of fat, drops of oil, and frequently true crystals or crystalline bodies. One of the commonest granular compounds present in almost all plants, with the exception of Fungi and some Algæ and Lichens, is Starch, the grains of which often accumulate in the cell in numbers greatly exceeding all other substances.

The most perfectly developed form of cells is found in certain families of Algæ, the Conjugatæ, Siphoneæ, and Diatomaceæ. Since in these cases one and the same cell unites in itself the organs for all vegetative functions, and at the same time a many-sidedness in the phenomena of life presents itself, the whole cell attains a high degree of differentiation; the separate parts,—the cell-wall, the protoplasmic body, and its contents,—show a variety of structure which does not occur elsewhere concurrently in the different parts of one and the same cell. Hence it happens that the same cell has in these cases often to go through the most diverse metamorphoses, so that besides its manifold development as to size, it also undergoes a series of temporary changes of form. Hence these forms of Algæ become of great importance for an accurate comprehension of the nature of the cell. (Book II. Algæ.) But above all, these cells are distinguished by this,—that, after they have attained the highest grade of development, they are in a condition to divide and to multiply, and at length, sooner or later, give up their cell-wall, contract their protoplasmic body, together with all its serviceable contents (starch, oil, chlorophyll, &c.), expel the water of the cell-sap, and form a new cell.

We may pass over the innumerable intermediate forms, and turn our attention at once to the other extreme, namely those plants of which each usually consists of thousands or even millions of cells, as is the case with Vascular Cryptogams and Phanerogams; and in which at the same time the different parts of the plant undergo an entirely different morphological development, and are adapted to different functions for the support of the whole. Here then we find that certain cells never attain their full development, they remain constantly in the condition of youth which is represented in Fig. 1, *A*; these however assist the whole by continually giving rise to new cells by division, which then, on their part, undergo a further development. Such cells, which serve exclusively for the purpose of producing new ones, are found at the extremities of all roots and branches, and abundantly at the base of leaves. The cells produced in these positions undergo a different development according to their situation, and usually in such a way that whole aggregations of them into layers or strings follow the same course of development. Some grow quickly in all directions, their wall remains thin, the great bulk of their protoplasm becomes transformed into chlorophyll, they are rich in cell-sap, and serve, as we shall see hereafter, for assimilation, *i. e.* the production of new organic substance, which is formed out of the elements of the absorbed nutritive material; in other parts of the same plants the cells extend greatly in length, their diameter remains small, they form no chlorophyll; a certain number remain succulent and serve to conduct certain assimilated substances; other cells of the same string thicken their walls rapidly in many ways, their septa become absorbed, numerous cells in the same row join into a long tube (vessel), from which the protoplasm and the cell-sap disappear; they serve then as air-passages for the interior of the plant. In their neighbourhood are formed the wood-cells; they are mostly fibre-like, extended in length, their wall greatly thickened, and its substance chemically changed (lignified); they form collectively a firm framework which supports the remaining tissues, lends firmness and elasticity to the whole, and is especially adapted for the rapid conduction of water through the tissues of the plant. In the tissue of tubers, bulbs, and seeds, most of the cells remain thin-walled; they become filled in the interior with albuminous substances, starch, fat, inuline, &c., which afterwards, when new organs are being formed, serve as material for the construction of new cells. In the same manner a considerable series of other forms of tissue could be adduced, cork, the testa of seeds, the stone of stone-fruit, &c., which all alike attain the needful firmness and strength by a peculiar development of their cell-walls, in order to serve as protective envelopes for the other masses of cells which are still capable of further development; their contents disappear as soon as the cell-wall has assumed these properties, and their purpose has been fulfilled.

Each of the forms of cell hitherto spoken of, occurring in one and the same plant, thus serves especially or exclusively for one purpose only; in correlation with this, either the cell-wall, the protoplasmic body, the chlorophyll, the cell-sap, or its granular deposits, is specially developed. Very commonly these specialised cells lose the power of reproduction and of multiplying by division; when they have fulfilled their function, they disappear, or their woody frame-work, the cell-wall, alone remains. The whole plant, of which these cells form a part, continues to remain as such; at definite places it possesses cells, which, at the proper time, again produce new masses of cells, and these again are adapted to fulfil for the time all these functions.

Sect. 3. **Formation of Cells**[1].—The formation of a new cell always commences with the re-arrangement of a protoplasmic body around a new centre;

[1] H. von Mohl, Vermischte Schriften botanischen Inhalts, Tübingen 1845, pp. 65, 84, 362.—Schleiden in Müller's Archiv, 1838, p. 137.—Unger, Botan. Zeitung, 1844, p. 489; H. v. Mohl,

the material required is always afforded by protoplasm already present; the newly constituted protoplasmic body clothes itself, sooner or later, with a new cell-wall. This is the only process common to all reconstruction of cells. A description which goes more into detail requires a distinction to be at once drawn between different cases, or we shall be led into erroneous generalizations, since there is great variety in the mode in which new cells are formed.

It appears to me convenient and natural to distinguish three principal types:—(1) The Renewal or Rejuvenescence of a Cell; *i. e.* the formation of one new cell from the whole of the protoplasm of a cell already in existence; (2) The Conjugation or Coalescence of two (or more) protoplasmic bodies in the formation of a Cell; (3) The Multiplication of a Cell by the formation of two or more protoplasmic bodies out of one. Each of these types shows a series of variations and transitions into the others. Great diversity arises, especially in the multiplication of cells. Two cases are here to be distinguished first of all, according as a part only of the protoplasm of the mother-cell is applied to the formation of the new cells (Free Cell-formation), or as the whole mass passes over into the daughter-cells (Division). The last, by far the most common case, again exhibits variations, according as the masses of protoplasm, which become separated and then collect around new centres, expel water and contract, and become globular, or not, and according as the cell-wall is secreted during the division or only after the complete formation of the new cell, and even after the appearance of cell-sap and nuclei.

In the course of the vegetation of a plant, different forms of cell-formation are brought into play. On Cell-division depends the formation of the vegetative parts of the plant, the production of the *Cell-tissue;* Free Cell-formation occurs in the production of the ascospores of Fungi and Lichens, and in the embryo-sac of Phanerogams; Cell-formation by Conjugation is limited, in its typical form, to single groups of Algæ and Fungi for the purpose of reproduction; the Renewal or Rejuvenescence of Cells is found in the formation of a single swarm-spore out of the whole contents of a vegetative cell in many Algæ; and analogous phenomena occur in the sexual reproduction of Cryptogams.

In what follows I purpose to give a summary of the different kinds of cell-formation according to the principles already indicated. The brevity required in an introductory treatise will be my excuse if I omit the details necessary for a more accurate knowledge.

A. Cell-formation by Renewal or Rejuvenescence of a Cell.—A good example is afforded in the formation of the swarm-spores of *Stigeoclonium insigne* (Fig. 3,

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Botan. Zeitung, 1844, p. 273.—Nägeli, Zeitschrift für wiss. Botanik, I. 1844, p. 34, III, IV, 1846, p. 50.—A. Braun, Verjüngung in der Natur, Freiburg 1850, p. 129 et seq.—Hofmeister, Vergleichende Unsersuchungen über die Embryobildung der Kryptog. u. Conif., Leipzig 1851.—De Bary, Untersuchungen über die Familie der Conjugaten, Leipzig 1858.—Nägeli, Pflanzenphys. Untersuchungen, Heft I.—Pringsheim, Jahrb. für wiss. Botanik, I. 1858, pp. 1, 284, II. p. 1.—Hofmeister, Lehre von der Pflanzenzelle, Leipzig 1867. [Schleiden's Contributions to Phytogenesis are in Taylor's Scient. Mem., vol. II. pp. 281-312, and Sydenham Society, 1847; Braun's Rejuvenescence was published by the Ray Society in Bot. and Phys. Mem. 1853; and Nägeli on Vegetable Cells by the same Society in their Reports and Papers on Botany, 1845 and 1849.]

page 4); the whole contents of a vegetative cell of a filament contracts, expels a portion of the water of the cell-sap; the arrangement of the differentiated protoplasmic body is changed, the bands of chlorophyll disappear; its form alters as it escapes from its cell-wall; from almost cylindrical, the protoplasmic body becomes ovoid, and shows a broad green and a narrower hyaline end; after the swarming is completed, the latter becomes the base, the green end alone grows at the apex as soon as the new cell clothes itself with a cell-wall. The observations of Pringsheim on Oedogonium also show that the direction of growth of the renewed cell is at right angles to the original direction of growth before the renewal; for the hyaline, or rooting-end of the swarm-spore, which afterwards attaches itself, is formed on the side (Fig. 4, *A*, *E*), not at the upper or lower end of the protoplasmic body. An essentially different arrangement in space of the entire protoplasmic body of the cell also takes place; the transverse becomes the longer diameter of the cell and of the plant arising from it. The material remains, as far as can be seen, the same, but its arrangement is different; this is morphologically determinate, and every new formation of cells depends essentially on a fresh arrangement of protoplasm already in existence; hence the rejuvenescence of a cell not only may but must be regarded morphologically as the formation of a new one.

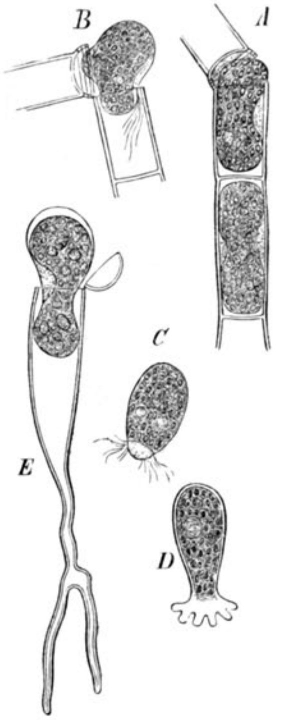
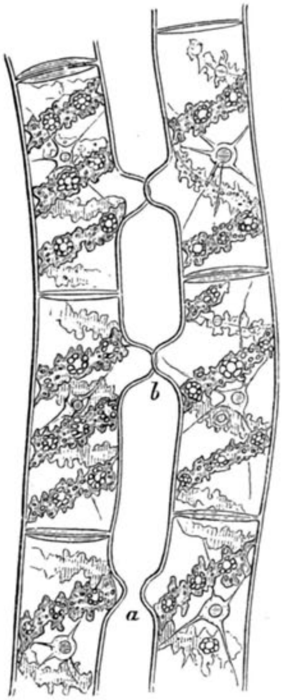


FIG. 4.—*A*, *B* escape of the swarm-spores of an Oedogonium; *C* one free in motion; *D* the same after it has become fixed and has formed the attaching disc; *E* escape of the whole protoplasm of a germ-plant of Oedogonium in the form of a swarm-spore (×350). (After Pringsheim, Jahrb. für wiss. Bot. I. pl. 1.)

B. Cell-formation by Conjugation.—The protoplasmic bodies of two or more cells coalesce to form one common protoplasmic body which surrounds itself with a cell-wall, and becomes endowed with the other properties of a cell. For the elucidation of this process, which presents many variations, we may observe the conjugation of one of our commonest filamentous Algæ, *Spirogyra longata* (Figs. 5, 6). Each filament (Fig. 5) consists of a row of similar cylindrical cells, each of which contains a protoplasm-sac; this encloses a relatively large quantity of cell-sap, in the midst of which hangs a nucleus, enveloped in a small mass of protoplasm, and attached to the sac by threads of the same substance; in the sac lies a band of chlorophyll, which is spirally coiled, and at definite places contains grains of starch. In this case the conjugation always takes place between the adjacent cells of two more or less parallel filaments. A preparation is made for it by the formation of lateral protuberances, as represented in Fig. 5, *a*; these continue to grow until they meet (*b*). The protoplasm-sac of each cell concerned then contracts; it detaches itself sharply from the surrounding cell-wall; rounds itself into an ellipsoidal form, and contracts still more by expulsion of the water of the cell-sap. This occurs simultaneously in the two conjugating cells. Next the cell-wall opens between the two protuberances (Fig. 6, *a*), and one of the two ellipsoidal protoplasmic bodies forces itself into the connecting channel thus formed; it glides slowly through it into the other cell-cavity, and as soon as it touches the protoplasmic body contained in it, they coalesce (Fig. 6, *a*). After complete union (Fig. 6, *b*) the united body is again ellipsoidal, and scarcely larger than one of the two which compose it; during the union a contraction has evidently taken place with expulsion of water. The coalescence gives the impression of a union of two drops of fluid; but the protoplasm is never a fluid; and, independently of other circumstances, there is a fact that shows that altogether peculiar forces are here active which are absent from all fluids;—the spiral band of chlorophyll of each of the two conjugating protoplasmic bodies is preserved in the contraction; it only becomes closely drawn together; during



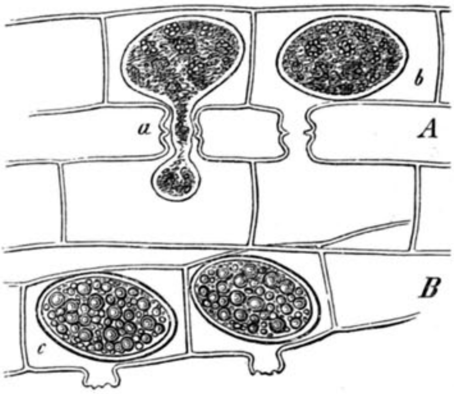


FIG. 5.—*Spirogyra longata*. Cells of two filaments preparing for conjugation, they show the spirally coiled bands of chlorophyll in which, at different places, lie wreath-like arrangements of starch-grains; small drops of oil are also distributed through them (cf. sect. 6); this is the behaviour of the chlorophyll after the action of strong sun-light; the nuclei are also to be seen in the cells, each surrounded by protoplasm, threads of which touch the cell-wall in different places; *a* and *b* are the protuberances preparing for conjugation (×550).

FIG. 6.—*Spirogyra longata*. *A* Cells in the act of conjugation; at *a* the protoplasmic body of one cell is passing over into the other; at *b* this has already taken place; the band of chlorophyll together with starch-grains is still partially recognisable. *B* the young zygospores surrounded by membrane; the protoplasmic body contains numerous drops of oil (×550).

the coalescence the ends of the two bands of chlorophyll place themselves together in such a manner as to form one band. The conjugated protoplasmic body clothes itself with a cell-wall, and forms the body called a Zygospore, which germinates after a period of repose of some months, and developes a new filament of cells. With greater or smaller deviations from this plan, conjugation takes place in a group of Algæ comprising a large number of species, the Conjugatæ, among which the Diatoms must be included, and in some Fungi. In the latter more considerable deviations occur (*e.g.* Syzygites, *Mucor stolonifer*). In *Spirogyra nitida* it also happens (according to De Bary, Conjugaten, p. 6) that one cell conjugates with two others, and takes up their masses of protoplasm; in these cases a Zygospore is the product of the contents of three cells. In the Myxomycetes the swarm-spores (Myxo-amœbæ), which are endowed with a peculiar motion, coalesce gradually in great numbers, and finally form large, motile, membraneless protoplasmic bodies, the Plasmodia, which only at a subsequent period are transformed into numerous cells.

In the cases hitherto considered, the uniting protoplasmic bodies are of equal size; the process of fertilisation in many Cryptogams differs only in the fact that the two protoplasmic bodies which coalesce are of unequal size, and otherwise of different properties. In Book II we shall treat in detail of the reproduction of Cryptogams; here we need only state that the male, motile fertilising bodies (Spermatozoids) of Cryptogams are naked protoplasmic bodies, which are considered to be primordial cells; in the female organ of these plants is a cell which opens outwardly, and contains a protoplasmic body which is fertilised by the spermatozoids. In cases which have been accurately observed (Oedogonium, Vaucheria), these coalesce