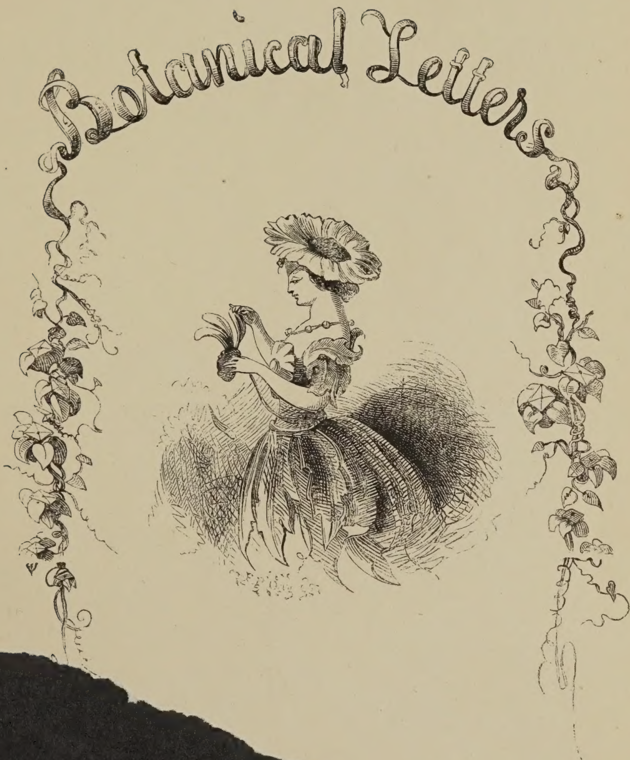
Botanical Letters To a Friend

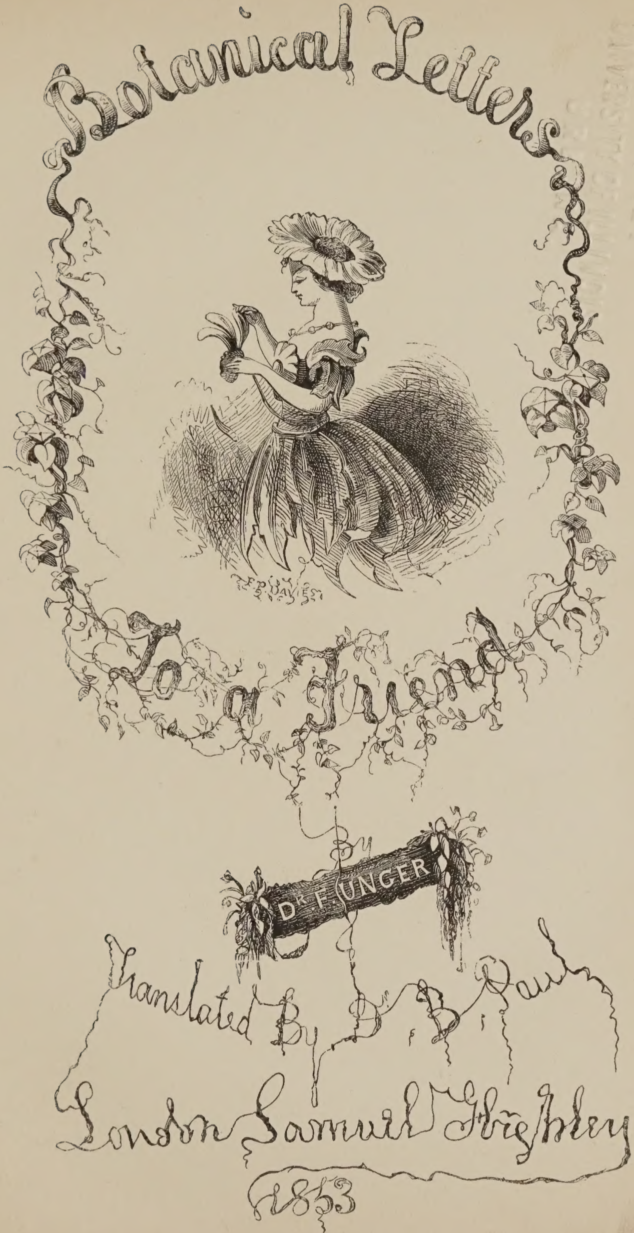
Half-a-Crown.

Doerner


Botanical Letters

LONDON:
PRINTED BY W. CLOWES AND SONS, STAMFORD STREET
AND CHARING CROSS.

A CALAMITE FOREST OF THE COAL PERIOD.


Botanical Letters
To a Friend
By
Dr. F. Unger
Translated By Dr. B. Paul
London Samuel Highley
1853

CONTENTS.

BOTANICAL LETTERS.

LETTER I.

DEFINITION OF BOTANY.

It cannot be denied that at the present day the natural sciences have acquired a prominence in the arena of intellectual activity superior to any other branches of knowledge, and that they especially characterise both the spirit and tendency of the age, as well as the direction in which it is striving to develope itself. There exists, at the same time, between these sciences a relationship so intimate; the support which they mutually afford to each other is so manifold in its nature; their transition into each other is so frequent; and they progress with such increasing impetus; that there is, indeed, a difficulty in doubting that, thus united, they will arrive at some valuable result, sooner than has hitherto been the case, while cultivated in a different spirit.

The investigation of nature and its activity is, moreover, so elevated a field of mental exercise, that, to the healthy and undepraved mind, it affords the most congenial and advantageous preparation for the higher intellectual occupations of life.

Although in former periods of culture the natural sciences have either been disregarded by the generality of men, or, when cultivated, were interwoven with many foreign elements, this must, probably, be regarded as a result rather of the impatience with which men strove to reach the goal of their thought and labour, than of any want of conviction that the solution of more difficult problems must give place to that of the less complicated ones.

Nevertheless, those branches of knowledge even which are concerned with the most simple conception of nature in its material aspect, have shared the same fate as all the other natural sciences; so that it is impossible to do otherwise than admit that the former, no less than the latter, are the offspring of modern time.

In this respect, mineralogy, botany, and zoölogy, are upon precisely the same footing. Whatever they may be they have become within a very short and recent period. Since several other natural sciences have already found their representatives before the general public, I will here venture to discuss the second of those named above; to examine somewhat more closely into its present condition; and not only to show in what kind of connexion it stands to its more immediate congeners, but likewise to determine what is its position in the general range of natural science. The interest which has always been taken in the *scientia amabilis* will, perhaps, be a sufficient excuse for my bringing it forward—of course in its holiday attire.

When we reflect upon the spirit which animated the labours of a number of investigators, especially during the latter part of the last century, and led them to seek for some knowledge of the extent and distribution of the plant world; its rich treasure of forms; its phenomena of vital activity; and even of its several phases of creation; the advance which has been made in botanical science cannot be regarded as other than satisfactory. The attainment of this happy result has been contributed to, not only by botanists, but certainly in an equal degree by physicists, chemists, geognosts, geologists, etc. New, and hitherto unthought-of, questions have not only been raised on all sides, but they have likewise either met with a satisfactory solution, or the path to it has already been struck out. The modest demands which were hitherto made upon the man skilled in the knowledge of plants have been considerably augmented; and the mere acquaintance with the coiffure, uniform, rank, and merit of the descendents of Greece's most fruitful goddess—subjects which in the age of Linnæus constituted the corner-stone of all botanical erudition—is now, in consequence of the repeated metamorphoses of this science, either entirely put on one side, or employed only as a groundwork, and that in a very restricted sense.

The botanical science of the present day is constructed upon an entirely different plan from that of an earlier period, and, consequently, has a tendency and aim equally distinct and different.

Although the necessity for a knowledge of the names of plants remains, upon the whole, the same as hitherto, although from the constantly-increasing material, and continual discovery of new forms, the distinctions between them are unceasingly multiplied, and it is requisite that the muster-roll should be maintained in good order, still these occupations have not wholly engrossed the attention of botanists. By an appropriate division of labour, it has been rendered possible for some to consider more general questions relating to the actual nature of the things we call plants; in what consist their life and functions; what connects them with the outer world; and what may be their purpose and destiny in the great economy of nature—questions which lie far beyond the boundaries of the botany of any earlier period.

When these investigations into the nature of the plant had once been entered upon, the transition into another department of science followed as a natural consequence. But, so long as these questions were considered only in their universal form, the results arrived at did not amount to much more than abstract and questionable hypotheses; it was not until, separating the general from the special point of view, investigators turned their attention to details, and attempted to reach the solution of the general problem by the study of particular instances, that their labours were crowned with anything like success. The fortunate turn thus taken in the cultivation of botany is but of recent date, and its result is in so far certain that it bids fair to give rise to a physics of plant organism.

But how far distant we still are from this end may easily be seen by the most superficial glance at botanical literature which, with no lack of voluminous works, does not possess one which accounts for any, even of the most ordinary, phenomena of plant life in a manner at all satisfactory. All the plant treasures that have been collected by naturalists of every clime; by travellers in the most remote corners of the world, not unfrequently at the risk or even sacrifice of their lives, and deposited in museums, botanical gardens, etc., where they have been studied and arranged with the most laborious and persevering industry; all these can do no more than furnish the raw material for scientific investigation which has yet to be undertaken. The matter is in nowise different with regard to the experience which has been gained in the culture of plants either of one kind or the other. Neither agriculture, nor forestry, the growth of fruit, or gardening, is yet advanced beyond the most meagre empiricism, and, unfortunately, occupy time and talents which are capable of more advantageous application. But we cannot reasonably be surprised at this, as we have already admitted being in the dark with regard to the most simple operations of plant life. It is but a little while that we have known, and that only in an imperfect manner, how the plant is nourished, how it grows, increases, and propagates. There is not a single plant of whose gradual alterations in form and condition, from the commencement of its growth to the termination of its existence, we have any knowledge. In this great field of scientific discovery there is as much to be done by the botanist as by the geographer in the interior of Africa or Australia.

But while contemplating that which lies before us, we will not look backwards with disdain; we will not be guilty of ingratitude to our predecessors, but congratulate ourselves on the results of their labours, however deficient they may be, bearing well in mind that it is only by means of them we are enabled to make any certain progress. Undoubtedly we shall have gained much merely in possessing some guide through this unknown region; and it is no less a saving of time and labour to be prevented from seeking or forcing an escape from our ignorance, where such is impossible. All this has already been achieved. There is, in this respect, no longer any impediment to our further progress. If, at the same time, we have returned again to the point from which we started, still the oppressive consciousness of an insurmountable obstacle has been removed, and we are in a position to press forward with renewed energy towards the desired object.

In this prospective and retrospective view of what has already been achieved, and what still remains to be done in this field, I will now attempt to present my readers with a delineation of plant life, as well individually as in its entire extent, constituting a portion of the vital phenomena of our planet.

The plant considered as a most skilfully-planned chemical laboratory; a most ingenious mechanism for the play of physical forces; as one of the simplest, and, consequently, most sublime structures ever designed or executed; the extent and distribution of this form of existence, made up of an indefinite number of parts; as well as the unity of style, and its developement in successive ages—these are the subjects which it is my intention to bring before you in the following letters.

Commencing with that which is most simple in plant life, the starting-point of our contemplations will be to trace back this complex structure to its several primary elements; whence we will follow out the construction of the individual objects; the general plan to which, notwithstanding their diversity, they are all conformable, and, as we shall everywhere recognise, the same principle of unity; finally, recombine the primary elements under a higher general conception.

May you possess inclination and patience to accompany me in the much-trodden, but unfortunately little-known, path I have marked out, and that not only without fatigue, but, perhaps, with a gain of intellectual activity.

LETTER II.

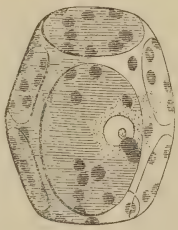
THE ELEMENTARY PARTS OF THE PLANT.

None who have to any degree accustomed themselves to the contemplation of natural objects, will be disposed to regard the plant merely as an aggregate of leaves, stalks, flowers, etc., in which the figure, colour, nature of the substance, etc., have been determined and arranged by accident. A regular succession of the several organs, a certain normal developement and unity of form and colour, must have attracted the notice of all who have attentively examined even a few plants, and compared together their respective organs. It is, moreover, impossible to fail in arriving at a conviction that there is throughout the plant world a conformity to some general plan; a truth of which a very striking indication may, without difficulty, be recognized in the arrangement of the ultimate parts of which all plants are composed.

Before proceeding further in the consideration of this subject, I must request you to direct your attention for a while to these ultimate parts of plants, the stones, as it were, with which they build themselves up, which communicate to them solidity and durability, utility and beauty, and without which their existence would be altogether impossible.

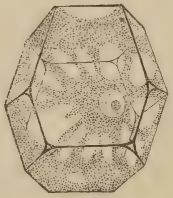
These ultimate parts of plants are not of such a nature as to belong to that class of material particles which are scarcely perceptible by the senses, still less are they analogous to atoms, but, on the contrary, always possess a definite bulk and a clearly distinguishable figure, which, although not in all instances perceptible by the naked eye, may by the aid of the microscope be studied even in their minutest details. It is, however, not only in the arrangement and connexion of these elementary parts, that our wonder is excited at the great art and skill which they display; this is still more evident in the structure of these parts themselves. It is scarcely possible to conceive anything more wisely and artistically contrived than a cell. A delicate membranous vesicle imperceptible by the naked eye, covering a nucleus of partly liquid, partly solid substances in one case, and in another a hollow space, surrounded by a membrane almost stone-like in its hardness, the one being gradually produced from the other. The accompanying figure is a considerably-magnified representation of a roundish somewhat flattened cell, with its contents partially visible through the delicate translucent membrane. How easy it is thus for the plant, by an appropriate distribution of these elements, so dissimilar in firmness, to employ the one here, the other there, according as it may be requisite; and thus on the one hand the firmness and durability of the plant, on the other, its constant increase and growth, are rendered possible. The threads which are employed for making linen and other woven fabrics, the wood of trees, the hard shells of many fruits, consist of such old, indurated building-stones of the plant, while the younger and still soft cells, with their juicy and granular contents, frequently serve as the food of animals and of men.

Fig. 1.



The forms which these ultimate parts of plants present in the different organs of the plant, and in different plants, are not less remarkable. While one portion of them maintain their original globular figure, others become flattened, and resemble hewn stones of a square and other more or less regular figures, bounded by definite plane surfaces. Thus fig. 2 represents a cell perfectly flattened on all sides, the original spherical surface being only perceptible at the corners. It was therefore to some extent pardonable, that

Fig. 2.



these integral parts of plants should be mistaken for crystals, and that their formation should be regarded as analogous to that of the cubes of rock salt and fluor spar, or of the twelve faced figures of garnet.

Other forms, differing more widely from the vesicular form, occur in the long cylindrical or columnar cells, as shown in fig. 3, and the flattened plate-like cells. The substances which, like wood, bark fibre, etc., are of such great utility for all the requirements of life, are nothing more nor less than such columnar plant-cells, with pointed ends, by which they are, as it were, welded to each other, and form those tough elastic fibres. Fig. 4 is a magnified representation of several contiguous cylindrical cells, with ends pointed and joined together. Their thick walls render them firm and tough, and likewise communicate these characters to the bark which they constitute. It would carry us much too far to enter into a description of all those deviations from the primitive-cell form which, resembling sometimes familiar and sometimes irregular or variously-distorted figures, take a share in the composition of the plant organism. There is, however, one form which I cannot omit to mention, because it is one of the most elegant of minute forms, the so-called plant vessels.

Fig. 3.

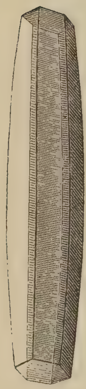
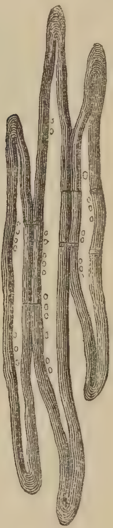


Fig. 4.



While all cells, even when resembling pipes and lengthened cylinders, are closed at their ends, there are cylindrical cells which burst and form openings at their ends, where they join other similar cells. Tubes of greater or less length are thus formed, which, enclosed by other cells, constitute a system of mutually-communicating pipes, called vessels. A portion of such a plant vessel, which, from the net-shaped markings upon its walls, is termed reticular vessel (*vas reticulatum*) is shown on a magnified scale in fig. 5. Generally speaking, a number of such vessels are grouped together, and surrounded by analogous, although upon the whole, different utricular cells, the whole constituting what has been termed vascular fibre.

Fig. 5.

The cells, according to their figure, form a kind of masonry, which is sometimes compact, sometimes porous in structure, consisting in different instances of rounded, quadratic, columnar or plate-shaped cells of various sizes, and which the anatomist technically calls cellular tissue. Thus fig. 6 represents cellular tissue, composed of roundish ellipsoidal and pear-shaped cells, which are merely in juxtaposition without being flattened, and consequently form a loose porous tissue (merenchyma). From the transparency of the cell membrane, the contents, consisting of green and other coloured vesicles, are distinctly perceptible; Fig. 7. Cellular tissue, composed of polygonal cells (parenchyma), the interior of which is exposed at the top and on one side by section. The individual cells are somewhat extended lengthways, and bounded by twelve planes. Their contents consist of a colourless watery fluid (cell sap) without any solid substances. The vascular fibres, from the circumstance that they usually possess greater firmness, may be compared to a skeleton

Fig. 6.

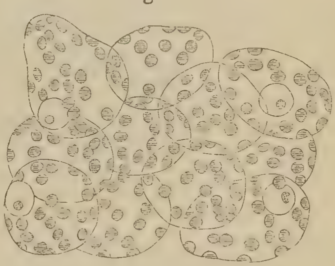
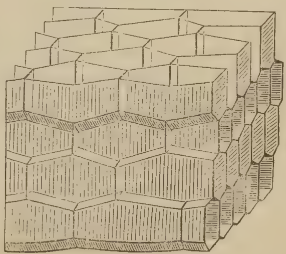
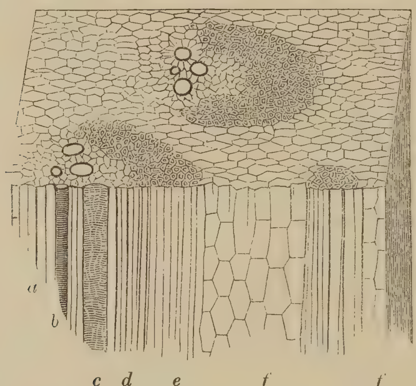


Fig. 7.



upon which the softer and more porous parts rest; but in reality they do not in any other respect resemble these half-lifeless parts of the animal organism, at least during that period when they are still in full activity. When we consider that the vascular fibres in their form, composition, developement, and connexion, appear to exercise a determinative influence in all formations of cellular tissue, it may be possible to recognize in them the sketch in conformity with which the details of all plant structures are carried out. The mere observation of the network of ribs in a leaf might be sufficient to suggest this idea. Fig. 8 represents a portion of a palm stem, with three bundles of vessels, of which the two front ones are exposed by

Fig. 8.



longitudinal, as well as transverse sections. In the larger of the two, at *a*, thin-walled wood cells are perceptible, at *b* a simple, and at *c* a reticulated spiral vessel, at *d* a bundle of so-called true vessels, at *e* thick-walled bast cells, which likewise recur in the smaller bundle of vessels. All these bundles of vessels are surrounded by parenchymatous cells *f f*.

If what has already been adduced has served to afford some little insight into the structure of plants, I may be permitted to direct attention to a few other peculiarities which may be easily recognized in the arrangement of these elementary organs. From the term cellular tissue which has been applied to the masonry of the plant organism, it is very probable that those who have not had an opportunity of examining it by the aid of magnifying lenses, will form the erroneous opinion that it has in reality a greater resemblance to a tissue than to a piece of masonry. This, however, is not by any means the case. It is well known to every one that the peculiarity of a tissue consists in its being composed of a number of thread-like parts running in one direction, and united by similar ones running transversely. There is no kind of cementing substance, but the compactness and strength of the tissue are solely and alone determined by the interlacing of more or less uniform fibres.

No such arrangement is found in the so-called tissues of the plant. Its elementary parts are, without any exception, microscopic; they are simply situated beside and above each other; they are not interlaced, not even those which are tubular, except sometimes in mosses, algæ, &c.; consequently the mass which they form resembles masonry rather than a tissue.

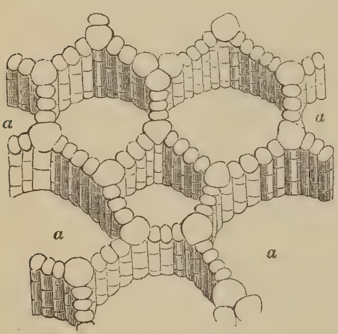
But this circumstance renders it imperatively necessary, in order that the whole may possess any degree of durability, that the individual elements should be united to each other. The cement or mortar by which this junction is effected is something very remarkable; and we shall subsequently have occasion to consider it, for the present merely pointing out the necessity for it.

But it will be asked, are there not then in the plant organisms, consisting frequently of myriads of cells, arrangements which support the combination of individual parts as well as the firm connexion of larger masses? It would seem almost self-evident that such arrangements are absolutely necessary in all plants, in order that they may, even for a short period, withstand the influence of exterior mechanical violence.

And it certainly is so. The plant builds its secret chambers and roofs them over with such art—it employs in the construction of the stem which bears its entire weight, such groundsels, buttresses, and cramps—that an architect could not proceed more correctly. Must not the solid vascular fibres, thin above and thicker below, which, separately or arranged in circles, traverse the whole length of the stem, be regarded as actual buttresses against the storms and wind, with which the slender plant stem has to contend? Is it not by the most appropriate means that the longitudinal fibres of wood are clamped together by the so-called medullary rays? And when, besides this, we take into consideration the flexibility and elasticity of the elementary parts, it becomes intelligible, how, in spite of the elements, perpetually bent upon destruction, here the oak, there the feeble reed, wave their heads defiantly in the air.

I have spoken of the secret chambers in the interior of the plant, and possessing, in almost all instances, a particular form. These chambers, sometimes large, sometimes small, resembling regularly-shaped rooms, romantic caves, or even dilapidated ruins, are termed by the anatomist air-passages. They are shown on a highly-magnified scale in fig. 9, as they appear in the leaf of *Acorus calamus*. In this plant the air-passages *a a a a* are bounded by the most elegant cellular tissue. The regularly-shaped chambers which, as the above term indicates, contain nothing but air, are, for the most part, beautifully arched, elegantly constructed, and represent, in fact, microscopic grottoes, columned temples in the midst of the compact cellular tissue of the plant. Other larger cavities present, in their interior, the marks of decay but too distinctly. Much may be learnt in this respect from every blade of grass.

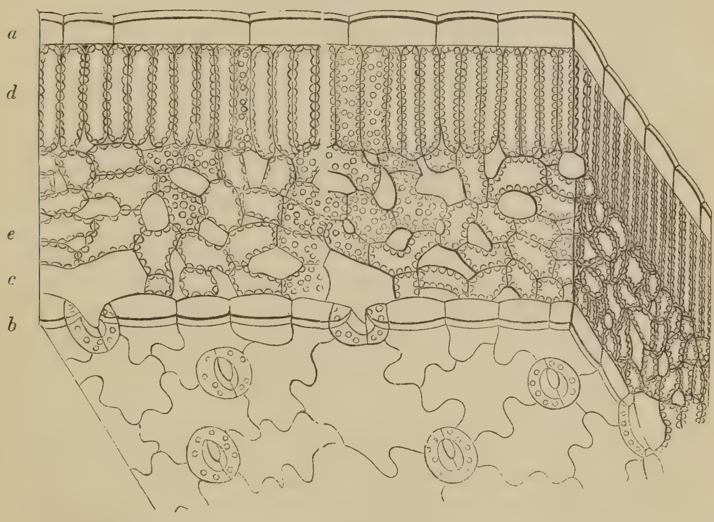
Fig. 9.



The most remarkable circumstance connected with these hollow spaces filled with air is, that they are, for the most part, connected with each other by means of much smaller passages which terminate outwards in innumerable open branches. The mouth of these minute shafts and galleries, leading into the interior by means of a great variety of channels, is always delicately formed, and generally of such construction that it can be closed, and the communication between the atmosphere and the interior of the plant established or interrupted according to circumstances. Such mouth-like openings, which the botanist calls stomates or stomata, are so numerous, that upon a single square line of the leaf-surface of the common monkshood (*Aconitum chamarum*), nearly one thousand may be counted, and these do not occupy so much as one-tenth part of that space.

A piece of this leaf magnified two hundred times in diameter is represented in fig. 10; *a* is the exterior layer of cells at the upper side and consisting of plate-shaped cells; *b* is the exterior layer of cells on the under side, where the stomates are

Fig. 10.

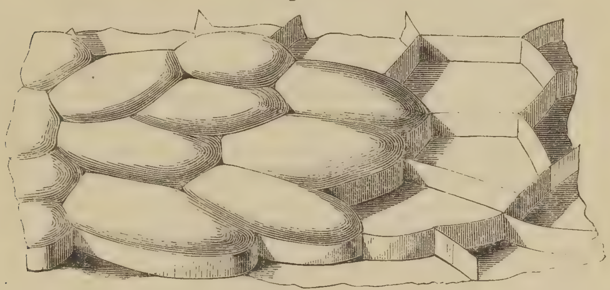


situated. At the sections it may be seen how these orifices, formed by two crescent-shaped cells, open into, with cavities, *c*, which communicate with each other throughout the entire cellular tissue of the leaf; *d* a layer of cylindrical cells near the upper surface; *e* a compound layer of irregular cells. It thus becomes intelligible how the atmospheric air penetrates even to the most remote parts of the plant organism, supplying it with various substances, and receiving others in exchange. Nevertheless, we should in vain seek for the air-channels and passages in those parts of the plant which are still in course of construction. It is not until after this has been completed that they are formed; they do not stand in any necessary relation to the new structures, and present the appearance rather of repositories, where things which are not capable of any further or immediate use are stored up.

In the plant such substances are represented by the resins, gum, ethereal oils, etc., which, although incapable of any application by the plant, are, nevertheless, of value to us. It thus frequently happens that we live upon the superfluities of nature, little suspecting that we are doing her a favour by taking something from her plenty.

As in all architectural works, requiring any great degree of accuracy, each stone must be truthfully measured, especially formed and adapted for the position it is intended to occupy; so is this equally necessary in the construction of the plant. There is no cell employed here whose form and dimensions have not been previously determined as with square and plumb-line, so that it is suited only to the place it occupies and for no other, fitting exactly into the depressions or elevations in its neighbouring cells. In observing a cellular tissue from any part of a plant, we cannot but be astonished at the beautifully-constructed compact masonry in which the appropriate elements are not only arranged in order, but are likewise firmly united so as to form one mass. How beautifully, for instance, do the pointed ends of the columns and cylinders fit into the spaces left by the juxtaposition of similar elements, both above and below, thus forming ligneous and bark-fibres!—how close and tight are the brick-like cells which compose this masonry, which I have already compared to buttresses, the purpose of which is to protect the columnar wall against lateral pressure, and without which they would not possess that firmness which they everywhere present! Again, the whole of this is covered with a protecting mosaic pavement, extending over the entire surface of the plant. A portion of this epidermis, consisting of closely-fitting tabular cells is represented by fig. 11. The upper surface of several of the cells is removed by section in order to expose the interior. It is impossible to imagine any roofing constructed with more closely-fitting tiles or a more delicate mosaic than the exterior cellular layer of plants, called, in technical language, the epidermis. Through this neither dust nor rain can penetrate, no particle of moisture can insinuate itself; and it is evident that the plant knows how to protect itself against atmospheric influences better than we can do in our most splendid and durable buildings.

Fig. 11.



But, although by means of these adaptations the plant endeavours to maintain, as far as possible, its integrity; it is not, on the other hand, entirely shut out from communion with the exterior world, from which, indeed, as we shall subsequently perceive, it derives all that is requisite for its existence. It is by means, partly of the air-cavities present on every part of the plant's surface, that it receives whatever supplies it may require, and discharges its surplus products.

It is not difficult to believe that in a structure so delicate and well arranged, each part has a particular use and a definite purpose, so that an harmonious working of all the individual parts is rendered possible; but that such a special utility extends even to the individual elements of the structure, cannot be inferred otherwise than from strict necessity. It is not until we know how each separate stone fulfils its functions in the perfect whole that we shall be in a position to form an opinion as to the stability, design, and harmony of the whole ; and so long as there is no attempt made to obtain this knowledge, we may, indeed, vainly declaim upon the conformity to purpose and the beauty of the plant structure, but shall never be able, in accordance with the principles of science and art, to form a true and adequate conception of the structure of a leaf, or even a hair. For this reason it is that we cannot too highly esteem the endeavour to establish the architecture of the plant upon a true scientific basis, and to obtain, in the knowledge of its elementary composition, a key to all that which is now a mystery to us. The man who has hitherto penetrated the furthest into this obscure region of research, who has attempted to examine stone for stone in their production and application, who has given us both ground-plans and elevations of some plant structures in which each element is marked with the number its architect intended for it, this man is Karl Nägeli. It is undoubtedly from him that we may look for the unveiling, not only of the most simple, but likewise of the most complicated structures of the plant organism, which we have hitherto merely wondered at but not understood.

LETTER III.

GENESIS OF THE CELL.

So far as we have yet proceeded, the comparison of the material composition of the plant with various parts of buildings has been of service in rendering our subject familiar and intelligible; but now the analogy begins to fail, inasmuch as we are about to inquire into the origin of the constructing material. Every architect procures his material from a greater or less distance; stone, bricks, lime, sand, water, and whatever else he may require, are brought to the place where the building is to be erected; and it is with these alone that he is able to carry out his work. But whence does the plant derive its stone, its mortar, etc., without which, in this as in the above case, the construction of any edifice of the same or similar elements would be impossible?

It is in this particular that the marvellous character of the plant economy presents itself most prominently; for we must remember that although it obtains the materials for all the purposes that it requires from without, still the preparation and working of these are by no means left to be executed by other forces; on the contrary, the plant makes its own stones, it burns and slakes its lime, works it into mortar, and unites in itself, in short, bricklayer, stone-mason, etc., as well as architect.

It was for a long time supposed that the plant was capable of effecting more than is really the case, and it was regarded as a kind of magician. It was believed that it derived from without only air and water, and that, by a kind of magical transmutation, it created everything which it might require, as, for instance, some alkaline salts, earths, phosphorus, sulphur, etc.: this belief still lingers in the minds even of some so-called intelligent agriculturists, who attach more value to the older chemical analyses than they merit. Modern chemists consider that it is altogether impossible for such a thing as a plant-cell—which, however, as we shall subsequently see, is the seat of powerful chemical activity

—to produce from oxygen, hydrogen, or carbon, even a single atom of phosphorus or sulphur.

Irrespectively however, of this point, we will, in the first place, direct our attention to the mode in which the plant, during its construction, continually produces fresh materials upon the spot, places them in the position they are to occupy, and cements them together with mortar; then, when we have acquired an insight into the wonderful operation, we will direct our inquiries to the preparation of the material substance requisite for the formation of its stone and cement; thus tracing with the more searching glance of the chemist that which we first regard only with the eye of the anatomist.

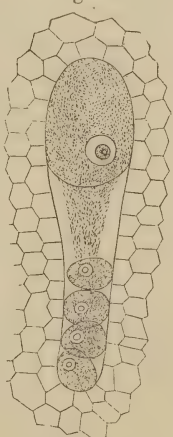
The insight into the formation of the building materials has cost the anatomist much toil, and given birth to many controversies. The matter is certainly not presented to us in so obvious a manner that the mere use of our eyes would make us masters of it. It is true that, unlike the architect who excludes all uninvited guests from any observation of the progress of his operations, the plant performs all its functions openly and without disguise; and if, notwithstanding this, we overlooked many things, or saw others in a false light, this was rather because, in our confusion, we did not know where or what to observe, and was likewise a consequence of our subjective conceptions, as well as of our inability to face the magic light which the plant presented to us. In short, it is only after much labour, and restless watching and search, that we have succeeded in arriving at a knowledge of the simple manipulation which the plant adapts in its constructive operations, so that now, when we know how this is effected, we feel more astonished at our own dulness than at this extremely simple process of the plant.

The whole mystery of the production of these building-stones of the plant consists in the fact that the plant developes each one that she employs from others previously existing. In this act these cells must themselves have become larger, to a certain extent, for otherwise the number of stones would only increase, without the edifice itself becoming larger; and of this there can be no doubt, as any comparison of a young and old plant will show.

Let us now examine, somewhat more minutely, this production of building-stones by the plant. As we have already seen, these building-stones of the plant are, properly speaking, not solid homogeneous masses, but variously-shaped membranous utricles, vesicles, etc., filled with soft substances and liquids of all kinds. Each vesicle which is employed in the building up of the plant is, without exception, formed in the interior of an already-existing cell; when its formation is complete, it is at once pushed out, and laid in the place which it is destined to occupy. Neither windlass nor pulley is requisite; the whole operation takes place so readily, and, as it were, spontaneously, that we may well be astonished that such a thing is possible. We will now examine how this is accomplished.

First, the old cell swells up considerably, increases in circumference, grows; but it must be remembered that it is not a mere growth that takes place here. As in a pregnant animal, new cells are formed in its body; when these have advanced so far in developement as to possess all the organs requisite for their independent existence, they are set at liberty; and the mother-cell which, during the continuance of these processes, not only devotes the whole of its contents to the formation of the brood of daughter-cells, but likewise suffers a diminution of its membranous envelope in consequence of the progressive enlargement, continues in a kind of dream existence, and is at last entirely consumed. Fig. 12 represents a remarkably large bag-shaped cell from the seed-bud of the biennial (*crepis biennis*). It is situated between parenchymatous cells which do not any longer enlarge. This mother-cell contains five secondary cells, of which the uppermost is further developed than the others. The daughter-cells originate, there-

Fig. 12.



fore, altogether at the cost of the mother-cells: their existence involves the death of the latter. Something very analogous is presented in the propagation of certain insects; the pregnant animals gradually increase in size to such an extent that they appear more like bladders. All the organs, all the functions of the mother, are directed to the production of her young, and after their birth there remains scarcely anything more than a dry, rent membrane. May not, therefore, the formation of cells by the plant likewise be termed a generation? And what else is the entire plant formation, with its myriads of cells, than the result of a continued generation of its elementary parts?

After this insight into the progressive developement of the stones, how different becomes the aspect of the masonry of the plant perpetually being renewed, and, as it were, growing out of itself. Here all kind of analogy with architectural operations ceases; we are unacquainted with any work of human hands or human invention which is even in the remotest degree similar to the building up of the plant temple. It is an invisible hand which inscribes upon its walls words as mysterious as those once written in the palace of Belshazzar. Nevertheless, we will follow up the formation of the cell still further.

Even while in the mother-cell, the position is determined which the secondary cells are to occupy; therefore, after their separation, no further displacement is necessary. If every cell, besides the capability of producing new cells, possessed sufficient energy to do so, only an irregular heap of cells would be produced; and, according to the fecundity of one or other of them, a larger accumulation of cells would be formed at certain points than at others, and the whole would thus acquire a disfigured appearance. It is only owing to the single circumstance that this capability of production is limited, that order and regularity are maintained, as it were, spontaneously in the formation of the plant organism.

Two facts here present themselves: on the one hand, it appears to be a constantly-prevailing normal condition, that almost all production is limited to the minimum which consists in the capability of the mother to produce only two secondary cells; while, on the other hand, these cells possess altogether different characters, if not in the first, at least in the last generations; so that while the one is active and vigorous, soon producing a new generation, the other in modest retirement passes a mere passive existence. Cells of the latter kind do not contribute to the increase in size of the plant structure, but by virtue of their more permanent character determine the duration of the plant, while cells of the other are soon consumed; consequently it is of the former cells that the plant is essentially composed. The arrangement of these cells, their maintenance of this permanent character, or the occasional cessation of it, attended by a renewed capability of reproduction which may go on indefinitely, determine that part of the whole phenomenon which refers to the dimensions and forms of plants. These series of generations have not as yet been at all accurately investigated in their dependence upon each other, or reduced to definite laws; but it is to be hoped that those investigations which have already thrown so much light upon the processes of plant formation which are hidden from the unassisted eye, will likewise penetrate those labyrinths into which no human eye has yet reached.

At the present time we only know that the formative cells exercise their functions chiefly at the outer part of the plant, as well at the apex as upon the entire surface, so that a continual elongation as well as a lateral growth is rendered possible.

It is at these parts, where, in rapid succession from generation to generation, such life and activity prevail that, even in the gigantic works of man, the stir and activity of the multitude of workmen present but a faint reflection of this animated and vigorous process.

Thus the plant grows gradually, elongating a new layer of elements after the other encloses the wood of the stem; but that it should not extend indefinitely, or raise itself to the sky, there is, as Göthe has remarked, a sufficient provision. In what manner we shall learn afterwards.

LETTER IV.

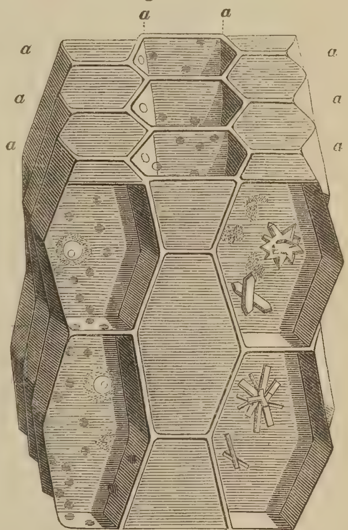
UNION OF THE CELLS; CHANGES RESULTING FROM THEIR GROWTH.

The structure of the plant, with the ever-renewed elements of which it is built up, now stands as a perfected whole before us. All is well arranged, each stone is laid in its place; but there is one thing essential to the execution of a durable architectural work which we have not yet taken into our consideration,—it is the exterior material union of the individual parts. Since each cell is in itself a whole, which, notwithstanding its origin from similar elements, is still destined to pass an independent existence, the mere bond of family relationship would, without any other means of union, be quite inadequate to secure the integrity of the plant, and to prevent the whole structure from being shattered to pieces like a house of cards by the slightest violence, or from being, as it were, the means of its own destruction. To meet this difficulty, Nature has adopted a contrivance for cementing together the several parts, chaining each cell to its neighbour in such a manner that even when, from a dissimilarity in their character and purpose, there may be any want of harmony between them, it cannot be attended with any consequences detrimental to the whole. The plant-cells, therefore, are, as it were, actually built up in their place, and cemented together with an appropriate mortar.

But the plant prepares for itself not only the stones of which it is built up, but likewise the cement employed in fastening them together; and here again it is the cell which not only performs the work, but likewise appears to be the only source whence the material itself is derived. The union and cementing together of the cells goes on even simultaneously with the formation and separation, so that the scarcely-perfect cell is already unable to change its position; and although furnished with life and energy for thousands of generations, resembles a chained Prometheus remaining during its entire existence fettered to its neighbour cell.

These phenomena of plant life result from the fact that this mortar or cement is prepared in the cell itself, and, penetrating through its walls, is transferred to the precise spot where it is required, and where it can exercise its influence upon the adjoining cell. This mortar or cement is sometimes more abundant than at others; and at the places where it is nearly or altogether absent, are formed those cavities, arched passages, and mazes running between the cells (intercellular passages), of which I have already spoken. It is natural to suppose that this substance which is deposited between the several cells should have received a special technical denomination; and, indeed, botanists, regarding it as the true mortar of the plant structure, have given it the name of intercellular substance. Fig. 13 represents a number of elongated parenchymatous cells, distinctly united together by this intercellular substance, *a a*, into a firm mass.

Fig. 13.



But the continual increase and arrangement of elementary parts do not constitute the whole activity of the plant. Not only the formative cells, but likewise the permanent cells, those which, after their production, alone continue and insure the duration of the plant, are subject to further alterations. Originally minute delicate utricles, they become gradually larger and stronger, assuming meanwhile the form which they are ultimately to retain, and which has already been described as cubical, polygonal, tabular, columnar, etc.

The increase in their circumference is, in most instances, attended with a thickening of their exterior membranous boundary or wall; and it is this process which constitutes the true growth of the plant, while the increase by multiplication of cells must be regarded only as a consequence of generative activity. Thus these two processes mutually associate themselves; and, while the increase of cells is not possible without certain operations of growth, this growth itself appears to be determined by previous cell formation.

But it is both of these processes conjointly which ultimately determine the increase of size in the plant; and while the enlargement of the cell never extends beyond certain and generally microscopic limits, so, likewise, the multiplication of the cells has, as we shall subsequently learn, a definite amount and purpose.

Fig. 14.

One phenomenon which, more than any other, is calculated to insure the duration of the plant as well as to provide for its sometimes considerable, and even enormous magnitude (as in the chesnut *dei cento cavalli*, the dragon-tree of Oratava, the Baobab (*Adansonia digitata*), the cypress of Oachaca) and to enable it to vie with the most ancient architectural monuments, is the further developement of the cell-membrane after it has attained, or at least approached very near, its limit of extension.

Although the original boundary of the cell is in all cases a thin homogeneous membrane, it frequently happens that at a later period it becomes thick and solid; and as in this state it is no longer capable of extension, this progressive thickening takes place by the deposition of incrusting substance upon the inner side of the cell-wall. As a consequence of this deposition the capacity of the cell must necessarily be more and more contracted, and finally, perhaps, reduced to a minimum. Such cells which are called thick-walled are distributed here and there throughout the elevation of the plant, and are generally of most frequent occurrence wherever there is any part which requires support or protection. Cells of this kind are consequently not only good as corner-stones, plinths, or paving slabs, but are especially employed in the construction of the pillars.

Unless the cells which constitute wood had thick walls, even the most gigantic trees, the most colossal plants, would be borne down by every blast like a slender blade of grass; and, in fact, the very existence of such massive plant-organisms as trees would be impossible if it were not for this character of the cells.

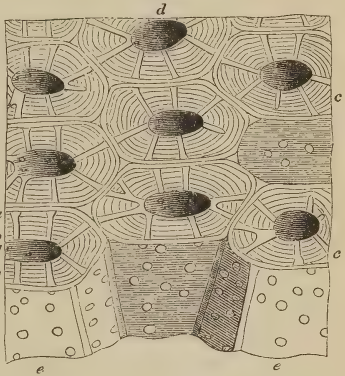
These thick-walled cells are of especial utility likewise at the exterior of the plant-structure; and when at this part, as is frequently the case, they even blend together and become covered with a kind of varnish, they constitute the best possible protection, resembling a macadamized or asphalt pavement. The same indurated covering is formed around some fruits and seed-vessels, whose function is to protect the germ. Judging from the extremely-delicate nature of the elementary parts, the plant would barely escape destruction, even for a short period, were it not thus strengthened and protected.

While considering this tendency of the plant, or rather the cell, to fortify itself against all kinds of antagonistic influences, and thus to acquire persistence and durability, the circumstances to which it owes its origin and developement must not be disregarded.

Among these circumstances the most important is undoubtedly the facility with which it procures the materials by means of which it exists, and is capable of further developement. While the cell strives, as it were, by the excessive formation of wall substance to shut off communication with the outer world, such provision must be made as will prevent this from becoming perfect, since in that case the further activity of the cell would necessarily be limited. It is obvious that the communication, whatever its nature, will be more difficult through thick walls than through such as are lighter and thinner. But although the plant is in reality compelled here and there to build such thick walls, that is, to make its usually delicate building materials more massive; it does not any the more omit to leave openings here and there, or at least to retain in places the original thinness of the walls.

That this is really the case has already been seen while considering the exterior cellular layer of the plant; but something very similar takes place also in the cell itself, that minute and originally closed space. However much the cells by the thickening of their walls may separate themselves from each other and from the outer world, a few, although perhaps closed, window-like apertures are always left; and although sometimes, deeply sunk in the wall, they may seem like prison windows, through which liberty can look with only one eye, still they give animation to the silent space and scare away death. Such little prison windows are present in some number in every cell, so tiny that an eye, even with a thousandfold its ordinary power, is scarcely able to see through them, an achievement first accomplished by our distinguished plant-anatomists, Hugo and Mohl. Not only is their singular structure remarkable, but likewise, and even more so, their direction and communication with other cavities; strikingly revealing the truth that, in the body of the plant, one cell cannot exist without the other, so as to become perfectly independent. Fig. 15 represents thick-walled cells, united by intercellular substance, from the fruit of a palm. Upon the upper plane of section may be seen, not only the concentric layers of the substance *b b* coating the original cell-wall *a a* from without towards the interior, but likewise the pit channels *c*, intersecting it in all directions, and opening into the contracted space of the cells *d*, but producing on the exterior the appearance of punctures, or as they are called pits, *e*.

Fig. 15.



The arrangement which by this object is effected consists in the corresponding situation of these little windows in the walls of the cell, so that by meeting exactly a communicating passage between the cells is formed. We shall afterwards learn how much the cell, and consequently the plant, owes to this wise provision, and that such an arrangement would not be advisable if perfect separation were desired.

But when the cell has once advanced so far in its developement that it has no room either for a marriage-bed or the apparatus of chemical and physical activity, for retorts, balances, and pumps, it may well be imagined as little more than a sepulchre, in which life and love lie buried and motionless for ever. So in truth it is in the plant-organism, and in all its integrant parts; and it is especially those parts which have, in the highest degree, enjoyed the pleasure of existence that fall into a death-slumber from which they never wake again. In the midst of the beautiful green temple one beam after another breaks in, one column falls above another, and long before the proud structure has ceased to wave its leafy crown joyously in the breeze, the death-worm has been gnawing at its heart. At last the whole decays; and just as it was built up, imperceptibly making a world of life dependent upon its existence, so it passes away without leaving a vestige behind.

LETTER V.

CHEMISTRY OF THE PLANT.

The most wonderful part of the formation of the plant is, and always will be, the art by which it produces from some few elements derived from the air and the earth, the whole material of its structure, which, as we know, is of the most varied character. This becomes still more remarkable when it is remembered that this material is in all cases derived from the cell, and consequently that the great numbers of different substances met with in the plant-world all originate from this extremely small microscopic body, and the processes which go on in and around it. Who would have thought of seeking in this minute space for a power and energy which, with all our art, we are unable to command in our chemical laboratories and factories?

I will now consider the plant, or rather the plant-cell, as an active, I might indeed say, never-resting spagyric,* labouring, although in different ways, both day and night, winter and summer.

From the exterior world the plant derives only a few elementary substances, the principal of which are carbon, hydrogen, oxygen, and nitrogen; for the quantities of sulphur, phosphorus, chlorine, iodine, as well as of potash, soda, lime, magnesia, silica, &c., which it likewise requires, are disproportionately small when compared with its consumption of the former.

One of the greatest necessities of the plant is water, not only because it is the means by which all other substances are introduced, but likewise because the plant is only able to exercise its secret art in what is termed the humid way—that is to say,

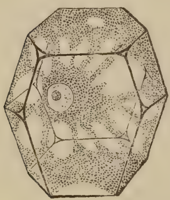
* The name spagyric, derived from σπάειν, to bind, and ἀγείρειν, to combine, was applied in the middle ages to the chemists (alchemists), as those who were able to dissolve, separate, and combine substances.

it operates only with aqueous solutions. When we learn from experiments, which have been made with great accuracy, on the consumption of water, that 26·910 square feet of meadow-land or of corn requires six million pounds of water during the period of vegetation, and an equal surface of forest rather more than less, we cannot but be amazed at the magnitude of this quantity, and be induced to examine how such a mass of water can be supplied to such a small surface, and in so short a time. It is evident that the inexhaustible sources of this supply, upon which the prosperity of the plant depends, can only lie in the heavenly gifts of rain, dew, &c.; and that, where the sky does not afford these gifts, the growth of plants, and even the existence of a scanty vegetation, are impossible. The absence of all kinds of plant-life in the deserts of Sahara and Libya, the sand ocean of Sehamo, or the western coasts of Bolivia, is a consequence, not of their being sandy or rocky tracts, but of the want of rain, or any kind of watery deposits, for in these districts it rains only once in twelve years, and that not always.

After water and its constituents, carbon is the most important requisite in the growth of plants, for on examining the elementary composition of any part of them, this element is always found to play some part, and, in most instances, the principal one. But then the question arises, whence does the plant-world derive the enormous quantity of this substance, which is far less abundant in the earth than water? It would almost seem as if the small proportion of carbonic acid contained in the atmosphere ($\frac{1}{1000}$ of its weight or $\frac{3}{10000}$ to $\frac{5}{10000}$ of its volume) were insufficient for the purpose; but the chemist has shown that the entire living and dead vegetation might derive from this source all the carbon they require without nearly exhausting it.

The fourth substance which must be numbered among the most indispensable requisites is nitrogen. While the first three substances above named principally constitute the corporeal part of the plant, and are especially employed in the formation of the cell-walls, it appears that throughout the entire constructive operation there is a necessity for some substance which, so to speak, sets the whole in action, supports its activity, and ensures its completion. This Archæus, the substance which fulfils this office in the plant, is nitrogen. It is nitrogen that sets the work in action, that renders the formation of each individual cell possible; and it is always to be found wherever there is anything to be done or made in the plant. While the activity of carbon, hydrogen, and oxygen, is limited to the boundaries of the cell-life, the activity of the nitrogen prevails in the interior in the nucleus of the cell, and gives the initiative to all the processes which take place.

Fig. 16.



(Fig. 16). Both the cell nucleus (cytoblast), that is the round lenticular-shaped vesicle with the nucleoli, as well as the granular substance (protoplasm) surrounding it, and distributed throughout the entire cell, consist essentially of nitrogenous substances. It is not easy to determine, at the present time, what may be the purposes and uses of all the other substances mentioned above, although it is in some instances plainly evident that they do take a share in certain operations appertaining to the general constructive process.

When the elementary substances have been introduced in the plant-organism into the cell from the exterior world, they are still by no means in that state which they are to acquire before becoming actually part of the plant. Even their introduction into the organism is only possible under certain circumstances, namely, the conditions corresponding to their nature and mode of agency; and this is still more the case with regard to their relation to each other as soon as they have become constituents of the cells.

The processes by which simple substances unite to form those new compounds, and by which both the contents of the cells and the boundaries of their activity—the cell-membrane—are formed, are still enveloped in deep obscurity. Although we are acquainted with the general chemical laws of their action upon each other, it has not yet been possible to acquire such a special knowledge of this mysterious operation of nature as would enable us to imitate it in our laboratories. The chemical agency of the cell is, as regards its synthesis, although not as regards its products, still a problem, and in this point of view the plant is the only alchemist there is.

By studying the chemical agency of the cell in its products, we may arrive at the following truths. The substances resulting from the combination of the simple elements are of various kinds as regards their composition, their physical characters, and their structure. They may, however, very appropriately be divided into four principal groups, which are, 1, indifferent substances, destitute of nitrogen; 2, indifferent nitrogenous substances; 3, vegetable acids; and 4, substances which perform the functions of alkalies.

Of these four principal groups, which comprise a vast number of substances possessing subordinate differences, only the first two include the substances which are the most abundant and frequent in the plant-world, some few of which take a share in the structure of almost all plants, and appear scarcely ever to be wanting, while others are of a more or less subordinate importance, and are met with in much smaller quantity, or frequently only in a certain class of plants.

The most frequent non-nitrogenous constituents of plants are 1, cellulose, or the substance of which the cell-membrane consists, and which was formerly called ligneous fibre; 2, starch (*amylum*); 3, sugar; 4, gum; 5, plant-gelatine; and a number of others which possess the most intimate relationship, and although presenting different external characters, are identical as regards their chemical nature. The chemist, who from the time of Hermes, has been accustomed to express himself in a symbolical language, includes all these substances under the formula C_{12} H_{10} O_{10}, and is able to produce from any one of them most of the others. A little nitric acid, or sulphuric acid, or alkaline salt, added to this or that one immediately converts it into another. The chemist finds no difficulty in converting starch into sugar, ligneous fibre into starch, etc., which is shown at fig. 17, as it occurs in the cells of the potato, and at fig. 18, highly magnified. In all the starch granules, a small nucleus is perceptible, around which are arranged concentric layers of starch. But this truth does no more than prove that the plant by its own power may perhaps effect such transformations, and indeed its production of one substance or another, according as it is required, is one of the most wonderful phenomena of plant life.

Fig. 17.

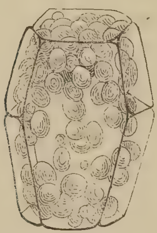
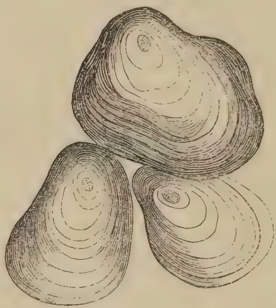


Fig. 18.



An example may serve to render this more intelligible. There is no plant, which when it developes itself from the seed, possesses those organs which subsequently furnish it with food. But the plant requires food during the early period of its existence, as well as afterwards, and indeed even more; since it is then about to increase its substance in all directions,—in short, to produce cells. In order to enable it to accomplish this important function, upon which alone its further existence depends, the germ is provided with a larger quantity of superfluous cell substance, in the form of starch, oil, etc., which it receives from the mother-plant. When the seed begins to generate, there is nothing more convenient and appropriate than to convert this reserve into current coin; and thus, as it were, spontaneously there is produced—from starch, sugar; from sugar, plant-gelatine; and lastly, from this the cell-wall by which the integrity of the cell is perfected, and one stone after another is added to the plant structure.

Many similar examples might be brought forward; for the transformation of one substance into another is not an unfrequent phenomenon of plant-life. The miracle of Cana is an every-day occurrence.

The chemist calls all substances of this and similar formulæ hydrates of carbon, which is as much as to say that they are compounds of carbon and water, or more properly of carbon (C) with the constituents of water (H and O). Sometimes there s an excess of hydrogen (H), or of oxygen (O), giving rise to the formation in the one case of fat oils, and in the other, of plant acids, for instance, citric, malic, tannic, and gallic acids. The agreeable taste and nutritive properties of many plants consist altogether in the combination of these several constituents of which the plant produces so great a variety.

The nitrogenous constituents of the plant are likewise either indifferent, or they present the characters of a base. All the young parts of the plant contain indifferent nitrogenous substances in proportionately large quantity. The glutin, albumen, and legumin, of plants belong to this class. They are all comprised under the general term of protein substances.

These protein substances are not only of great importance in the general process of plant formation, giving rise to every operation, and regulating its progress, being, as it were, the actual machinery, without which there would be no activity, but they are at the same time the substances without which animal life cannot be conceived, inasmuch as muscle, blood, milk, etc., the substances by which animals are distinguished from all other beings, are in reality not made in or by the animal itself, but are derived ready formed from plants. This deeply significant relation between two classes of beings apparently so different, undoubtedly indicates the existence of a more intimate connexion between them than has generally been suspected. When, therefore, Liebig says, the animal organism is a higher kind of plant, whose developement commences with those materials with whose production the life of the plant ceases, this is saying no more than what is perceived by the most ordinary experience.

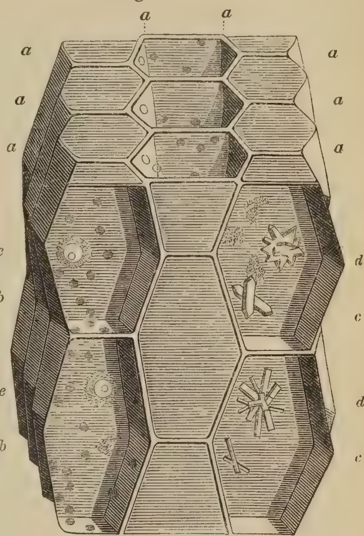
The nitrogenous alkaloids, like the plant acids, are to be regarded less as necessary constituents of the plant, than as by-products of the cell laboratory, and their use, as well as that of the inorganic bases which are absorbed from the earth, may be only to establish a chemical neutrality in some parts of the plant which could not be effected, except by substances of such decided characters. Wherever it is impossible to bring such differences into equilibrium, when on the contrary they increase and accumulate, the further existence of the whole structure is placed in danger. Without this constant self-protection, the plant must be destroyed by the strife and conflict of its elements and constituent substances.

When the establishment of this equilibrium is either wholly or partially impossible, the necessary consequence is disease and death. Such a permanent sickness from this source is frequently met with affecting our cultivated plants; consequently both by the horticulturist and the agriculturist very much remains to be done before they can avoid this source of error in the treatment of crops. What Liebig has achieved in this direction, as dietist and prophylactist, is sufficiently known to every one.

If now we once again glance at the interior of the plant, and consider the various operations which are ever proceeding there in silence, we cannot adequately express our astonishment at the series of different chemical processes which take place in one and the same microscopic laboratory, and at finding that in the web of cells of even one and the same plant, or part of a plant, indeed often in adjoining cells, the most diverse chemical products are formed. Here is a cell filled with watery plant sap, in which gum or mucilage is dissolved; there is one in which sugar is likewise present; this is filled with starch granules, that with globules of oil,—in one place are whole groups of cells filled with green, red, yellow, or blue pigments, in another they contain bunches or druses of crystals. Fig. 19 represents parenchymatous cells, containing green vesicles (chlorophyll vesicles) *b*, with crystals *c*, and groups of crystals *d*. In some of them the cell-nucleus is still present. It is hardly possible to conceive anything more varied and manifold than the picture presented by a section of any kind of plant when viewed through the microscope.

How altered appears now the delineation we have hitherto carried out of a masonry, consisting of homogeneous masses, and to which we have compared the plant, in which each stone not only represents a house in itself, but also one in which the most diverse operations are carried on! It may indeed be said that a glance into this marvellous structure, where from story to story we discover new and unknown spaces, where, with all the penetration of the eye, it is scarcely possible to penetrate beyond the vestibule of the first one, reveals to us something little different from what we learn by the study of the remote regions of space where the nebular films of the world islands hide from us in the same manner what goes on behind them.

Fig. 19.



LETTER VI.

ABSORPTION AND DISTRIBUTION OF THE PLANT'S FOOD; SEPARATION OF WATER.

If we once again picture to ourselves the cell, we can only conceive of it as a chamber closed on all sides. In order that it may exist, increase in size, and even build new chambers in its interior, the requisite materials for this purpose must be obtained from without. Carbon, hydrogen, oxygen, nitrogen, and whatever else may be needed in the shape of alkalies and earths, can, under the circumstances, be introduced only in the gaseous or liquid form: the carbon only as carbonic acid, the nitrogen as ammonia, the earths and alkalies only as salts, and always dissolved in water. The cell filled with a greater or less quantity of liquids can only absorb these raw materials, constituting its food, when brought into immediate contact with them. In this circumstance lies the whole mystery of the absorption of food and its transfer throughout the plant in those instances in which the plant consists of more than one cell. Although there is no pump or other engine to effect this operation, the whole goes on with as much precision as the work of the most perfect machinery, and, at the same time, so imperceptibly, that there is in reality no necessity for the application of any other force than that which results from the reciprocal action of liquids of unequal density, or of dissimilar molecules. Here again is a manifestation of the wisdom of the plant-architect, who rejects all kinds of apparatus, and yet arrives more certainly and quickly at the desired end than the constructor of the greatest monuments of human art. We have already had occasion to marvel at the achievements of the plant as a chemist, and our surprise will not be less excited when we come to consider its physical activity and ingenuity.

The first and most important business of plant-life consists in the provision of liquid nutriment with which the plant almost always comes in contact by means of its lower extremities. The water saturated with small quantities of carbonic acid, ammonia, and a few saline substances, is there brought into contact with the outermost cells of the plant filled with liquids which, though of a different kind, are always saturated.

It is further a general physical law, that when dissimilar and miscible liquids are brought into contact with each other, they cannot remain so for an instant without a reciprocal action.

When a glass containing some water is very slowly and carefully filled up with red wine, these liquids will continue for some time to present sharply-defined boundaries, which gradually become less distinct, and finally disappear altogether, when it will be found that there is no part of the whole mass in which the wine and water are not mixed in the same proportions. The same result is brought about, although somewhat more slowly, when two liquids are separated by a membrane, or when a bladder containing one of them is dipped into the other. The bladder does not hinder the reciprocal action of the liquids, except with regard to time, for they both continue to penetrate the bladder, and thus coming in contact, are finally reduced to equilibrium. When the more-concentrated liquid is contained in the bladder, a larger quantity of the less-concentrated liquid will be transferred into the bladder than of the former into the latter. The bladder will thus become filled, and finally burst. When, on the contrary, the more-concentrated liquid is outside the bladder, its contents will become gradually lessened, and it will finally collapse. Of these two conditions of action only the former prevails in the plant, for the cells are everywhere in contact with the dilute nutritive liquid, which is consequently introduced into the cells; or, to express the phenomenon in the language of the physicist, an endosmose takes place.

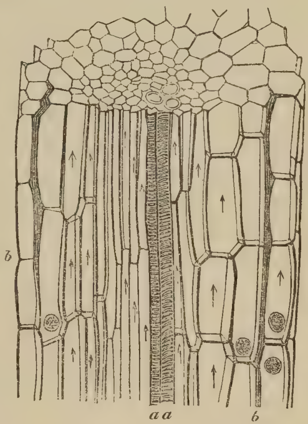
From a knowledge of the usual degree of concentration possessed by the contents of the cells, it is even possible to calculate that the transfer of liquid into the cell takes place with a force equal to the pressure of an atmosphere and a half, consequently that it is an instance of a very general physical agency which admits of being estimated and measured.

Again, not only the absorption, but likewise the further transport and distribution, of the sap throughout the plant, takes place in precisely the same manner, provided that the various cells of which it consists contain liquids of different kinds, and possessing different degrees of concentration, which is the case.

Solutions of gum, sugar, and protein substances take a very different share in this process; and all other circumstances being the same, those cells which contain the largest amount of protein substances receive the greatest quantity of sap. And as it is the young cells, while in a state of developement, that contain the protein substances in greatest abundance, it follows that the flow of the sap is especially directed to them. But this circumstance is likewise attended by another, which is directly connected with the developement of the cells, and consists in this, that if the direction of the sap-current is thus determined, the developement of the cell must be likewise dependent upon the same fact. These originally round cells, through which there is a continual flow of sap in the same direction, will therefore receive a copious supply of food, and consequently have a more rapid growth, so that the course of the sap-stream may be inferred from the increase in size presented by the cells. All elongated cells, and such as possess pipe-like, cylindrical, or prismatic forms, obviously owe their configuration to this circumstance; and the vessels mentioned above are no other than such cylindrical cells which have soon become old and inert, but through which at a previous period the sap-stream flowed most vigorously; and even in the most perfectly-developed plant, the bundles of such cells and vessels (vascular bundles) indicate the former, and, to some extent, the present course of the sap-current.

When a white-flowered hyacinth is watered while in its pot with the clear juice of the kermes berry (*Phytolacca decandra*), the flowers present a reddish tinge, which cannot be owing to anything but the absorption of the intensely-red juice of these berries by the roots of the plant, and its diffusion through the stalk into the colourless cells of the floral envelope. When all these parts of the plant from above downwards are examined anatomically, the path of the sap-current may be very distinctly recognized. A magnified section from the lower part of the floral envelope, represented in fig. 20, shows that all the cells marked with arrow-heads contained the red juice of the kermes berries, and have transferred it higher upwards in the same direction. Further, it appears that neither the spiral vessels, *a a*, nor the air-passages *b b*, take any share in the transfer of sap.

Fig. 20.



It follows, however, as an obvious consequence from this arrangement that the plant does not stand in need of any such channels for the circulation of the nutritive liquids as are necessary in the animal, where the nutrition and the reproduction of substance are subject to conditions altogether different.

It will be seen, therefore, from what has been described above that the entire absorption and distribution of the juices of the plant, and consequently its nutrition and growth, are dependent upon the nature of the cell-membrane, and upon the progressively-increasing degree of concentration of the liquid contents of the cell. Unless the cellulose, or substance of which the membrane consists, possessed the property of being permeated by watery liquids without being dissolved, the cell could have no permanent existence in contact with water and moisture, and the introduction of nutriment into the interior would be impossible. And again, without consecutive increments in the concentration of the sap contained in the cells, the transfer from one cell to the other could not be effected.

In order to bring about this latter object, two operations are indispensably necessary, one of which constantly regulates the necessary degree of concentration independently of any chemical alteration, the other determines the transformation of the absorbed liquid, and tends to the same result by chemical means. Both processes, frequently disturbed by their mutual reaction, nevertheless prevent any stagnation of the sap-current, and at all times insure the necessary supply of constructive materials to every part of the plant. The one process is called evaporation, the other assimilation.

Plants, with the single exception of those which are aquatic, even when consisting of only one cell, are always partially exposed to the atmosphere, which cannot remain without influence upon them. The most striking effect of this influence is the evaporation of water from the cellular membrane, which is, however, always kept full by replacement of this liquid from the interior. The result of this process cannot be any other than the gradual and progressive concentration of the sap in the interior, and the further consequence of this is, that the sap-current is directed to that part where the need of water is greatest.

If in polycellular plants the cells of the outermost layers were constructed like those of the interior, it does not appear that there would be any reason why the replacement of liquid should not take place to an equal extent in all of them, and why the sap-current should not be equally directed towards the periphery of the plant.

However, this is not the case ; for the cells constituting the periphery are furnished with many adaptations which hinder and retard the evaporation, in consequence of which it becomes possible for other portions of the cellular tissue to draw up the sap. It is only by means of this admirable contrivance that the plant is able to direct the sap-current flowing from cell to cell precisely to those parts where the developement of substance especially takes place.

Nevertheless there are some parts of the plant which are particularly subject to the evaporation of water—for instance, all those which present considerable surfaces as the leaves. These organs, inasmuch as they facilitate evaporation, may be regarded as the principal means of renewing the contents of the cells, and of determining the general mutation of substances which constitutes assimilation, and consequently as the prime lever of the plant's growth. When it is remembered that a single leaf of moderate size exhales, on the average, from sixteen to thirty-two grains of water daily, and that this quantity calculated for the entire plant, or for an acre of land, amounts, in the first case, to at least two pounds, and in the latter to 60·000 pounds, the statement already made that the consumption of water upon an acre of cultivated land, during the period of vegetation, amounts to six million pounds, becomes readily intelligible. Still of this enormous quantity of water scarcely one-third is actually appropriated by the plant in the formation of its various constituent substances.

LETTER VII.

PHENOMENA OF ASSIMILATION.

I MAY probably venture to assume that none of my readers will infer from the account given of the processes which accompany the absorption of water, as well as its separation by evaporation, that the water merely passes through the plant mechanically. It is indeed true that the water flowing through the plant-organism is especially the source of its activity; but it is quite as true that it carries with it at the same time, in the shape of carbonic acid, ammonia, &c., the raw material for the purposes of construction to which likewise it contributes itself, inasmuch as it ceases to some extent, at least, to be water, and thus takes a part in the general mutation of substances. It would at the present time be a very extravagant proceeding to attempt to trace the water, or any of the other substances dissolved in it, throughout either their course in the plant or their several phases of transformation; so much, however, is certain, that, having penetrated into the cells, they soon lose their original character, and that those substances only which are unessential for the change, *i.e.* the production of new substances, travel from cell to cell more or less in their primitive form, and are again separated not unfrequently in the same state as they are absorbed. The sap juices of the plant, from whatever part they are taken, contain with few exceptions neither carbonic acid nor ammonia, nor salts of humic acid, but almost solely other combinations of the elementary substances, showing consequently that the former have already been converted more or less into assimilation substances. A number of phenomena not unimportant for the plant itself, as well as for the general economy of nature, are referrible to the degree of energy with which this process of chemical mutation proceeds, and which is naturally dependent upon external conditions, especially those of temperature and light. The most important of these phenomena is the relation of the plant to the atmosphere surrounding it. But here likewise we must not expect to meet with any processes that are not consistent with chemical and physical laws.

It may very distinctly be perceived by a comparative examination of what the plant receives from without, and the substances which it has subsequently produced, that there is no inconsiderable surplus of unconsumed oxygen. This oxygen must be separated, and as the plant-sap itself is able to absorb only a very minute quantity, the whole of this substance must be exhaled into the atmosphere. Experiment has indeed proved that this is really the case; and further it has been observed that under those conditions which conduce to a more rapid mutation of substances, and consequently a greater consumption of nutritive substances, the discharge of oxygen is considerably augmented. It may indeed readily be imagined that the activity of the plant visibly increases under the direct influence of the sun and diffused light, and under these circumstances the evolution of oxygen from the plant is considerably increased. When leaves or any green parts of plants are brought under water and exposed to the direct influence of the sun, they soon become coated with bubbles of air, which, when collected and examined, prove to be oxygen. Consequently the quantity of oxygen gas thus disengaged by the grass of meadows, or the trees of a forest during bright summer days, cannot be inconsiderable. The shade of the trees invites us not only by its coolness, but likewise, although without our being conscious of it, by the agreeable sensations which necessarily accompany the respiration of air richer in oxygen. With this more rapid consumption of nutriment, the carbonic acid introduced by water is under the circumstances insufficient, and the various parts of the plant, wholly deprived of carbonic acid, seek some other means of obtaining what that source is inadequate to furnish. For this purpose, however, all those parts of the plant which are situated at its circumference, and are in contact with the atmosphere, are especially well adapted.

By the examination of what is introduced into the plant from without, and what it subsequently forms from those substances, it may be ascertained with the greatest certainty, that there is no inconsiderable surplus of oxygen thrown off. This oxygen must be got rid of by the plant; and as the juices are themselves only capable of absorbing a very small proportion of it, the whole excess must pass into the atmosphere.

The sap-juice contained in them becomes charged with carbonic acid in the same manner as when water is exposed to the air. The plant thus obtains a quantity of carbonic acid, which is frequently equal in volume to its entire liquid contents. It is evident then that the exhalation of oxygen is accompanied at the same time by an absorption of carbonic acid, and that both processes are entirely dependent upon the chemical and physical agencies in and around the plant. It cannot therefore reasonably be regarded as singular, that under altered conditions in which the influence of light does not play a part, and under which all the processes of assimilation are retarded, an entirely different and almost opposite result should be brought about.

Let us examine by night the same plant which during the day disengaged oxygen, and absorbed carbonic acid from the atmosphere. Since the activity of the absorbent organs appears to be the same at all times when there is a sufficient supply of nutriment, while its consumption and the assimilative process are lessened, it cannot but follow that the carbonic acid should accumulate in the juices of the plant to such an extent, that it can no longer be wholly retained in solution, and that wherever there is an opportunity it should be disengaged unaltered.

For this purpose again those parts of the plant which are situated at the circumference, and in contact with the atmosphere, are the best adapted, and the same organs which by day show a tendency to absorb even the minute quantity of carbonic acid present in the atmosphere, are the means of discharging much larger quantities of the same gas during the night. It follows quite naturally, from this circumstance, that on account of the deficiency of free oxygen in the plant-juices, a transfer of this gas from the air, in other words, an absorption of it, should necessarily take place; however, this absorption is always very minute, and according to experiments which have been made with reference to it, amounts at the utmost to only 4·5 or 6·5 per cent. of the volume of liquid contained in the whole plant.

The disengagement of carbonic acid by night is far from being equivalent to the absorption of this gas during the day. Consequently the plant always consumes more than it returns to the atmosphere. It follows from this, that the air in valleys, and at moderate elevations covered with a rich vegetation, is certainly at times somewhat poorer in carbonic acid than that of higher regions. But the constant motion of the atmosphere immediately tends to restore the disturbed equilibrium, and to bring its constituents into order.

Thus then we see that even under all conditions, provision is made for the growth of the plant, that it finds almost everywhere what it requires, and therefore that its existence is not in the least degree dependent upon accidental circumstances.

Although we are still uninitiated and scarcely capable of explaining the most simple processes which take place in the production of plant-substances, we may still perceive that there is no one of them which has not its laws; and that the formation even of an atom of sugar or cellulose is preceded by a multitude of preparatory operations, and gives rise to as many further processes of vitality in the plant. How it is that from the carbonic acid salts absorbed by the plant, there are gradually produced salts of oxalic, pectic, and other plant-acids, and finally, after further combination, the bases sugar and the allied hydrates of carbon, cannot unfortunately be explained now; but it is very different as regards the nitrogenous bases and the protein substances, towards any conception of whose formation we do not possess the most insignificant data.

But the light which has been thrown upon this hitherto obscure branch of botanical science by a German physiologist,

J. M. Schleiden, crowded as it is with false hypotheses, the brilliant result which by the acuteness of his intellect he has secured to science, admits of our entertaining a hope that the darkness is now dispelled. If the future cultivators of plant physiology will make it their duty to employ retorts and tests for themselves, and not leave this task to the chemist, who, striving towards other objects, furnishes them only with such results as may happen to present themselves, we may then anticipate more important results for this hitherto-neglected study, which in return would not remain unproductive, but elevate agriculture, the most important branch of industry, to the position of a rational art.

LETTER VIII.

CONFIGURATION OF THE PLANT. FUNDAMENTAL ORGANS.

By the formation of organic substances from inorganic compounds of elementary substances, the plant is provided with gum, sugar, cellulose, protein, &c.; but much remains to be done before these substances can appear in the form in which we meet with them as parts of the cells. The force, in virtue of which they acquire a definite form, is certainly different from what is ordinarily termed chemical affinity; and without any more intimate knowledge of it, the term vegetation has been applied to it. It is this force which determines the aggregation of protein substances into globular masses, which causes the deposition upon each of them of a layer of cellulose; thus laying down the plan of the configuration of the cell. It is the same force, likewise, which repeats this operation an infinite number of times; and thus not only determines the developement of compound arrangements of cells, but likewise provides for the multiplication of them. In short, the vital force, that force the nature of which has hitherto remained unknown, the true architect of the plant, is that to which it owes its origin, its existence, and propagation, and upon which, likewise, ultimately depends the diversity of form, in which the idea of the plant has clothed itself.

Although we recognise in nature many processes which resemble the formation of the elementary parts of plants, as, for instance, the formation of crystals; still on examining them more closely it is found that the production of the former is widely different from that of the latter bodies; and consequently that the cell and the crystal, the plant and the mineral, cannot, upon any ground, be compared with each other.

But when we advance beyond the production of the cells, the mode of their connection gives rise to so many questions, that we willingly devote greater attention to this more accessible department of the investigation than to those recondite problems which we are scarcely able to fathom, even with the aid of the happiest abstractions.

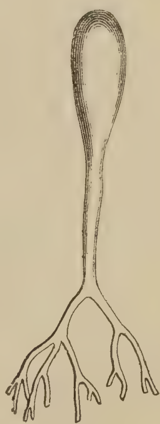
On reviewing the plants of any region of the earth, of any period of its history, it is only possible to recognise one single fundamental distinction among all the various differences of form. All plants, without exception, are either single cells, that is, they consist of only one cell, or are multiples of a greater or less number of cells, The former are the unicellular, the latter the polycellular plants. From the varied configuration of the cell it may easily be foreseen that even unicellular plants may assume a great number of different forms; but this diversity of form must always be inferior to that of more complicated individuals.

Since we have already seen that the multiplicity of cells in the plant is only a consequence of the generative faculty of the originally individual cell, the question naturally suggests itself, whether the unicellular plants are destitute of this faculty? This question may be answered both affirmatively and negatively. Negatively, inasmuch as the unicellular plants are capable of propagation, and affirmatively, inasfar as there is a considerable difference between the propagation of the two kinds of plants; so that, what the first are able to achieve, as it were, at the first attempt, the latter can effect only by a series of generations.

It is a profoundly wise conception which prevails throughout the entire range of animated nature, that at the same time that the individual being is subject to extinction, still its existence in time is provided for by its capability of putting forth germs possessing the faculty of developement. Not only the production of such germs, but likewise their separation from the maternal body, and their individualization, is determined by that process which is usually termed propagation. It is only by the continual formation of self-separating independent cells that a plant remains unicellular. When this is not the case, when the cells which are produced do not separate from the mother-cell, even when they cease to be further productive (permanent cells) a cell-multiple is formed. But it is also possible that in such cell-multiples, self-separating cells, true propagation-cells may be produced, after series of successive cells. The entire immense formation of plants, extending over the whole earth, prevailing throughout all periods, tends solely and alone to the earlier or later attainment of this end; and the flood of various configurations, the thousandfold forms of plants, are in reality nothing more than the expression of these oscillations between boundaries indefinitely distant. The only endeavour of the plant is to accomplish the formation of the propagation-cell; and when it does not rapidly achieve this end it is compelled to adopt the most manifold means, to enter upon the most singular preparatory labours, and thus to give rise to that which we term the plant, and which presents itself to us under such a vast diversity of aspects.

It would be foreign to the purpose of these letters to follow up the consideration of the vegetative force in all its phases; still we must not neglect to glance over at least the most essential particulars of the plant form.

Fig. 21.



It is a circumstance of great importance as regards the significance of the fundamental form of the plant-structure, that even in the unicellular plants we may here and there recognize an arrangement of certain parts, similar to that presented in the most complicated cell-multiples. In the first instance, the round vesicle becomes extended in two opposite directions, forming thus a pipe, with one end turned towards the earth, and the other prolonged into the air, as is shown in Fig. 21 which represents an unicellular plant belonging to the algæ (*botrydium argillaceum*, Wallr.). The presence of nutritive substances in the soil, and their absorption, on the one hand, as well as the need of air and light for their assimilation, on the other, appear to be the principal circumstances which determine the transformation of the cell into a utricle growing upwards and downwards, a type of the stem and root or axis. Nevertheless it does not remain stationary at this point. In both directions secondary processes are thrown out, as it were, repetitions of the axis; those at the descending part being more or less bag-like; those at the part above ground being also bag-like, though different from the others.

In this simplest of all forms in which the plant appears, may be recognized all the essential organs which, even in cell-multiples again tend to make themselves sensible. The first endeavour is directed towards the building up with cell elements of an axis, possessed of a tendency to prolong itself in two opposite directions, a living magnet attracting and repelling at both poles, the negative pole directed towards the earth, the positive pole towards the air and the light, and maintaining, with the earth as well as with the air, a constant interchange of substances, by means of which it is alone able to exist.

There is scarcely any instance in the plant world of the mere formation of this axis. The tendency to multiply itself is always prominent; and thus similar cell-multiples are put forth from the primitive series as secondary axes; in the lower stage of developement imitating the form of the primary axis, and deviating more or less from the axial form in the more highly-developed parts of the plant world. Thus are produced upon one side of the axis, those variously-formed supplementary organs which are termed leaves; while, at the other side, the original axial or cylindrical form is maintained with but few modifications in the radiations of the root.

To this fundamental form of the perfect cell, as it appears in some algæ (*botrydium*, *valonia*, *caulerpa*), etc., which presents itself in the most simple cell-multiples, all the most varied and diverse forms of the plant world may be reduced; and although it sometimes appears as if the linear arrangement of the elementary parts did not predominate, it is in reality only hidden, partly by the preponderance of other tendencies of developement, and partly by the subsequent developement of masses which have no causal relation to it; so that even in the most distorted and decisive plane forms, we are able to detect the original linear arrangements.

We may therefore say, with perfect justice, that the plant, divested of all accidental attributes, is, as regards form, essentially a system of axes. This is very distinct and obvious in all the less highly-developed plants; and from the mosses to the most perfect plants, the axial configuration presents itself, so that they have long been characterized by a corresponding term intended to express the difference between them and all other plants which have not very happily been termed foliaceous plants.

LETTER IX.

THE PLANT CONSIDERED AS A LEAVED AXIS.

If the formation of the plant were limited to the production of a single axis, upon which sooner or later, and after more or less numerous generations of elementary parts, the developement of reproductive cells was ultimately achieved, there can be no doubt that the greatest monotony would prevail in the plant world.

But the emancipation from such restriction, the progressive developement of the plant, is necessarily attended with the capability of producing new axes, and consequently of assuming the greatest multiformity. With the appearance of the secondary axes, the door is opened, through which the unfettered power of vegetation developes itself in all directions. That which presents itself to us as diversity of configuration in the plant world, and produces so pleasing an influence upon our senses, as well as upon the imagination, is ultimately dependent upon nothing else but the formation of these secondary axes.

It was certainly a long time before the observing intellect, the more penetrating judgment, and the power of combining details into one harmonious whole had broken a way through the labyrinth of plant forms, and succeeded in uniting under a few easily intelligible forms that endless multiplicity of configuration which almost overwhelms the power of conception. Now that this gigantic work has been achieved, it is an easy matter to recognize even in the most strange and fantastic forms the one primitive law of formation. With this magic formula we may wander, not only through the meadows and woods of our native land, but also among the giant and pigmy growths of other regions; and in whatever countries, mountains, or valleys they may occur, we need not be in fear of meeting with anything inconsistent. If then the supplementary parts of the axis perform so important a part in the general phenomenon of vegetation, it is certainly worth while to examine somewhat more closely their influence upon the configuration of the plant. But this must be done by considering not only the general mutability of their form and character, but likewise the sequence of their appearance. We will do this separately.

First, as regards the configuration of the secondary axes: this in the simple cell-multiples, differs less from the form of the primary axis than in the higher plants; the luxuriance of form which presents itself in the latter has scarcely any limit, the deviation from the original cylindrical form which the leaf undergoes is here of the most varied kind. Nevertheless it is the plane form which gradually predominates; so much so, that the general conception of the leaf is almost universally associated with this form. The simple conical cylinder axis of the plant becomes thus in general a leaved axis. This expression for the more perfect plant form may be regarded as the most universal, the most comprehensive. Everything, therefore, which appears upon the axis, is only leaf. In the leaf the whole configuration is exhausted, and precisely on this account the greatest luxuriance of form in the plant world is presented by the leaf. There is nothing beyond the formation of the leaf on the axis, and whatever the plant is unable to achieve in this is unattainable by it. However great, therefore, the diversity we recognize in the axis, this is produced not by itself, but by the leaf.

To form a true conception of the subject of leaf formation, which will probably appear an intricate maze, you must allow me to lead you by a somewhat circuitous path to a point from which, before entering, you may obtain a general view of it.

It was a happy idea of our great poet prince, in order to comprehend the vast diversity of plant configuration, not to involve himself in the endless complexity of details, but to contemplate the whole subject from a greater distance, and in a more general manner. In this way everything presented itself to him under a different aspect, the apparently essential became accidental, the accidental essential; in short, he perceived the forest which before could not be seen because of the trees.

In all the higher plants, foliage, flowers, and fruit were regarded as essentially different parts. It was Göthe who first recognized in the flower and fruit the recurrence of the foliage, so that according to this mode of viewing the subject there is no essential difference between these three principal parts of the plant.

When we regard the subject somewhat more definitely, it becomes evident that it is the leaf, which in its protean capability of transformation, in the power of gradually assuming another form, occupies first the lower, then the upper part of the axis, and ultimately by combination at the apex, produces the flower and fruit. The parts of the fruit, as well as those of the flower, are certainly not to be regarded as anything more than whorls of leaves—leaves which indeed differ both in their character and position from other leaves, although in no other way than in degree, so that a constant progression is recognizable throughout all forms of leaves. This mode of regarding the plant must be of essential influence with reference to the knowledge of its configuration. It is not the diversity of form, but the fundamental unity in that diversity which is here the most prominent feature, Fig. 22.

Fig. 22.

In order that this may be perfectly intelligible, let us go back to the origin of the leaves.

All the rudiments of leaves originate soon after the formation of the axial point, and follow it continually, so to speak, step by step. As the axis elongates, they are developed laterally one after the other, elongating, like the stem at the apex, until perfectly formed, and then expanding in a contrary direction from the free end towards the ground. The leaves and axis, therefore, do not essentially differ from each other, except in the fact that the growth of the former is limited, while on the contrary, that of the latter is unlimited. The whole diversity of leaf forms depends upon the energy and the different directions with which the cell mass is produced and distributed.

While the leaves are quite young, they are without exception alike, their diversity is not developed until the period of their growth and increase in mass. The young leaves of the flower and of the fruit have exactly the same appearance as the leaves of the stem, consequently we are justified in entertaining the opinion that there is no essential difference between the leaves of the stem and those of the flowers and the fruit, or between the respective regions of the axis. Nevertheless it cannot be denied, that in attaining their perfect developement, differences become gradually perceptible.

These differences, more or less distinct, frequently present themselves from leaf to leaf, but in the most striking manner, after considerable intervals, and more comprehensive alterations. In this respect the plant resembles a building consisting of smaller and larger apartments arranged above each other, in which, although the same character prevails throughout, a constant increase in elegance and decoration is perceptible in the higher stories, while at the same time it does not the less present, as well in the exterior form as in the interior arrangement, such peculiarities as indicate a different application and a sharper separation of the parts. Certain leaf structures present likewise, even externally in the plant, the plinths and other projecting portions of the masonry separating the successive stories, and in the interior an equally unmistakable difference is manifested in the form and contents of the parts corresponding to the exterior.

It might indeed almost be said that the analogy between the plant and a building does not become distinctly perceptible until the formation of leaves and their mutual succession take place, while the upper parts of the axis situated between the leaf formations would, from their simplicity, scarcely have been able to give rise to a structure presenting such beautiful and connected sequence in its arrangement.

LETTER X.

LEAF FORMATIONS.

After what has preceded, it will be evident that it is a matter of the first importance to become acquainted with these stories of the plant structure, to point out their peculiarities, and sufficiently to consider the architectural combination between them.

In order that this problem may become solvable, it is necessary again to lay aside the idea of a primitive unity of all leaf organs, and to consider them in accordance with their different characters, but at the same time to unite under one point of view, and one form of expression, such objects as are evidently related and analogous. By thus reviewing the production of leaves upon the stem or axis, we find that there are seven such groups, or, as I shall call them, formations.

I speak here only of the more perfect kinds of plants, leaving out of consideration the less perfect ones, in which the leaf formations are less numerous. These leaf formations are:—1, the lower stem-leaf formation; 2, the true stem-leaf formation; 3, the upper stem-leaf formation; 4, the calyx-leaf formation; 5, the flower-leaf formation; 6, the stamen-leaf formation, and 7, the fruit-leaf formation.

Fig. 23 is an ideal representation of a perfect plant, with its essential organs. The several regions of the leaved axis are divided into seven formations, the upper ones being artificially elongated so as to be more clearly distinguishable.

Upon the same principle that the geognost characterizes a number of different strata as belonging to one formation, inasmuch as they contain embedded organic remains of the same kind, which indicate a great revolution in the life of our planet, so the botanist considers under the same denomination a series of similar leaf forms as a connected; whole for here likewise may be recognized a great revolution in the formative tendency of the plant—the completion of one of its stories.

It will perhaps not be without some interest for my readers to follow me from story to story, from formation to formation, while I perform the office of an experienced guide, furnishing answers to such questions as may suggest themselves, directing attention to this or that particular, and generally assisting them in the consideration of this subject. Nevertheless I must confess to being myself only a student in this branch of the science, and that I only repeat to you the words of a master whose name you shall learn hereafter.

Fig. 23.

The lower stem-leaf formation, which occupies the undermost story, includes all scale and sheath-like leaves. Fig. 23, form *a*. They are characterized in form by a broad base and limited height; in substance, by a frequently fleshy cartilaginous or leathery consistence, and a dull yellowish or dark colour. All these characters show that these leaves are wholly or partially excluded from the influence of light and air, and have remained as it were at the lowest stage of developement, and nearest to the primitive form. They thus especially mark the basement story of the plant structure; or, in other words, that part of the axis which frequently, though tending upwards, remains concealed in the earth, and like the root, serves for the fastening of the plant.

This basis of the plant is frequently confounded with the root, a circumstance solely owing to its situation and striking difference in external appearance from the other parts of the axis. All rhizomes, subterranean buds, such as onions, potatoes, &c., belong to this formation, and even some parts of the stem above ground. It not unfrequently happens, moreover, that they are much contracted in length, so that the leaves appear crowded and covering each other.

The second formation, that of the true stem-leaves, fig. 23, form *b*, corresponds properly to the ground floor of a building. It is generally a very extensive structure, particularly characterized by the multiplicity of organs which are properly termed leaves. They are distinguished by a greater longitudinal extension, with less breadth of base, expansion at the upper and contraction at the lower ends, a more membranous nature, and a green colour. They are moreover divided both longitudinally and laterally, thus giving rise to such a rich diversity of forms as is scarcely anywhere else met with. The longitudinal incision gives rise to the production of the lobes, and the lateral segments or leaflets, the lateral incision gives rise to the production of the most varied and complicated forms of leaf. The system of veins likewise corresponding to the exterior configuration is very manifold in its character.

The leaves belonging to this formation likewise originate from very simple forms, cotyledons, which sometimes scarcely differ from those of the first formation; but a considerable developement very soon takes place, and they pass gradually into the next succeeding formation. A great part even of the more perfect plants commence their structure with this story, the basement being wanting; still the structure is not on this account less durable, less pleasing to the eye, or less imposing; I might indeed almost say, that it is essential to its magnificence to commence immediately with this story, and to leave the secure fixing of the groundwork to the descending part of the axis, or, in other words, to the root

The upper stem-leaf formation, fig. 23, form *c*, follows next in order, and, as its name indicates, is situated above that last mentioned. The leaves belonging to this formation approximate in some degree both in form and character to those of the first formation, since both the petiole and the expanded form, as well as the green colour, disappear, more or less, but they are distinguished from them by the narrow base and more delicate structure, which is not much inferior to that of the following formation. To this class belong sheaths, bracts, glumes, &c. They present but little that is strikingly remarkable, in consequence of their minuteness, and are sometimes even imperceptible; but as regards the general structure of the plant, they are by no means insignificant, inasmuch as they determine, and are the means of effecting the construction of the next story, and thus in a certain degree establish the harmony between the lower and upper parts of the plant structure.

The most considerable difference in the general production of leaves occurs in the calyx-leaf formation. Fig. 23, form *d*.

Here the leaf appears both in its form and position to be totally altered. Although in general resembling, as to substance, the stem-leaves, it is considerably smaller; and perhaps even by this means renders the approximation of analogous leaves possible, which henceforth succeed each other vertically, at scarcely appreciable distances, and therefore reveal their connexion more distinctly than is the case in the previous leaf formations. With the calyx leaf commences the extreme antithesis in the plant axis—the flower and the foliage—for the fruit appears for the most part subordinate to the flower, and exercises less influence upon the façade of the structure.

The calyx-leaves are more massive, coarser, and greener than the upper-stem leaves; they have again a broader base, a very slight or even no expansion, and no petiole; they are equally destitute of any incision, and thus strikingly present a retrogression, an alternation such as frequently occurs in certain members of one formation.

The following formation, that of the flower-leaves, fig. 23, form *e*, presents, on the other hand, a very decisive advance.

These leaves are especially distinguished from all others by the delicacy of their tissue, as well as by the purity and diversity of their colour. The flower-leaves situated in the same crowded manner as the calyx-leaves, form what is called the corolla, the most admirable combination of all that constitutes delicacy and beauty. Deprive the flower of the corolla, and it sinks at once to mere unheeded foliage; give to it fragrance and harmony of colour, and it becomes an incarnation of loveliness.

The art of floriculture consists solely and alone in the enlargement and decoration of this part of the plant.

The flower-leaves are generally longer than the calyx-leaves, but narrower at the base; they present for the most part a considerable expansion, but no decisive developement of petiole. In consequence of a radiated, forked, or feather-like incision, they acquire the vast diversity of form, as well as by means of mouldings, excrescences, duplication of surfaces, &c., which give rise to the production of the so-called double flowers. Nevertheless the two leaf formations of the calyx and the corolla, do not always present marked distinctions, but, on the contrary, blend sometimes in such a manner, that the corolla resembles a calyx, and the calyx a corolla. However, the more frequent occurrence is the total, or almost total, subordination of one or other formation, or the interfusion of both into one; this latter case occurs, for instance, in a large section of plants as a general rule, and the resulting formation alternating between calyx and corolla, is called a perigone.

The corolla is succeeded by the stamen-leaf formation, fig. 23, form *f*. The term leaf here does not appear to be a very appropriately-selected expression, for the leaf-like character disappears here entirely, and it is its function alone which continues.

The stamen-leaves are the smallest and most remarkable leaves of the flower, with a decisive developement of petiole, and small expansion which passes into the bag-like enlargements of the lateral parts—anthers. It is only in a few instances that the leaf-like character becomes more prominent, but then it is at the cost of the production of anthers. The so-called double flowers, in which there is a malformation of the anthers, communicating to them the full appearance of flower-leaves, are sufficiently indicative of this. Every one is acquainted with double roses, pinks, ranunculuses, etc., whose increase of flower-leaves depends exclusively upon the transformation of stamen-leaves into flower-leaves.

While the leaves of all other formations have a certain duration, and are not to be regarded as transient phenomena any more than the axis, the contrary is generally the case with regard to the stamen-leaves. Their existence is very precarious, and dependent upon the more or less rapid developement of the anthers. But this circumstance indicates that the aim of the plant, in this direction at least, must be achieved in the developement of the stamen-leaves, and especially of the anthers.

Finally there is another formation, that of the fruit-leaves or carpels, which forms the uppermost story of the plant structure, fig. 23 *a*. Here likewise the leaf-like character is less obvious, and principally because the individual leaves of this formation are always more crowded together than those of any other, and generally even grown together, forming a cavity in which the axis terminates in numerous radiations.

Further the fruit-leaves are thicker, larger, and greener than the other leaves; they rise from a smaller base, but expand immediately, while the upper part contracts in a petiolar manner, forming the style. These leaves have a longer duration than any others, and still continue to be developed when the others are for the most part dead. It is these leaves, together with their enclosures, that in the first instance form what are called fruit-buds, from which afterwards the fruit is developed.

Whatever else appears upon the axis after the fruit-leaves, belongs to the last offshoots, or rather breaking up of the axis; these are the seed-buds upon which neither definite axes nor parts of leaves can be distinguished, and which consequently scarce belong any longer to the morphological individuality of the plant.

Thus with the construction of the fruit-leaf story, the axis, and consequently the developement of the plant, has attained its end. In what this end consists, and how attained, shall be considered in a subsequent letter.

LETTER XI.

ARCHITECTURAL ARRANGEMENT OF THE PLANT PHYLLOTAXY.

The study of the structure of the plant as a whole, and in accordance with the larger and more obvious sections, or, to keep to our architectural comparison, the various stories, necessarily leads to an examination of the more minute details of the processes by which the whole structure is raised, as well as of the relations of measure which must necessarily exist. The consideration of this point comes so essentially within the domain of architecture, that we cannot do otherwise than adapt our mode of contemplation to the laws which obtain in that art. It is only in this way that it becomes evident that in the plant world, as in other parts of nature, definite relations, and an invariable proportionality exist, upon which all phenomena, and especially those of developement and configuration, are dependent. When, as we have already learnt, the plant builds its body by its own means, according to a self-projected plan, it may well be expected that it will do so in accordance as well with the laws of stability, as with those of architecture.

Although in this respect we have not yet penetrated to the full depth of the prevailing order and regularity, it has not escaped observation, that the square and plumb-line have their application even in the construction of plants.

I will now lead you to a consideration of these geometrical relations, commencing with the most simple of them.

Whatever plant we examine, we are at the first glance struck with the truth that the symmetry here prevailing in the arrangement of the several parts, differs from the symmetry of most architectural structures in the circumstance that it is not made dependent upon a few predominating directions, but is carried out with an equal developement in all directions. It is thus that the plant structure is distinguished in a very striking manner, and independently of a few exceptions, from the structure of the animal body, in which there are always corresponding members right and left, before and behind. The plant has no right and left, no front and back, and although this is sometimes apparent in the distichous arrangement of their supplementary parts, and even in the axis, still it is always very limited, and derived from the predominating mode of arrangement. An uniform disposition of parts on all sides is called concentric; and it is such a concentric arrangement that almost universally prevails in the plant structure, and is especially evident in the axis and its appendages the leaves. In this respect, therefore, we cannot compare the plant either to a palace or any other cubical parallelopiped or pyramidal structure, but only to one which is round and similar upon all sides, to a temple or tower. We have already become acquainted with the various stories succeeding each other at more considerable distances. We have now to consider these stories more closely in their details and respective peculiarities.

Even a superficial glance convinces us that it is not merely one or other story, as perhaps the calyx or corolla, which presents an especial regularity in the arrangement of the leaves, but that sometimes this regularity likewise prevails in the region of the lower, true, and upper stem-leaf formations. A smaller extent and a somewhat more crowded situation of these leaves frequently manifest a symmetry the same as that which generally prevails in the flower. We cannot therefore avoid ascribing to the lower regions of the plant the same conformity to law with regard to the disposition of parts as prevails in the other regions of its stem.

While the plant was regarded as the result of all manner of accidental influences, or at least as an inexplicable conjunction of the most diverse formative tendencies, it may readily be conceived that there was no probability of recognizing any definite laws in the elements of the leaves which contain the most effective expression of constructive differences, and in their succession.

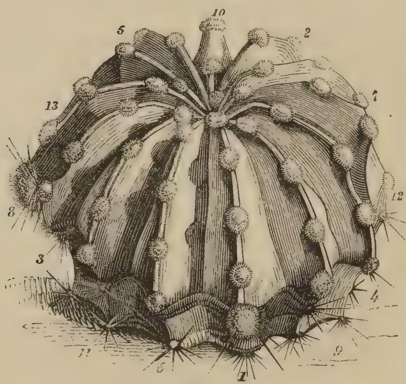
The penetration of Karl Schimper first dispelled this mystery, drew from before the eye the veil that had hindered our observation, and then the arrangement of the leaves upon the stalk, as well as in the flower, presented itself as a simple law for the formal expression of which but little more was requisite.

In the first instance the truth became perceptible, that most leaf formations do not consist of a succession of leaves situated at irregular distances from each other, but that a definite proportionality prevails, which though less marked in the vertical distances, is nevertheless constant and unalterable in the horizontal distances between the leaves; further, that this proportion, though not always the same, is still capable of alteration only after a definite series of leaf groups; and finally, what is most important and confirms the unity of the law, that the alterations of measure likewise bear a certain proportionality among themselves. These laws have with endless labour been deduced from an immense number of facts presented by the most diverse plant forms, and at the present day we doubt no longer that the same law presents itself in the arrangement of even the smallest leaves, and in the most different formations. Let us now enter upon a more extended consideration of this law.

The most distinct and striking advance that the plant makes in the erection of its tower-like masonry, is undoubtedly the shooting out of a leaf. The leaf is the stage upon which it advances in its progress towards the attainment of its aim, and whence it continues pushing out stage after stage. We perceive that these stages are not all alike, but that after several immediately successive stages, there is a point of cessation—an interval—and the fact that in this way successive series of stages are formed one above the other, is less distinctly perceptible, and much laborious observation is requisite before it can be recognized as an universal law. When the series of stages are separated by knots, as in the stalks of grasses, and many other plants, the law is obvious, but such is not always the case, and these intervals are frequently much concealed, and appear almost like a continuous succession of stages. But it is at the same time extremely remarkable that these intervals recur sometimes even after one stage, though more frequently after 2, 3, 5, 8, 13, 21, sometimes, indeed, not till after 34, 55, 89, 144, 233, and 377 stages. The more numerous the stages in any interval, the lower or more compressed they are, generally speaking, but at the same time broader, so that it takes only one or two stages of the interval to extend round the whole circumference of the axis, while in all other cases 2, 3, 5, 8, 13, &c., revolutions are necessary, a circumstance which communicates to the breadth of the stages a very definite architectural proportion, which may be expressed most simply by $\frac{1}{1}$, $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{5}{8}$, $\frac{8}{13}$, $\frac{13}{21}$, &c. These intervals have been characterized in technical language by the term leaf-series, or leaf-cycles; and by means of horizontal projections, it has been made very clearly perceptible that the advance from leaf to leaf takes place in every plant, and every part of a plant, without exception, in a spiral line. When, moreover, the leaves of numerous leaf-cycles are situated at a small vertical distance, a spiral arrangement is recognizable in the exterior appearance, but it is not of this fact that we are now speaking. While these are characterized as the only true succession of stages in the arrangement of the leaves by the name of fundamental spirals, the others may appropriately be termed secondary spirals.

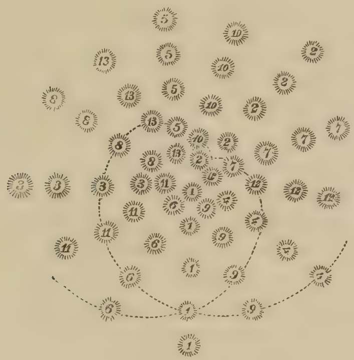
Fig. 24 represents a plant of the *Echinopsis multiplex*, Zucc., of the natural size. The thorns are removed from the bud

Fig. 24 *a*.



supports, so that these, as well as the ribs upon whose edges they are situated, may be better seen. The position of the bud supports, or what is the same thing here, the suppressed leaves, is according to the $\frac{8}{13}$ order; that is to say, the bud supports succeeding each other in an ascending direction are so disposed, that the fourteenth is situated exactly over the first, the fifteenth exactly over the second, the sixteenth over the third, and so onwards. When, as in the accompanying projection, fig. 24 *b*, the outermost numbers 1, 2, 3, 4, &c. are joined by a

Fig. 24 *b*.



line, a spiral is thus obtained, which is termed the fundamental spiral. But this is not the line, which at once strikes the attention on looking at this plant. The lines formed by connecting on the one hand the numbers 4, 9, 1, 6, 11, 3, 8, 13, 5, 10, 2, etc., and on the other by the numbers 6, 1, 9, 4, 12, 7, 2, etc., are far more obvious, and are called the secondary spirals. The former is the less inclined in its ascent, the latter the more inclined of the two.

When the construction advances according to any one of these successions of stages which may be most simply expressed by the above series of fractions, it does not always remain confined to that particular order. In every leaf-formation, consisting of one or more such intervals or leaf-cycles, there may be a change from one proportion to another. Several successive leaf-cycles with a position of $\frac{5}{8}$ may pass into others of $\frac{8}{13}$ and $\frac{13}{21}$ as well as into less complicated ones, for instance, $\frac{3}{5}$ and $\frac{2}{3}$.

There can be no doubt that this passage from one order of succession to another is determined not alone by the specific peculiarity of the vegetative agency; but frequently also by its degree of energy, to which, likewise, must be ascribed the greater or less vertical distances of the leaves, and the interfoliar spaces thus produced upon the stem, with their generally but not specially definite proportionality.

It is evident from these laws as well as from their more casual modifications, that a high degree of luxuriance must prevail in the architecture of the plant; and we cannot, therefore, wonder at finding that plants with leaves, even of a similar or identical form, present the greatest diversity in the exterior aspect. In this respect, indeed, the plant resembles a Proteus, changing from one form to another without our perceiving how it assumes or divests itself of its magic vest.

While this change is less obvious in the passage from interval to interval, it becomes more prominent in the passage from one leaf-formation to another, and thus a more marked distinction is produced than would otherwise be the case from the form and character of the leaves. In short, the stories of the plant are thus separated externally, so that the architectural arrangement of the plant is altered above each cornice without the style itself being affected. This is least striking in the lower stories, and much more so in the upper ones. After a simple order of arrangement in the leaves of the lower and true stem-formation, there is frequently a very complicated arrangement of upper stem-leaves, as is the case, for instance, in the composite *Dipsaceæ*, *Proteaceæ*, *Piperaceæ*, *Aroidæ*, etc.

The greatest change in the appearance of the plant is always produced by the passage from the foliaceous part of the stem to the flower; the complicated arrangements of parts are here reduced again to the most simple plan, and thus the calyx, corolla, and stamen-leaf formation, as well as that of the fruit leaves, are characterised by the simplicity of the order in which their elements are disposed. Fig. 25 *a* represents a longitudinal section through the flower of saxifrage, and fig. 25 *b* the corresponding ground plan.—*f* is the uppermost stem-leaf; *c* the five calyx-leaves; *p* the flower-leaves; *st* the 2×5 stamen-leaves, all in $\frac{3}{5}$ order; lastly, the two fruit-leaves *cph* (*Carpophylla*) disposed in $\frac{1}{2}$ order.

Fig. 25 *a*.

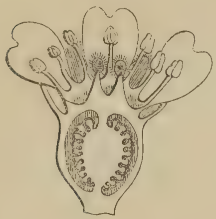
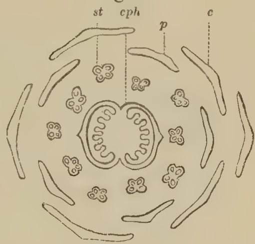


Fig. 25 *b*.



But here there is still another peculiarity which is seldom met with in the lower-leaf formation—I allude to the so-called verticillate arrangement. It is certainly true that whorls do actually occur in the true foliar region; and, indeed, whorls consisting of two, three, four, and five leaves. The simple opposite situation of the leaves, their opposite and rectangular position, together give rise to whorls, consisting of two and four leaves; but in all instances this can only result from the reduction of the vertical distances to a minimum, so that the spiral line, instead of ascending, runs almost or quite in the same plane.

This compression of the spiral line, in which the leaves succeed each other, is to be regarded as a general rule from the calyx-leaf formation, upwards; consequently, all the succeeding leaf-formations appear like closely contiguous rings of leaves, and the whole thus acquires an entirely peculiar aspect. Besides this, the number of individual leaf-cycles is very small, seldom exceeding two or three, so that the upper stories of the plant thus acquire an appearance totally different from that of the lower stories. It is only the all-pervading law of leaf-sequence which shows the connexion between the upper and lower parts, and enables us to perceive in the former only a further perfecting and ennoblement of the lower structure.

There is, however, still one circumstance to which I must direct your attention, a circumstance by which the architectural aspect of the flower acquires an especial charm, which by no means depends so much upon the multiplicity of forms in the leaf-organ as upon their arrangement. In the lower parts of the plant-axis the individual leaf-cycles follow each other without intermission, and frequently in great number. After each revolution of the spiral, the next cycle commences exactly over the commencement of the former one, and so onwards. The natural consequence of this is, that the homologous members of each separate cycle are situated exactly above each other. There must necessarily appear to be as many vertical series as there are elements in one cycle, thus, 2, 3, 5, 8, 13, etc. These series certainly appear more distinctly, in some instances than in others, in a particularly marked manner in the Echinocactus plants, in which the perpendicular ribs of the stem are produced by the interfusion of the superposed leaf.

The case is different in the flower. Even when only two similarly membered leaf-cycles follow each other as well as when dissimilarly membered cycles are associated, there is never an uninterrupted progression. It is only in this way that notwithstanding the crowded position of the leaf-cycles, the leaf-elements do not cover each other. The measure of progression in the succeeding leaf-cycles is increased exactly so much that the elements of it come to be situated between those of the previous cycle; the consequence of which is, an alteration of the leaves which, as may readily be conceived, is not without its influence in the agreeable impression which the flower always produces in us. Thus, then, there presents itself in the flower, together with the greatest simplicity of elements, the most beautiful harmony in their arrangement, so much so, that the architectural aspect of the flower becomes really a model of perfection in this respect; and, as the history of constructive art teaches us, it has always exercised a determining influence upon all the architectural works of man.

This simplicity, however, does not appear to be universally prevalent. In some instances more complicated relations of position present themselves even in the flowers, especially such as are composed of a great number of elementary leaves. Examples of this fact are furnished by the cactus plants, the nymphæ, the *Calycanths*, etc. Nevertheless, the latter are especially well adapted to render the unity of the flower structure recognizable. Fig. 26 represents a flower branch of Calycanthus floridus. The enlarged vertical section Fig. 27 *a*, with the aid of the ground plan, fig. 27 *b*, will enable us to gain some insight into the somewhat complicated structure of this flower; *f* indicates the origin of the true stem leaves which have been removed; *p* the coloured leaves of the floral envelope or perianth; *st*, the stamen leaves; *stab*, the abortive staminal organs. Besides these, *m* represents the pith substance of the flower-stem, and *g* the seed-buds, gemulæ, situated upon its superior expansion. The diagram, fig. 27 *b*, will serve to give a more accurate idea of the relations of position in the flower,

Fig. 26.

Fig. 27 *a*.

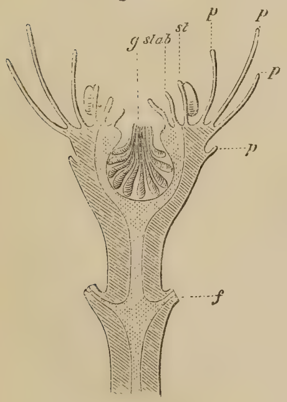
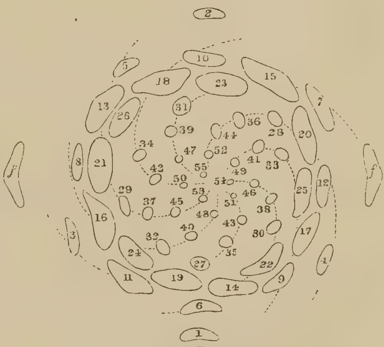


Fig. 27 *b*.



where, after the two opposite leaves *f f* there follow from 1 to 28, the leaves of the floral envelope at first reduced in size, then larger, and then again becoming smaller, after these, from 29 to 41, the stamen leaves (*st*), and lastly, from 42 to 55, the abortive staminal organs in the order pointed out. While in the first six leaves there is a perceptible tendency towards lower arrangements of the leaves, all the others stand in definite positions. This retrogression occurs in almost every flower in other ways.

There are, indeed, very numerous deviations from this general regularity in the arrangement of the leaves which has with good reason been called leaf order or phyllotaxy; still these deviations do not by any means affect the validity of the law, but rather soften its iron rigour; so that the plant thus gains infinitely in expression of liberty. Among these, for instance, may be named the displacement of the leaves on one side by the unequal thickening of the stalk sides, the unequal growth of the leaf base, and a torsion of the axis itself—circumstances which result from unequal nutrition, unequal influence of external agents, etc.

LETTER XII.

PROPAGATION OF THE PLANT.

In glancing over the history of botany, it is without difficulty perceivable, that on no subject within the province of this science, have so many different theories been held as on the propagation of the plant. The obscurity of this process, on the one hand, as well as the influence which it exercises upon the whole range of developement and configuration on the other, have at all times led to its being regarded as the most mysterious, and, likewise, the most important function of plant life, and sufficiently explain how, as the starting-point of all botanical knowledge, it should so repeatedly have been a subject for discussion, and how easy it was to form erroneous views with regard to it.

Even at the present time science must not flatter herself with the belief that the veil has been removed from before this sanctuary of plant life. However, it has at least been possible to catch a glimpse of the principal points of the external phenomena, to distinguish between the various phases in which this process presents itself throughout the whole plant world, and to recognise what is essential in it, and what is more or less casual.

We have already in treating of the growth of the plant entered upon the subject of its propagation. We then found that every increase of mass is the result of reproduction of one cell from another; but the difference between that propagation which consists in an increase of mass and propagation in the more restricted signification of the term, consisting in the formation and separation of germs of new individual life, remained hidden from us.

We will now attempt to ascertain in what respect these two processes differ, and likewise describe the various modes in which the true propagation is effected in the plant world. For this purpose, it will be advisable, as in all other cases, to direct our attention to the more simple forms.

My readers will remember that I have frequently spoken of plants consisting of only a single cell. As might naturally be supposed, the propagation of these plants is as simple as their life. One or more cells formed in them separate spontaneously from the mother-cell which has thus propagated itself. When the mother-cell is round and tolerably uniform in structure on all sides, every part of the individual bears an equal share in the propagation, and the daughter-cells, even at the time of their separation, perfectly resemble the mother-cell.

But when the mother-cell has passed through a certain progressive developement, when it has become larger, when it has experienced opposite changes in configuration, then the individual or vegetative life, and the propagation, become more and more independent of each other. The mother-cell then forms reproduction cells only after a certain definite time, and at one particular part; and, further, these reproductions do not in any sort resemble the mother-organism in the first instance. As instances of the former and more simple mode of propagation, may be mentioned several chrœococcaceæ, and of the latter mode, the species ascidium, botrydium, but still more the species vaucheria, caulerpa, etc.

It cannot be denied that some plants, almost as simple in structure, present a somewhat higher mode of propagation, but then the propagation cells which are separated, do not originate immediately from the mother-cell, but are produced by means of one or more intervening generations of cells, which in contradistinction to the true propagative generations are called vegetative generations. These vegetative generations produce a multiplicity of cells, which adhere together in a more or less intimate manner, until the last or transition generation succeeds, which separates and commences the new cycle. The cells of the transition generation are, for the most part, of a different form from the cells of the vegetative generations, and may very easily be distinguished from them. An example of this may be found in a small algaceous plant, the *Scenedesmus* *acutus*, Meyer ; a representation of which, in the transition generation, is given in Fig. 28.

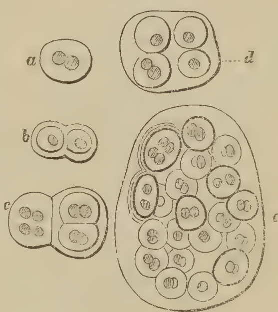
Fig 28.

But even these mediate vegetative generations do not remain alike throughout, but present differences at their beginning and end, so that the transition generation appears as a third member in the mode of propagation.

Henceforth, however, even the reproductive cells assume a dissimilar configuration ; and thus the first impetus is given towards a dualism which extends to the most perfect plants, and certainly is not without a vast influence upon the whole configuration of the plant, and especially upon those parts in which, after long series of mediate vegetative generations, the antithesis is developed to the fullest extent.

While in the strictly unicellular plants, and those of the same kind which are associated together in groups, each cell appears in the character of a reproductive cell, the possibility of propagation in the cell-multiples is transferred solely to the cells at the apex, while the permanent cells take no part in the performance of this function. Fig. 29 represents the *Gloeocapsa opaca*, Nägeli, a very minute algaceous plant, in the various stages of propagation from *a* to *e*, in which it forms two, three, four, and more individuals associated together in a group. But in this antithesis by which each cell-multiple first acquires its existence, the heterogeneity of the reproductive cells of all cell-multiples is already prefigured, and we cannot wonder that the whole propagation of the plant is subject to this dualism. There are then two kinds of reproductive cells, which, even in the most simple unicellular plants, present themselves as conditional to

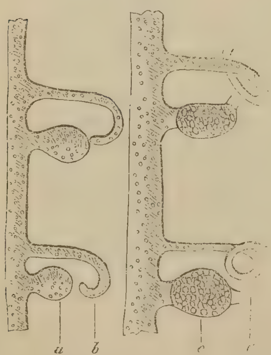
Fig. 29.



the propagation, and throughout the most diverse forms of cell-multiples determine in a similar manner the propagation. If then this dualism in the configuration of the reproductive cells, except in the most simple forms of plants, is once recognized, the most important question which suggests itself is indisputably that which refers to the mutual relation of these diverse reproductive cells—is their mutual reaction necessary for the propagation?—and in what manner does this reaction take place?

As far as observation has hitherto extended, a threefold mode of propagation has been recognised. The different reproductive cells do not react upon each other immediately. Both forms may be capable of reproduction, although, in most instances, only one of them is so, and when separated from the mother-plant propagates the individual. The second mode of propagation requires a mutual reaction by immediate contact. While in this act, the one reproductive cell is exhausted, the capability of individual developement is first awakened in the other. The third mode of propagation lastly consists in a complete union of both kinds of reproductive cells, from which is produced a third, the germ of a new series. It is remarkable that, in this process, one of the two reproductive cells frequently acquires an active change of position by means of peculiar motive organs, or that, at least, an approximation is effected as a result of growth. The first indication of this fact is presented even in the strictly unicellular plants, whose branch, or rather leaf-forming protuberances, the seat of propagation, affect the formation of reproductive cells by their approximation and mutual union, as is the case in *Vaucheria sessilis*, Lyngb. Fig. 30 represents, according to Nägeli, small fragments of this plant; *a* is the germ branch, and *b* the reproductive organ before

Fig. 30.



their conjunction; *c* the germ cell in the germ branch after conjunction; *d* the empty reproductive organ likewise after conjunction.

It is here quite indifferent whether this dualism is or is not regarded as a difference of sex; so much, however, is certain, that it is a condition prevailing throughout all instances of propagation, and which although it does not always present itself obviously in the phenomenon, does not the less appear to be the ultimate spring of action. The fact, that, in many instances, especially among the less highly-organised plants, the one form of reproductive cells presents both in figure and in power of motion a great resemblance with the spermatozoa, which determine the propagation of animals, at least admits of the conjecture that there is no essential difference between the sexual propagation of animals and plants. This manifest sexual difference extends from the fuci, or perhaps, more properly, the characeæ onwards throughout the lichens (?), liverworts, mosses, ferns, and equiseta, or horsetails, and becomes less prominent only in plants of a higher order, but is not therefore as such less undoubted.

Fig. 31.

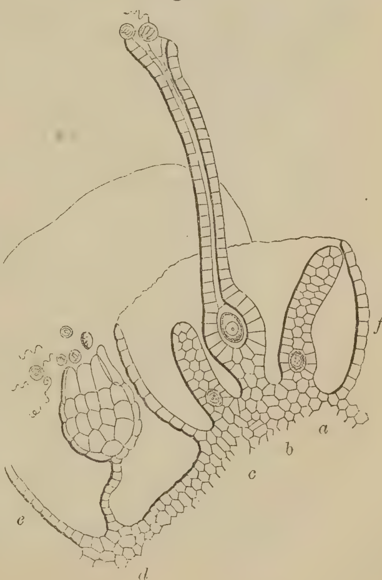


Fig. 31 represents a flower of *Jungermania complanata*. (Partly after W. Hofmeister). Three archegones *a b c*, enclosed in a perianth *f*, two of them are not yet impregnated while the third *b* is just impregnated. The germ vesicle is still simple. Beside it is an antheridium *d* supported by a leaf *e*.

It is already open at the apex, admitting of the escape of the spermatozoida, some of which are free, while others are still enclosed in their mother-cells. A part of them have already attached themselves to the aperture of the ripe archegonium or sporocarp.

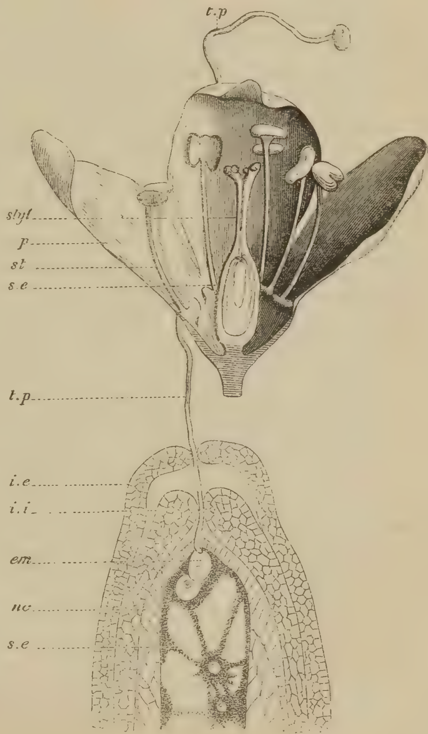
Permit me now to describe, somewhat more minutely, the mutual reaction of the two kinds of reproductive cells in the flowering plants. It is these which are almost always before our eyes, and which attract our attention, most of all, precisely in this phase of activity during their flowering.

In the greater number of plants the capability of forming reproductive cells appears to be gradually developed through an indefinite series of cells. The same dualism which is manifested between the permanent and reproductive cells at the origin of these series, and which gives rise to the antithesis of axis and leaves, presents itself ultimately on the apex through an indefinite gradational succession as reproductive cells, and, as the aim of the formative agency, terminates the progress of the plant structure. Two organs of the most extreme antithesis become the supporters of the reproductive cells, the stamen on the one, the peripheric side, the seed-bud at apex of the axis upon the other or central side. The seat of the formation of reproductive cells in the stamens is situated in the centre of the stunted leaves.

Here from one cell there are soon developed series of cells, in whose interior, and after a *transitory cell* formation, the reproductive cells, called pollen-cells, are produced. When they are perfectly developed, the enveloping cell-membrane — the anther—is rent, and the reproductive cells set free. It is these cells which form the pollen.

While this happens in the last stages of the metamorphosis of the leaf upon the stem, a very similar process is taking place in the terminal parts of the axis. The axis exhausted by the continuous formation of leaves, puts forth above the last spiral of fruit-leaves only one more small continuation, which either remains simple or divides, and then attaches itself to the fruit-leaves, and becomes so closely united with them that they can no longer be distinguished from it. From this continuation of the axis which generally projects into a cavity formed by the variously-convoluted fruit-leaves, and which is termed the placenta, originate series of cells, which likewise produce in their interior reproductive cells. The whole apparatus employed in this process is called the seed-bud, and consists of a nucleus of cells over which one or more sheath-shaped envelopes are gradually extended, so that, ultimately, there remains only a very small channel of access to the nucleus: this is called the micropyle. The series of cells from the apex of which this apparatus is developed, and which soon becomes a support of greater or less length, called the funiculus, finally assumes a very different position in relation to it, according as the developement of the former consists in an equable or one-sided production of elementary parts. In short, there is in the centre of the apparatus a cell, perhaps the terminal cell, which increases considerably in size, and produces, in its spacious interior, several small unconnected cells, which float in the liquid contents. These are and can be nothing else than reproductive cells.

Fig. 32.



The above-named organs and their arrangement will be rendered more distinct by the drawing, fig. 32, which represents a magnified section of the flower of buckwheat (*Fagopyrum emarginatum*). *p* is the floral envelope, *s t* the stamen with the anthers expanded. Some pollen-cells have attached themselves to the stigma of the style where they have already become elongated, and penetrated through the stigma canal into the embryonal sac *s e*.

The accompanying more highly-magnified section of the upper part of the seed-bud, shows the entire course of the pollen utricle *t p*, its penetration through the micropyle of the external coat (*integumentum externum*) *i e*—the inner coat (*integumentum internum*) *i i*—the nucleus into the embryonal sac *s e*, where it comes into direct contact with the embryonal or germ cells.

These latter reproductive cells which have originated from the axis, do not appear to develope themselves spontaneously any further, and would be dwarfed or entirely broken up if they did not receive from without some impulse to further developement. The liberated pollen-cells likewise, although perfectly formed, share the same fate. It happens, however, that the detached pollen-cells and the cells of the embryonal sac come into contact, and then while the former shrivel up and die, the latter acquire the capability of further developement, which ends in the separation from the mother-plant of the entire apparatus above described, and which is now a seed, and places the young plant in such a position that it can henceforth carry on its construction independently. This construction naturally goes on entirely in accordance with the type of the mother-plant.

The reproductive cells of the seed-bud are, generally speaking, enclosed in it, and this is itself enclosed in the cavity of the blended fruit-leaves, that is in the germen; but this does not prevent the detached reproductive cells of the stamens from coming into immediate contact with them.

This happens in the following manner. Even the situation of the germen is of such a kind, that from among the thousands of pollen-cells which are set free after the bursting of the anthers, some few are certain to come in contact with it, and particularly with its apex. This apex, which is formed by the blending of the fruit-leaves, and which, according to their form, is sometimes shorter, sometimes more elongated, forming what is then called the style, is expanded into a somewhat broader part of the stigma.

These pollen-cells, which the stigma receives, are prepared for a further developement, growth, or germination, by means of a continually-secreted sap, and, in such a manner, that, in fact, their exterior membrane is left behind, and a cell utricle developed from them, which may either remain simple or put forth branching protuberances. But the thus germinating pollen-cells would soon come to an end, notwithstanding the nutrition of the stigma secretion, if they were not in a position, by means of their penetrating end, to make a way through the loosened cells of the stigma, and between the series of slightly-coherent cells of the style.

This they always succeed in effecting after some time, and several or at least one pollen cell penetrates even into the cavity of the fruit. There are then but few obstacles to overcome. The apex of the growing pollen utricle easily reaches even as far as the seed-bud, and there finds an unimpeded passage through the opening of the seed-capsule to the seed itself. Lastly, however, the cells of the nucleus must be penetrated; which is effected the more readily, since they are still very delicate and pliable, and as meanwhile, also, the embryonal sac has, by its expansion and the displacement of the upper cells, in some degree approximated towards the pollen utricle.

In the embryonal sac itself likewise the germ-cells have drawn near to the surface, and even touch the interior side of its membranous wall. It is, therefore, easy for the pollen utricles, which have penetrated thus far to come into direct contact with the germ-cells, from which they are separated only by the membrane of the embryonal sac; and, indeed, the pollen utricle spreads itself out upon the surface of the embryonal sac, so as expressly to effect this contact wherever it may be possible. The consequence is, that while the pollen-sac gradually dies from the interior outwards, a further cell-formation takes place in one of the germ-cells, probably that nearest to the pollen utricle, and terminates at last in the formation of the basis of a new plant. Whether, in many instances, during this process the embryonal sac is not entirely absorbed at the point where the two reproductive cells come in contact, so that they are then brought into direct contact, is, although not improbable, not yet sufficiently determined by observation. So much, however, is certain, that in all the more highly-organized plants, there is nothing beyond a mere contact action of the two kinds of cells, while in the lower spheres of the plant-world, a blending of the two is no rare phenomenon.

Thus then the more highly-developed plants manifest, even in their propagation, a triumph over their material nature; and while, in other cases, an intimate blending of both elements is necessary for the production of a new germ in them, a simple contact and a mere dynamic transfusion is sufficient to effect the purpose. It is, in fact, a kiss with which the flower-bearing plant celebrates the most beautiful act of its renewal.

LETTER XIII.

FORMATION OF SHOOTS.

With the equalization of the difference of sex, the dualism which gave a direction to all the functions and activity of the plant is reconciled, the end of individual life attained. It is no longer possible for it to achieve anything beyond this; consequently the flower in which this equalization takes place terminates the formation of the plant completely and finally.

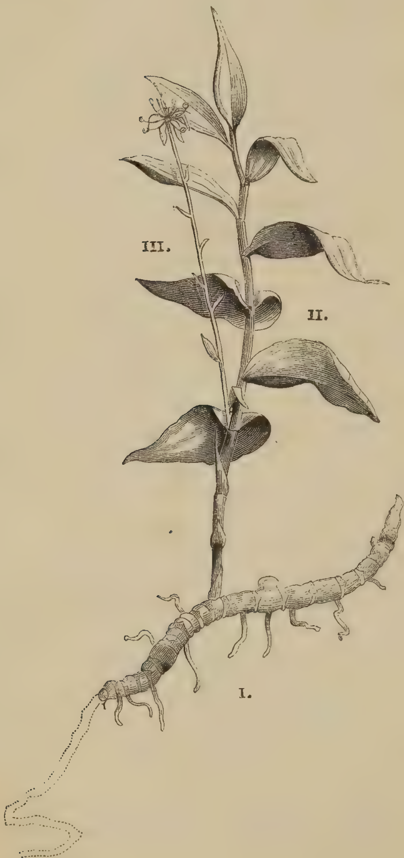
Yet the plant does not always, indeed scarcely ever does, succeed in attaining this end in the above-mentioned sequence of its developements. The normal structure of the plant is in so far only an ideal as that it is seldom realized in nature. Instead of this ideal, regular indeed and beautiful in and for itself, but by its nature extremely limited and ephemeral; a constructive tendency exists in the plant, which is capable of rising above all the limitation of time and space, which bids defiance to all eventualities, and in magnitude and might exceeds all the works which human intellect and perseverance could ever produce.

But it is only by the power which the plant possesses of checking itself in its ideal direction and developement, of opposing obstacles to itself, and being thereby excited to renewed efforts, that it, as it were, overpasses its circumscribing limits, and completes only in a series of spontaneous developements, that which it would otherwise have reached with only one effort. The plant, as a series of connected developements, becomes therefore a vegetative individual in which one phase succeeds another.

Let us now pass from the consideration of the plant to the consideration of this vegetative individual. The bluebell shall here serve us as a guide.

It would be a great mistake to assume, as would appear on a cursory observation, that there is in this plant a simple succession of leaf-organs, originating from one and the same axis, up to the seed-bud. This is not the case. The axis which is developed from the seed-kernel can never achieve the formation of the flower; on the contrary, its productive activity entirely terminates with the formation of the under-leaf and stem-leaf series—the latter being completed in a few leaf-cycles. Without the formation of a new axis, which proceeds from the preceding one, and completes what the former leaves incomplete, the attainment of the aim of this plant would be impossible. Now the second axis, which begins not with the under-leaf formations nor with the stem-leaf formations, but immediately unfolds the upper-leaf region, bears on its summit the flower, and brings to an end the work begun in the first axis. This plant may therefore be legitimately termed biaxial. We meet such biaxial plants almost everywhere in the

Fig. 33.



vegetable kingdom, but especially among flower-bearing plants; nor is it always with a succession of two axes that the plant terminates, but a series of three, four, and even five, axes is not unfrequent.

The annexed drawing of a triaxial plant, fig. 33, will serve to illustrate what has already been said. In it may be recognized certain individual elements of existing plants, which are however combined in an ideal manner, so as to reduce the formation of shoots to the most simple form. I. First shoot with lower stem-leaf formation alone. II. Second shoot with lower and true stem-leaf formation. III. Third shoot with upper stem-leaf formation, terminated by the flower.

That this succession of axes, like all the formations of the plant, is a result of generative agency, might be assumed à priori; but it is likewise confirmed by anatomical investigation, in so far as they appear to indicate that every formation of branches proceeds from one cell of the axis, becomes, by its succeeding generations, a complex of cells which seeks by independent developement, as it were, to separate or emancipate itself from the developement of the mother-axis. This independent developement, bringing all the elements of formation into one direction, it is, which enables such complexes of cells also to lay claim to the character of independent axes. It cannot be denied that, in this process, as well as in the generative functions of the reproductive cells, a propagation of the plant is achieved. It proceeds, however, and cannot do otherwise than proceed, from a singleness of activity, and consequently is subordinate to that dualistic generation. The individuality of the formative tendency, as well as the frequently-occurring division from the mother-plant, distinguishes it from mere progressive growth.

The phenomena presented by the formation of new axes are very diverse, and can here only be considered in their leading characteristics. Each new axis appears originally contracted—the leaf-elements separated from each other by the smallest intervals—the whole being, as it were, concentrated. In this condition they are called buds. After the widening of the intervals, and developement of the supplementary organs, they are called shoots or runners. The bud thus indicates only the youthful condition of the runner; but may, moreover, be the bearer of the most diverse leaf formations. There are, therefore, runners with lower stem-leaf, runners with true stem-leaf, runners with upper stem-leaf, and, finally, runners with flower-leaf formations. Indeed, even with the flower-bearing runners, one or other formation of the flower, for instance that of the stamen-leaves, or that of the fruit-leaves, may be wanting.

This does not, however, prevent the union of several leaf-formations in one and the same runner, so that it may, to a certain extent, become more perfect than another.

Any part of the plant axis, even the descending part, can produce buds. Their local succession presents no such fixed law as that of the leaves :—a fact which shows that their formation consists in something altogether different from the formation of leaves. Still, it very frequently happens that the point of origin of the leaf likewise indicates the point whence the formation of the runner takes its origin. Buds in the axils of leaves are among the most common phenomena of the plant-world.

The region of sucker-formation, that is, the section of leaf-formation, from which the runner is developed, is of great importance and influence with regard to the appearance of the plant. It is, as regards this point, a general law that all runners originate only from the lower regions of the axis, never from the upper. It is, however, very different whether a runner is thrown out from the lower stem-leaf, the true stem-leaf, or the upper stem-leaf region. The circumstance that the apparatus for the female reproductive cell in the higher plants is called runner and seed-runner arises only from the exterior resemblance, and must therefore be passed over for the present as altogether apart from the nature of the runner.

In the same way that the region of runner developement exercises a determinative influence upon the vegetative individual, so in an equal degree does the succession of runners, or the order in which the more or less developed runners follow each other, determine the presentation of the individual in its perfect integrity. In this succession of shoots, the dependence of one runner upon another is distinctly recognizable, and the complete developement of the individual likewise depends upon the progressive succession of the several runners. A phenomenon which is also recognized in the animal world as a succession of dissimilar generations, tending ultimately to the production of an individual capable of reproduction.

Although in the animal world this change of reproduction is met with only in the lower classes of animals, it is found in the succession of runners in the plant-world as one of the most general phenomena to which here inversely perhaps only the lower plants form an exception.

As quite apart from this succession of shoots, which undoubtedly appears as an essential feature, since the sexual propagation of the individual is dependent upon it, must be distinguished the formation of multiplying shoots which stamp the individual with the form it actually presents. Thus it happens by no means exceptionally, but almost as a general rule, that the formation of a shoot induces the formation of a greater or less number of co-ordinate shoots equal to it in every respect. Consequently the functions which would otherwise devolve upon one individual, are by this adaptation transferred to a number of similar individuals. If therefore one or other process should prove abortive in any one of these individuals, it is taken up again by the succeeding one, and the maintenance of the plant species is thus by far less perilled than would be the case if the succession of shoots was simple.

This becomes more distinctly prominent in the shoots of the last order, whose function is the sexual propagation of the individual, and if at the same time the developement of the flowers is not simultaneous, the influence of exterior conditions, however antagonistic, will not endanger the existence of the individual, still less that of the species. Indeed the reinvigoration of many plants depends ultimately upon this repetition of shoots, without which perhaps they would never achieve their purpose. The formation of the asparagus plants, the vine, the lime, etc., depends upon such shoots.

Nature has therefore taken every precaution that the ultimate purpose of the plant may always be attained in the most perfect manner, and even the apparently-superfluous shoots we have just spoken of, are not without their utility in its general economy. But this repetition of similar axes likewise exercises the most striking influence upon the configuration of the plant, which thus presents itself as a family of ultimately-related and mutually-supporting individuals. It is only thus that the plant becomes a plant stock, upon which thousands of individuals of different ages live in mutual dependence tending towards the same end; and when the transitory flower, with its innumerable blossoms, unfolds to us a power of charms, such as is found nowhere else in the plant-world, the tree stem with its thousand branches and twigs, in each of which dwells a dryad, excites in our feelings the presentment of a majesty and harmony similar to that which presents itself indistinctly to the mind on the contemplation of world systems.

Lastly, the actual multiplication of the vegetative being by the shoot must not be overlooked. Many shoots, for instance the propagating shoots, possess the peculiarity of separating while in the young state, as buds from the plant stock, and thus propagating the biologic individual; others again do this only after their perfect developement. Man has not been behindhand to take advantage of what nature has here suggested with regard to the plant, and a great number of useful plants are multiplied by means of the tubers, bulbs, and buds separated from the mother-plants.

Among the plants whose buds and groups of buds separate spontaneously are a number of bulbous plants, as for instance, the fire lily (*Lilium bulbiferum*); and the strawberry potato, and many others are instances of those in which the connexion of the buds must be gradually separated. Fig. 34 represents a young plant of *Solanum utile*, with six pairs of leaves. From the axils of the first pair of leaves—the green leaves, two lower stem-leaf shoots have originated, as well as from the following pair of leaves, and these have already struck into the ground. Although not enlarged into tubers, as in the potato, they still serve for the propagation of the plant, inasmuch as their connexion with the mother-plant soon terminates.

Fig. 34.

There can be no doubt that this formation of propagating shoots, which have likewise been called buds, is expressed even in the lower kinds of plants. The spores of mosses and liverworts, the germ-cells of lichens and algais, are evidently nothing more than the result of attempts at propagation without the antithesis of true reproductive cells. And thus we find, even back to the extreme limit of the plant-world, a provision which secures the maintenance of the plant species, even amid the most unfavourable circumstances, and although the individuals themselves may be very short lived.

With the skill of a master, Alexander Braun has succeeded in reducing, under one point of view, the whole of this difficult and intricate subject of shoots-formation, and has, without doubt, thus introduced more clearness into our conception of the plant structure and formation, than the most minute anatomical researches have hitherto been able to do. It is to him, therefore, that we are indebted for the most extensive and important part of our knowledge of plant architecture.

LETTER XIV.

UNITY OF RACE AND OF THE HIGHER CATEGORIES.

It is an incontestable fact that the plant reaches its goal only by a series of renovations. It hovers between the acquisitions and the effort to acquire, between annihilation and re-birth, till it succeeds in again uniting the phases of its productive activity, proceeding one from the other in ever-widening divergence. The formation of the cells, the erection in leaf-cycles and leaf-formations, and finally, production and succession of sucker, are nothing but wider and narrower circles in which the death and resurrection of the plant appear. Whilst in the animal organism the same metamorphosis proceeds, noiseless and concealed throughout all the organs, in the organism of plants every member becomes stiff and permanent, and every new part overlies the old, darts triumphantly beyond the goal of previous attainment. The whole is therefore not only a unity, it is also a concrete of unities; so that the entire gradation, the entire transformation and renewal, can be contemplated at one glance.

In a similar sequence does the plant proceed in its propagation. Unaltered permanence is no longer possible, and even if the individual ceases, it reconstitutes itself in the same manner in its progeny. Hence arises a series of individuals, locally separate indeed, yet ever connected into a unity, into a whole, by the course of generation. However life may fluctuate in the series of these individualizations, all its members in reality cohere, though the thread breaks which holds them together in their origin. It is therefore the sum-total of these apparently distinct individuals which we denominate species; and it cannot be questioned that this idea comprehends not merely an aggregate of unities, but a series, in which every member possesses a certain relation to the other members. This relation, however, is none other than the relation in which one cell stands to others, one leaf-cycle and one leaf-formation to others, and finally one sucker to others.

From this it follows that the species is in its nature the same as a series of cells, a succession of leaf-cycles and leaf-formations, a succession of suckers, *i. e.*, an organic whole. Consequently the species must present all those peculiarities which universally pertain to organic beings. Among these we reckon above all others—firstly, the production from a germ; secondly, the developement into a perfect whole; and thirdly, the giving-up of individuality after the achievement of their destiny.

In the life of the species, therefore, all these impulses, which in individuals frequently follow in quick succession, must again appear, as equally essential, at longer intervals. In one word, the species must have a beginning, a succession of further stages of developement, and an end.

Unfortunately the short space of time which single observers can devote to the phenomena of this course of life in the species is far too little for discovering, experimentally, these stages, even in only one or other species. The cessation of a species only, or its commencement, could in any degree be matter of actual experience, as being limited to a shorter space of time; yet as, even in this, the observations of many generations must be consumed, while but the smaller number of plants have, on account of their influence on man, occupied his attention, and it may easily be conceived that we are altogether in uncertainty on this point also; only from the animal world start up here and there significant facts, which admit of our suspecting analogous phenomena in the plant-world.

But even admitting that the species of plants, like the species of animals, have their period of existence, that is, an allotted term of life, it is possible to explain their extinction, as the consequence of a constant decrease of productiveness; but the source from which they spring, their advent in nature, cannot be explained, although we may meet with them suddenly among the already-existing species. The question of the primordial condition of the species, of its relation to the subsequent species and to nature in general, is not yet solved.

If we conceive the species, as has been customary hitherto, as an aggregate of similarly-formed (similarly-natured) individuals—in which not a single quality permanently alters (immutable characteristics), as the experience of our observation shows—we are inevitably impelled, in the explanation of this question, to the conclusion that the origin of a species could not possibly have taken place from any of its precursors. There is nothing for it, therefore, but to assume that forces beyond the pale of the organic world co-operate in the production of the species—an assumption which, if not in actual contradiction to the universal operation of inorganic forces, yet sounds at least like a miracle.

Far otherwise does the matter present itself, if, following the track of analogy, we regard the species as a sum-total of elements capable of production, and therefore of alteration; in which indeed no metamorphoses are to be perceived, except in lengthened periods, but in which, within the compass of many centuries (wherein it may be certainly computed that the generations of existence of every organic being can be comprised), the germination, growth, blossoming, fructification, and ripening, of the species follow none the less.

It would, however, be erroneous to assume that the diversity of species consisted only in this pròcess of metamorphosis; but who can deny that new combinations of the elements arise out of this permutation of vegetation ever reducible to a certain law—combinations which emancipate themselves from the preceding characteristics of the species, and appear as new species? I must not be asked "When?"—nor how such offshoots from the already-existing species arose. On these points, nothing but the history of the developement of the whole plant-world can possibly afford a solution. But this much is clear—that this change of generation relating to species can belong neither to the youth nor to the old age of the species, but to the period of its greatest strength, its highest developement, as well in extent as in energy of vegetation.

Nevertheless, phenomena strike us, even in our fragmentary term of observation, which are significant in supporting the above views, and which, even if they do not, as was supposed, invalidate the theory of stability of species, still clearly reveal the great process of metamorphosis of one species into another, and consequently the comprehension of these within a higher unity. These phenomena are such as belong partly to normal life, partly to morbid and uncontrolled vegetation. The deviation of particular characteristics from the normal condition in the succession of generations is one of the commonest phenomena. According to the greater or less permanence of these deviations, we call the one a variation (*variatio*), the other formation of race. To what an extent these often proceed our garden plants show, in which we are scarcely able, often quite unable, to recognize the progenitors. That these deviations arise not altogether from an alteration of outward influences, such as from a change of light, air, moisture, soil, or so on, is demonstrated by the fact, that two similar kinds of plants frequently become altogether different under these circumstances.

Whilst the vegetation of both is equally strongly affected, it is arrested in one, whilst it produces no effects on the other. The endeavour, therefore, to trace the diversities of species to the effect of outward influences, such as the nature of the soils, assuredly misses the true cause. Equally insufficient, though not without significance, proves the effect which the reproductive activity of one kind of plants exerts over the other, whereby in the higher, as well as in the lower growing plants, even in mosses and ferns, arise hybrids, entirely new species as it were arising from the combination of two pre-existing species. Their duration, although lasting some generations, is, nevertheless, always short, so that such bastards are never in a condition to dispute and attain their citizenship among the other species of plants born their equals.

Finally there remain in the balance the phenomena of abnormal vegetation, as not unimportant influences in the constant presence of a transformative plant-growth. Who is not familiar with the signs of transformed vegetation which meet him in every meadow, in every garden? Not only do stem and leaves expand to an excessive degree, a different texture, other constituents, etc., appear; even into the once so regular order of the leaves diversity enters, the cycles alter, the succession of formations is disturbed, and transformations of the strangest kind present themselves. To whom are the so-called double flowers, perfoliate blossoms, incised fruits, and so on, unknown? It is, in all cases, the impatient vegetation which here concealed, there openly, produces these phenomena. Fig. 35 represents a perfoliate lily (*Lilium candidum*) in which all the parts of the flower are converted into a leafed branch. The flower-stalk of the plant thus acquires a perfectly-different appearance.

Fig. 35.

And how could this spirit of change, this representative of the unconstant, of the transitory, fail to transgress the narrow bounds of peculiarity of species? It were scarcely credible. If then we must dismiss as incorrect all previous observations on the changes of types of species, we yet cannot avoid recognising, in the genius which marks the species, seeks to preserve its unity through all times and localities, and does in truth preserve it, the strength which not only converts water into wine, but is able, with similar magic power, to transmute also one species into another. But if all distinctions of species sink into nothing before this magic wand, how can it be doubted, that in the higher categories, the same generic unity reigns, that they likewise are but the result of propagation in distant zones? We should much err if we did not ascribe a *real* existence to these unities included in one general view by the mind. If the universal unity of the plant-body is rendered possible only by the production of all its single elements one out of the other, then is this unity in the whole creation of the plant-world, assuredly in like manner possible only by the originating of one member from another, one species from another, one genus, one family from another. And as in the plant-body, not even a single cell can be produced from any extrinsic source, equally impossible is it for a species, a genus, an order, etc., of plants, to be produced from any extrinsic source, and not to have proceeded from a previous one.

Thus rises up to our astonished gaze not only the wonderfully-proportioned structure of the visible plant-form, but this, itself, extends into regions to which our mortal eye is no longer able to penetrate. Not only the individual plant, but the whole plant-kingdom is an edifice—an edifice for which the thousands and thousands of parts, as leaves and flowers and single cells, serve as building-stones.

LETTER XV.

THE PLANT-WORLD IN ITS LOCAL DISTRIBUTION.

(*Geography of Plants.*)

The reader will excuse me, if, without reference to the immeasurable size which the plant-garden of the world presents, I yet have the courage to escort him round it, and to direct his glance, if not to all sides, still at least to the most important points. Everything great appears to us first in its true magnitude, when we have formed a correct idea of it; and I may affirm, that the green structure of the globe exemplifies the axiom no less than anything else. We may assume, *à priori*, that the garden which we tread is not a maze in which no track, however slight, appears to direct the steps. Had not men like Alexander von Humboldt, Wallenberg, Schouw, Von Martius, Robert Brown, Wallich, Reinwardt, Blume, Parker, Webb, Desfontaines, Hooker jun., Griesbach, and others, already chequered it in so many directions, I would certainly not venture to be your guide, or dare hope to conduct you to the desired goal.

Through whatever gate we enter the park, whatever path we adopt and follow, the same principle will everywhere impress us, that a manifold variety of forms, an intermingling of the most diverse forms even upon the smallest surfaces, is the most prominent feature in the character of the vegetable world. It might almost be supposed, that a conformity to law in the order of the various members of this part of nature would not exist at all—would even be utterly impossible on account of the indefiniteness of developement on the one hand, and the mutability of extrinsic influences on the other. Yet it is not so; for there appears, in all respects, a more or less intimate interweaving of the most diverse forms, so that the glance is attracted immediately here and there to different plants socially coexistent, attracted together, if not, indeed, in accordance with their nature, yet, by their mode of life and purposes; and here is seen a meadow, there a wood, there a heath and prairie, there a moor. Indeed in these common localities of similar tendencies, it frequently happens, that certain closely-allied species predominate, and in their intimate connexion more or less exclude everything of a foreign nature. A pine-forest, a coast-line of mangle trees (*Rhizophora mangle*), a heath-country of *Erica*, express a far closer community than the flower-carpet of the Alps, the tree-dotted meadow, or the impenetrable primæval forest. These conditions are not by any means at first a consequence of the labour of man, whose hand has doubtless powerfully influenced the state of vegetation—they are much rather to be considered primitive, or to have been at least settled long before all influence of that kind was exercised. Although this original character may be variously influenced by the cultivation of the soil, in such a manner, that by culture, the association of particular species is favoured, still, upon the whole, the alteration is slight; and, as soon as the protection of culture ceases, it becomes but too soon evident that the original condition is restored. Man, as the assumed lord of creation, has, for the use of his habitation, but too often to his shame experienced that he is in a condition to direct the existing order of single members of the vegetable world only in a very limited sense; and indeed, that, where he sought to wield exorbitant power, he is confined within narrow limits by a might to him unknown. It very soon appears that a particular territory is assigned to every product of the earth, which it cannot change without perilling its very existence. See the Alp-rose brought down from the forest-stream into the valley, how it longs vainly for the pure air; consider the seed transported from the woods of the West Indies, from the Gulf Stream to the coast of Norway, how, before it has so much as germinated, it succumbs already to the inclemency of the climate. Or is the plant indigenous to the majestic granite headland, which the storm transports in safety to the neighbouring chalk-rock, better there? Or the grass sprouting in loose sand which the floods have imbedded in soft clay? In vain do even the mightiest powers of nature appear to fight against the existence of vegetation, without being able to alter anything whatever that lives; and we are hence compelled to acknowledge that there are immutable laws by which one place of location and propagation has been assigned to this plant, another to that.

The law of dependence on heat has beyond question made itself sensible as most influential. All plants bow to the iron sceptre of this influence, whether their circumambient element be air or water. Even if a certain degree of temperature does not actually associate cognate plants, it nevertheless effects the association of plants, which, in their nature and capacities, are more than any others similar in their relation to this agent. In this manner the difference of vegetation presents itself in its most comprehensive features, according to the distribution of temperature over the earth; and we distinguish most palpably a vegetation of the polar regions, of the temperate zone, of the warmer latitudes, and of the tropics, and yet minor gradations of difference which lie between those earth-belts. As, however, the temperature diminishes all over the earth, according to elevation, as well as according to latitude, so do the zones of vegetation, succeeding in horizontal direction, correspond in like manner to such as present themselves at parts of the earth's surface which are in greater or less degree elevated above the everywhere uniform expanse of water; and we have in our mountains from below upwards, the same gradation and diversity of vegetation which the succession of latitudinal zones presents, only here in quicker succession, just as the diminution of temperature graduates here in a more rapid scale than there. We cannot then but subscribe to this position, that the vegetation of the polar regions and of the loftiest mountain-peaks of the earth, which reach the impregnable boundary of snow and ice, agree in their physiognomy in like manner as the plants of warmer climates and of the tropics throughout the whole earth. How much does the vegetation of Terra di Fuego, of State Island, of the Maldives, of Kerguelen's Island, and of the South Pole, the vegetation of the North Zone, and the vegetation of our central European Alps, the Andes, the Himalayas, etc., present a common complexion, which extends not only to the general habitus, but even to similarity of order, genus, and species !

As an example, we may cite the universally-spread species of the *Ranunculus*, *Geranium*, *Epilobium*, *Saxifraga*, *Poa*, *Festuca*, *Carex*, etc., whose representatives are met with on the icebound inhospitable shores of Victoria Land, and of Spitzbergen, as well as on the desert peaks of the Alps, Andes, Himalayas, etc. The same observation applies to the other zones.

Next to climate, the nature of the soil, or, to speak more generally, the support of the plant, has much to do with the distribution of the vegetable kingdom. If climate marks out certain regions for the various plants, their support is the arbiter which has arranged them in certain districts, and even assigned them fixed stations. The need for specific means of nourishment, notwithstanding that the materials of nourishment are distributed everywhere, causes in plants similar in nature a tendency to congregate in masses more or less closely, according as the nutritious matter they require is offered them within a greater or less extent of surface. Hence arise the two great classes of land and water plants; the second class being subdivided into fresh and sea water plants, according to the difference of their native element; as the land plants are, according to the physical and chemical nature of the soil, into marsh, land, and rock plants, into turf-plants, salt-plants, and plants peculiar to chalk, gypsum, clay-slate, granite, etc. We perceive in the immense variety of the physical and chemical character of the earth, the conditions of an equally immense variety of the districts occupied by peculiar plants. How influential prove in this matter even the identity and diversity of vegetation, produced by the greater or less diffusion and change of certain geologic formations, every land, every mountain, shows.

The quantity of water present in the atmosphere, and the moisture of the air and earth dependent upon it, present, like the temperature, certain normal conditions in their distribution over the surface of the globe; and if, with regard to the quantity of water falling, the zones of periodical deposition are less regular, still vegetation does not appear on that account to be

F 2

less influenced. Not only the presence, the strength, and the luxuriance of vegetation depend on it, but also the periodicity of its waking and sleeping. As warmth and cold in and beyond the temperate zone produce a stagnation and resurrection of vegetation, so do the moisture and the dryness of the air and the earth, in the warmer latitudes, cause a similar alternation. But, where warmth and moisture are felt equally in a high degree, a luxuriance of vegetable beauty also follows,

Fig. 36.

which expresses itself as well in multiplicity of form, as in the large developement of the individuals. Whilst, therefore, we pass lightly over the mountain vegetation and the meadow lands of the polar regions, we must hew a path through the inextricable thickness of the primæval forests of the tropics, as of

Brazil, the East and West Indies, the Sound Islands, etc., and even the damp Chonos Islands, and we are not secure against being held fast and environed by creeping plants, winding, and parasitic plants, towering one above the other.

Fig. 36 represents a primeval tropical forest in Brazil (*Pedra da Onça*) according to the drawings of Benjamin Mary. (*v.* Martius, Flora Brasiliensis, fasc. x., tab. phys. xxxiv.) This landscape comprises a group of rocks covered with the most luxurious vegetation, through the midst of which flows a small brook. The trees consist of palms and various other tropical species, upon the living and dead trunks of which flourish whole swarms of larger and smaller herbaceous plants, among which the eye is especially attracted by the climbing large-leaved *Pothos* and *Caladium*, the beautiful leaf-bunches of the *Bromelias*, and the *Tillandsia usneoides* hanging from the branches. Here masses of thirsty plants crowd towards the water, while there others appear to soar up in the air, twining themselves from tree to tree, making the jungle still more impenetrable, and rendering it difficult even for the burning rays of the sun to reach the ground.

But, although all previous outward influences have appeared as conditions of similar configuration in the plant-world of greater or smaller districts, and always produced, according to their more or less regular distribution over the earth's surface, a vegetation sometimes monotonous, sometimes varied even in smaller spaces, still there has not by any means been such a grouping of plants as would have brought the kinds cognate in their morphologic character into closer contact. The low carpet-like vegetation of the north is not exclusively marked by moss in one part, by grass forms in another, in a third place by umbelliferous plants, nor are the forests of the tropics formed sometimes by fig species, at others by cisalpine and leguminous plants. An intimate intermingling even of the plants related in locality, or in their nature, is everywhere to be remarked, and constitutes so prominent a feature in the physiognomy of the various plant formations, that it very rarely occurs that nearly-related forms either possess themselves exclusively of the soil, or even predominate largely. On this condition of the predominance of certain plants linked together by the laws of relationship, rest finally the characteristic features which this or that district, this or that tract of land, possesses, and which, although they do not always prominently strike the eye, may yet be detected by observation, and justify us in dividing the whole surface of the earth into regions according to these peculiarities of vegetation, in the same manner that is required in the distinction of the various races of the great human family. In the same way that we have a region of the Chinese, the Hindoos, the Æthiopians, etc., so are there the regions of *Camellias*, *Celastrinias*, *Sertanimias*, *Stapelias*, *Mesembrianthema*, *Cinchonas*, *Cacti*, etc., although in fact the mass of plants does not always appear determinative any more than, in the former case, the nature of prominent races of men. Who can deny that a dense cloud hovers over the primary cause of the diversity of the races of men? and who can question that the influences which effected this and not another classification of plant-groups over the earth, are quite as obscure to us? At all events, the key to the understanding of the one secret, as of the other, must be sought in earlier and departed conditions; yet who would not conjecture that here, as everywhere in nature, the simplest condition formed the basis?

If the plant species in its original appearance is a progeny of primæval vegetation, as I have endeavoured to render probable, and if this assumption leads at length to even fewer and simpler first types, an equally great difference of all the derivative types must be recognized as necessary from the ever-increasing districts of diffusion in which the original forms of the first ages appeared. As therefore the original forms occupied the whole earth, the derivative types produced in particular localities are generally distributed over the whole extent of terra firma and the surface of the earth. It was not possible, however, that of the cognate forms, some only should be found at any certain spot, and others in other parts of the globe, but the utmost possible diffusion of them must have been the consequence, independently of the fact that external difference of climate, soil, etc., manifoldly aided and increased the original distinction.

If, then, we are no longer in a position to discover the originally-created group of plant-forms, this arises truly not from the deficiency of them, but from the manifold intertwining and intermixing of their subsequently-changing boundaries, as the circles produced by bodies falling into smooth water can only, with the greatest difficulty, be marked according to their number and the spot at which they originated.

But this complex intermixture of vegetation is of great advantage to the spiritual as well as the corporeal needs of man. Whilst, on the one hand, the perception of unity in multiplicity is thereby awakened and sharpened, the same fact has rendered it possible for the human race to spread over the whole earth and to find the conditions of its existence everywhere. The labyrinth which, to the ignorant, the plant-garden of the world appears to be, becomes, therefore, to those gifted with insight, an expression of the most perfect harmony, a veritable Eden, for the enjoyment of which he lacks only innocence.

LETTER XVI.

CHRONOLOGICAL ASPECT OF THE PLANT.—HISTORY OF THE PLANT-WORLD.

We have already occasionally referred, on entering upon the casual conditions of the phenomena of the world of plants, to the consideration of its earlier stages. The world of plants, as a many-membered whole, and the grouping of the members over the surface of the earth, are matters which, without a conception of their essential process of developement, can never be known in their true significance. This, and much besides, compel us to note, not merely the most recent aspect of the plant-creation of these ages, but also the old age of the time before. But we must not promise ourselves any great gain from treating the dual aspect of this Janus-head, were we in a position to learn in its backward-gazing conntenance aught even of the state immediately preceding our epoch.

Independently of the fact, that through the want of all historic traditions, of all monuments of the earlier times, no detailed image would be possible, this would, moreover, teach us little, for all historic epochs embrace periods far too brief, since changes of such a kind as occur in the life of species cannot possible appear within such narrow limits of time. Only periods which extend far beyond the historic treatment of human existence, can afford us light on such matters. But inasmuch as we require such an extended epoch, for a productive consideration, it is not enough to look back to that period which immediately preceded the existence of the human race; indeed, in order to find remoter data for these conditions of vegetation, recourse to still earlier epochs is requisite; and thus, if our view be complete and consistent, we arrive at the contemplation of a whole series of consecutive periods up to a time when the first pulsations of life became at all perceptible.

Only in this succession of the conditions of plant-life lies the history of their developement, as well as the "because" to the "why," which we should not be able to utter by any other process.

If it is to be assumed as a positively-ascertained truth that not a drop of water sinks lost into earth, not an atom of the all disappears, that absolutely nothing passes away without a trace, then there lies in this truth the greatest solace for that science which proposes to itself the contemplation of events, the changes of things, and their fate in time. For every condition is the consequence of a previous condition, and this ever points further to a series of earlier conditions; so that we need only a single key to penetrate from the last secret to the first. This key, however, is not yet found to the slightest things, and still less to the world of plants. Instead, therefore, of investigating the earlier stages by means of the existing stages, so as to show these as necessarily preceding phases, we have nothing for it but to inquire whether no monuments exist which precede the succeeding periods of creation, and which are not yet quite destroyed by the tooth of Time.

On proposing to ourselves these antiquarian researches, our labour will not be altogether in vain. By careful investigation of the various earth-strata and rock-formations, we soon come to medals with well-preserved inscriptions, soon to utensils and implements of many a sort, and even to the foundations of buildings which present to us a not indistinct picture of once-existing conditions. The medals relating to the history of the world of plants are the impressions of leaves and other portions of plants; the utensils are fossils; the foundations of the building the layers of coal, lignites, and the like. All this, however, speaks as clearly of a time of an earlier existence of the plant-world as the phases of its developement are manifested in their various forms and the succession of them.

The search for metals so useful to man has induced him, from the most ancient times, to open the secret depths of the earth; the tendency to improved well-being has further and further increased the need of them, and has induced man to penetrate ever deeper and in all directions. It was inevitable, if the work was to be of any avail, that even greater advances should be made in the knowledge of the structure of the earth's foundations, or, as we should rather say, of the earth's surface. The united experience hence resulting produced what is called mining, geognosy, geology, and so on.

All antiquity has, nevertheless, produced nothing towards the history of organic being, nor, consequently, of plants secreted in the superficial earth-strata. In its eyes, gold superseded all else; it overlooked the hidden gold-lumps which were by those obvious grains. For the first time, some centuries ago, when an inspired and imaginative mysticism sought to raise the veil of Isis, petrified shell-fish, bones of dragons and monsters, received attention; and even so was the eye delighted with the lovely impressions of the foliage of unknown plants, and prepared from petrified wood, objects of art of numerous descriptions.

Yet was palæontology, the forerunner of a history of organic life, scarcely a lisping infant. The greatest progress occurred first through the necessary opening of the layers of fossil fuel. Who would have imagined, two hundred years ago, that in coal, wholly and entirely related to the mineral kingdom, lay buried nothing less than the remains of an immense vegetation of the antique world? Who would have conjectured that, in the impressions of leaves, bark, fruits, seeds, &c., occurring on the limits of these layers in the barren stone, as well as in its here-and-there preserved structure, we should succeed in reading the history of its appearance? Who, in fine, would then have entertained the ardent hope of finding there a standard of time, and reckoning the millions of years which elapsed in the construction of the plant-world of the present time? Though the geologists have given the historical inquirer a more complete idea of the succession of rock-strata and of stratification, and made the mode of their origin intelligible, still the former have, on the other hand, not neglected, step for step, to collect the organic remains from the lowest to the uppermost strata, which, although mostly decayed, are still recognisable, to compare them together, to arrange them, and by means of these significant vestiges of earlier periods of creation, to form an idea of all the various kinds of animated beings and their forms.

Hence arose very soon the undoubted principle that the world of plants, like the world of animals, had, from the earliest ages till now, suffered a mighty revolution. All doubts concerning the imperfection of our inquiries were solved; and if, at present, all the materials do not lie before us from which the extant creations of the world of plants developed their luxuriance, yet are the essential members of that vegetation, whose origin is lost in uncalculable ages, assuredly hidden from us no longer.

From the collection of all contributions hitherto furnished, from Sternberg and Lindley to Adolphe Brongniart and Göppert, it results, as a certain fact, in the history of vegetation, that, with the seven great geological periods (including the present one), the world of plants also, which is divided into seven chief stages, has gradually developed itself step by step.

The first or transition period is marked by the predominant character of the most simple forms of plants, so is the coal-period by the preponderance of the so-called vascular cryptogamia, the trias-period by the Monocotyledons, the jura-period by plants which bare seeds, and so on, till the present seventh period, which is named after the predominant influence of the dialypetalous plants. These investigations show, moreover, very clearly, that even the first of the periods of creation began with a number of plant-forms which might serve as a standard for all the rest, that is those in which the germs are to be found of all the subsequent developements; in a word, with plants which may in fact be regarded as true primitive forms. Thus the foundation of the whole plant-world is not by any means a one-sided lineal progression, but a radiation broadening out on all sides, and in their primitive shapes is contained the whole of the existing vegetation, as though in a chalk-drawing made from meagre outlines.

The plate forming the frontispiece represents a calamite forest of the coal period. This strange vegetation belongs to the early age of our planet, in which, although the four principal groups of plant-configuration (*Thallophyta*, *Acrobrya*, *Amphibrya*, and *Acramphibrya*) were already developed, only the first section of the latter, the *Gymnospermæ*, existed.

We do not find here any higher plants than the equisetaceous trees, a few herbaceous and tree ferns, and the singular *Stigmaria ficoides*, peculiar to marshy places.

A torrent of water overthrows the lofty, hollow, and brittle stems of the calamites, and, like the winds in our turf-bogs, increases the mass of plant substance, which is afterwards gradually converted into coal. A dreary desert, inhabited by no higher animal organisms, it appears as if appropriately selected as a scene of the wildest storms, continuing for centuries.

Could it happen otherwise in this constant spontaneous developement of vegetation, which gradually became perceptible in the epochs of creation, than that with the advent of new forms the earlier should one and all come to this end and extinction? Thus proceeds the ideal of the plant, as at first from cell to cell, from leaf to leaf, from sprout to sprout, from individual to individual, here also in continuous destruction and new-birth of genera in unbroken undulation of renewal, one epoch of creation determining the other, each new, each strange, each proceeding from the earlier elements modified, but ever ennobled.

How utterly different does the plant-world of the present period appear to us now that the world of life which, through thousands of inadequate attempts, ripened to its present perfection and general diffusion, reflects in the multiplicity of its species its whole history! Is it possible that the ultimate significance of the hitherto-unexplained impression which a fern, a pine-wood, a cycada, or a grass-field, produces upon us can remain concealed? Is it not the long-closed grave of the coal-beds that here opens itself, the mysterious obscurity of the jurassic period, the trias period, that speaks to us from them? As all ruins of fallen grandeur bear an air of lamentation, so the last remains of those departing forms cannot do otherwise than speak to us in tones of melancholy.

This language, mixed with the joyous expression of forms in the state of highest developement, is the most marvellous contrast which penetrates through the eye to our ear, and especially, perhaps, alone explains the pleasure or dislike which, in sensitive men, is excited by one or other plant; but for the thinking man it is, and always will be, a duty to penetrate to the innermost mysteries of their existence and significance.

At the commencement we compared the plant to a piece of architecture. The elementary construction from cells, their combination and arrangement into masses, the structure of its body in the form of superposed stories, all admit of manifold comparison with the construction of buildings. There is however yet another comparison which is not less appropriate than the previous ones. It is the comparison of the various styles of architecture, and their respective ornamentation with the historic character of vegetation.

In the same manner as the former was developed from the most simple forms, and gradually passed into the Indian, Egyptian, Malay, and into the antique style of the classic nations of the Old World, from out of which, again, the Byzantine, the Moresque, the Gothic, and all modern styles of architecture grew up, so we find that the architectural style of the plant-world has been abundantly altered. And in the same way as it appears strange to us, when we recognise beside the half-buried buildings of the Toltek the slender light roof of the Roman; beside the ruined temples of gods the closed cottage; beside pyramids and the graves of kings the mean straw hut; the impression is no other than that which we experience on seeing in the shade of dying pine-woods the laughing-rose; in the oak thicket, grey with age, the smiling little violet; and the truth that life must be regarded only as a transient form of existence forces itself more clearly and prominently upon the perception.

LETTER XVII.

NATURE OF THE PLANT.—ITS POSITION IN THE SCHEME OF CREATION.

There still remains one, and indeed the most essential, point to be considered, in order to complete the picture which we have endeavoured to give of the plant. This is its position in the general series of organized beings, of which it is itself merely a member.

Not only in the organism of the plant as an individual being, but in the life of the species, as well as the entire plant-world, does the most intimate interconnexion of all individualities manifest itself. It appears that this bond of relationship extends still further, touching and penetrating a class of beings which reaches far beyond the still self-enveloped plant.

We may in conclusion be allowed to consider somewhat more closely how intimate is this relation between plants and animals, how intimate the interpenetration in a material, as well as an ideal, direction between the two.

The precise boundaries of both kingdoms of life have long been an important problem to all those who are accustomed to regard all things according to fixed and definite normals. The vulgar notions of plant and animal, which are sufficiently definite in reference to the middle parts of their respective kingdoms, appear to be no longer adequate when the boundaries are approached. A manifold interlacing of characteristics appeared to become more distinctly recognizable in proportion to the ardour with which it was attempted to discover differences both in structure, chemical constitutions, and the vital functions. At one time it was believed that a distinction between plant and animal had been discovered in the elementary organs, and their mode of reproduction, in the structure and arrangement of the organs. At another time, the relations of material elements appeared to promise certain boundaries; and, even if that were not the case, these indications were believed to lie in the vital phenomena, especially in the phenomena of motion, which would remove all doubt as to whether the subject belonged to vegetable or to animal organism. It may indeed be said that anatomists, chemists, and physiologists, have, with united energies, put plants and animals to the rack, in order to extort some answer to this question. But what was the result? While the greatest ingenuity was exercised in the endeavour to maintain those distinctions which had once been laid down, the investigations made both by the chemist and by the physiologist, led to continual encroachments by one or other of them into the opposite department of science; so that at the present time the solution of the problem has not advanced one step. On the contrary, it has become still more obvious that every attempt of the kind is a crusade into a region of mystery, where both parties become embroiled, not only with each other, but among themselves. I will not therefore desire of my readers to take any part in this dreary and fruitless controversy, but rather from some secure retreat to watch the combat, and perhaps even thence to derive some conception of the means by which these conflicting views might be reconciled.

In putting an end to any dispute, or in solving any problem, much depends upon the disputed point being stated with as much simplicity and clearness as possible, upon the avoidance of any complication likely to divert the attention, and upon putting the subject in the most naked form possible. To apply this principle to our own case, we shall do wisely not to confront the plant as a perfectly-developed being with the perfectly-developed animal, much less to seek for points of resemblance in the still more complicated vital cycles of each. We shall undoubtedly approach more closely to our aim by prosecuting our investigation of the elementary parts, and acquiring a more intimate knowledge of them.

In the previous letters upon the plant-cells, it has been shown that they are the elements of which all parts of the plant consist, which compose every organ, and govern the whole impulse of vital economy in the plant. The cell, as we have already shown in several places, is the factotum, without which the existence of the plant would be impossible. But at the same time the cell is still more than this, if we exclude from consideration the individual. It is in the propagation of plants, the bond which unites one individual to another, and likewise renders the life of the species possible; but it is undoubtedly, at the bottom, the Proteus which determines beyond the species, the higher organization of the plant-world into families, orders, etc. In short, the cell is not only the starting point of the individual life of the plant, but at the same time the starting point of the life of species and all higher unities; it is indeed likewise the starting point of the whole plant-world.

It is therefore in the cell, and nowhere else, that the concentration of the whole being of the plant must be sought.

Hitherto we have only cast a passing glance at the nature and construction of the cell. It will now well repay our trouble to penetrate somewhat deeper into the sanctuary of so immense a series of entities.

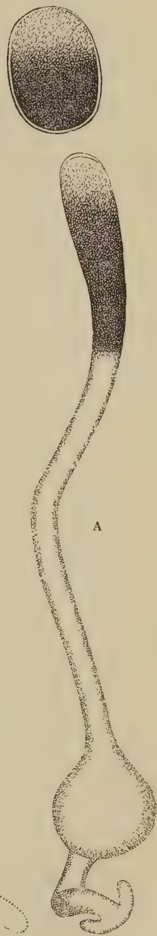
The cell is a vesicle imperceptible to the naked eye. When, however, it is magnified three hundred or four hundred times, we find not only that it consists of a liquid different from the solid envelope, that developement of various kinds takes place both in the interior and on the exterior, which contributes to their anatomical as well as chemical differences, but under favourable circumstances, we can partly observe the working of this minute economy.

When the uninjured cell is observed in full operation, as it appears in its youth, no difference can yet be detected between its contents and boundary; but in the content itself, there very soon appears a vital centre, produced in the form of a tiny vesicle. This leaflet, named nucleus, causes, very soon after its first appearance, a remarkable separation of the half-liquid contents. A tough, liquid, granular substance, detaches itself from the residue, which displays a more watery nature. This, called protoplasm, unites itself as well to the vital centre as to the periphery, and thereby binds both together with many radiating, simple, and branching threads.

It is a charming spectacle to observe in the so-far perfected cell, the active flow of this vital sap from the centre to the periphery and back.

Fig. 37.

B



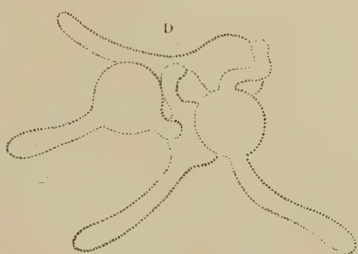
A

The most manifold motions even in the most opposite directions are seen in close proximity in the same thread-currents. All is activity and motion in this protoplasm, nevertheless the remaining part remains motionless, and is only here and there drawn into the current of the stream. These streams are moved by no pulsating veins; there is no pumping apparatus which forces them from the centre of the cell and back again. This marvellous substance, this self-moving wheel, is a protein substance, consisting of the same nitrogenous compound that is present in every animal.

C

In some instances (but as far as our experience yet extends, only in the lower plants) the developement of this protoplasm advances beyond the exterior boundaries.

D



It is not a mere motion of the liquid mass which goes on, but a developement of half-solid thread-like processes, capable of performing other motions than those of circulation. When such cells are set at liberty by the opening of the mother-cells in which they have been formed, they commence motions entirely independent of the latter, and when they are in water, swim about freely in it.

Fig. 37 is a young plant of *Vaucheria clavata*, Agdh, at the period of the ripening of the fruit; that is, when the first germ-cell is pushed out. B is the germ-cell after being detached from the mother-cell, and floating freely. The extremely delicate ciliate processes of the membrane by whose vibrations the motion is effected are shown at C, magnified a thousandfold. They will be seen to be of equal size, and to cover the whole surface of the egg-shaped cell. D is a group of young germinating plants of the same kind, less highly magnified.

The thread-like ciliæ upon their surface serve at this time the purpose of rudders, in the same way as the ciliæ and hairs of infusoria. Neither the form, the chemical nature, nor the power of contraction, without which the ciliate or quivering motion would be inconceivable, distinguish these vegetable cells from analogous animal forms, and, to connect them even still more closely with the latter, dots of colour present themselves as indications of organs sensitive to light.

But this burst of life in the plant-cell is of short duration, and ceases in the ciliate swarming cells sooner than in others. After a short time, these feelers, with which they strive to penetrate further into the exterior world than by the roots, are drawn in, the cell again becomes smooth, and cellulose is soon deposited upon its surface, which renders the incarceration complete. The vigorous play of motions does indeed continue for a longer or shorter period, even under the rigid envelope of the cell-membrane, and it is at this time especially that the reproduction of the cell goes on by the formation of new vital centres; but this last spark of life is soon extinguished, and the victorious forces of molecular attraction, affinity, etc., reduce the cell gradually within the domain of inorganic nature.

Nevertheless it appears that the manifestation of this vigorous vital action is reserved to only a few cells in the body of the plant, although not for its entire duration, at least for some time. These are the reproduction cells. While all permanent cells are capable of manifesting their higher nature only in the motion of their juices, the reproduction cells break all the bonds which govern the former, and, even although only for a few moments, enter into the most unrestrained activity.

In some series of the vegetable kingdom, in which, as we have seen, the duality of sex does not appear to be fully developed, such reproductive cells become swarming cells in other series; the one reproduction cell does not acquire such a degree of freedom, but the second one moves the more unrestrictedly extended lengthways, as spermatozoids, whose motions are far from being understood in respect to their relation to fructification (fig. 39).

A, Fig. 38, represents a spermatozoid of *Asplenium septentrionale*, detached from the mother-cell in which it was formed, and moving rapidly in water by means of the ciliæ. It is magnified × 1200fold. B, spermatozoids of *Equisetum arvense*, magnified × 500fold. C, a spermatozoid just escaping from the mother-cell.—(*W. Hofmeister.*)

Fig. 38.

In the intermediate part of the vegetable kingdom, lastly, comprising all the more highly-developed plants, this primitive vital tendency is almost entirely stopped under the armour of the cell-membrane, and rendered irrecognizable.

Since this higher vital tendency of the cell is, as we have seen, such a universal phenomenon in germinating organisms, but appears in such unequal intensity, it may indeed be said that the developement of the plant rather deviates from than tends towards a free natural state; and in so far plants and animals are antagonistic and mutually-deviating manifestations of a general natural vitality. It is quite as certain that they are, however, alike in origin, for here all marks of distinction cease to exist, and there is a gradual transition from one to the other.

It follows, therefore, obviously from this, that the key to the mystery of vegetable life lies in the primitively-similar foundation of life of the animal and vegetable kingdom, from which indeed both have sprung, but have branched off in different directions.

The animal nature is in the plant as it were caged, and this imprisonment is expressed throughout its entire existence, in its formation, and relation to the animal kingdom. They are the tears of Cypria, the blood of Hyacinth, which in the form and colour of the flower whisper to us a melancholy strain. The complaining Dryad expresses the whole soul of the plant.

Thus in melancholy seclusion does the plant achieve its life-destiny. But the fettered and slumbering world-spirit, which here scarce dares breathe, is the same which in animals bursts its bonds for ever, and, lastly, sings its hallelujah in man.

W. CLOWES AND SONS, STAMFORD STREET AND CHARING CROSS.

1/7 = 35c