OUTLINES

OF

STRUCTURAL AND PHYSIOLOGICAL

BOTANY.

"From the time when the constant subordination of the imagination to observation was unanimously recognized as the primary fundamental condition of all healthy scientific speculation, a vicious interpretation has often led to much abuse of this great logical principle, causing real science to degenerate into a kind of sterile accumulation of incoherent facts, the only essential merit of which could but be that of partial exactitude. It is important therefore fully to understand that the true positive spirit is (in reality) not less removed from empiricism than from mysticism. Between these two aberrations, equally fatal, we must always hold our course * * *. The laws of phænomena really constitute science, to which facts, properly so-called, however exact and numerous they be, ever furnish but the indispensable materials * * *. The true positive spirit consists especially in *seeing* that we may *foresee*, studying what *is*, that we may conclude what *will be*, according to the general dogma of the invariability of natural laws*."

---

* Aug. Compte, Discours sur l'Esprit Positif.

OUTLINES

OF

STRUCTURAL AND PHYSIOLOGICAL

BOTANY.

BY ARTHUR HENFREY, F.L.S. ETC.,

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LATE BOTANIST TO THE GEOLOGICAL SURVEY OF THE UNITED
KINGDOM.

WITH NUMEROUS ILLUSTRATIONS.

> "....Au lieu d'une science circonscrite, je trouve un champ immense, où le moindre végétal me fournit des sujets nombreux de réflexion....Je sens auprès de moi, à mes côtés, une intelligence et une sagesse qui excitent toute mon admiration."—VAUCHER.

LONDON:
JOHN VAN VOORST, PATERNOSTER-ROW.
MDCCCXLVII.

PRINTED BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.

TO

ROBERT BROWN, ESQ., D.C.L.,

ETC. ETC. ETC.,

THIS LITTLE BOOK

IS

DEDICATED,

AS A HUMBLE TRIBUTE OF RESPECT

AND

ADMIRATION.

PREFACE.

THE progress of science is the result of the advancing march of observation and generalization, by which we endeavour to acquire a knowledge of the conditions of things, and to harmonize their relations with the laws of our understanding. An inevitable accompaniment of such progress is the accumulation, from time to time, of a mass of facts and subordinate inferences, which, unless reduced into principles somewhat more general, are so many stumbling-blocks to the inexperienced.

In the Natural Sciences, especially, the accession of new information, whether from original investigation or from the persevering application of repeated examination and comparison to received views, is continually modifying the very fundamental doctrines on which our superstructure of knowledge temporarily rests, and thus, at certain stages, arises the necessity for the revision of the whole, the rejection of superseded and superfluous disquisitions, and for the assumption of new points of view, from which to regard much of that with which we have been previously acquainted.

From such and analogous causes originates the production of new books of the nature of the present, and in them is to be found the justification of those who devote themselves to such tasks.

It perhaps may not be unbecoming for the author of this little manual to offer more personal reasons for its appearance, especially as it may seem to argue some boldness, not to say rashness, to have undertaken a subject of such extent and intricacy. In explanation I may say, that although a new claimant on the attention of the public, my time for some years, subsequent to the completion of the general scientific studies included in a medical education, has been exclusively devoted to Botany and the related sciences, and this with a view to attain clear, general and universal notions of the present state of the subject, by the diligent examination and practical testing of the works of past and present authorities, since on such a basis must original observation rest with the greatest security and look forward with the best prospects.

Information acquired in this manner has naturally been accompanied by the adoption of certain peculiar views, which will be found in the following pages. At the same time great care has been taken to consider and introduce, where desirable, all information furnished by investigators at home and by our foreign fellow-labourers, up to the latest possible date; and I am anxious to express my obligations to the authors of the works enumerated, whose researches, among those of many others to whom it was impracticable to make distinct reference, have enabled me to execute this work.

Further, I may say, that although the idea of this undertaking had been floating in my mind previously, the immediate instance of its execution was the desire for such a text-book expressed by botanical friends whose position and experience rendered them fitting judges of the necessities of the time.

My chief object has been to give a concise view of the actual state of our knowledge at the present time, to the exclusion of all hypotheses hazarded without sufficient grounds or negatived by experience. The various points are treated as they rise progressively in complexity; by this means the development and morphology of tissues and organs are more readily explained, and at the same time conduces to the simplification of the subject, by leading to a recognition of the unity of plan throughout the Vegetable Kingdom.

Those however who merely wish to become acquainted with the general structure of organs, without reference to the elementary tissues, may pass at once to the fourth chapter.

ARTHUR HENFREY.

London, February 1847.

ERRATA.

Page 5, line 21, *for* bring *read* brings.
— 35, — 21, *for* border *read* bordered.
— 36, — 7, *erase* V. fig. 5.
— 94, — 36, for *Lianas* read *Lianes*.
— 131, — 34, *for* XII. fig. 2. *read* XII. fig. 1.
Description of Plate V. fig. 16. for *Berberis* read *Diphylleia peltata*.
Description of Plate VII. fig. 8. *for* tri-pinnate *read* decomposed.

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INTRODUCTION.

At the outset of a work on Physiological Botany, it might naturally be expected that a definition of a Plant would be given. An absolute definition however is impossible in the present condition of our knowledge of organized nature; in fact, some philosophers have even denied the possibility of defining the limits between the organic and inorganic world—between a crystal and a cell. Without admitting the validity of this view, which, although plausible in theoretical expositions, is practically negatived by very slight investigation, it must be allowed that the axiom "*Natura non facit saltus*" holds good so far as relates to the organic creation; the Animal and the Vegetable Kingdoms, so distinct and opposite, both in appearance and function, when taken in their entirety, approach gradually by their lower tribes, until at the extreme point they meet in a simple cell, which stands as it were *on* the limit. Here all our means of diagnosis fail us; we cannot assign *this* as a subject to either, exclusively, since it possesses characters in common with both: the power of motion we had hitherto regarded as exclusively belonging to animals; the nutrition by absorption through an external membrane, so remarkably distinctive of plants. We must be content then to take general characters instead of a definition—characters founded on whole kingdoms instead of on individuals, and thus to come to an appreciation of the important relation they bear to each other.

The chief differential chemical characters may be stated thus :—

Animal structures are generally quaternary compounds, consisting of carbon, oxygen, hydrogen and nitrogen ; they consume oxygen and exhale carbonic acid, are resolved into carbon and ammonia when burned, and restore the elements to the air or earth by transforming organic substances into mineral.

Permanent Vegetable structures are generally ternary compounds, consisting of carbon, oxygen and hydrogen ; they give off oxygen and fix carbon, are resolved into carbon and acetic acid when burned, and derive their elements from the air or earth, transforming mineral substances into organic.

The general differential vital characters are :—Animals possess the faculty of nutrition, which takes place by absorption through a membrane *lining* a stomach or cavity open to the external medium ; they have sensation and voluntary motion.

Vegetables possess the faculty of nutrition, which takes place by absorption through a membrane *surrounding* an internal cavity, which is a closed sac ; they do not possess sensation or voluntary motion.

These characters, sufficiently precise for our purposes, are open to many objections, as will be seen when we come to speak of certain organs, which undoubtedly belong to true vegetables; but they are the best which circumstances will allow of; and the difficulties of the subject, as here indicated, will sufficiently account for the absence of speculative views when treating of those structures in plants which have been invested with so many fanciful analogies.

The morphological doctrines, for the origin of which we are indebted to the "many-sided" mind of Goethe, have had more influence perhaps than any other theory ever propounded in Phytological science, in consolidating and simplifying our notions of vegetable structures. The conception of the transformation of an ideal leaf as a type (for it must not be understood that the organs are *actually leaves* altered) into all the varied forms of stamens, carpels, &c., gives us a clue which guides us through the most complicated assemblages of organs, and enables us to detect analogies under the most dissimilar appearances, while it offers a ready explanation of the frequent and otherwise unaccountable irregularities and diversities in the complete organs which give their peculiarities to many tribes of plants, and bring them into relation with the universal laws of development. They are kept strongly in view in the following pages, and are extended also, in accordance with the views of the most distinguished physiologists, to the cell and its combinations.

The unity of the subject will be still further perceived from the introductory notices on the chemistry of vegetation, which show what slight modifications the various proximate elements are of each other, and how easily they may be mutually convertible.

Analysis is for the observer, synthesis for the teacher; and it is hoped that the adoption of the synthetic mode in its most rigorous form in the following pages will enable the student to comprehend clearly the nature of the structure of plants and the relations and functions of their different parts, at least so far as our knowledge at present admits: there are many points on which much observation has yet to be bestowed; much that we are really altogether ignorant of; more of which our knowledge is negative. In such cases it is better to state clearly and decidedly the fact of our ignorance, than to give *mere* hypothesis; and this will serve to explain what might otherwise appear to be meagre information on doubtful points.

OUTLINES

OF

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CHAP. I. CHEMICAL COMPOSITION OF VEGETABLES.

Sect. I. INORGANIC CONSTITUENTS.

1. *Carbon* (C) is the most abundant and important element of plants. It forms the hard parts, and enters so extensively into the most delicate structures, that these remain visible when almost every other substance has been removed by charring or similar processes. When plants have become converted into coal naturally, they retain their organic form so perfectly that the ultimate tissues may be discovered by the microscope. Carbon however is never found free in plants.

2. *Hydrogen* (H) and *Oxygen* (O) are the next in importance, and in the more essential organic elements are frequently found in the proportions which form water. Free oxygen is given off by plants. So also is hydrogen, it is said, from Fungi decomposing in water.

3. *Nitrogen* (N) is found combined with the preceding in some most important substances. The statement that it occurs free in Fungi does not rest on satisfactory evidence.

4. *Chlorine* (Cl), *Iodine* (I), and *Bromine* (Br), combined in various salts.

5. *Sulphur* (S) and *Phosphorus* (P), in combination as sulphuric and phosphoric acids; with proteine, as constituent elements of albumen, caseine, &c.

6. *Silicon* (Si), as silica, especially in the Grasses, Equiseta, &c.

7. The other elements which have been indicated are, various metallic bases, found principally as oxides combined with inorganic or organic acids: viz. *Potassium* (K); *Sodium* (Na);

Calcium (Ca); *Magnesium* (Mg); *Aluminium* (Al); *Iron* (Fe); *Manganese* (Mn); and *Copper* (Cu). All but the last two are common; copper, as far as we know, is rare.

BINARY COMPOUNDS.—The most important are,—

8. *Oxygen compounds.*—Water (HO), by far the most essential. *Ceratophyllum demersum* consists of water ·90, solid matter ·10. Carbonic acid, CO^2*, forms with water the chief nutriment of plants. It is given off free by plants in the dark; also by ripening fruits, &c. by daylight. The absorption of carbonic acid and its decomposition by the liberation of oxygen, is one of the most important offices of plants in the economy of nature. Oxalic acid, $C^2 O^3$, HO, probably present in all plants, occurs free in many succulent kinds, as Ficoideæ, Cacteæ, &c.

9. *Hydrogen compounds.*—The most important is ammonia, NH^3. This appears to be the source of nitrogen in plants, which derive it both from the air and from its salts in solution in the water about their roots. Free ammonia is given off occasionally, *ex. gr.* from the sap of the birch and the vine in spring, and from some plants rendered unnaturally succulent by cultivation, as beet-root.

Hydrogen combines as acid with chlorine (hydrochloric), iodine (hydriodic), bromine (hydrobromic), and yields these to metallic bases; chlorides, &c. being formed.

10. *Salts.*—These are found either dissolved in the juices or crystallized; most abundantly in green parts where the vital activity is greatest (as in the leaves), and sparingly in the wood. A certain amount of them appears essential to the growth of the plant, a circumstance which has attracted a great deal of attention from agricultural chemists. It is probable that most of the carbonates found in the ashes of plants are formed from compounds of organic acids during incineration.

The most important salts are the alkalies combined with vegetable acids, with chlorine, bromine and iodine, perhaps with sulphuric and phosphoric acids; as has been said, it is a question if carbonates of the alkalies occur in living plants; next, the earths with vegetable acids, especially oxalic, with carbonic, sulphuric

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* The numbers affixed to the chemical symbols signify the number of atoms or equivalents of the elements contained in a compound.

and phosphoric acids; lastly, the metals, in, as yet, undetermined combinations.

11. Almost all plants contain—

1. Acetate and malate of lime in solution in their juices.
2. Citrate and tartrate of lime, either as acid or neutral salts.
3. Oxalate of lime, crystallized. This occurs in various forms (IV. figs. 7 & 8); the delicate crystals have been called raphides, and lie in bundles of from two or three to several hundred in a cell.

Carbonate of lime and sulphate of lime are also found as crystals.

Sect. II. ORGANIC CONSTITUENTS.

12. The organic compounds formed by the union of the four principal elements, carbon, oxygen, hydrogen and nitrogen, may be divided into two classes: viz. 1. Those which appear essential to vegetable life even in its simplest forms, these compounds varying in relative importance at different epochs and in different examples of organic existence. 2. Those which are not essential to plants in a general sense, but which give the peculiarities to the chemical composition of different tribes, classes, and even individuals.

* *Essential Organic Compounds.*

13. PROTEINE COMPOUNDS.—In the interior of all cells in course of development, and in all those retaining the power of propagation, we find a mucilaginous substance, at first homogeneous, but subsequently becoming somewhat granular, of varying degrees of density, and often of a light yellow colour; it is rendered wholly granular, or coagulated by alcohol, and is coloured dark brown by iodine. It is usually accumulated as a layer investing the inner surface of a delicate membrane of nearly identical composition, lining the walls of the cells (the primordial utricle).

This matter, which appears necessary to the simplest processes of vegetation, is composed of C, H, O and N, with the occasional (perhaps constant) addition of P or S, or both. The modifications of this matter have received the collective name of mucilage

(*Schleim*), but this is apt to lead to error, as they differ very much from gum; the name therefore suggested by Mohl ought certainly to be adopted, as leading to no false chemical interpretations, but expressing the physiological value: he calls it Protoplasma. Various names have been given by chemists to the modifications of this protoplasma, *ex. gr.* albumen, gluten, gliadine, gelatine (*Leim*), diastase, legumine, &c.

Liebig and Mulder have divided these forms into three groups,—Albumen, Fibrine and Caseine (gluten is chiefly fibrine with modified albumen). Mulder has shown that these are all derived from one basis, which he calls Proteine ($C^{40}\ H^{31}\ N^{5}\ O^{12}$, Mulder; $C^{48}\ H^{36}\ N^{6}\ O^{14}$, Liebig); and that vegetable albumen, fibrine and caseine have the elements C, H, N, O, nearly in the same proportions, namely those of proteine, their differences arising from various combinations with sulphur and phosphorus. Thus caseine is 10 Pr. + 1 S; fibrine, 10 Pr. + 1 P + 1 S; albumen, 10 Pr. + 1 P + 2 S.

The protoplasma appears to have the power not only of becoming changed into other bodies, but by *contact* or catalysis, as it is called, of altering other bodies while it remains itself unchanged. This will be alluded to hereafter.

14. Cellulose (*Woody fibre, Sclerogen*).—The substance of which cellular membrane is composed is tough, elastic, colourless and transparent, insoluble in all known menstrua. It is changed by concentrated sulphuric acid or caustic potash into starch; it expands when moist, contracts when dried; it is permeable by fluids, but varies much in density, as may be seen in the difference of consistence of different deposits of cell-membrane, being sometimes almost gelatinous, at others very hard and very little affected by moisture. It often acquires a dark colour with age, and the internal layers in the ligneous cells of fully-formed trees appear to differ a little in chemical composition as well as appearance. The modification has been called *lignine*, and may be removed from the cellulose by nitric acid. The composition of cellulose is as follows:—

	C	H	O
Cellulose from willow and box-wood ...	12	9	9
———————— oak	36	22	22
From various membranes (Payen)	12	10	10

Lignine, separated from cellulose, is said to contain $C^{35} H^{24} O^{20}$.

15. **Amyloid.**—This has been described by Schleiden as apparently a slight modification of the last, or an intermediate state between cell-membrane and starch, found in the cotyledon cells of some plants, *Schotia speciosa, Tamarindus indica*, &c. It is cartilaginous while dry, gelatinous when moist; soluble in boiling water, strong acids or alkalies; insoluble in ether or alcohol. When moderately firm it is coloured blue by iodine, losing this colour and becoming yellow by soaking in water.

16. **Vegetable Jelly** (*Vegetable mucilage* of the chemist in part; *Bassorine, Salep*).—This substance is horny or cartilaginous when dry; moist, it swells up in a gelatinous manner, and becomes gradually diffused throughout cold water. It is transparent, and soluble in hot and cold (?) water; in caustic alkali (perhaps converted into an acid). It is not affected by alcohol, ether, fatty or essential oils, and is not coloured by iodine. On one side it passes by various modifications into cellulose (*ex. gr.* the cell-walls of Fucoids) and amyloid (*ex. gr.* some kinds of horny albumen); on the other into amylum (*ex. gr.* the mucilage of the Orchis tubers), and often further into gum and dextrine. Probably pectine and its compounds are closely related here.

17. **Starch** (*Amylum, Amydon*).—Starch in a dry state appears as a white powder composed of transparent granules, crackling between the fingers, insoluble in cold water, alcohol, ether or oils; soluble, or at least swelling up and suspended, in boiling water, from which on evaporation it gives a tough jelly, and when quite dry a transparent glassy substance, which swells up and yields a kind of mucilage with water. Iodine, even in very minute quantities, strikes a deep blue colour with this solution; this colour is supposed to result from the extreme division of the iodine, and not from any chemical combination.

	C	H	O
Starch consists of	12	10	10

It appears to pass gradually into amyloid, by the starch of lichens, and is closely allied to cellulose, sugar, &c. By the action of heat and diastase, the solution of starch is converted into dextrine and then into sugar; the same process occurs naturally in plants when the starch stored up in cotyledons, buds, tubers,

&c. is required for nutrition. The peculiarities of the form and structure of the granules will be alluded to hereafter.

18. Dextrine.—A soluble substance found in almost all parts of plants, may be obtained from starch by boiling in water for some time (indeed some writers assert that it is the matter contained in the interior of the granules), by roasting, or by the action of sulphuric acid or diastase, which, if continued further, convert it into grape-sugar. Its composition is $C^{12} H^{10} O^{10}$.

19. Gum (*Arabine, Vegetable mucilage* in part).—Very soluble in water, from which alcohol precipitates it. The solution, kept near a boiling temperature for some time with sulphuric acid, is converted into grape-sugar. Its composition is $C^{12} H^{10} O^{10}$, the same as that of starch. Arabine yields ashes containing lime.

The chief distinction between gum and dextrine is, that the former is not so readily changed into sugar by the action of dilute sulphuric acid; moreover, gum appears as a true secretion, while dextrine is assimilated matter prepared for the purposes of nutrition.

20. Sugar.—Pure sugar, in a solid state, is crystallized and transparent, very soluble in water. There are several kinds capable of undergoing fermentation, *ex. gr.* cane-sugar, grape-sugar (sugar of starch, of honey), and uncrystallizable sugar. The sugar of mushrooms is mannite, and will not ferment.

It is but sparingly soluble in alcohol; not at all in ether or oils; it will mix with solution of iodine. Composition of the principal modifications :—

	C	H	O
Cane-sugar	12	9	9 + 2 H O.
Grape-sugar	12	14	14

It is found very abundantly in solution in plants, especially in growing parts, such as buds, germinating cotyledons, &c., in ripe fruits, the stems of grasses (*Saccharum officinarum*, &c.), and in fleshy roots, as the beet. It is found crystallized in rare instances, as in the nectary of *Fritillaria imperialis*.

21. Inuline.—A substance much resembling starch, found in some of the Compositæ. Its composition differs from starch in not containing so large a proportion of the elements of water; otherwise the characters are similar, except that it is coloured *brown* by iodine.

22. **Fixed Oils and Wax.**—The fixed oils sometimes take the place of starch in cotyledons, as in some of the Cruciferæ, some Compositæ, and many other plants. They are found in the cells of the fruit, the roots, and other parts.

Wax occurs abundantly in some classes, in the leaves, the fruit, &c. It also forms an important part of the chlorophylle or green colouring matter.

23. From the close resemblance of the composition of all these matters, it will readily be conceived how they may be mutually convertible. The real nature of the processes is yet unknown, but we know that these changes, as the passage from cellulose into starch, starch into dextrine, from dextrine and cane-sugar into grape-sugar, from grape-sugar into gum (in the fermentation of the juice of the beet), with the exception of the first, which is only effected by sulphuric acid, can all be produced by the nitrogenous substance, protoplasma or mucilage, out of the plant.

We may conclude therefore that similar operations go on in the plants in a similar manner, and in them takes place equally a metamorphosis of "sugar into dextrine, dextrine into starch, amyloid, cellulose, mucilage; of wax into sugar, of sugar and starch into wax, of starch into fixed oils, of fixed oils into sugar and dextrine." All these changes may take place with the mere taking up or separation of water and oxygen, and these in fact constitute the chief vital processes of the plant, as far as nutrition is concerned.

** *Organic substances produced during Vegetation.*

24. **Chlorophylle** (*Fecula viridis, Chromula, Phytochlore, Green colouring matter*).—This is the substance giving the peculiar green colour to plants. It is of a waxy nature, soluble in alcohol and ether, but insoluble in water, and occurs as a fluid of a viscous nature either in an amorphous condition or enveloping peculiar granules. These granules are said to consist of a mucilaginous matter (which gives the form to the granules) and wax, and they have most frequently starch in their interior. They are exceedingly abundant in the cells of the leaves, and appear to have a close relation to the process of separation of oxygen by

the influence of light, which takes place there; they seem also to be reservoirs of nutriment, when containing starch.

25. COLOURING MATTERS.—These consist of soluble and insoluble matters; the former occur as fluids filling peculiar cells of plants; the latter are generally granular and somewhat resinous, soluble in ether, &c. The red fluid colouring matters, rendered blue by alkalies, and the blue reddened by acids, all contain nitrogen, according to Liebig, but not as a base.

26. TARTARIC ACID, CITRIC ACID AND MALIC ACID.—These organic acids are abundant in all succulent acid fruits, and are closely connected with the metamorphoses of sugar and its allies. Their composition is—

Tartaric acid	$C^8\ H^4\ O^{10},\ 2\ H\,O.$
Citric acid	$C^{12}\ H^5\ O^{11},\ 3\ H\,O.$
Malic acid	$C^8\ H^4\ O^8,\ 2\ H\,O.$

Some other organic acids are also met with in peculiar plants, as the valerianic, meconic acids, &c.

27. ALKALOIDS—Constitute a class of organic compounds containing nitrogen, not absolutely essential to vegetable life, but giving plants their most active principles in regard to officinal uses. They are found in vegetable juices, seeds and roots; they act on vegetable colours like inorganic alkalies and neutralize acids forming salts, generally crystallizable. They usually occur in combination with vegetable acids, as the meconate of morphia, kinate of quinine, &c.

28. TANNIN (*Tannic acid*).—This is a very peculiar substance, found most abundantly in various barks, galls, &c., but is also present in leaves and other parts, most probably where the vegetative processes are becoming less active, as it appears to be a product of oxidation of the tissues. Thus 2 eq. of cellulose, $C^{24}\ H^{18}\ O^{18}$, united to 16 of oxygen, leave, by the abstraction of 10 of water ($H^{10}\ O^{10}$) and 6 of carbonic acid ($C^6\ O^{12}$), one equivalent of tannic acid $= C^{18}\ H^5\ O^9,\ 3\ H\ O$. The chemical changes however are at present little understood.

29. VISCINE (*Bird-lime*) AND CAOUTCHOUC—Are abundant in many plants, and possibly they may originate from altered cellular matter. They possess carbon in large proportion, pure

caoutchouc being a hydro-carbon. Viscine is a transparent, glutinous matter, insoluble in water, found in the berries of *Viscum album,* in the fruit of some plants, and, according to Schleiden, in the green twigs of *Ficus elastica.* A somewhat similar substance is secreted on the stigma of Asclepiadeæ, and the staminal glands of Apocyneæ. Caoutchouc appears to be nearly allied to viscine. It has the character of an excretion, and is present in the milky juices, especially of Urticeæ, Euphorbiaceæ, and Apocyneæ, in the form of little globules suspended as in a kind of emulsion.

30. HUMUS (*Humin, Humic acid, Ulmine, Ulmic acid, Coal of humus,* &c.).—These (or rather this, for they appear merely to be different forms of decaying vegetable fibre) may be divided into the soluble form, humic acid; and the insoluble, humus, or coal of humus. They are products of the slow decay of plants, absorbing oxygen from the surrounding atmosphere, and the carbonic acid thus produced is the form in which they yield nutriment to living vegetation.

31. Many of these compounds are found in peculiar cells, or in what have been called the milk-vessels, and are probably produced by purely chemical action. New compounds, similating the alkaloids, have already been obtained by chemists artificially, and the progress of chemistry will doubtless hereafter explain much that is uncertain in regard to the processes going on in the tissues of plants.

CHAP. II. ELEMENTARY STRUCTURE.

Sect. I. THE CELL AS AN INDIVIDUAL.

32. The simplest plants with which we are acquainted consist of a closed sac or utricle (I. fig. 8); the most highly organized originate under a similar form, and, by the investigation of development, we ascertain that all vegetable structures whatsoever are made up of such utricles (I. figs. 1–10), variously modified according to the conditions under which they are produced and the functions to which they are destined. Here then we have the fundamental organ, in a particular sense complete in itself, and endowed with the power of reproduction.

A cell consists of a membranous closed vesicle, the typical form of which is spherical, other figures being supposed to result from the mutual pressure exerted by a number growing in a confined space. This supposition however is only admissible in certain cases, as will be seen hereafter. Cells, as has already been stated, make up the whole vegetable structure; some of their modifications have been distinguished from the general mass of utricular tissue, under the name of vessels; if the statements generally received, that vessels are formed from rows of cells by the absorption of their septa, be true, they must be regarded as compound organs, and therefore will more properly be considered in the next section.

33. DEVELOPMENT AND PROPAGATION.—This portion of the history of cells is at present in an imperfect state. All that we certainly know is that they increase in number, by each cell producing (normally) two or four new cells. The mode in which this is effected has been variously described by various authors. In order to render the explanation of the different views entertained of the formation of cells more readily intelligible, it will be advisable first to advert to certain bodies found in their interior.

34. Lining the internal surface of the wall of all young cells is a layer of a more delicate nature, having all the characters of a

membrane. This membrane, the *primordial utricle* of Mohl, is apparently composed of mucilage (protoplasma), at first transparent and homogeneous, but afterwards granular and more or less opake. It is easily detached from the proper membrane of the cell by water or acids (I. fig. 2); also by tincture of iodine, which colours it brown and causes it to contract. Since it is immediately applied upon the cell-wall, it encloses all the other contents of the cell.

35. Probably the next in importance of these, as far as development is concerned, is the nucleus (I. figs. 2, 4, *a*); this is a small spherical or lenticular body, composed of granules of a mucilaginous nature, generally with a sharply defined border, and having in its centre a bright point (sometimes two or more), called the nucleolus (I. figs. 2, 3); this nucleolus is not always visible in small nuclei, and the granular structure of old ones often obscures it. The nucleus may be adherent to the primordial utricle (II. fig. 6), or lie in the centre of the cavity (II. fig. 16, *a*); in either case it is originally the centre of a radiating system of mucilaginous filaments extending through the cell (I. fig. 3), and in the latter these filaments serve to suspend it, and hold it in connexion with the primordial utricle. The absolute position of the nucleus, though regarded as important by several observers, cannot be of essential moment, since it often moves with the other contents of the cell, as may especially be remarked in the cells of *Vallisneria* (IV. fig. 12, *a*). The two structures just described may be characterized as transitory, as in most cases they disappear soon after the commencement of the formation of the secondary layers on the walls of a cell; sooner in woody structures than in parenchymatous, where traces of the primordial utricle often remain for a long time (I. fig. 7). The existence of the primordial utricle in a normal condition in a cell generally indicates that the cell still retains the power of propagation, and it is consequently always found in cambium cells, &c. (I. fig. 10).

36. Starch granules which are found in cells (II. fig. 24) may also be considered as transitional formations, but of a different class; they are not agents of development, but means; they are the accumulations of nutritious matter analogous to the fat of

animals; the assimilated substances being stored up in a form not *directly* available to the production of new tissues, the general economy of the plant is maintained in equilibrium. According to Nägeli, the formation of starch takes place in *Caulerpa prolifera* in utricles; the granules are formed from the mucilaginous contents, and are set free by the dissolution of the enclosing membrane (II. fig. 2).

The researches of Karl Müller go to prove that the starch granules are formed out of the cytoblast, after the perfect formation of the cell. These points are not yet clearly made out; but my own impression is, that the starch is formed in peculiar utricles, resulting from the division of the primordial utricle into a number of small vesicles, after the completion of the cell in which it is contained. I have found such utricles in cells where no other process could apparently be taking place; the evidence however is not yet sufficient (I. fig. 4).

But the granules seem also capable of another mode of increase, as indicated by Mr. E. J. Quekett, viz. multiplication by division. I believe I have seen this taking place in potato starch (I. fig. 15, *b*), and in the starch of the corm of *Crocus aureus* (I. fig. 16, *c*).

The granules vary much in size; the larger ones usually present a number of concentric striæ around a point (*hilum*, nucleus) situated towards one end of the granule. The real structure of starch granules is at present an unsettled question; the two theories most worthy of notice are: 1. The granules are cells, the striæ representing the layers of increment deposited on the inner surface of the cell-wall, which is supposed to be of a different chemical nature (containing caoutchouc); the point or dot then answers to the cavity or a pore leading to it. 2. The starch granules are solid; the striæ represent layers of increment deposited round a central nucleus. The former theory appears to me to come nearer the truth: we meet with gelatinous secondary layers in cells (as in the cotyledon of *Schotia speciosa*) very much resembling such starch cells; they swell up in the same way in dilute sulphuric acid, and are coloured blue by iodine. By some of the advocates of the cellular theory of starch it has been asserted, that the inner portions consist of dextrine; that the cause of the insolubility of starch in cold water is the outer layer, and when this is dissolved by acids, &c., the dextrine is set free. These views are at present hypothetical.

37. Chlorophylle, the green colouring matter already alluded to (§ 24.), is usually found in the form of granules (I. fig. 18), but also occurs in an amorphous condition, as in *Spirogyra* (*Zygnema*). It has been suggested, however, that here it invests a spiral mucilaginous filament, invisible on account of its tenuity; this opinion has arisen from the spiral band appearing to be channeled.

Nägeli states that the granules, like starch, originate in utricles. He says that these at first appear to contain a green fluid; granules are formed in this, and when they have attained a certain size, the utricles are dissolved and the chlorophylle granules set free. The formation of chlorophylle does not occur so early in the life of the plant as that of starch.

My own observations lead me to believe that chlorophylle is nothing more than altered starch. The starch granules become changed on their surface, with the liberation of oxygen, by the action of light; the process may extend gradually inwards until the starch is wholly decomposed. The mucilaginous matter (§ 24.) is probably dextrine, also derived from starch. In an early condition the chlorophylle granules are of a very light colour, and are tinged blue by tincture of iodine.

The chlorophylle granules are either free, lying on the walls (I. fig. 17, *a*), or accumulated in heaps (I. fig. 17, *b*) in the centre of the cell (often round the nucleus), or adherent to the primordial utricle.

38. These appear to be all the usual contents of developing cells. It will be seen that the relative importance of the parts which they are respectively supposed to play in the processes there occurring, has been differently estimated by different observers.

Of all the hypotheses that have been proposed, of the nature of the process of cell-formation, only three appear worthy of note, in the present condition of our knowledge of the facts. These are as follows:—

1. The formation of free cells from nuclei, in the cavity of the parent-cell: this view was proposed by Schleiden.
2. The formation of new cells by the division of the mucilaginous investment of the interior of the cell (primordial utricle) into two or four perfect, closed sacs, *around* and *by* the whole outer surface of which a new layer of membrane is simultaneously formed for each portion, these constituting the new cells. This is the theory of Nägeli.
3. The gradual division of the primordial utricle into two portions by an annular constriction and infolding, the fold growing inward to the centre, and a layer of permanent cell-membrane being also deposited by each lamella of the fold, gradually from the circumference to the centre. This view was advocated by myself as the *universal* mode of cell-formation, in a paper read before the British Association at Cambridge last year, and has been more fully developed in a recent memoir by Mohl.

39. 1st, Schleiden states that cells can only be produced in a fluid which contains sugar, dextrine, and mucilage. This takes place in two ways: 1. Part of the mucilage of the cell is aggregated into a more or less roundish point, the cytoblast, and converts the fluid on its surface into a gelatinous and relatively insoluble substance; a closed gelatinous utricle is thus formed (II. figs. 3, 4, 5); this absorbs the external fluid and increases in size so that the mucilaginous body becomes free on one side, on the other it adheres to the inner wall. It then either forms a new wall on the free side, and thus becomes enclosed in a duplicature of the wall, or remains free, and then is usually dissolved and absorbed (II. fig. 7). During the gradual extension of the utricle, the gelatine of the wall is in general converted into cellulose and the formation of the cell is completed. 2. The other mode is the second one indicated above as supported by Nägeli, the possibility of which in some cases is admitted by Schleiden.

Against the theory of free cell-formation it is urged, and it is a weighty objection, that the earlier processes are not proved by direct observation; we cannot see them take place, and the subsequent phænomena do not appear to warrant the assumption that this is in consequence of the imperfection of our means of investigation. A still more important one is the fact that two cells may be formed by the division of a parent-cell without any change in the position of the contents, such as bands of chlorophylle or the like. This is a decided proof that the two new cells did not originate free, of small size, and afterwards grow to fill the parent-cell, since in that case the contents of the parent-cell must have been *outside* them, and must necessarily have been dissolved, absorbed, and re-deposited internally*.

40. 2nd, Nägeli's theory is as follows: all young cells consist of a membrane enclosing mucilaginous contents, at first homogeneous, afterwards granular; they usually possess a nucleus which may be either lateral or central, and in his opinion also consists of a membranous utricle enclosing mucilage, and having one or more denser white points (nucleoli) in its interior. A dense layer of mucilage of the cell lies as an investment all over the inner surface of the cell-wall, and often loses itself gradually interiorly in the general mucilage of the cavity; the chlorophylle granules are sometimes imbedded in it. This parietal investment has the power of secreting gelatinous membrane on its outer surface, forming *layers of thickening*, while *in contact* with the cell-wall, but *distinct membranes* if *separated* from it. The production of new cells (II. figs. 18, 19) takes place by the division of the mucilaginous sac into (normally) two or four similar sacs occupying the same space and position, each containing a proportion of the original cell-contents. A layer of membrane is simultaneously deposited all over the exterior of each of these, and the parent-cell then becomes dissolved and removed. The relation of the nuclei to cell-formation is not evident, but they are almost always visible; even in cases where they cannot be made out, they are often probably concealed in the heap of granular matter usually present in such instances.

To this theory I object, that there is no explanation of the

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* The apparently starch-producing utricles (I. fig. 4) alluded to (§ 34.) may have contributed to deceive Schleiden and his followers. They could not have indicated cell-formation, from the nature of their position and relations.

mode in which the mucilaginous sac (or primordial utricle) becomes divided, and the evidence of the simultaneous deposition of the septa is insufficient; this will become apparent in the consideration of the next theory.

41. 3rd, The formation of new cells commences by the doubling inward of the primordial utricle, so as to form an annular channel (II. 10); this gradually increases in depth till it divides the utricle into two portions, each a perfect closed sac (I. fig. 1, II. fig. 9); following the infolding of the primordial utricle, takes place a deposition of permanent cell-wall from each lamella (II. figs. 9–11, figs. 13–15); and that this takes place gradually is proved by the maintenance of the continuity of the cavities of the two utricles where the construction is imperfect, but where the deposition of the septum can distinctly be perceived at the circumference. This is shown by Mohl in *Conf. glomerata* (II. fig. 12), and I have myself observed it in the hairs of the stamens of *Tradescantia* (I. fig. 2) and *Conferva* —? (I. fig. 14, *d*). The layers of the septa are continuous with the layers of thickening in the interior of the lateral walls (II. 15, *a*).

42. It is quite undeterminable at present what function the nucleus serves in the cell; I believe, with Mohl, that it is intimately connected with the chemico-organic changes of the cell-contents, and that it is concerned in the elaboration of the mucilaginous granular matter, which has been well named by Mohl the protoplasma of the cell.

43. Growth and Figure of Cells.—I have said that the typical form of a cell is a sphere. This is the case when they are perfectly free from pressure, or when nutrition goes on equally in the whole membrane (I. fig. 2). But from the account given of the process of multiplication of cells, it will be seen that they must be produced in various forms as segments of the figure of the dividing parent-cell (I. fig. 8). When free, these usually develope so as to acquire a spherical or elliptical form, which, by the reciprocal pressure of contiguous cells, is converted into a dodecahedron.

The nutrition, and consequently the development of a cell, may be unequal in different parts of its walls; then we have cylindrical (I. fig. 19) or elongated fusiform cells; by pressure these assume the figure of a six-sided figure (IV. fig. 8); in the former case with parallel ends, in the latter either oblique or pyramidal. If the unequal growth take place in more than two directions, we may have stellate cells (II. fig. 20). Very frequently the cells enlarge principally in the direction of the plane of one surface; tabular cells are thus produced, having the upper and lower surfaces parallel, or if one grows faster than the other, becoming plano-convex (I. fig. 27). The sides may be either regular or irregular, in contact or with intercellular spaces; these however are not usual in tabular cellular tissue, as it generally occurs where condensation and strengthening are necessary.

44. The walls of a cell increase in size by intus-susception up to a certain period, but do not always maintain a regular thickness; wart-like protuberances are found both on the outer (II. fig. 30) and inner (II. fig. 32) surfaces of the primary walls or cells, and in the spores of some Confervæ we have the development of processes resembling the cilia of animals; sometimes over the whole surface (II. fig. 25, *e*), in other cases only at one particular point (II. fig. 25, *a–d*).

The primary membrane also probably increases equably in thickness by the deposition of new layers from the primordial utricle.

45. In certain parts probably of all plants are found peculiar spiral filaments, having a striking resemblance to the spermatozoa of animals. They have been long known in those organs called the antheridia of Mosses, Hepaticæ and Characeæ (II. figs. 28, 29), and have more recently been discovered in peculiar cells on the germinal frond of Ferns (II. fig. 26, *b*, *b*), and on the very young leaves of the buds of Phanerogamia. They are formed in peculiar cells, and when these are placed in water they are torn by the filament, which commences an active spiral motion (II. fig. 27). The signification of these organs is at present quite unknown; they appear, from the researches of Nägeli, to resemble the cell-mucilage or protoplasma in composition, and are developed from it. Schleiden regards them as mere mucilaginous deposits, similar to those connected with the circulation in cells, and he contends that the movement of these bodies in

water is analogous to the molecular motion of small particles of organic and inorganic substances, and depends on mechanical causes.

46. SECONDARY DEPOSITS OF CELLS.—At a certain period of the life of a cell its walls cease to increase in thickness by intussusception, and all additions are made in the form of new layers applied to the internal surface. It is generally admitted that all secondary layers have a tendency to form, not a continuous membrane, but a spiral band. This formation being assumed as the type of all secondary deposits, we may institute a division of the modifications into two classes, from the consideration of a very important relation between the band and the cell-membrane, viz. when the deposition of the band commences *before* or *after* the cell has attained its full size. In the first case we have *Fibrous cells*; in the second, *Porous cells*. When it continues through both periods we have cells of a mixed character.

47. FIBROUS CELLS consist of cells having a fibrous spiral band in their interior (I. fig. 23), which, with the growth of the cell, frequently undergoes considerable changes of position and relation to the primary cell-membrane. It may be wound either to the right or left, the former being the most general direction; there may also be two or more bands in the same cell, wound in the same direction (III. fig. 1). That two occur, wound in opposite directions, and thus crossing at each half-turn of the spiral, is improbable, and rests upon an erroneous observation of Link, whose own figure contradicts the description.

Originally the turns of the spiral are in contact, and as the cell subsequently increases more or less in size, these turns are removed from each other proportionately. The less the cell grows, the more firmly the spiral band is united to the membrane. Sometimes the turns of the spiral grow together, producing a great variety of appearances, *ex. gr.* rings, reticulations, &c., or even so much as to leave only a series of narrow slits at intervals between them.

The most common forms of spiral cells are—

A. *Annular cells** (III. figs. 3, 21, *b*), where the cell-membrane

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* In these descriptions cells and vessels are taken indiscriminately, as the latter are regarded as rows of cells.

grows much faster than the fibre; some of the turns of the latter remain adhering together by their edges, and become separated from those above and below; occasionally the rings are not wholly detached, the fibre is stretched so as to unite two rings, or a ring with several convolutions of a spiral. The fibre is here generally very loosely attached to the membrane, sometimes free.

B. *Spiral cells* (III. figs. 2, 4), with open convolutions, unrollable; the fibre either simple or compound; the cell increasing rapidly in size, and very slight or no adhesion of the fibre.

C. *Spiral cells* (III. fig. 1), with close convolutions, unrollable; the membrane expanding very slightly and the fibre being firmly adherent, the former breaks when the spiral is unrolled. The fibre either single or compound.

D. *Reticulated, Ramified* and *Scalariform cells* (III. figs. 5, 6, 11–13). The membrane growing moderately. Adherence of the membrane and fibre, and of the convolutions of the latter with each by their borders at various points, particularly at the angles and parts opposite intercellular spaces.

In old cells the primary membrane has become absorbed, and the spaces between the rings, convolutions or reticulations are thus converted into holes. It is probable that this does not take place until after all deposition has ceased, and the cells in such cases may be considered as dead (III. figs. 11, 12).

The deposition of new layers does not continue very long, in regular spiral bands in most cases; but occasionally, where they adhere firmly to the wall, they become so much thickened that their greatest dimension is perpendicular to the surface of the cell (IV. fig. 14).

48. Porous Cells are those in which the spiral structure is generally much less evident, in consequence of the more intimate union between the convolutions. The cell growing very little after the deposition of the secondary layer, this only exhibits narrow slits or irregular pores. Two kinds of porous cells may be distinguished, which appear to differ slightly in their original formation, viz.

A. Cells with simple pores, the commonest form in cells and in those sides of vessels contiguous to cells (I. fig. 25).

B. Cells with bordered pores, arising from the presence of a lenticular cavity between two adjacent pores (most frequently found only between contiguous vessels) (III. figs. 7, 14–19).

The *simple* pores appear to arise merely from a slight separation of the convolutions by extension of the outer membrane, to which they, for the most part, adhere firmly; their form is very irregular, and also their number and distribution in the cell. When they have the form of slits, these usually take a spiral direction, so as to be oblique as regards the axis of the cell (III. fig. 16). They correspond with the pores of adjacent cells, and when they are slits these necessarily cross. They frequently differ in diameter in different parts, where, from the large amount of deposition, the canal has attained a considerable length, becoming funnel-shaped; or even, according to a figure given by Schleiden, the canals may unite successively in pairs until a large number open into the cavity of the cell by one pore (II. fig. 34). Cells with bordered pores appear to be formed by the occurrence of bubbles of air between the cells (or vessels) at the points where the pores are subsequently produced; then either the convolutions of the spiral are separated by the protrusion of the wall by the air-bubble, or the original spiral deposit is not applied over the projecting portions. The former explanation seems the more reasonable, but the point is yet undecided.

These bordered pores, which are most common in ligneous tissue, consist of an infundibuliform canal, closed at the bottom by the original membrane, and abutting on the hollow space which separates it from the corresponding canal of another cell (III. figs. 8, 18). These are particularly characteristic of coniferous woody tissue. Between these two forms of porous cells we have a third and intermediate kind, where a spiral fibre occurs in addition to regular pores (III. figs. 9, 10). It is most probable that the fibre originates before the cell is full-grown, and that the deposition of new layers proceeds in the usual manner subsequently to that period. Sometimes the spiral fibre is not wound in the direction of the long axes of the slits, but *vice versâ*.

Although the pores usually correspond to similar pores in other cells or vessels, instances occur of very large pores opposite intercellular spaces, while those of the same cell corresponding to other cells are very small.

The canals of several pores may coalesce into one during the deposition of new layers in the interior; and this latter process may continue to such an extent that the cavity of the cell is at last almost obliterated (III. figs. 28, 30).

It has been already said that the portions of primary cell-membrane in fibrous cells free from deposits may be absorbed or dissolved; the same takes place in old porous cells, which frequently communicate freely by their pores, which are open in that case only; in their original condition they are always closed by the primary membrane, and their contents are only in relation by endosmosis.

Sect. II. CELLS IN CONNEXION—TISSUES.

49. The different modifications of the cell unite together and with each other to form various compound structures. The most abundant and widely-diffused is the form of true cellular tissue called

50. PARENCHYMA.—Schleiden's arrangement of the different kinds of Parenchyma may be advantageously adopted, as at the same time simple and comprehensive:—

- A. Imperfect Parenchyma—where the cells are in contact at very few points.
    - 1. *Round* or *elliptical Parenchyma,* composed of spherical or ellipsoidal cells: very abundant in succulent plants (I. fig. 28).
    - 2. *Spongiform Parenchyma*—composed of cells of irregular outline, for instance stellate, and in contact at the extremities of their rays or other projecting points: in air-passages and the lower half of the parenchyma of most leaves (IV. fig. 1).
- B. Perfect Parenchyma—where the contact between the cells is as perfect as possible.
    - 1. *Regular Parenchyma.*—The cells almost regularly polyhedral, no particular dimension predominating: found especially in the pith of plants (III. fig. 24, *f*).
    - 2. *Elongated Parenchyma.*—Formed of elongated polyhedral, cylindrical or prismatic cells: in rapidly grow-

ing plants in the cellular tissue of Monocotyledons (III. fig. 21, *a*).

3. *Tabular Parenchyma.*—Generally composed of four-sided tabular cells: in external structures, such as epidermis, &c. (IV. fig. 21.)

These examples serve to indicate the general character of parenchymatous tissue, but it will readily be understood that we may have many intermediate or aberrant forms, the enumeration of which would but uselessly occupy space here.

51. Another form of cellular tissue occurs in some of the lower plants, which will be most conveniently alluded to here, viz.

Interlacing or *matted tissue* (*tela contexta*), which consists of long thin-walled filiform cells or strings of cells inextricably entangled with each other. In the Fungi the cells are very delicate and readily deliquesce (IV. fig. 2). In the Lichens they are dry, tenacious, forked or branched.

52. THE INTERCELLULAR SYSTEM.—This general term is applied to express collectively all the various kinds of intervals left between cells, which are seldom perfectly in contact with each other at all points. The following important varieties present themselves:—

A. Original gaps left by the imperfect apposition of cells.
   1. *Intercellular passages.*—Generally triangular canals, running all round the angles of cells; almost always present.
   2. *Intercellular spaces.*—Left between cells of irregular figure, especially in spongiform parenchyma (I. fig. 28).

B. Spaces making their appearance subsequently to the perfect formation of the cells.
   1. *Reservoirs for peculiar secretions.*—Produced by the effusion of the secretions from contiguous cells; distinguished into—
      a. Reservoirs bordered by dense and firm cells, probably inseparable: the turpentine canals of the *bark* of Coniferæ, &c.
      b. Reservoirs bordered by delicate cells, probably separable, containing proper juices: the milk-vessels of

Mammillaria, Rhus, &c.; the gum-canals of Cycadeæ; the turpentine-canals of the *wood* of Coniferæ (IV. fig. 13).

2. *Air-cavities.*—Produced by destruction of parenchyma; either—
   - *a.* Air-passages, where a particular portion of the parenchyma of spongiform tissue becomes torn and absorbed; the walls of the canals are smooth, and they are divided from each other by septa composed of a permanent layer of cells: in *Canna, Nymphæa,* &c. (IV. fig. 1.)
   - *b.* *Lacunæ,* where a large portion of parenchymatous tissue is destroyed by the extension of neighbouring parts. The walls remain rough with the remains of torn cells: the cavities of the stems of Grasses, Umbelliferæ, Compositæ, &c.

53. INTERCELLULAR SUBSTANCE.—Some tissues, particularly in the Algæ, exhibit cell-cavities separated by large deposits of what has been called intercellular substance. I take Mohl's view of this and of cuticle also, as will be seen hereafter, and consider that this substance is all formed inside the cell; the innermost layer being less dense than the remainder, simulates a primary membrane lying internal to the secondary layers; the real primary membrane is on the exterior of all the secondary layers, but is often undistinguishable from them. Schleiden and others regard the intercellular substance as a secretion from the outside of the primary wall.

54. VESSELS (*Vasa, Tracheæ,* &c.).—If the walls separating the cavities of a row of elongated cells become absorbed, so that they communicate freely, they form long tubes, which are called vessels, and according to the modifications the walls of the cells undergo, they take the corresponding distinctive names of spiral, annular, reticulated (*Trachenchyma*) or porous (*Bothrenchyma*) vessels. The formation of vessels by the anastomosis of cells takes place generally at a very early period, but occasionally the destruction of the septum takes place at a later period, and a ring is then distinctly visible. The spiral vessels generally terminate in a point or elongated cone, but are also sometimes branched

and are not applied directly end to end, but rather overlapping. Porous vessels are most frequently terminated by an oblique flat septum, applied directly to the reversely-facing septum of the vessel above, and communicate in old vessels, through the absorption of the membrane between the secondary deposits (III. fig. 12).

55. Perfect vessels generally contain air; however not only may fluids occur in them, but new cells. Those which have been stated to be formed for the storing up of starch in the autumn are not produced in the vessel, but by the extension of the neighbouring cells, which make their way through the dots or slits and expand into an utricle in the cavity of the vessel. It is uncertain whether perfect constriction and division take place at the isthmus, thus allowing the cell to become free in the cavity (II. figs. 21–24).

56. VASCULAR BUNDLES.—In all flowering plants and in the higher Cryptogamia, a certain portion of the cells acquire a peculiar character at an early period, becoming elongated; the ends of contiguous cells being absorbed, they are converted into long tubes or vessels. This process takes place according to a definite plan, and these portions of the tissue, very distinct from the parenchyma, are called vascular bundles. The cells out of which the vessels and wood are produced differ from common cellular tissue, even from the period of the completion of their primary membrane; they are elongated, with very delicate walls, and are the cells which, by propagation, increase the *individual* plant. They are called the

Cambium Cells—and are found at the growing point, such as the apices of stems and branches, and the outer side of vascular bundles.

The bundles of vessels are distinguishable into three classes.

57. SIMULTANEOUS VASCULAR BUNDLES—where the whole of the bundle appears to be developed at the same time. They consist of vessels usually all of similar character, surrounded by delicate elongated cells resembling cambium, and these are bounded by a denser tissue composed of longish porous cells. They occur in the vascular Cryptogamia; in the stems of Ferns the vessels are usually scalariform; in Lycopodiums, spirals

closely wound; and in the subterraneous stems of Equisetums, annular, with the rings very closely approximated (III. figs. 22, 23).

58. PROGRESSIVE VASCULAR BUNDLES.—The peculiarity of these is, that the different parts are developed in succession, and they therefore consist of tissues in various stages. Externally are found cambium cells, which are older towards the interior and pass into long cells (or as they have been erroneously called, *fibres*) and vessels. They are of two kinds:—

59. A. *Definite Bundles*—are so called because the cambium cells at a certain period, always within the first vegetation period or first year, undergo a change which renders them incapable of further propagation. The vessels are usually arranged in a line or in two lines, converging toward the interior; externally to or on the two sides of the line are a few large porous vessels, and the whole are intermingled with and enclosed by a number of elongated thick-walled cells, which generally (not universally) define the limit of the bundle by the dissimilarity to the neighbouring more delicate and shorter parenchyma cells. These bundles are characteristic of the Monocotyledons (III. figs. 20, 21).

60. B. *Indefinite Bundles*—take their name from the fact that the cambium cells do not cease to propagate and produce new tissues externally during the life of the plant, but increase the thickness of the bundles from within, outward indefinitely, by their conversion into vessels and wood-cells. These are the vascular bundles of Dicotyledons. We have here to distinguish—

a. The Primary Vascular Bundle—in which is comprehended all that is produced in the first year's growth. The inner half of this corresponds with the complete bundles, except that the vessels are more abundant and less regularly arranged; but the outer half is composed of cambium cells, which are not very distinct at the sides and front from the surrounding parenchyma (III. fig. 24).

b. The Wood (lignum).—The elongated cells produced from the cambium layer, as they increase in length alter somewhat in shape. The previously rounded or truncated extremities are extended in a conical form and insinuate themselves between the extremities of those lying above and below, thus producing a very peculiar form of tissue, which is called *Prosenchyma* (II. fig. 24). Some of these retain their elongate, slender, fusiform figure, and are called ligneous cells (*woody fibre* of the old authors); others unite in perpendicular rows and are changed into vessels. In the Coniferæ, Cycadeæ, and some other plants, they are all developed into wood-cells of a peculiar character. The portion of the wood formed in the early part of the year is usually composed of larger, thinner-walled cells, and contains more vessels than that subsequently formed, where the vessels occur more sparingly and the cells are closer and with thicker walls. By an alternation of these processes a marked division is visible between the growth of subsequent years; the concentric circles thus produced are called the annual rings.

61. The vascular bundles are parted by septa of cellular tissue growing from within toward the surface of the stem. These portions of the parenchyma are called

Medullary Rays—which may extend either from the pith to the bark, or both originate and terminate in the wood.

62. It has been said that the woody tissue is formed of elongated cells with conical extremities (Prosenchyma). This must be accepted only as a general rule, to which many exceptions occur. In the Coniferæ and Cycadeæ the wood consists wholly of large prosenchymatous cells with pores (III. fig. 7); it is difficult to determine whether these should be called *vessels* or not. A somewhat similar difficulty arises in the wood of *Mammillaria*, which consists of rows of cells with large spiral fibres (IV. fig. 14), the cavities communicating freely.

On the other hand, the wood is sometimes almost wholly composed of parenchymatous cells. In *Bombax pentandra* it almost wholly consists of parenchymatous cells, with isolated long prosenchymatous cells here and there interposed (V. fig. 9). In some cases the wood is composed of alternating layers of parenchyma and prosenchyma, and again in *Avicennia* (?) of large porous vessels with a few porous parenchyma-cells interposed (V. fig. 10).

The wood of most plants however is chiefly composed of long thick-walled prosenchyma, with a variable number of porous vessels.

63. Tissue of the Liber.—Very long cells are met with in the parenchyma, most frequently just external to the cambium

cells, but also in the pith, the bark and projecting angles of stems. These are of the same form as prosenchyma, but much longer; they have thick walls, the deposits sometimes even obliterating the cavity. The layer met with at the inner border of the cells of the bark is called the liber (III. fig. 26). In the Apocyneæ and Asclepiadeæ the liber-cells are particularly long, seldom branched, with thick walls, often exhibiting spiral fibres; sometimes their cavity is wholly obliterated in one place, while in others it is expanded. They are very distinct in the latter condition and contain the true milky juice (V. fig. 6).

64. MILK VESSELS (*Laticiferous vessels*).—Long, branched passages, with sometimes thin, but in older instances very thick walls, exhibiting lamellæ, sometimes marked spirally. They contain the milky juices (III. fig. 25).

Their development has not been made out, but it appears most probable that they are intercellular passages which become lined by a proper membrane. The lamellation and occasional spiral markings of this are the only points in which these vessels agree with those proved to originate from cells.

65. EPIDERMAL TISSUE.—The external layers of cells in the Phanerogamia and higher Cryptogamia have a distinct character from those they envelope. The following are the most convenient divisions of the different modifications of these cells:—

1. *Epithelium.*—Very delicate cells, without intercellular passages; produced on the surface of internal cavities, as in the ovarium (IV. fig. 9). It is subsequently developed into
2. *Epiblema.*—Compact flattened cells, not very smooth; no intercellular passages opening externally (IV. fig. 10). If in water or under ground they remain unaltered; otherwise they change into
3. *Epidermis*—and its
4. *Appendicular organs.*

66. EPIDERMIS.—This generally consists of flattened tabular cells, which in many cases becomes greatly thickened at their upper surface and sides. The real nature of these thickening layers is at present doubtful. It is frequently possible to remove the superficial membrane of a leaf by maceration, or even simply by stripping off; and as this does not always retain traces of the

lines of union of the subjacent cells, and moreover is affected in a different manner by reagents, it was imagined formerly that it was an independent structure, which was called the cuticle. The fact of its production by the walls of the epidermal cells has been proved, but the question remains whether it is a secretion of *extra*-cellular substance on the outside of the cells, the individual portions formed by each cell becoming blended with those of surrounding cells at the time of secretion; or, whether the cuticle is nothing more than the internally deposited secondary layers of the epidermis cells; this is the opinion entertained by Mohl in opposition to Schleiden, Treviranus, &c., who maintain the external secretion. It is a point of great difficulty to decide, but I believe that I have succeeded, with Mohl, in tracing the primary wall through the thickened cuticle to the surface (IV. fig. 17) in some instances; the primary wall undoubtedly undergoes great changes as it becomes further removed from the cavity of the cell, and not only gives a different colour with tincture of iodine, but becomes intimately blended with the walls of circumjacent cells. But the colour given by iodine indicates little more than comparative *condensation* of structure. In stripping off the cuticle too, the epidermal cells are often deprived of their upper wall; if the cuticle were secreted by the *outside* of the primary wall, the adhesion would be slight at the point of formation, and the extra-cellular substance would separate from the cell-wall, as it would be much weaker from its more recent production. When the secondary layers of epidermal cells are formed (and they are often produced to a very considerable thickness), the evaporation of fluids and gases from the subjacent tissue is prevented; to allow of this and at the same time to regulate it, what are called stomata are formed. These are passages between the cells of the epidermis bordered by cells of a peculiar form (IV. fig. 18); there are generally two, of a semilunar form, their convexities directed outwards; by contraction the semilunar form becomes crescentric, thus leaving an oval slit between them, and the degree to which they open is regulated by the hygroscopic state of the tissue. These stomata vary considerably in appearance and position in different plants (II. figs. 40–48); sometimes they are on a level with the epidermal cells, very frequently at the point of junction of the epidermal cells with the parenchyma below, and in the Proteaceæ they are formed of three or more cells (II. fig. 44). They are usually at the surface and open to the intercellular passages of the parenchyma, but in some cases they are situated on the walls of a cavity which contracts to a small orifice on the surface of the epidermis (II. fig. 46); in this case the regulating semilunar cells may be wholly wanting.

The stomata are most abundant on the under surface of leaves, frequently wholly wanting on the upper, especially on those having a dense shining cuticle. The development of stomata has been followed out by Mohl in *Hyacinthus orientalis.* In the lower part of young leaves, between the epidermis cells, smaller cells may be perceived with their transverse diameter greater than their longitudinal. A septum is formed longitudinally according to the usual process of cell-multiplication, and these two layers subsequently separate from each other, leaving the slit or orifice of the stomata open (II. figs. 35–40). He considers it probable that Mirbel was in error in supposing the orifice to be produced by the absorption of a cell in *Marchantia.* The original cell might divide into four instead of two, and thus we should have an opening border by four cells.

It has lately been ascertained that the cuticle penetrates the stomata of many plants, and in some even sends prolongations into the intercellular passages between the epidermis cells and those of the parenchyma, but it is observed that it is wanting at the points of contact between the cells; a further proof of the internal deposition of the cuticular layers, as secondary layers are not generally deposited so readily, and at all events leave pores at points opposite neighbouring cells, while they are always more marked at the angles or points opposite intercellular passages.

67. APPENDICULAR ORGANS.—Consisting of—

1. *Papillæ.*—Expansion of the epidermal cells into slight elevations, vesicles, or even filaments (IV. fig. 4).
2. *Hairs,* formed of one or more delicate cells prolonged from the epidermis; of various forms and arrangements, *ex. gr.*

Simple hairs (*pili simplices*), (IV. fig. 23).
Branched hairs (*p. ramosi*).
Stellate hairs (*p. stellati*), (IV. fig. 27).
Clavate hairs (*p. capitati*).
Glandular hairs (*p. glanduliferi*), when the upper cells secrete peculiar juices (IV. fig. 22).
Scales (*lepides*), (V. fig. 5).

3. *Setæ*, formed of thick-walled persistent cells.
4. *Stings* (*pili urentes*).—Generally consisting of a tolerably dense pointed cell, terminating below in a globular expansion secreting an irritating fluid. Here refer also the gum-clubs (*gummi keulen*) of Meyen, found beneath the epidermis of *Ficus*, etc. They are cavities in the parenchyma, from the upper part of which is suspended a globular mass, which in the fully developed state consists of crystals. They are apparently nothing else than undeveloped or metamorphosed hairs or stings, as will be evident from the comparison of the figures (IV. figs. 21, 24, 26).
5. *Thorns* (*aculei*).—Pointed, generally conical processes formed of densely packed woody cells.
6. *Warts* (*verrucæ*).—Several thickened cells united in a hemispherical or similar form.

68. Cork.—Beneath the epidermis of stems flat tubular cells are produced which break through the epidermis and form what is called bark, or when highly developed and elastic, cork, which is especially abundant in the second year of the life of stems (IV. figs. 5, 6).

69. Root Membrane (*velamen radicum*).—In most tropical Orchidaceæ and some Aroideæ a layer is found upon the epidermis of the roots, which generally consists of cells with spiral fibres containing air.

CHAP. III. GENERAL CONSIDERATIONS ON THE PHYSIOLOGY OF THE ELEMENTARY STRUCTURES.

70. As it is one of the great characteristics of plants that they are closed sacs or assemblages of sacs, the property of organic membrane, permeability by fluids, which produces the phænomena of endosmose and exosmose, becomes of the highest importance, since it must be the basis of all nutrition and secretion. It is known that when two fluids of different density are separated only by animal or vegetable membrane, currents are set up of unequal force, the passage of the light fluid into the dense far exceeding in rapidity that in the opposite direction. Thus as the contents of plants are continually becoming inspissated by evaporation and the separation and evolution of gaseous matters, new materials are proportionately furnished by the lighter fluids by which their absorbing organs are surrounded.

This endosmotic process is most beautifully exemplified in the nutrition of plants. According to Dutrochet, who first discovered it and recognized its physiological importance, the relative force of the currents of the following organic products and water is—animal albumen, 12; sugar, 11; and gum, 5·17. As animal albumen is very closely connected with the proteine compounds (§ 13.) which are found in developing cells, we see the adaptation of the densities to the activity of the vital processes of the plants. Where development is most active, the densest fluid is found: starch, insoluble, is formed where the assimilated products are to be stored, and as they are required for nutrition, it is converted successively into gum (or dextrine), sugar and protoplasma.

71. ASSIMILATED MATTER.—The only form in which inorganic substances are taken up by plants is that of solution in water; even to aërial roots, many Algæ and Fungi, which appear

to derive their nutriment from the air, the presence of aqueous vapour is necessary. The matters most essential to plants are carbonic acid and ammonia; between these and water a series of chemical changes go on in the cell by which are produced two classes of elements, those possessing and those devoid of nitrogen. The nitrogenous substance makes its appearance as a homogeneous mucilage, the protoplasma; those devoid of nitrogen are sugar, dextrine, starch, &c. As an example of the chemical changes of nutrition, we may take the formation of the plant called the *mother* of vinegar during the acetous fermentation of alcohol. This consists of utricles composed of cellulose, containing a small but apparently definite quantity of proteine. Assuming the presence of carbonic acid and ammonia in the atmosphere in contact with the alcohol, we may tabulate the chemical changes thus:—

	C	H	N	O
74 of water (HO)	...	74	...	74
94 of carbonic acid (CO^2)	94	...	...	188
2 of carbonate of ammonia ($H^1 N^3 CO^2$).	2	2	6	4
From which are formed—	96	76	6	266
1 of proteine	48	36	6	14
4 of cellulose ($C^{12} H^{10} O^{10}$)	48	40	...	40
212 of oxygen	...	...	...	212
	96	76	6	266

And as 4 equivalents of oxygen unite with one of alcohol to form acetic acid, 53 equiv. of alcohol are changed into vinegar.

72. The theory of the formation of the matters which do not contain nitrogen may be thus stated:—

	C	H	O
12 of carbonic acid (CO^2)	12	...	24
24 of water (HO)	...	24	24
	12	24	48
By respiration are removed—			
24 of oxygen	...	...	24
Leaving	12	24	24

Equal to 1 grape sugar + 10 water ..	12	14	14 + 10 H O.
or 1 starch, 1 cellulose, 1 dextrine, + 14 water	12	10	10 + 14 H O.
or 1 cane-sugar, 1 woody fibre (box or willow), ½ inuline ($C^{24} H^{18} O^{18}$), + 13 water	12	9	9 + 13 H O.

73. The actual nature of the processes by means of which all these changes and modifications are effected is still a mystery. Chemists have sought to throw a light on it by analogies drawn from inorganic phænomena, such as the action of spongy platinum on oxygen and hydrogen, &c., referring them to what has been called catalytic action, or the influence of contact substances, and the "spontaneous activity" of certain bodies, such as diastase, &c., in changing the arrangement of the atoms or molecules. These speculations do not afford the slightest practical information; they are merely applications of new names to known processes. We know that sulphuric acid by the aid of heat converts starch into dextrine and sugar, alcohol into ether, the latter change being merely the abstraction of combined water. Diastase also converts starch into dextrine and sugar, albumen, proteine, &c.; sugar into alcohol, alcohol into vinegar; but here the changes are always the consequence of a vital process—of respiration—the fixation of carbon and hydrogen and the liberation of a proportionate amount of oxygen, which in a nascent state is peculiarly fitted to enter into new combinations.

74. Light is almost always necessary to the development of plants; certainly to the formation of their colouring matters and all those constituents containing a large proportion of carbon. From the researches of Mr. Hunt it appears that the different rays of the spectrum exercise different kinds of agency on the vegetable economy. He found that the blue rays were most favourable to germination and the development of succulent tissue, while they evidently kept back the reproductive powers: yellow rays were most favourable to the formation of flowers and seeds. Hence it would appear that the yellow rays are most

concerned in the fixation of carbon: in germination there is usually an oxidation of stored-up carbon, of starch or fixed oils, while the reverse of this necessarily takes place in the maturation of the seeds. That light is essential to the respiratory process, is evident from the fact that the liberation of oxygen does not go on during the night, but is replaced by the evolution of carbonic acid in small quantity, probably from oxidation of the tissues.

75. SECRETION IN CELLS.—In addition to the processes of assimilation above described, a number of other chemical changes and combinations are effected in the cells of plants. These may be divided into two classes, the *general* and *special*. The *general* include the formation of chlorophylle in leaves, and of starch (or fixed oils), which appear to be produced in a manner analogous to that by which cellulose is secreted, and to result from the excessive energy of nutritive power at certain periods exerted in providing stores of nutriment against other times when those functions are less actively performed. The green colouring matter of the chlorophylle appears to be connected with the decomposition of carbonic acid by the agency of light, but that is all we know of it. The *special* are those produced in particular plants and under peculiar circumstances, such as the formation of the alkaloids, &c., with the essential oils and the caoutchouc globules of the latex.

Besides these, there are others which take place in consequence of the presence of various inorganic substances in solution in the water which the plants absorb. Some of these seem to be deposited in the tissues by the evaporation of the water; they are essential to the health of the plant (as the phosphates to the Cerealia), and serve in many cases to strengthen their tissues mechanically, as the silica which is found in the cuticular layer of the Equiseta and Grasses. Others are found united to organic acids, such as lime with oxalic acid, which occur in large quantities in the cells of many plants.

Other substances again appear to result from the oxidation of tissues, such as tannin, resin, &c.

The actual steps of all these processes are unknown to us; in fact we do not yet know the real nature of the assimilated matter, so that we have no firm basis for reasoning on the subject. We know that sugar, starch, cellulose, &c. consist of a definite number of atoms of carbon, oxygen and hydrogen, but not how they are arranged (for calling them "the water and carbon" explains nothing), neither do we know how the first combination is produced.

76. **Growth of Cells.**—In the earliest stages the cellular membrane increases by intus-susception of nutriment, but also, and after it has attained its destined size exclusively, by the deposition of new layers over the whole internal surfaces. These are sometimes so numerous that the cavity of the cell becomes almost obliterated (III. fig. 30). These walls would seem to present a series of stages between a condition just removed from starch, taking a blue colour with iodine when a slight acid is applied, and that of lignine, the densest form of the unazotized ternary compound.

77. **Movement of the Cell-contents.**—We find in the cells of plants apparently two forms of circulation of their fluid contents; from recent observations however it appears probable that these may be reduced to one general plan.

In the cells of *Vallisneria* we observe a circulation of the chlorophylle granules and the nucleus round the walls, passing up one side in the direction of the length of the cell, across and down on the other in a continuous stream (IV. fig. 12): in *Chara* an oblique streak is seen in dividing the cell longitudinally into two portions; the stream passes up on one side and down on the other (V. fig. 4). In the hairs of Phanerogamic plants, in spores, pollen, and probably in *all* very young cells, the circulation takes another form—that of a network of anastomosing currents, the chief streams radiating from the nucleus (II. fig. 32). In all the forms the circulating medium appears to be a mucilaginous fluid (the protoplasma), which in the cases of *Vallisneria* and *Chara* is an uniform investing layer on the inner surface of the cell.

From the recent researches of Mohl, it appears probable that the reticular currents are produced from a homogeneous protoplasma in the following manner. This substance originally fills the whole cell-cavity, but with the growth of the cell, hollow spaces make their appearance in it resembling vesicles filled with water; these enlarge, and after having attained such a size that the protoplasma has acquired a honey-combed* appearance, they become continuous and the mucilaginous matter remains as a network, not only on the surface, but sending filaments across the cell-cavity; these filaments sometimes become very firm, and are persistent on the cell-wall for some time after the circulation has ceased. The analogy here to the circulation of *Vallisneria* is made out by supposing the mucilage to be hollowed into one cavity only in the cells of that plant.

The cause of this motion is quite unknown, but it would seem to have some reference to the fact of the cells living *in water*. In all cells of plants growing in air the circulation ceases at an early period.

78. MOTION OF CELLS.—The spores of some of the lower Algæ present some remarkable phænomena of motion. They consist of cellules furnished with appendages resembling cilia (II. fig. 25, *a–e*), which enable them to swim about in water like animals. *Thuret* and *Kützing* have found in these a red spot resembling the so-called eye of *Ehrenberg's* green monads. The fact of the development of these spores from undoubted plants like the Confervæ, goes far to prove that the Diatomaceæ, &c., and even *Volvox* and its allies, are plants. In this case the existence of spontaneous motion in plants would be a well-marked character of vegetable life; but we are still in the dark as to the causes and nature of such phænomena.

79. PROPAGATION OF CELLS.—When a cell has attained a certain stage of development, it either undergoes the process of division, or its independent formation is continued by extension and the deposition of new layers as it becomes a portion of a permanent structure. The manner in which cells are multiplied by division has been already described. When they have completed the series of changes peculiar to the production and growth, they may be considered as indifferent or dead as regards the life of the plant. Some become filled with hard ligneous deposits, as in heart-wood of trees; others contain only air, as the vessels, pith and bark-cells, or some peculiar homogeneous secretion, such as the cells containing essential oils, resins, &c.

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* Sit venia verbo.

80. The so-called milk-vessels may be regarded as intercellular passages containing peculiar secretions not essential to the *life* of the plant. The pretended circulation of the latex was a groundless hypothesis, and arose from erroneous observation. These intercellular passages of course anastomose; their walls become thickened by the deposition of the suspended matters of the juices, and when they are cut across, the fluid through gravitation escapes freely from the open ends (IV. fig. 13).

81. The physiological processes which take place in a cell are modified in a very important manner by its relations to other cells. When a number of them become united into a tissue, they will be subject in very different degrees to the agency of external influences. A portion of them will necessarily be in immediate contact with the atmosphere, and this must have a most material regulating power over the conditions as to moisture. In some instances this is prevented by the increased thickness of the cell-wall, in such situations as the epidermis of many leaves and stems (IV. fig. 17); but where no provision of this kind is present, the temperature and hygrometric state of the surrounding air will control the evaporation and the inspissation of the cell-contents; the endosmotic process consequently will be in exact relation to it. The contact of air moreover allows of the absorption of gaseous matter, such as carbonic acid and ammonia; also of oxygen under certain circumstances, such as the absence of light, the reverse of which, on the contrary, proportionately favours the activity of the respiratory process.

While a portion of the cells are thus directly under the influence of external agents, the remainder owe their nutrition to the interchange of the cell-contents, produced by the endosmose between contiguous cells, and by this process a certain degree of equality is maintained in the conditions of the cellular tissue throughout the whole plant. Vegetables have no peculiar vessels carrying nutrient fluids, but their vessels do facilitate the distribution of the water absorbed by the roots, since their open tubular structure is particularly favourable to capillary attraction. The air also obtains admission into the interior of the various organs, in many plants, by the stomata, and must exert a modified influence on the cells bordering the intercellular passages and lacunæ (IV. fig. 1).

82. As a general proposition, it may be stated that the functions of all the individual cells of a particular tissue are alike, or very similar, but to this rule there are many exceptions. Frequently large portions of parenchyma produce a particular substance, while the bundles of the liber (III. fig. 26) and the milk-vessels contain the same matters throughout the plant. But we often find cells in the same parenchyma, some crowded with starch, others filled with an essential oil, while others again contain fluid colouring matters. Cells in which the deposition of secondary layers has almost obliterated the cavity, are found in the midst of thin-walled parenchyma. These facts indicate the individuality of cells, and that this is not merely a characteristic of their earlier reproductive condition, but runs through their whole life.

83. In the parenchyma made up of these individual cells, the latter are found arranged in various degrees of regularity, containing the most diverse substances and of very variable figure. The most abundant products in large masses of parenchyma are starch, as in the tuber of the potato; fixed oil, in cotyledons of the Cruciferæ; gum, in the roots of some of the Malvaceæ; a kind of emulsion composed of oil and albumen, in the cotyledons of the almond; assimilated matter and chlorophylle, in all green leaves; various coloured fluids, in petals; and air, as in pith, &c.

84. In some tissues cells are found, apparently separated from one another by considerable spaces occupied by solid matter (§ 53.). Some writers (Schleiden and others) assert that this is a substance secreted by the outer wall of the cell. Mohl, on the contrary, contends that it is always within the cell, although this is not at first apparent. The peculiar configurations found upon pollen granules and the spores of the Cryptogamous classes have been described as secretions from the outer surface, but this point is not well made out. The gelatinous layer also which invests most of the Confervæ and some Ulvæ is regarded by Schleiden as a secretion; the same uncertainty attaches to all these points as to the real nature of the cuticle. My own opi-

nion is, that they are all deposits *within* the cells, whether they be cellulose, gelatinous matter, or silica (as in the Grasses and Equiseta).

85. The ligneous cells of the vascular bundles, when the cavities have become nearly obliterated by the concentric deposition of secondary layers, cease to carry the nutritive juices; but as they are still to a certain degree within the influence of air and moisture, chemical changes take place within them, by which the peculiar products, such as tannin, extractive matter, colouring matter (as in the heart-wood of ebony, &c.), are most probably formed.

86. The so-called milk-vessels (III. fig. 25, IV. fig. 13), in which Schultz imagined that he saw a regular circulation of fluid, are reservoirs of the peculiar milky juices, produced in great abundance in many plants. The physiology of these structures is however in a very imperfect state; we have no rational explanation of their functions.

87. The cells of the epidermis are generally filled with a transparent, often colourless fluid; sometimes they contain other matters, such as resin, &c. That portion of the wall exposed to the direct influence of the external air is provided with a layer of a substance of a waxy nature, which to a certain extent prevents the transpiration of gases or fluids, and often attains considerable thickness. At a subsequent period the secondary layers of assimilated matter are deposited (§ 66.) (IV. fig. 17), which form a dense envelope, only permitting the passage of the gases, &c. through the stomata. In *Cycas revoluta* we meet with a curious phænomenon: the secondary deposits of the epidermis cells are furnished with pores extending from the cavity some distance through the substance of the cuticle.

88. The hairs of plants sometimes present peculiar modifications of structure. In *Drosera* we find a spiral fibre within the hair. Others are made up of several cells (IV. fig. 22). Stings consist of elongated cells generally terminating in a globular head, and surrounded at the base by a projecting ring of the epidermal cells. When the head is broken off, the acrid fluid contents of the long cell are forced upward by the turgidity of

those surrounding its base. Most hairs exhibit a circulation in the earlier period of their existence.

A curious occurrence has been noticed in the hairs of the stigma of *Campanula*. About the time of the fecundation these hairs become retracted within themselves, the upper part being intus-suscepted within the lower (IV. fig. 25). No satisfactory explanation of the mechanism of the process has been given. Other hairs are furnished with a viscid secretion upon their expanded apex, as in *Drosera*.

CHAP. IV. THE INDIVIDUAL PLANT.

Sect. I. MORPHOLOGICAL CONSIDERATIONS.

89. In a former chapter it was stated that certain plants consist of a simple cell, and that all plants make their first appearance under that form; it is only at the extreme lower limit of the vegetable kingdom however that they remain in such a simple condition. The primary cell divides, but as an evidence of an advance in the scale of organization, these cells do not become independent of each other; on the contrary, remaining attached, they subdivide again and again, till we find individual plants composed of an innumerable mass of such cells. The plant thus begins to acquire parts or organs destined to perform functions distinct from each other, and subservient to the general nutrition and propagation of the whole.

Looking at vegetables in their generality, we may say that a plant consists of three parts, the leaf, the stem, and the root; although in the lower classes it is often the case that one or even two of these are wanting. Advancing again, as in the case of the cell, we find that a plant may be composed of one of these individuals, or phytons as they have been called, producing its like, the progeny immediately obtaining an independent existence; or the new individuals may remain attached almost to an unlimited extent, constituting highly compound plants, the different organs or phytons of which undergo very various modifications of form and acquire very distinct functions. Thus in a flowering plant, or as a stronger example in a forest tree, every leaf is to be considered as essentially a distinct individual; but as a member of a compound body, working for the general benefit of the whole. In obedience to the requirements of this, they undergo modifications to fit them to execute distinct offices in the economy of the plant; some are destined to the nutritive functions, others to the reproductive; and among these latter we find them still further losing their individuality, and becoming blended in all their parts with their fellows, until almost all trace of their real origin is lost.

This is the substance of the doctrine of Morphology, the most important generalization in the whole science of Botany, as affording a clear and systematic view of the vegetable kingdom as a whole (in addition to the important relations it establishes with zoology); this general statement is as much as can be indicated at the present stage of the subject, the proofs and elucidations of the theory being those very facts to which the greater portion of the following pages will be devoted.

90. The presence or absence of the middle portion or stem of the typical phyton characterizes the most important distinction in the condition of plants, and on this ground the primary divisions are established.

Plants which have no axis, but consist of cellular expansions, are called stemless plants. The filamentous or foliaceous expansion is called a *Thallus*, from whence the division has received the name of Thallophytes.

Plants which possess an axis or stem interposed between the leaves and roots, either simple or compound, are called Cormophytes.

Sect. II. THALLOPHYTES.

91. Although the absence of a stem or axis characterizes the Thallophytes, it by no means follows that they always possess leaves and roots. The Thallus in its various forms is made up of a congeries of cells, which at one time assume the form of a filament, combining the offices of leaves and roots in the individual cell or cells; at others, of a mere foliaceous expansion; or it may partly consist of a foliaceous expansion, while filaments are developed, apparently serving as roots to the other cells. The various forms may be arranged under the following heads:—

1. The Filamentous Thallus consists of strings of elongated cells, either arranged as simple filaments or branched and anastomosing (V. figs. 1, 2). The examples of this are presented by the Algæ, especially the *Confervæ.* The Characeæ may perhaps be included: in these the Thallus is composed of a number of rows of cells applied together and sending off branches. The

real absence of an organ analogous to a stem is shown by the fact that the growth all takes place at the apex, while there is no increase at the opposite end; since when a stem is present, development of new structure takes place at both extremities, from the leaf and from the root (V. fig. 3).

2. The Flocculent Thallus is frequently very similar to the last in structure, but the filaments are more branched and interlaced; the cells are very delicate, and from the close approximation of the parts of the tissue, the whole Thallus, as seen by unassisted vision, often exhibits the appearance of a woven fabric. It is found only in the Fungi, where it is sometimes very delicate, as in the Moulds, &c. (*Hyphomycetes*) (V. fig. 6); sometimes very dense, as in the fleshy Fungi (*Sarcomycetes*); or it may resemble membrane, as in the gills of the Agarics (*Hymenomycetes*).

3. The Pulverulent Thallus, which is found only in the lower Lichens, is an assemblage of cells hardly assuming a distinct form; they are but loosely connected and have no very clearly defined limit (V. fig. 7).

4. The Crustaceous Thallus, also characteristic of the Lichens, exhibits an advance in organization. It consists of a tough membranous expansion, composed of irregular interlaced cellular tissue, has a distinct border, and is often provided with filiform processes on the under side, which appear to have something in common with the roots of higher plants.

5. The Membranous Thallus is made up of cells the walls of which undergo very considerable thickening, so that under the microscope the Thallus appears at first to consist of a homogeneous membranous substance (intercellular substance of many writers), with little cells scattered here and there through it (V. fig. 8). The true explanation of this has been alluded to before (§ 53.). This form of Thallus is often developed to a very great size in the Algæ. It occurs in some Lichens (*Collema*) and in most of the Nostochineæ, Florideæ and Ulvaceæ.

6. The Frondose Thallus presents itself under three different forms, viz. the leaf-like or Foliaceous (V. fig. 9), the shrub-like or Fruticulose (V. fig. 10), and the stem-like or Chordaceous. The first is found in the Lichens, the other two both in them and the Fucaceæ. It is a more highly developed form of Thallus

than any of the preceding, as it consists of a collection of roundish cells, united so as to form a cortical layer, which encloses a medullary portion composed of irregular, elongated and somewhat woody cells less densely aggregated.

The Fruticulose and Chordaceous forms apparently indicate a sacculate or tubular condition of the foliaceous expansion, in which the edges of the latter are curved up and united together, so that the upper surface of the frond becomes the interior.

92. All these may be said to develope and grow in a centrifugal manner, the filamentous always producing new structures at the apex, the other forms at their borders; this of course refers only to the vegetative growth. The Thallus being the sole organ of these lower plants, must necessarily also serve the offices of reproduction, and here the individual cells appear to have a value analogous to the individual phytons of higher orders, and to be capable of undergoing modification under peculiar circumstances fitting them for the performance of those functions by which the germs of new independent individuals are developed. The consideration of these processes must be reserved till the reproductive organs of plants in general can be examined.

Sect. III. CORMOPHYTES.

93. The Cormophytes or plants possessing a stem are distinguished from the Thallophytes by the presence of the intermediate portion of the phyton, which, as a centre from which development takes place, determines a growth in two diametrically opposite directions, of the leaf upward, of the root downward. But although this universal distinction into three portions is clearly to be made out by the *comparative* examination of various plants, the modifications of form which the central portion or stem undergoes often render it somewhat difficult to recognise its presence or define its limits. The central portion may be either a mere point of departure for the two growing points, or it may be developed sufficiently to separate these by a considerable interval.

The mode in which these phytons are superposed and combined in plants, causes very various relations of position between their component parts, the structure of the stem depending upon the peculiar arrangement of the vascular bundles belonging to the individual phytons, and its mode of growth on the nature of the bundles entering into its composition.

The Cormophytes are divided into three great classes, according to the condition in which the embryo or new plant is found at the period of its becoming independent of the parent plant.

94. In the lowest class the embryo or spore appears as a simple cell or congeries of cells, and it is only in germination that this acquires the three divisions or merithals (V. fig. 12).

95. The next class has the embryo composed of a single phyton. In this may be recognised parts corresponding to the foliar, the cauline and radicle merithals; that organ which represents the leaf is called the cotyledon or seed-leaf, and *encloses* the cauline portion (V. fig. 13).

96. The third class presents us with a more complex embryo; it is formed of two or more phytons cohering together, the cauline portions being applied face to face (V. fig. 16, *e*. 17).

97. These three classes have received the names respectively of Acotyledons, Monocotyledons and Dicotyledons, and in addition to the different conditions of the embryo they have the three different kinds of vascular bundles: viz. the bundles of the Acotyledons are *simultaneous* (§ 57.); those of the Monocotyledons *definite* (§ 59.); of the Dicotyledons *indefinite* (§ 60.).

CHAP. V. THE AXIS AND ITS APPENDAGES.

Sect. I. STEMS.

ACOTYLEDONOUS STEMS.

98. The lowest form of stem found in this division is that of the Mosses and Liverworts. In these orders we find no vessels; the plants are wholly composed of cellular tissue; the foliar part of the phyton is a mere expansion of this tissue, sometimes strengthened by a bundle of ligneous cells, which are continuous with a central axis of a similar wood character, the cauline portion, while the radicles are filiform elongations of the surrounding parenchyma (V. figs. 22, 28).

99. The Lycopodiaceæ and Marsileaceæ present the first trace of vascular structure. Within the cellular envelope of the stem is a cellulo-vascular axis, consisting either of one *simultaneous* bundle or of several, united by delicate parenchyma (V. fig. 29). These bundles have a flattened character and are variously curved and twisted in their course. The vessels are annular or scalariform. The growth of these stems takes place only at the apex.

100. The stems of Ferns exhibit a higher degree of development. A transverse section of the stem of an arborescent Fern displays a number of vascular bundles disposed in a circle around a cellular central mass; the whole being enclosed in a cellular envelope, which in old stems is very dense at its periphery (V. figs. 31, 32). The vascular bundles grow only at their extremities, following the development of the stem, which takes place at the cellular apex; thus the diameter of these stems never increases. The phytons are applied one upon another, in course following a spiral line around the stem. Where arborescent Ferns branch, the sum of the diameters of the branches corresponds to that of the trunk, and it is a mere division of the axis (V. fig. 32).

The ramification which is found throughout the various Acotyledonous orders is always of this character; it never arises from lateral buds, but the axis bifurcates and thus becomes possessed of two terminal buds.

101. In all these plants the vascular system of each phyton (where they possess vessels) may be divided into an ascending or cauline, and a descending or radicle portion. These originate from a point in the cellular tissue of the new phyton, and the cauline portion is formed by the development of rows of cells situated between this point and the ring of vascular bundles, into which it is *inserted*, or rather with which it becomes continuous, while above it is developed out of certain rows of the cells growing upward to form the petiole and leaf. The radicle portion does not appear to be formed regularly; where it occurs it is continuous with the lower end of the cauline portion, and is gradually developed out of cells lying between this point and the periphery of the stem, varying much in the degree of obliquity of its course toward the surface, where the root is produced.

MONOCOTYLEDONOUS STEMS.

102. A transverse section of a monocotyledonous stem presents the ends of a number of definite vascular bundles scattered through a parenchymatous mass (V. fig. 33), the bundles being more numerous toward the periphery of the stem. In a vertical section we see the bundles forming arcs proceeding from the periphery downward to the centre, and thence outward again to the surface (V. fig. 34). These arcs interlace with each other and often take a spiral course around the axis of the stem in their passage from above downward. To understand the true relation of these bundles with each other, it will be necessary to examine the monocotyledonous stem in its earliest condition.

In a germinating monocotyledonous embryo we find the cotyledon or seed-leaf enclosing the second leaf in its interior; the cotyledon splits above to allow the plumule to ascend, and the radicle makes its way *through* the lower part of the cotyledon (V. fig. 14). The third leaf again is developed from the cellular mass in the interior of the second, but its descending portion does not burst through as from a sheath. The descending portions of its vascular bundles pass through the cellular tissue of the second leaf, between the vascular bundles of the latter, thus become external, and reach the epidermis to pass into radicle fibres. Each vascular bundle in like manner originates at the point where the new leaf or phyton is developed out of the nucleus of cellular tissue at the apex in the centre, and is gradually elongated into an ascending portion which passes upward into the petiole, and into a descending portion which passes outward and downward a little above the ascending bundle of the leaf below. It must not be imagined however that the *descending fibres break through* the cellular tissue; no interruption of continuity takes place within the stem; the vascular bundle is formed out of cells *in the place where it is subsequently found*, in consequence of the law of development of the plant. We say that the fibres *descend*, because the middle portion is that which first becomes distinctly developed into a vascular structure.

The ascending portion of the vascular bundle may pass into a leaf on the side of its *decurrence* or at the opposite side. The descending portion is developed in a course of varying obliquity toward the periphery of the stem, where it either *breaks through* into a radicle fibre or is lost in the cortical layer of the stem.

103. This view of the development of the monocotyledonous embryo gives a key to the structure of the apparently very complicated stems which occur in this class of plants. In all its forms, whether cylindrical, like the Palms, a flattened cone as in bulbous plants, or branched as in the Dracæna, the structure is essentially the same; the modifications arising in the two first from peculiarities in the arrangement of the leaves; in the last from the development of axillary buds and the formation of branches, with a corresponding increase in the radicle or descending system.

104. That conical mass at the base of a bulb, whence the leaves constituting the tunics arise, is a monocotyledonous stem, little developed (V. fig. 23). Here all the elements of this form of stem are to be found; the centre exhibits the cellular axis terminating above in a small and very delicate mass of cells at the growing point; this body is called the *phyllophore*. The

vascular bundle of the lowest leaf or tunic of the bulb originates in the centre of the base, sends a descending portion downward into the most central root, and an ascending portion outward to the base of the outermost leaf. A little above this originates the second bundle, the descending portion of which necessarily crosses or passes beside the ascending portion of the first bundle, and goes to a more external rootlet. In this manner proceed all the fibres or bundles, the descending portions of each crossing the ascending portions of all those below it, to reach a radicle fibre.

105. By a continued development of a bulb upward, without increase of diameter, the descending fibres terminating at the periphery instead of breaking through to form roots, we should have a Palm stem (V. fig. 24); by the growth upward exceeding the increase of diameter and the descending fibres passing downward when they have reached the periphery of the stem, we have the stem of Dracæna (V. fig. 25). The stems of Grasses are formed in the same way, but the rapid development of the peripherical portions of the stem causes a rupture of the central cellular portion, and thus produces a fistular character. The descending fibres also branch and are in part directed inward, so as to cross the central cellular portion, and by further development of ligneous matter become woody diaphragms (V. fig. 26).

106. The central cellular portion of a monocotyledonous stem corresponds to the pith of Dicotyledons, but is not enclosed in a proper sheath of vessels, and possessing no distinct medullary rays, communicates freely with the general parenchyma of the stem by the spaces between the vascular bundles. There is no portion corresponding to the bark of Dicotyledons, but the ligneous peripherical layer, composed of the terminations of the fibres, may be considered as analogous to the liber (V. fig. 33).

Dicotyledonous Stems.

107. The stem of a dicotyledonous embryo—that is, the organ formed by the combined cauline portions of the two phytons of which it is composed—originally consists of cellular tissue. Some of these cells soon become developed into vessels and prosenchymatous ligneous cells, so as to form the *indefinite* vascular

bundles (§ 60.) which are arranged in a circle around the central portion of the parenchyma; the ring of vessels is also surrounded by an external zone of cellular tissue, and the two systems of parenchyma, the pith and the bark, are connected by radiating processes of cellular tissue which pass between the vascular bundles, and are called the medullary rays (VI. fig. 1). In a short time the fibro-vascular bundles increase very rapidly in proportion to the parenchyma, and the medullary rays appear as mere lines (VI. fig. 2). The stem then presents the following regions:—1. In the centre the pith or medullary parenchyma (*a*). 2. The fibro-vascular circle (*b*). 3. The cortical parenchyma (*c*). 4. The epidermis (*d*).

The stems of herbaceous plants, living only one year, remain in this state of development; the proportion of the pith and medullary rays being usually very great in relation to the fibro-vascular portion.

108. The stems of Woody plants, living more than one year, undergo further changes, but in the first period they resemble the stems of herbaceous plants, the fibro-vascular portion being sometimes in a larger proportion. Since the vascular bundles of Dicotyledons are of the *indefinite* character, the increased thickness of this portion of the stem arises from the horizontal growth of the *original* bundles in the subsequent years; this constitutes the most important distinguishing character of these stems.

A transverse section of a yearling branch of the Rose exhibits the following structure:—The pith, which occupies a large proportion of the total diameter, is formed of large cells, loosely aggregated, and diminishing in size as we proceed from the centre toward the circumference, the outermost at this period containing chlorophylle; from these cells, which form a close, fine tissue, are continued the medullary rays, of similar structure, dividing the fibro-vascular ring into a number of bundles (VI. fig. 4).

The bundles, presenting a wedge-like form, are composed of vessels and elongated prosenchymatous ligneous cells, or as they have been called, woody fibres. That portion of the bundles in contact with the pith is composed of unrollable spiral vessels, and as these extend all round the pith, they are named collectively the medullary sheath. Among the ligneous cells which constitute the greater portion of the bundles, are scattered many large porous vessels, distinguished by their larger orifices.

As we follow the fibro-vascular bundles to their external border, we find they lose themselves in a very fine and delicate cellular tissue (the cambium layer). This is the point of separation between the wood and the bark, and is the point where all new horizontal growth takes place. Exterior to the cambium layer, and corresponding to the outer border of the wedge-like bundles of wood, are found other fibrous bundles, the liber, composed of cells much longer and tougher than those of the wood. This liber is the inner layer of the bark; beyond this are the layers of large but delicate cells containing chlorophylle, called the cellular envelope, and the outermost brownish cubical cells of the *suberous* layer clothed by a layer of flattened epidermis cells. Laticiferous vessels or canals are found frequently in the liber and cellular envelope.

A vertical section of a stem shows that, at the apex, the fibro-vascular ring and the liber gradually lose themselves in cells, while the cambium layer and the medulla become continuous and are enclosed in a layer of cellular tissue, forming part of the cortical system and clothed with an epidermis (VI. fig. 3, *a*).

The medullary parenchyma terminates below in a conical process enclosed in the prolongations of the lower extremity of the ligneous ring, which finally loses its *annular* character, and as a solid cone forms the root of the plant, clothed with a layer of cellular tissue of a delicate structure, continuous with the cortical parenchyma of the stem (VI. fig. 3, *b*).

109. In a stem which has accomplished a second year's growth, we find that in the situation where we found the cambium in the yearling stem, two new layers have been formed, corresponding in structure with those layers upon which they are applied (VI. fig. 5). The wood or fibro-vascular ring has received a layer of porous vessels and ligneous cells, and the bark an additional layer of the elongated cells of the liber. These two new structures are separated as in the former case by a "cambium layer" of very delicate cells, from which another development of the same kind takes place in each succeeding year. The

concentric layers of wood thus formed occupy nearly the whole diameter of the stem, the cortical layers being very thin and scarcely distinguishable from one another.

110. This is what may be called the *normal* structure of a dicotyledonous stem, but in some trees, especially natives of the tropics, we find great apparent departures from this type. These modifications of the wood and bark will be most conveniently treated of under the heads of the different regions or structures into which they have been divided above.

LIGNEOUS SYSTEM.

111. *Pith.*—The original shape of the pith, seen in a transverse section, is that of a star, the rays formed by the medullary rays (VI. fig. 1), but the growth of the ligneous bundles almost obliterates these, and the stellate figure is reduced either to a circle or a polygon (VI. fig. 2). Sometimes however it becomes square or rectangular, or it may be, triangular, and there are stems in which the pith assumes the form of a cross.

The figure of the pith does not seem to have any relation to the external figure of the stem or the arrangement of the leaves; in fact it is not always similar in all parts of the same stem.

112. It appears to have a certain determinate size in all stems or branches, after attaining which it neither increases or diminishes. The small size of the medullary cavity in large trunks has led to an idea that the pith is gradually encroached upon and finally obliterated by the development of the woody tissue; but this is an error arising from the small *relative* size; exact measurements have proved that it remains of that diameter which it acquires in the first year's growth.

113. In stems, especially those of herbaceous plants undergoing rapid and great development of the cellular axis, such as some of the large Umbelliferæ, fibro-vascular bundles are found traversing the pith. Since the vessels of these are of the unrollable spiral kind, the bundles would appear to be portions of the medullary sheath deviating toward the centre. Laticiferous canals also are frequently found in the pith, and, occasionally, bundles of ligneous cells resembling those of the liber.

114. In its earlier conditions the pith appears to possess a

very active vitality; being filled with nutrient juices, the cells often become thickened by the deposition of new layers in their interior, as is shown by the existence of pores upon the walls. The seat of its functions however is continually being carried upward, and the cells by age thus lose their importance, contain only air, and finally the tissue is often broken up so as to leave lacunæ of various sizes in its centre. This rupture of the medullary parenchyma occurs very early in plants when the pith is large and the growth rapid, producing fistulous stems.

115. *The Wood.*—The fibro-vascular bundles constituting the first year's layer (§ 60.) of wood, consist of a number of spiral vessels accumulated next the pith (the medullary sheath) and of lignified prosenchymatous cells, among which are intermingled large porous vessels. The bundles of the second year originating from the cambium cells contain no unrollable spiral vessels. In the examination of old stems, we often find the rings of the successive years defined by the orifices of the large porous vessels which are most numerous at the internal border of the annual layer; this is the case in the Oak and the Elm, &c. In the Lime, Hornbeam and other trees, the large orifices are wanting, but the annual zone is almost wholly composed of small porous vessels; at the external border, however, there is a layer of the ligneous cells forming a line of demarcation. Some woods have the boundary defined by a layer of cells resembling those of the medullary rays, and this layer of parenchyma occasionally acquires greater thickness, as in the Sumach, where the several concentric lamellæ are composed of large cells, coloured like the pith. The wood of the Coniferæ is wholly composed of porous cells of a peculiar character (III. figs. 17, 19), and the annual rings are marked by the difference of the thickness of the walls, resulting from the deposition of secondary layers.

116. By the increase of the ligneous deposits within the cells of the wood, the cavities at last become almost obliterated, and thus the wood is rendered almost impermeable by the fluids. This process takes place in the order of the age of the rings from the centre toward the circumference, and is very evident in those trees where the wood becomes dark-coloured, as in the Ebony, Iron-wood and similar trees, where two distinct portions may be perceived; one, the external, retaining the character of young

wood capable of transmitting fluids, which is of a lighter colour and is called the *alburnum* or sap-wood; the other forming the central portion of the trunk, dark-coloured, hard and dry, which is called the *duramen,* the perfect or heart-wood. In tropical woods, the limit between these portions is often distinctly defined; in temperate climates the change takes place more gradually, and in many trees the *duramen* remains uncoloured, as in what are called the white woods, *e.g.* the Willow, the Poplar, &c. The strength and durability of the wood are generally in direct relation to its colour.

117. The annual rings vary much in thickness in different kinds of trees and in different parts of one stem. The softest woods, growing most rapidly, have the broadest rings. The variety of the seasons in different years influences the relative amount of wood formed, and the age of the tree is another modifying cause. An old tree grows more slowly but more regularly than a young one, and moreover at a certain period of its life it developes its tissues more vigorously than at any other; the Oak for instance is said to grow most between the ages of twenty and thirty years. External influences will cause the annual layers to be very much thicker in one part of the circumference, so that the pith becomes excentric.

118. The repose during the winter is assumed as the cause of the defined limit of the layers in temperate climates, but this does not explain the formation of rings in tropical trees. There, however, the dry season accompanied by the fall of the leaves offers a corresponding season of repose. This leads to the idea that if a tree were submitted to conditions so that its vegetation should be alternately active and suspended, several zones might be formed in one year. And this does occur among plants (especially herbaceous) found in temperate climates.

The absence of distinct zones is a more frequent phænomenon, even constant in many ligneous plants, and is evidently independent of climatal conditions, being characteristic of certain species, genera and indeed certain entire families. The *Cacti* offer an example. Single circles are met with, each the product of several successive years. The *Cycas* cultivated in our conservatories presents us with this condition.

119. *Medullary Rays.*—These are the vertical plates of cellular

tissue extending from the medullary to the cortical parenchyma, and interposed between the fibro-vascular bundles. When these are continued through the ligneous zones of all the succeeding years, they are called large or primary rays (VI. fig. 5); those which originate after the first year at the margin of the corresponding annual layer are the small or secondary rays (VI. fig. 6). These are present even when the distinction of the zones is not evident, and thus indicate obscurely the successive nature of the formations. When the fibro-vascular bundles are perfectly perpendicular, the cellular plates of the rays extend from the top of the stem to the bottom, but most frequently the partial bundles are flexuose in their vertical course, and the medullary rays then occupy the spaces left between these deviations.

The medullary rays are often broader and exhibit greater evidences of vitality toward the periphery of the wood where they unite with the cortical system. In the alburnum they are filled, according to the season, with starch or nutritive fluid, and often contain chlorophylle. They appear therefore to be more closely related to the cortical system than to the pith.

CORTICAL SYSTEM.

120. This, distinctly opposed to the ligneous in the direction of its development, is separated from the wood by the delicate tissue which has been called the cambium layer, and is divided into three regions:—1. the Liber; 2. the Cellular Envelope; and 3. the Suberous Layer with its epidermis (VI. fig. 4, *e, f, g*).

121. *The Liber.*—Opposite to the fibro-vascular bundles of the wood are found bundles of ligneous cells much longer and more slender than those occurring in the wood (VI. fig. 4, *e*). Their walls become greatly thickened by internal deposits, and this tissue acquires a greater degree of tenacity than any other vegetable structure, thus becoming peculiarly valuable for economic purposes, furnishing materials for cordage, &c., while the toughness of the cells allows of advantage being taken of their delicacy, as in the case of flax. The bundles of the liber are separated by medullary rays, generally continuous with those of the wood, but much larger and of less compact character, and

these two structures form together a zone, concentric with the woody zone, called the *endophlœum.*

The bundles of the liber are sometimes perpendicular, and thus are separated by continuous plates of tissue like the wood; but more frequently they are flexuose, and thus form a sort of network, in the interstices of which the parenchyma of the rays is situated (VI. fig. 7). The layers of liber of successive years, also, are separated by zones of cellular tissue. As the stem increases in size, the interstices of the network of the liber bundles must become enlarged; the rays dilate in proportion, by the multiplication of their cells, so long as the tissue retains its vitality.

122. THE CELLULAR ENVELOPE.—This (VI. figs. 4, *f*. 5, *g*), also called the *mesophlœum*, is continuous with the parenchyma enveloping the liber bundles and is distinguished from the suberous layer which surrounds it by the green colour of its polyhedral cells, which possess thicker walls and are more laxly aggregated, leaving passages and often even large spaces between them. Among the cells containing chlorophylle there often occur others enclosing masses of crystals.

123. THE SUBEROUS LAYER (VI. fig. 4, *g*. 5, *h*).—This region of the bark is so called from its extraordinary development in some trees, producing the substance called cork. It has also been named the *epiphlœum.* It is composed of one or many rows of cubical or oblong cells, intimately connected and with thin walls. They are destitute of granular contents, and at first uncoloured, but frequently become brown as they grow older. In some cases they develope no further, in others they multiply and their thickness increases more or less. In the Cork-tree (*Quercus suber*) the cells are not all of the same form and size, but at certain distances they are more compressed or tabular, the layer of tissue thus appearing to be subdivided into many secondary layers. In the Birch the tabular brown cells undergo greater development than the others, which are white and delicate, and thus they become more readily ruptured by the increasing size of the stem, and separate in little flakes. In the Beech the tabular cells alone develope.

124. The parenchymatous system of the bark always retains

a very active vitality and unceasingly produces new cells, not merely in one situation, but in many simultaneously. Besides the formation of the annual layer of the liber and the cells enveloping it, the suberous layer increases by the multiplication both of the large and of the tabular cells, and all these developments seem to proceed independently of one another.

The relative mode of development of the different parts influences that of the bark in general, and the nature of the external layer or periderm.

In the cases above-mentioned the suberous layer manifests the greatest increase. The liber and cellular envelope then grow slowly and gradually, remaining in the bark, the periderm being formed of a tabular layer of the suberous envelope, developing alone or growing beneath a mass of cork, which soon dies and is thrown off in large plates. In other cases the suberous envelope undergoes no development, disappears with the epidermis (which is always soon destroyed), and then the periderm is produced on the surface or in the substance of the cellular envelope. Thus in the former instance the periderm, formed upon the cellular envelope, as in the Plane, is pushed off by another layer developed beneath it, and is detached in plates. Otherwise, the Periderm developed more interiorly pushes outward both cellular and fibrous (liber) layers, which separate either in scales composed of the parenchyma and liber of several zones, which remain long attached together, as in the Oak, or in thin flakes, as in many Proteaceous trees. In the Vine and Honeysuckle each annual zone of liber throws off that of the preceding year. In the Larch and the common Pine, the cellular envelope developes very extensively, and thus forms a false cork which separates in scales.

125. Laticiferous canals are abundant in the inner layers of the bark, and as their functions are exercised peculiarly in young tissues, they soon die and are pushed outward by succeeding developments.

126. From the foregoing considerations it is evident that the cellular system of the bark is incomparably more active than that of the wood, which ceases to grow, and in fact dies, after the complete formation of the first zone. The medullary rays therefore must be regarded as belonging rather to the former than the

latter, especially as they occur in greatest number and size in the region next the bark. They appear to originate from the cambium layer.

127. Lenticels.—On the surface of many young barks are found little spots slightly projecting; these grow with the stem, but chiefly outward, so that they form projections always increasing in size. They are developments from the cellular envelope which push their way through the parts covering them till they reach the surface, where they are bounded by the suberous tissue which they have traversed. The numerous lenticels keep up a direct relation between the interior of the bark and the air, after the stomates have ceased their functions through the destruction of the epidermis.

Sect. II. The Root.

128. The root is that portion of a plant prolonged downward from the stem; the point of junction of the two is called the *collum*, which is regarded as the base of the root. In a simple phyton it is the lowest of the three divisions or merithals, and forms the radicle of the embryo. The acotyledonous embryo having no distinct parts possesses no radicle (V. fig. 12, *a*). In the monocotyledonous embryo the radicle exists as the mere terminal point of the stem (V. fig. 13, *r*). In the dicotyledonous embryo it is more developed (V. fig. 15). In plants composed of a collection of phytons, the radicle merithal of every phyton above the lowest internode is generally modified so as to become part of the stem or woody axis, but in some cases it becomes free, and is developed in the form of aërial or adventitious roots. The most characteristic distinction between stems and roots is afforded by the structure and function of the parenchyma: in the stem, as we have seen, the epidermis often becomes very dense, and is provided with stomata or lenticels; the medullary parenchyma continually increases the size of the stem by the development of new phytons; and the stem in each period of its growth increases in length in all the new parts simultaneously until the full development of that annual or periodical portion is completed. Stems produce leaves.

129. Roots are covered with a very delicate epidermis or epi-

blema, and are devoid of stomata, which are replaced by the papilliform or hair-like prolongations of the epidermal cells, fitted for the absorption of fluid, and which are called spongioles. There is no medullary parenchyma (except by the occasional prolongation of the lower extremity of the pith, as in the Horse-chestnut), and the growth takes place both in length and diameter by the development of annual layers of the cortical and ligneous portion. The roots do not grow throughout the whole length of each annual production, like stems, but merely at the apex. The roots produce radicle fibres or fibrillæ, instead of leaves. Buds do occur in some cases on roots, but these are analogous to the adventitious buds which are sometimes developed in the cortical parenchyma of stems, and not to those normal buds originating in the axils of leaves. The fibrillæ of the roots wither after a certain time, like the leaves of stems. The vessels of roots are analogous to those of the stem, excepting that as there is no ascending portion, the unrollable spiral form is not found (at least only in exceptional cases which have been described by some authors, and these unsatisfactorily); the ligneous fibres are precisely similar in structure, but more densely filled with ligneous deposits.

130. The cellular system often acquires very great development. The cells of the roots, which are usually destined to the absorption of fluids for the nutrition of the stem, sometimes also act as reservoirs for the storing of assimilated nutriment, becoming filled with various juices or large quantities of starch or inuline. In such cases the roots become enlarged in various situations, or even in all parts. The whole tap-root or axis may become enlarged, as in the Turnip or Carrot, or some or all of the subdivisions of a compound root may expand either in one point, several (VI. figs. 9, 11) or (VI. figs. 8, 10) throughout. These enlargements are called tubers, and the roots are said to be tuberous.

ACOTYLEDONOUS ROOTS.

131. The simplest form of the roots of this class are mere cellular fibrillæ, which supply the young stem with nourishment. When this has become developed it gives origin to adventitious

roots; that is, the radicle merithal of each phyton becomes free. Roots are usually produced all round if the stem be erect, or on the lower side if the stem be horizontal.

In the arborescent Ferns these adventitious or free roots accumulate in such numbers that the base of the tree becomes increased in a conical form to two or three times the thickness of its real stem.

The roots of these plants correspond in the nature of their elementary structures to the stems from which they grow; cellular in the cellular plants, as the Mosses; in the Lycopodiaceæ and Ferns, &c. they contain fibro-vascular bundles. These bundles, however, are generally central in the roots, enveloped in a layer of parenchyma, which, in situations where it is in contact with the bundle, forms a hard brown or blackish layer. In some Ferns and Lycopodiaceæ the fibro-vascular bundles lie within the external cellular portion of the stem for some distance before they become free in the roots. In old stems of some Lycopodiaceæ this parenchyma is separated from the central fibro-vascular column, and such descending bundles are found lying in the interval.

MONOCOTYLEDONOUS ROOTS.

132. The radicle of germinating monocotyledons does not appear as a direct continuation of the stem, but breaks through the radicular extremity of the embryo (V. fig. 14, *r*). A layer of the superficial cellular tissue clothes this radicle as with a sheath at its base. Hence the embryos of this class have been called endorhizæ, and the sheath formed by the radicular extremity is termed the *coleorhiza*.

The roots of monocotyledons are usually compound, and the branches are occasionally again divided. These partial roots, forming together the compound, are only temporary formations; if the stem is perennial they die in the order of their production, from the centre outward, new roots being developed in circles continually more external. The aërial roots commonly occurring in this class frequently exhibit this phenomenon. They are produced from various parts of the stem: in the Palms the base of the stem becomes covered by the production of a large number of these adventitious or free roots, giving the base a conical form; in the Pandanus they are developed in a continually enlarging spiral, the most recently formed being the largest and arising high up on the stem; the death of the lower roots and the gradual destruction of the base of the stem often cause these free roots to become finally almost the sole connexion between the stem and the earth. In *Dracæna* the descending portion of the fibro-vascular bundles which belong to the radicle system do not become free and develope adventitious roots upon the stem, but are found as *wood* beneath the cortical layer, until they reach the base of the stem, where they are united to a certain extent by parenchyma, so as to present a root somewhat resembling that of a dicotyledonous tap-root. *Cordyline australis* has two such main divisions, called by Mirbel *souches* (VI. fig. 14). Here however the monocotyledonous structure is retained, the radicles are developed centrifugally, and break through the cortical parenchyma, which clothes them with a coleorhiza. The flattened stems in the bulbs of our climates exhibit also the centrifugal development of radicles (VIII. fig. 18).

133. The anatomical structure corresponds to that of the stems. The fibro-vascular bundles are mostly situated toward the exterior, and a fibrous layer is often found beneath the cortical parenchyma. In small rootlets the bundle is sometimes reduced to a single vessel surrounded by cellular tissue. A difference of relative position occurs between the elements of the bundles in roots and stems: the large porous vessels of the bundles are most external in the stem; in the root they are the most internal in relation to the axis of the root.

DICOTYLEDONOUS ROOTS.

134. In this class we find the root presenting a great central aggregation of the descending system, corresponding and opposed to the stem. This kind of development of the root gives rise to what is called the caudex or tap-root, and is especially remarkable in trees, where its ramifications have frequently a definite relation to the size, number and extent of those of the stem. The caudex does not generally become prolonged down very far into the earth, but its branches acquire a great lateral develop-

ment. Although this corresponds in some degree to the ramification of certain stems, the form and size of the stems and roots do not bear a constant relation. Either of the two systems may be proportionately much more extensively developed.

135. The structure of the root may be considered as resembling exactly that of the stem devoid of pith, and consequently without the unrollable spiral vessels of its sheath. This is the real structure in most herbaceous plants, but not in all trees. The Walnut for instance, and the Horse-chestnut exhibit a pith highly developed, extending to a considerable distance in the root.

136. The growth takes place by the periodical production of new layers of wood and bark over the whole surface. The increase of length is strictly terminal, no interstitial growth of the cells occurring; the ramifications are prolongations from the parenchyma of the cortical system, in which the fibro-vascular bundles are very quickly developed, and become continuous with those of the parent branch.

137. It has been mentioned that adventitious buds may occur under peculiar circumstances upon roots, even as they do in the bark of the stem. Adventitious roots may also be produced from the stem, a striking example of this being afforded by the rooting of cuttings by which plants are propagated in horticulture. The anomalies of stems, such as the coherence of contiguous ramifications into one, the formation of concentric rings of parenchyma, as in certain Menispermaceæ stems and some of the climbing woody Convolvulaceæ of Brazil, are frequently repeated in the roots.

Sect. III. THE LEAF.

* *Anatomical Structure.*

138. The leaf may be regarded as an expanded mass of the cellular tissue of the cortical system, through which ramify, in the more highly developed classes, numerous vascular bundles.

139. AËRIAL LEAVES.—The lowest form of leaf, called a *frond*, consists wholly of parenchyma; next we find this strengthened by bundles of prosenchymatous cells, and enclosed in an envelope of peculiar epidermal cells with stomata. In the highest con-

dition, in addition to these, they possess spiral vessels and many special arrangements of the cells and their interspaces, destined to the formation and storing of peculiar secretions. Of this character are the cells and intercellular reservoirs, containing oils, resins, &c., the glands and milk-vessels. In their development leaves appear to pass through corresponding stages, as they originate as little cellular expansions on the apex of the stem.

The form of the leaf is determined by the arrangement of the vascular bundles, which are in communication with those of the interior of the stem, and branch out in various directions; these branches uniting again, form a network of a denser texture than the intermediate parenchyma, and are what is called the skeleton of the leaf. The cellular tissue consists of the epidermis, which forms a complete sheath to the leaf, the orifices of the stomata being the only means of communication between the interior of the leaf and the external air. The tissue filling up the intermediate space, varying very much in quantity, is called the *diachyma* or *mesophyllum*, and is composed of layers of cells filled with chlorophylle, which give the green colour to the leaf, and others often containing various secretions, as oils, starch, &c. The cells of these layers are usually of two kinds, the upper cylindrical or prismatic, the lower spherical or very irregular and thus leaving large interspaces between them. Large cavities of this kind are found corresponding to the stomata; these communicate with the various intercellular passages of the leaf, the petiole, and thus with those of the stem (VI. figs. 15, 16).

The vascular system is double, consisting of an ascending and a descending portion; the ascending portion, which is continuous with the medullary sheath, becomes continuous at the apex of each nerve with the descending portion, which is beneath and in contact with it throughout its ramifications. This descending portion at the base of the petiole becomes continuous with the bundles of the liber (VI. fig. 18).

140. The leaves, those expansions which are generally green and of a flattened form, arise originally from the apex of the stem or some of its subdivisions, and are afterwards situated at the sides; hence the leaf and its various modifications have received the name of lateral organs, as distinguishing them from

the stem and root. The base of the leaf is that extremity by which it is attached to the stem; the other extremity is the summit or point. The base is generally attenuated into the form of a slender stalk, which is called the *petiole*. In some cases the petiole becomes dilated at its base, so as to embrace a more or less considerable portion of the circumference of the stem, forming what is called a sheath or *vagina*; but more commonly this expanded portion is partially or totally detached, and then presents the appearance of a little leaflet of variable form on each side of the base of the petiole; these appendices are called *stipules*.

The leaf is thus composed of three portions, the laminar, the petiolar, and the vaginal, which last may exist in the form either of stipules or a sheath. In many cases all these parts are visible (VII. fig. 24); in some plants the number is reduced to two or even one. The lamina is generally the most extensive and conspicuous portion, exercising those functions of the leaf necessary to the life of the plant; but the stipules are occasionally more developed than the limb, and replace it in these economical relations.

141. The two surfaces of the lamina are called the faces or *paginæ*; the borders, the *margins*. In most plants the leaves are horizontal or a little oblique, the superior face looking upwards, the inferior downward or a little outward. In New Holland, according to Mr. Brown, the leaves of many of the trees (*Myrtaceæ*) are situated vertically upon the stems, the faces being directed laterally.

In aërial leaves the epidermis of the two faces varies considerably in appearance and structure. The upper face generally has a much more dense cuticular layer, and either is devoid or but sparingly furnished with stomates. An exception to this occurs in floating leaves (as in *Nymphæa*), where the upper face, in contact with air, is pierced with stomates; while the lower face, resting on the water, has none.

The lower face, besides its abundant stomates, is often clothed with hairs or scales, like the epidermis of young stems. In all leaves the stomates are only found in situations corresponding to cellular tissue, never opposite the fibro-vascular bundles.

142. SUBMERGED LEAVES.—Leaves growing under water exhibit a very different structure from those above described. They have no epidermis, and consequently no stomates. The fibro-vascular skeleton is also wanting, the nerves consisting of elongated cells. The leaf is altogether composed of parenchyma; the cells of which the thickness is made up being only in two or three rows, they are in almost immediate contact with the water; they are generally regular, intimately connected and full of green granules. The intervals are not often elongated into passages or expanded into *lacunæ*; but very thick leaves sometimes exhibit *lacunæ*, which are then very regular, completely closed in by the bordering cells and do not communicate one with another (VI. fig. 17). The cavities appear to serve merely as air-reservoirs to diminish the specific gravity of the leaf. Aquatic leaves having no epidermis or solid skeleton quickly shrivel up when removed from the water.

** *Form of Leaves.*

143. The fibro-vascular bundles of aërial and the elongated cells of aquatic leaves, which are generally visible externally and often project on the under surface, are called the *nerves* or *veins*, and their arrangement the *nervation* or *venation*.

On this arrangement, and the degree to which the intervals between the nerves are filled up by parenchyma, depends the form of the leaf. The nerves remain collected together in the petiole, and the point where they separate to be distributed to the expanded portion marks the distinction between the petiole and the lamina.

The simplest form is the *acicular*, where the bundle remains undivided, giving the entire leaf the form of a petiole, terminating in a point, as in the leaves of the Pine, Larch, &c. (VI. fig. 20).

Most frequently however the bundle separates into several, and these secondary bundles spread out, either in one plane, giving the leaf dimensions of length and breadth, or in different planes, when the thickened leaf acquires also depth.

144. In the former case again the nerves of the lamina may be parallel with the petiole, or form an angle with it. Sometimes the bundle divides into several equal portions, which spread out

in a divergent arrangement, called the *palmate* nervation, whence the leaf is said to be *palminerved*; sometimes it continues from the petiole to the summit of the leaf, sending off secondary bundles to the right and left, forming the *pinnate* nervation, and the leaf is then called *pinninerved*. In the latter case the principal nerve continued from the petiole is denominated the *median* nerve or *costa* of the leaf: the lateral nerves forming angles of all degrees with the median are the secondary nerves. When the secondary nerves diverge from the summit of the petiole all in one plane, radiating like the spokes of a wheel from the axle, the nervation is said to be *peltate* (VI. fig. 22).

In the pinninerved leaves the secondary nerves may be given off from the median at any angle; they may be all equal, long or short, or unequal, by decreasing from the base to the summit or *vice versâ*, or increasing up to a certain point and then diminishing; this maximum point being situated either in the middle of the leaf or above or below it (VI. fig. 21).

145. When the nerves separate, to be distributed in different planes, the lamina either consists of a flat expansion variously folded upon itself or of a thickened solid mass. To the first condition may be referred the *fistular* leaves (as in some of the species of *Allium*) and those uncommon forms where the leaf assumes the figure of a hood, a pouch, an urn, &c., as in some of those modifications called *ascidia*. In the second condition the parenchyma fills up all the intervals between the nerves, and the leaf acquires a solid form, its surface being curved or divided into several plane faces. These solid leaves are often sufficiently regular to allow of their being characterized by the various geometrical terms, as prismatic, pyramidal, cylindrical, &c.; at other times they are so irregular that they are described by names borrowed from various familiar objects, and are called for instance ensiform, linguiform, gibbous, &c.

146. The flat leaves have many distinguishing characters derived from the distribution of the parenchyma in relation to the nerves. When it fills the interstices completely, and the margin of the leaf exhibits an unbroken line, the leaf is *entire* (*integrum* VI. fig. 21). When the parenchyma does not reach the margin at all points, the outline of the leaf presents many degrees

of irregularity. The borders thus *cut,* as it is called, vary in form and receive names founded upon the extent to which the parenchyma is developed, and upon the depth of the salient and re-entering angles presented by the marginal outline. When the margin is slightly cut or notched, the projections are called *teeth,* and the leaves are *dentate* (VI. fig. 24); or if the teeth are sharp, and point all in one direction, *serrate* (VI. fig. 26); where the teeth are rounded, the leaves are *crenate* (VI. fig. 25).

The margins are frequently more deeply cut, and the divisions then are called *lobes.* The names of the lobes vary with the depth of the incisions: if they reach to midway between the margin and the median nerve, they are called *fissures,* and the termination *-fid* (VII. fig. 1) is subjoined to the adjective denoting the number or arrangement of the fissures. If they reach almost to the median nerve, they are *partitions,* and the leaf is *-partite* (VII. fig. 2); if the parenchyma is divided down to the nerve, the lobes are *segments* and the leaf is *-sect* (VII. fig. 3). The last three names are usually employed in combination, as when the fissures, &c. are three, five, or indefinite in number, *tri-fid, quinque-fid, multifid,* &c., or are arranged like the palmate or pinnate veins, *palmatifid, pinnatifid,* &c., the words *-partite* and *-sect* being used in the same manner.

147. In all these forms the parenchyma diminishes in proportion as it becomes more distant from the median nerve or axis, all the lobes being continuous in the centre, except in the last condition; but even there each segment adheres to the median nerve to a considerable extent, and exhibits the greatest breadth at its base. In compound leaves we have a different arrangement; the segments are only attached to the median nerve by means of the secondary nerves, which there appear to bear the same relation to the median nerve as the petiole does to the branch from which it originates. The segments thus assume the character of so many leaflets independent of each other; but their real nature, as parts of one leaf, may be recognised by the fact that they are all situated in one plane, and that the main petiole separates in one piece with all its leaflets from the stem when the leaf dies.

In the leaves called *compound* the median nerve is the *rachis* or *common petiole,* and the segments are *leaflets* or *folioles.* If the median bundle of each leaflet remains undivided for any distance from its base, this portion is called the *petiolule.*

The compound leaf thus formed presents modifications analogous to those of the simple leaf, depending upon the palmate or pinnate nervation. Thus they are *palmate* (VII. fig. 4) or *pinnate* (VII. fig. 5). When the term *pinnate* is used alone, it denotes this latter form. In the compound terms applied to the various kinds of leaves the termination *-foliate* is employed, *e. g.* a leaf is called *bi-*, *tri-* or *multi-foliate.* They often arise in pairs (VII. fig. 5), and these are called *juga,* whence the epithets *bi-*, *tri-* or *multi-jugate.* When a pinnate leaf has no terminal leaflet, it is *abruptly-pinnate* (VII. fig. 9); where the median nerve or *rachis* bears a terminal leaflet, the leaf is *impari-pinnate* (VII. fig. 5).

Leaves still more complicated in the arrangement of their parts result from further division of the nerves. All that has been stated with regard to the divisions of the secondary nerves may be repeated of the nerves of the 3rd, 4th or 5th order, &c., each of which may bear the same relation to that from which it arises as the secondary nerves do to the median. In simple leaves the lobes may here be entire or variously divided, as before (§ 146), and these divisions again subdivided. The prefixes *bi-* and *tri-* are used to indicate the number of times the leaves divide; for instance, a *bi-serrate* leaf has serratures, the margins of which are again serrated (VII. fig. 7); a *bi-pinnatifid* leaf is a pinnatifid leaf, the lobes of which are again divided into lobules, arranged in a similar pinnate manner (VII. fig. 6). Beyond this double division the parts generally become so small that it is not thought worth while to examine the exact arrangement, and all those leaves where the lobes are very numerous and indefinitely divided are confounded together as *laciniate* or *decomposed* leaves.

In compound leaves the leaflets themselves may be dentate or lobed. But when these subdivide it is usually in repeating the primary division, each being decomposed into leaflets (*f. decomposita*) or even dividing again (*f. supra-decomposita*). The leaf is then said to be twice or thrice pinnate (VII. figs. 8, 9) or palmate (*bi-*, *tri-pinnate*; *-palmate*). The secondary nerves thus become so many *rachides* or *partial petioles.*

Space will not allow of all the varied forms of leaves being described here, and indeed such descriptions belong rather to glossology than to organography; the knowledge of them is necessary to the comprehension of descriptive botany, but not in the examination of structural or physiological peculiarities. It is sufficient here to indicate how the distribution and arrangement of the constituent parts, the nerves forming the skeleton and the parenchyma which is the *essential* portion of the leaf, determine the various appearances, and to remark that the differences are only in the relative degree of development of these, since the compound leaf presents, not a greater variety of parts, but the same part repeated a greater number of times.

148. PETIOLE.—The usual form of the petiole is that of a little branch interposed between the stem and the leaf, and supporting the latter. It is composed of the fibro-vascular bundle going to the leaf, the bundle being enveloped in a continuation of the cortical parenchyma; the epidermis of this portion, like that covering the nerves of the lamina, contains no stomates.

149. The vessels passing from the stem, with the accompanying cells, undergo some changes when they make an angle at the base of the petiole or other lateral organ. The elementary organs of the bundle are here shorter, and their ends are applied together in a smaller extent. After they have attained a certain degree of development, the mutual adherence of these parts becomes very slight, and they fall apart by their own weight or are detached by very slight external force. The point where this takes place is called an *articulation,* and such a structure frequently occurs at the spot where two organs are in contact, as at the nodes of the stem, and the origin of branches or leaves.

Leaves which are frequently articulated with the stem are then continuous with it at their narrowest part; thus after a certain period, when they have fulfilled the offices to which they were destined and have withered, they fall. In a large number of plants they fall in the course of the same year in which they were developed. When they are not articulated (as in the Oak) they frequently remain attached through the winter, or even after the death of the plant.

Persistent leaves are generally found to be simple; compound leaves are almost always articulated, and here the folioles often are articulated with the partial petioles and become detached. This is sometimes taken as a distinctive character of *true* compound leaves.

150. After the petiole has become disarticulated, a slight protuberance is often perceptible upon the stem at the place where it was attached. This is originally continuous with and forms a base for the petiole, and then is called the *pulvinus*. The scar left by the separation is the *cicatrix*, which frequently exhibits toward its centre, little points denoting the extremities of the vascular bundles. These are variously arranged, and the arrangement, with the general form of cicatrix and pulvinus, frequently affords characters by which a stem may be recognised when its leaves are all removed.

151. The petiole is generally shorter than the lamina (VII. fig. 8); sometimes equal to it, sometimes longer. When it is tolerably thick and short, it supports the lamina without bending. If it is slender, long, or of soft texture, it forms a curve proportionate to the weight of the leaf. Its form is often cylindrical, but generally it is rounded or convex below, and flat or grooved above. The petiole of certain plants is flattened horizontally, while in a few the greatest diameter is in the vertical dimension: the lateral flattening of the petiole gives the peculiar mobility to the leaves of the *Populus tremula* or Aspen.

152. PHYLLODE.—In some forms of petiole the bundles, instead of remaining united until they reach the lamina, separate and become connected only by a flat expansion of cellular tissue like that belonging to the blade of the leaf. The organ thus formed is called a *phyllode* (VII. fig. 9, *b*), and closely resembles a leaf. It may be distinguished by the nerves being all nearly parallel and equal, uniting again at the apex, while the nerves of the true leaves of the same plants are pinni-nerved. The phyllode occurs especially in the New Holland *Acacias*, and in these its *margins* look up and down, while the faces are lateral. The phyllodes often bear true compound leaves upon their summits.

153. The curious organs which have been denominated *ascidia* or pitchers appear to be modified petioles. If the two margins of a phyllode were rolled inward and united in their lower half,

a pitcher like that of *Heliamphora* would be formed (VII. fig. 14). Various forms of these *ascidia* occur, as in *Sarracenia* (VII. fig. 12), and *Nepenthes* (VII. fig. 13), where the lamina is found as a sort of hood or lid to the pitcher; but other *ascidia, e. g.* those of *Dischidia* and *Marcgraavia,* are formed from the lamina and not the petiole. The dilated petiole bearing the irritable lamina of *Dionæa* (VII. fig. 11) probably fulfils the office of the leaf.

154. Sometimes the petiole is undistinguishable, as in *connate* or perfoliate leaves especially; here the bases of opposite or the posterior lobes of solitary leaves encompass the stem and cohere by their margins (VII. figs. 15, 16).

155. The petiole of a large number of the Monocotyledonous plants consists of a sheath enveloping the stem, and in the Grasses this is furnished with a peculiar organ called the *ligule* (VII. fig. 17 *a*), which appears to be formed by the epidermal layer becoming raised up and folded upon itself where it passes from the superior face of the leaf on to the stem.

156. Stipules.—These are generally small foliaceous bodies situated at the base of the petiole (VII. figs. 18–20). They resemble leaves in structure and appearance, and are subject to similar modifications; they may be membranous or scale-like, or be transformed, like leaves, into spines or tendrils. From the great tendency to cohere by their margins, they vary much in their relations with each other and to the petiole.

The vascular system of the stipules is intimately connected with that of the leaf. In some plants, as in the Rose, the stipules consist of two wing-like expansions adherent to the petiole. The fibro-vascular bundles here pass out from the stem, separate while passing through the flattened stipulate portion of the petiole, and then unite again above (VII. fig. 18). These are called petiolar stipules. But the bundles may remain permanently separate and the stipules exist as free leaflets attached at the base of the petiole, as in some Willows (VII. fig. 19). When the stipules remain unconnected with the petiole, they frequently cohere with each other by their margins; that is, in opposite leaves, each with the corresponding stipule of the pair opposed; in alternate leaves, with outer margin of its own fellow, and thus encircling the stem (VII. fig. 21). Sometimes they cohere by their inner margins (VII. fig. 20), forming what is called an *axillary* stipule; and when they cohere extensively by both margins, a sheath, vagina or *intra*-foliaceous stipules are formed, embracing the stem (VII. fig. 22), as in what are called the *ochreæ* of *Polygonum*. Where the stipules of opposite leaves unite by their outer margins, an *interpetiolar* stipule (VII. fig. 24) is formed; but they may cohere only at their bases, and thus we get two interpetiolar stipules; and in the Rubiaceæ we sometimes find these resembling the true leaves in size and form, and the whole appearing to be a whorl of six leaves.

157. Stipules are not found in all plants, but their small size often causes them to be overlooked; their presence or absence is generally constant throughout each natural order. They are not always persistent, but fall off soon after the expansion of the leaf; in the Fig and the Magnolias they form the covering of the leaf-buds, falling off as these open.

When leaves possess stipules they are said to be *stipulate*; in the contrary case, *exstipulate*. The leaflets of compound leaves are sometimes furnished with little stipules or *stipelles*, and are then called *stipellate*.

158. TENDRILS and SPINES.—By the non-production of the expanded parenchyma, any portion of the fibro-vascular system of leaves and their appendages may take the form of elongated herbaceous processes, which generally have a tendency to twine round any body with which they come in contact; these are called tendrils. In some cases, as in the Leguminosæ, they are formed from the continuation of the midrib beyond the lamina, or from the rachis of compound leaves; in the latter case either consisting of a little tendril, taking the place of any of the leaflets (VIII. fig. 1), or a larger one replacing the leaf itself, as in *Lathyrus Aphaca*, where it is said to be *petiolar*. Sometimes they are situated at one or both sides of the base of the petiole, produced from the lateral bundles, corresponding to those which in other cases produce stipules.

Instead of tendrils we sometimes find hard spines in the same situations; that is, at the extremities of the mid-vein or lateral veins of leaves, as in the Thistles, or replacing stipules or even leaves themselves. Tendrils and spines of this nature must be distinguished from those which are modified branches, as the tendrils of the Vine, the spines of the Plum, &c. The discrimination becomes easy, since when these organs are modified branches they always arise from the axil of a leaf. They are also readily distinguishable from thorns, as the latter are mere appendages of the epidermis, analogous to hairs (§ 67.).

159. The stems of the three great divisions of Cormophytes presented us with well-marked distinctions, and an examination of the leaves in the same point of view enables us to recognize special arrangements of the parts entering into their composition, which are equally characteristic. The nature and relative positions of the bundles forming the nervures of leaves offer three very distinct types; the peculiar distribution in some orders, analogous to the peculiarities of some stems, being only exceptional cases.

LEAVES OF ACOTYLEDONS.

160. The nervures of the leaves of Mosses and Liverworts, where they exist, offer no trace of vessels. The bundles consist of cells of a more elongated form. In the Lycopodiaceæ a single small bundle of spiral vessels is found. In the Marsileaceæ numerous bundles occur, while in the Ferns the venation of the leaves acquires considerable development. The leaves are very often highly compound, and the nerves ramify almost more extensively than those of cotyledonous plants. The fibro-vascular bundles, which contain the scalariform type of vessels, and are enclosed in a layer of the blackish cellular tissue, as in the stems, traverse the petioles, and on reaching the lamina branch out in various directions. The palmate nervation occurs sometimes, as in the *Adiantum*, but the pinnate is the more common. The terminal divisions of the veins, however, in either case are bifurcations.

LEAVES OF MONOCOTYLEDONS.

161. In the leaves of this division (excepting in one or two orders) we do not find the nervation reticulated. They are either all parallel, as in the *Iris*, &c., or there are parallel secondary nerves given off from one great principal. Monocotyledonous

leaves therefore are generally entire; in the Palms even, where they are pinnatisect or palmatisect, the lobes are almost parallel and have straight veins.

162. The vaginal portion of the leaf acquires very great development in the Monocotyledons, enclosing a great extent of the stem. In many plants the axis appears to be almost wholly made up of sheaths, enclosed one within another. In the Grasses, as has been stated, the upper portion of the sheath forms a peculiar process called the ligule (§ 156.), which is supposed to be analogous to the stipules. The sheath is continuous with the stem by a large portion of its circumference, and is *not articulated*. When dead therefore the leaves do not fall, but wither upon the stem. If the nerves are quite parallel from the base to the apex, the leaf has the form of a flat riband, as in *Typha*, &c., and it is then difficult to say whether the organ is a petiole or a limb. But in other cases the nerves diverge a little from the base to the centre, and then converge again at the summit, and thus produce the appearance of a limb, like that of the Dicotyledons (Orchideæ, &c.). When the secondary nerves take a new direction where they separate from the principal, a limb is formed by their lateral extension, very distinct from the petiole they formed below. In most cases however the leaf resembles a *phyllode* or foliaceous petiole, rather than a true leaf with petiole and lamina.

163. A few Monocotyledonous orders offer exceptions to the above remarks, viz. the Araceæ, Smilaceæ and Dioscoreæ; in these the nerves branch and anastomose, producing a reticulated nervation contained in a distinct lamina.

LEAVES OF DICOTYLEDONS.

164. The leaves of dicotyledonous plants present very distinct characters. Here we find leaves articulated, really compound, having their margins dentate, crenate, or divided into angular or sinuous lobes. The nerves arising from each other generally form acute angles and subdividing become intermingled in their ultimate ramifications.

There are, however, some dicotyledonous leaves with parallel veins, as *Ranunculus Lingua*, &c. Some authors refer all these cases to *phyllodes*, which, as we have seen, are always straight-veined, and are transformed petioles.

The general description of leaves which has been given precludes the necessity of entering more at length upon the leaves of dicotyledonous plants, since the structure and most important modifications of form have been already pointed out.

ARRANGEMENT OF LEAVES.

165. The laws of the arrangement of leaves, or Phyllotaxy, have been very carefully investigated and reduced to mathematical precision, but since they do not seem to have any very direct practical bearing in the present condition of our knowledge, it is obviously unadvisable to allow a lengthened exposition of them to occupy a place in an elementary work. The chief fact that comes out of the inquiry is, that leaves and all their modifications have normally a spiral arrangement on the axis or stem, and that the mathematical formula for the relative position of the organs, though different in different plants, is remarkably constant in the same species.

In stems where the leaves arise one after another with the interposition of a certain length of the axis between them, the leaves are called alternate, and this, the commonest condition, offers the most favourable opportunity of detecting the spiral arrangement.

Alternate leaves are rarely placed exactly upon opposite sides of the stem; the second leaf will be found to arise rather on one side of the point above and opposite the first, and the third on one side of a line perpendicular to the first. In the Apple the sixth leaf comes to be directly over the first, and a line drawn round the stem connecting all their bases will be found to be a simple spiral passing twice round the stem. The point where a leaf is found coinciding perpendicularly with the first, indicates the completion of a series or *cycle*, and thus in the Apple the cycles are series of fives. Carrying the examination further up, we shall find the seventh leaf over the second, the eighth over the third, &c., until we reach the eleventh over the first and sixth, completing a second *cycle*.

This arrangement in cycles of fives is that most common in

Dicotyledons, but others also occur. The Lime presents a very simple condition. Here the second leaf is directly *opposite*, and the third directly *over* the first; the latter completing one spire and being the point where the second commences. This arrangement, which is called *distichous*, is found in many Monocotyledons, but spires containing three leaves, forming the *tristichous* arrangement, are the most characteristic of that class of plants.

The spire becomes much more complicated where it contains many more elements, but the relations are found to be constant, and in plants exhibiting such forms the spiral arrangement becomes much more apparent, as in the *Pandanus* or Screw-pine, the Pine-apple, and among the Coniferæ.

A little consideration renders it evident how this spiral disposition of the organs ensures the symmetrical distribution of the leaves, and the equable formation of new parts deriving their assimilated nutriment from them. A proof of this influence is afforded by the manner in which the form of the stem deviates from the cylindrical in those plants where the spiral arrangement of the leaves is least obvious. The various organs resulting from the higher states of development of the typical organ, namely the floral envelopes, and even the carpels (as in the Coniferæ), are all subject to the law of spiral disposition, and the importance of this view in elucidating the structure of the flowers will hereafter be seen. In a large number of plants the law of arrangement just described does not at first appear to hold good, namely in those which have *opposite* or *verticillate* (IX. figs. 1, 2) leaves. But opposite leaves may be supposed to proceed from two spirals proceeding up the stem simultaneously, or from the non-development or shortening of the alternate internodes. The *whorl* or *verticil*, again, may be conceived to originate from the non-development of the internodes of a whole cycle, each spiral cycle being thus reduced to a circle. Examining the succeeding whorls, we do not often find the leaves of the second perpendicular to the first, but with their midribs over the intervals between those below. Supposing the leaves to be opposite, the second pair would stand at right angles to the first (*decussate*) : if the whorl contained three, it would require a greater number of series before the leaves would again correspond vertically. In these cases the number of cycles or whorls required to complete the vertical coincidence constitutes a *rectilinear* series, and in opposite leaves consists of four cycles; where the whorls are composed of three leaves, of six, and so on. If the *pairs* do not cross exactly at right angles it will require several pairs to form a series, and these pairs follow a spiral arrangement like that which is commonly found in alternate leaves.

166. Some authors contend that the normal arrangement of leaves is verticillate, and that the spire arises from the breaking up of this by the elongation of the stem. Those on the contrary, who contend that the spiral is the typical disposition assume that the elongation is suspended from time to time, to allow of the accumulation of the cycle into a circle, and that each internode separating these circles is made up of as many internodes or cauline *merithals* as the whorl contains leaves.

167. The opposition or alternation of leaves is generally constant in the same species, but the transition from one to the other occasionally occurs on the same stem, as in the Myrtle, the *Antirrhinum*, and in rapidly growing shoots of opposite-leaved trees. Monocotyledons seldom have opposite leaves.

168. The place where a leaf arises from the stem is often called the *insertion*, and this may be *radical* when it arises from the stem below the surface of the ground, or *cauline* when arising from the main stem; those belonging to the branches are sometimes called *ramal*; when upon the flowering-stems they are called *floral* leaves or *bracts*.

Only one leaf arises from one point, but by the formation of an almost undistinguishable axillary branch the bases of a number of leaves may be brought in contact, so as to produce *tufts* of leaves or *fascicles*. The Larch offers a good example of this condition (VIII. fig. 5), the whole foliage of the branch becoming developed without any growth of the axis.

BUDS—VERNATION.

169. The axis or stem developed from the embryo in germination continues to increase in height by the superposition of new phytons, until the season of rest approaches. A certain number of leaves and that portion of the stem upon which they are borne

then become developed in a peculiar manner; the axis is shortened into a small cone, and the leaves reduced to little cellular expansions, variously folded and closely packed. These collectively constitute a bud, and are formed by the extension of the medullary system. A bud consists at first of a little conical projection of the pith, which is confounded at its apex with the cortical parenchyma. As it grows, vessels become developed around the cellular centre, and the cortical parenchyma soon exhibits little conical processes of cellular tissue, which are the future leaves. The new vessels and ligneous fibres become continuous with those of the part from which the bud has been produced; but the process of medullary parenchyma belonging to the bud of a branch is soon cut off from the old pith by the formation of a quantity of a denser tissue at the point of departure of the branch, the pith of which thus becomes defined at its base in the same manner that the pith of the parent stem is defined at the root.

170. Besides the *terminal* bud, which effects the elongation of the stem in the original direction, all leaves have the power of producing buds in their axils. The axil is the angle between the leaf or petiole and the stem from which it originates, and it is in this spot alone that branches can be formed, all lateral extensions of the plant resulting from the development of *axillary* buds (VIII. fig. 6).

The buds therefore only differ in their function from seeds or embryos in the fact that the former continue the individual while the latter continue the species; for although the buds or rather the leaves are to be regarded as distinct individuals in a certain sense, still they are parts of one compound whole, and all have a closer affinity than that existing between the parent plant and the seedling. All new plants produced by cuttings or scions will *exactly* resemble in their new development the parent of which they originally formed part, while new plants from seeds have merely a *specific* identity.

171. The buds thus formed are destined to produce a generation of leaves to succeed that in the axil of which they are produced, and when this withers and falls the bud remains either in an active or passive state, according to external circumstances.

In temperate climates the buds remain dormant through the winter, and develope when the spring brings the favourable conditions. In tropical climates, where there is scarcely any interval of repose, or indeed anywhere when the conditions of temperature are not hurtful to the young bud, its leaves are almost exactly like those which are afterwards to be produced on the branch in course of formation. But where the buds are subject to the temperature of a winter, such structures would evidently be destroyed by the frost; in such circumstances the leaves of the bud are of a different nature; they are converted into what are called *scales*, which closely envelope the delicate *punctum vegetationis*. These scales vary in form and substance in the modifications which they undergo to render them fit to protect the internal parts. Commonly they acquire a slightly horny texture, or they become imbued with some substance, such as *resin*, which is insoluble in water and a bad conductor of heat. In some buds, as in the Willows, the scales are furnished with a thick down.

The leaves or scales are either so much developed as to cover one another completely (VIII. fig. 8), or, as is more frequently the case, they are rather shorter than the complete bud, and are *imbricated* (VIII. fig. 6); that is, the bases of the upper scales are covered by the summits of the next below, and so on. The scales then generally present a spiral arrangement, like the carpellary scales of the Pine cones.

Those buds which have their leaves unaltered, as is the case in tropical trees, and in rare cases in the inhabitants of temperate regions (*e. g. Rhamnus frangula*), are said to possess *naked* buds. Where they are converted into the *defensive* structures above described, they are called *scaly*.

The scales have received various names, such as *tegmenta perulæ, hybernacula,* but the term *scale* is sufficient, although they do not constantly possess this distinct form. The leaf thus modified is reduced to one or other of its parts. If the scales are formed by *laminæ*, the bud is called *foliaceous*; if by enlargement of *petioles* (*vaginæ*), *petiolaceous*; when the lateral expansions or stipules subserve this office, the buds are *stipulaceous*; stipules and petioles united enclose *fulcraceous* buds.

172. The true leaves in the interior of the bud, as their laminæ

begin to acquire volume, become rolled up in different ways, so as to take a form adapted to the small round space they occupy. This state is called the *vernation* or *prefoliation*, and each modification has its peculiar name. Each leaf considered individually may be *reclinate* (VIII. fig. 14, *a*); *conduplicate* (fig. 14, *b*); *plicate* (fig. 14, c); *convolute* (fig. 14, *d*); *involute* (fig. 14, *e*); *revolute* (fig. 14, *f*); or *circinnate* (fig. 14, *g*). These modifications may be complicated one with another; the lamina may be folded or reclinate on the petiole, or the petiolets of compound leaves may fold toward the rachis, and this again upon the petiole itself. The Ferns present examples of very complex prefoliation.

The leaves, considered in combination, may form a vernation which is *valvate* (fig. 15, *a*); *imbricate* (fig. 15, *b*, *c*); *induplicate* (fig. 15, *d*); *equitant* (fig. 15, *e*); *half-equitant* or *obvolute* (fig. 15, *f*).

These terms are applied not only to the leaf-buds, but to all parts undergoing similar modifications of form. It is chiefly in young parts that they are found, and we shall see them occurring again when we come to examine the development of the floral organs.

CHAP. VI. RAMIFICATION.

173. In the foregoing chapter we have seen that the branches are produced from buds which are either terminal or situated in the axils of leaves; these branches, bearing leaves, become in their turn covered with buds, whence originate another series of branches, which will be followed by a third, fourth, &c. If the stem be taken as the primary axis, the branches arising from it may be called secondary axes; those which spring from the secondary, tertiary, and so on. The words branch (*ramus*) and twig (*ramulus*) are applied to these divisions, but the sense in which they are used is not very strict, depending to some extent on the plant in question, and thus having frequently only a relative value. That which is a branch of a herbaceous plant would be but a twig of a tree.

174. Since the buds are developed in the axils of the leaves, it would appear necessary that branches should follow the same laws of arrangement as leaves, and that we should find them in a spiral, opposite or whorled position, like the leaves. This is the case to a great extent among herbaceous plants, where most of the buds become developed into branches; but even here there are frequently a number of axillary buds which remain undeveloped, and in ligneous plants this is still more common. In addition to this suppression of axillary buds, a second modifying cause which interferes with the correspondence of leaves and branches arises from the production of additional buds in other situations.

175. The terminal bud, which has been already alluded to (§ 169.), is the most constant in its existence. This is destined to continue the growth of the primary axis, and is first seen in the condition of the *gemmule* of the embryo. When the first term of growth is approaching a close (in temperate climates at the approach of winter), the development of leaves and stems becomes arrested, and a bud is formed at the summit of the axis. In the

following season this bud is developed, and the growth of the axis is subsequently arrested a second time in a similar manner, to form a bud for the year following. Such a stem consists of a number of branches superposed upon one another; and in a dicotyledonous tree the number of ligneous rings will consequently diminish in succession as they are examined from below upward; and if the situation of the successive buds could be determined by the examination of the stem, the age of the tree might be determined.

In many plants this terminal bud is the only one which is developed, and as there is then no lateral ramification, the stem is simple. Such stems are most frequent among the Monocotyledons, but a few examples occur in dicotyledonous plants, as in the Cycadeæ.

176. The non-development of axillary buds is sometimes irregular, and occasioned by local or special causes; thus want of light, poor soil or mechanical obstruction, may cause the buds to be abortive, to develope but slightly or die. But the process often takes place with great regularity. In the Firs, where the leaves, which are very numerous, are arranged in a spiral line, the branches appear to be assembled in whorls at distant intervals. Here the buds are alternately abortive for a certain distance up the spiral, and then a certain number are developed in the axils of successive leaves, the turns of the spiral being so close that they look like whorls. In the case of opposite leaves, frequently only one axillary bud is developed, and then, in the next pair the bud of the leaf on the opposite side produces the next branch; so that in opposite leaves, where the pairs are all in one direction, we have alternate distichous branches; where they cross obliquely, often a regular spiral (as in some of the Caryophylleæ). Many modifications arise from these influences, and it may be stated in general terms that the arrangement of branches may vary from that of the leaves by a tendency of one series of buds, bearing a constant relation of position to another series, to become abortive.

177. If the terminal bud be abortive while the axillary are developed, the stem will be very short or almost undistinguishable; the plant will grow laterally, either in all directions, or

only in a certain number if non-development of buds is occasioned by any of those constant relations just alluded to. In some cases the stem produced by the germination of the embryo soon ceases to grow, while a lateral branch takes upon itself the character of the main axis of all subsequent developments. The stem is often buried to some extent in the soil, and thus the branch arising low down may originate *in* the ground as well as above it. This occurs in the plants which are commonly known as perennials. In the first year they pass through the regular conditions of an annual plant, but at the approach of winter they die down to the ground only, beneath the surface of which the root and the base of the stem, bearing several buds, continue to live. In the following spring each bud developes into a stem, which is often thick and fleshy, and elongates considerably before producing leaves; in this condition it is called a *turio,* and the *Asparagus,* in the state in which it is eaten, affords a good example of this.

178. The subterraneous branches may elongate under ground, and then they generally produce adventitious roots. This modification has received the name of *Rhizoma,* and acquires quite the appearance of a root (VIII. fig. 16). Sometimes it continues its course horizontally, producing buds on its upper surface, which develope into branches and rise up vertically; sometimes the *rhizoma* itself turns upward and exhibits its extremity, furnished with a bud, above ground; in the latter case it generally gives origin previously to another branch resembling it, which takes its place and grows horizontally. These creeping rhizomata often acquire great length and present a series of cicatrices upon the upper surface, indicating the position of the successive shoots (VIII. fig. 16 *a, a*).

179. The *Bulb* is another form of stem peculiar to Monocotyledons, which in its modifications bears a direct relation to the aërial buds. They are divided into the *tunicated* (VIII. fig. 17 *a, b*), *scaly* (VIII. fig. 18), and *solid* (VIII. fig. 19 *a, b*) bulbs. These are subterraneous stems, bearing buds which are either terminal or axillary. The scales of the tunicated bulbs envelope the base of the stem, and being modified leaves are capable of producing buds in their axils. The scales of the second kind are imbricated like

those of the buds described in § 171, but are generally of a thick fleshy consistence. Solid bulbs are almost entirely made up of the enlarged stem, with very few tunics. The little buds which are produced in the axils of the leaves are called *cloves*, some of which may be developed upon the same bulb, and, in a few plants, for several years; others become in their turn distinct bulbs, and adhering but slightly to the parent, which dies after a certain time, become detached.

In the solid bulb there is frequently only a single bud developed, at one side, which becomes a new bulb and produces a second lateral bud, commonly on the opposite side, according to the usual alternation of leaves and branches. The difference between rhizomata and solid bulbs is very slight, depending almost wholly on the separation of the new buds from the parent. The conical base of the bulb (V. fig. 23, VIII. fig. 17 *b*) is generally considered as the stem, but is in fact at its origin a branch of the parent bulb.

180. Lateral branches taking upon themselves the office of stems in this manner may also originate above ground. Increasing the plant thus in a horizontal direction, they receive the name *creeping* stems. These pseudo-stems are generally slender and flexible, and produce buds and leaves at certain distances. The first portion forms a terminal bud, which sends up a rosette of leaves and produces adventitious roots below, which bury themselves in the ground. In the axils of these leaves new buds produce new branches, which extend for a certain distance and then terminate like the first. The Strawberry and *Ranunculus repens* afford good examples of this form of ramification (VIII. fig. 21).

These lateral shoots, which are commonly called runners (*flagellum*), wither after a certain time, and each rooted bud or tuft becomes a distinct plant. This natural process is imitated in the horticultural process of *layering*, in which a branch is bent down, so that an internode is buried a slight depth in the ground. It sends up leaves and produces roots, and may then be detached from the parent plant. In succulent plants the buds may be detached and planted separately before they have produced roots, as from the nature of their tissues the leaves can provide for their own support for a time. Such a cutting is called a *propagulum*.

181. Another instance of the tendency of buds to become in-

dependent of the parent plant is seen in that modification of the aërial bud called a bulbel (*bulbillus*). This is closely analogous to the bulb, and consists of an axillary bud developed in a peculiar manner. The scales are few in number and thickened, sometimes even blended together into a solid mass, having that fleshy consistence which all organs acquire when they are destined to be for any time self-dependent for nutrition. They gradually become detached from the axil where they are produced, and falling upon the soil reproduce the plant like a seed, presenting a distinct transitional condition between the bud and the embryo; *Lilium bulbiferum* and *Dentaria bulbifera* offer good examples (VIII. fig. 13).

182. In all the examples hitherto noticed, the branch, taking upon itself the office of the stem, retains its lateral position. In certain plants however it becomes so much more strongly developed than the central axis that the latter is pushed aside and the branch takes the vertical direction. The true nature of the parts is indicated by their relative position. The stem exhibits at certain intervals leaves without any axillary buds, and opposite to the leaves are small herbaceous branches. The continuation of the stem is thus between the leaf and the branch, and is therefore produced by the axillary bud of the former, while the herbaceous branch represents the abortive stem. In *Ricinus* and *Phytolacca* this arrangement is very evident, since the new axes produced by the axillary buds do not acquire the vertical direction, but make an angle with the internode below.

183. The preceding forms of ramification are consequent on the non-development of terminal or axillary buds. The arrangement of the branches may also be modified by the displacement of the buds, where they appear to originate at a distance from the axil. These *extra-axillary* buds may be produced by the complete abortion of certain leaves, or by the adherence of their petioles either to the stem or to the base of the axillary branch. Anomalies in the arrangement of leaves arise from these causes, as in many Solanaceæ, but flowers exhibit the greater proportion of such cases, and they will be more conveniently considered in speaking of those organs.

184. Cases diametrically opposed to the ramification conse-

quent on non-development are produced by the multiplication of buds. In rare instances we find what are termed *accessory* buds, where several buds and branches arise in the axil of one leaf (VIII. fig. 9). Sometimes they are situated immediately over one another; usually there are two, but more occur in some plants, as in the Walnut and Honeysuckles, where a series of three, four or five buds may be observed, which in the first increase in size from below upward; in the second in the contrary direction. Sometimes the accessory buds are placed side by side, and then it appears as though each stipule produced a bud beside that belonging to the petiole. This is the case in Willows and Poplars, and is the origin of the little branches that shoot out for a time in pairs from the recently cut logs of such trees.

185. The multiplication of buds most frequently consists in the production of those which have been alluded to as *adventitious* or *lateral* buds.

All the cellular portions near the surface of a stem appear to have a tendency to organize into buds when any local cause excites the vitality or accumulates the nutritive juices. Besides the stem, we find other parts, such as roots exposed to the air or leaves which are more or less fleshy, producing these buds either on their borders (*Bryophyllum calycinum*, *Malaxis paludosa*, VIII. fig. 10), or even on the surface (*Ornithogalum thyrsoideum*, VIII. fig. 11). They may be produced artificially by ligatures or wounds, which arrest the juices and cause turgescence of the parts operated on. Their form differs from that of normal buds; they are not so large, and do not possess the external system of leaves transformed into protecting scales. Produced while the plant is in active vegetation, they are at once developed; they generally make their first appearance as little excrescences, which, after becoming slightly elongated, acquire leaves. Those which occur upon leaves much resemble the bulbels (§ 181.).

186. Peculiar structures are sometimes developed in the substance of the cortical parenchyma, those bodies which in the first condition are called *nodules*. They have also been termed *embryo-buds*. They occur in the bark of certain dicotyledonous trees, such as the Cedar, Beech and Hornbeam, in the form of irregular spheroids of a woody consistence. The centre is occupied by pith, com-

pletely enclosed in a woody layer traversed by medullary rays (VIII. fig. 12); a new layer is developed every year, and as many as twenty-five have been noticed. The ligneous mass increasing in all directions often reaches the wood of the tree, with which it becomes blended, forming what is vulgarly called a knob, which may then be complicated by the double growth of the woody axis and the nodule. When several nodules, distinct at their summits, meet as they approach the surface, they form a large rounded projection, known as an *excrescence*. Sometimes they give off a branch which seldom becomes much developed, but suffices to indicate the analogy to adventitious buds.

187. Although the developments of the stem may be situated beneath the surface of the ground and produce adventitious roots, and, on the contrary, roots become aërial and by the development of adventitious buds acquire leaves, we are enabled, from the foregoing considerations, to fix upon characters by which roots and stems may always be distinguished. Stems are known by their always producing buds in the axils of leaves, arranged in a regular manner; the leaves indeed vary in appearance very considerably, their size, form, colour and consistence being liable to modification; but the regular arrangement and the nature of the buds always characterize a true stem; their absence, a root.

There is occasionally some difficulty in determining the point, as in such subterraneous branches as those which form the tubers of the Potato. The expansion of the branch here closely resembles the expansion of the roots in the tubers of the Dahlia, &c. The eyes, as they are called, are however true buds, which develope branches above ground; while the aërial buds may be made to form tubers by burying them in the ground.

188. When a stem rises in the vertical direction alone, and has acquired a certain magnitude, we distinguish the lower portion or *trunk* destitute of foliage, and the upper portion, the head or cyme, covered with leaves. The bare condition of the trunk results from the abortion of all the axillary buds, as in the Palms, for the stems of which the name of *stipes* has been proposed. An approach to such a condition may arise from the incomplete development of the lower buds or the fall of the branches. In cultivated lands we see examples in *lopped* trees of bare trunks

thus produced by the hand of man. When the growth of the main trunk has been arrested by the removal of the terminal bud, the trunk is short and thick, as is seen in *pollard* Willows, &c.

189. Plants sometimes appear to possess several stems, since the inferior branches arise at or below the surface of the ground, and taking an erect position, acquire almost an equal degree of development. These lateral branches which acquire adventitious roots are removed by gardeners under the name of *suckers* (*surculi*), and planted as distinct individuals. Some tropical trees, as the *Ficus indica* or Banyan, send down shoots perpendicularly from their lateral branches, which reaching the earth bury themselves and form adventitious roots.

190. Trees are divided into several classes, according to the size they acquire at the termination of their growth. When a plant exceeds many times the height of a man it is called a tree (*arbor*), with the diminutive (*arbuscula*) where it does not exceed more than five times. Not exceeding three times the height, and branching below, it is called a shrub (*frutex*), with the diminutive (*fruticulus*); an under-shrub (*suffrutex*) does not exceed the length of a man's arm. If the under-shrub is low and branches much at the base, it is called a bush (*dumus, dumetum*). The adjectives *arborescent, frutescent, suffrutescent*, and *bushy* (*dumetosus*) are used in the same sense as the substantives from which they are derived.

191. If the stem cannot support itself, it becomes, if lying upon the earth, *procumbent*; if adhering to some erect body, *climbing* or *scandent*. Climbing stems may either be rectilinear, as the Ivy, or they may curl round their support, receiving the name of *twining* stems, and describing spirals which turn regularly to the right (*dextrorsum*), as in the Hop, or to the left (*sinistrorsum*), as in the Convolvulus; or first in one direction and then the other, irregularly and at intervals. In temperate climates most climbing stems are herbaceous, although some are woody and acquire appreciable size, as the Honeysuckle, Clematis, and especially the Vine.

These are analogous to the *Lianas*, Menispermaceous and other trees occurring in the tropics, which twine round and reach the summits of the loftiest trees, then return upon themselves or in a straight line, passing either from branch to branch or from tree to tree, binding them together and frequently killing them by the constrictions they form. In this irregular course they lose all regularity of arrangement of organs, and the leaves are often far distant from each other and from the flowers.

192. The ramification influences the general figure of the tree in various ways not yet alluded to. If the branches pass off at a sharp angle, they become nearly erect (*recti*); if at an obtuse angle they spread out (*patentes*), examples of these two being presented by the Poplar and the Cedar. In trees which are called pendulous or weeping, the branches, long and weak, fall by their own weight into a reverse position, as in the Weeping Willow. The *patent* branches sometimes arise near the level of the ground and spread horizontally, forming a close, dense expansion, as in some species of *Mespilus*. The relative *length* of the upper and lower branches also modifies the figure of the tree.

193. Dicotyledons present us with the greatest number of true stems attaining in trees all the development of which they are susceptible, and usually much branched above. Perennial herbaceous plants offer examples of lateral and horizontal development.

These substitutions occur in the majority of the Monocotyledons, as in bulbs and rhizomata. When the true stem attains great development it is usually unbranched.

Acotyledons do not come within the same laws, since they have no true bud or gemmule in their embryo. Among them occur the only *true subterraneous stems*, as in Ferns and Marsileaceæ. When the stems ramify it is by a double terminal bud, and is consequently a kind of bifurcation.

CHAP. VII. PHYSIOLOGY OF VEGETATION.

194. Having now become acquainted with the general structure and arrangement of those organs on which the maintenance and development of plants depend, we are in a condition to take a comprehensive view of the processes in which their vitality manifests itself, and to estimate the physiological importance of the various parts which we have hitherto examined chiefly with reference to their anatomy and special or individual functions.

The vital processes are so intimately connected, and so greatly depend upon each other, that divisions into distinct classes or systems of function must be in a great measure artificial. But an arrangement sufficiently natural may be found by taking the phænomena in the order of their succession in the life of the plant; these indeed move, as it were, in a circle; the highest function, development, being at once dependent on and reproducing those of absorption and respiration; but since *absorption* must precede all else, and is that function which is most particularly dependent upon external circumstances, it affords a convenient starting-point. Next in order will follow the *circulation*, or to speak more correctly, the distribution of the fluids absorbed, bringing them within the influence of *respiration* and *assimilation*, to render them fit materials for *development* and *secretion*. The term nutrition does not appear to be applicable to any process in vegetable life. Unlike animal organisms, where absorption is continually removing effete structures, to be replaced by the nutritive powers, the organs of plants are produced by development, which continues up to a certain point; the organ after this merely acts in consequence of mechanical structure, and when effete dies and decays. In plants all is *growth*, as distinguished from the *reproduction* of removed or decayed parts, which is the office of the nutrition of animals*.

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* Of course this generalization does not apply to ultimate or ele-

ABSORPTION.

195. From what has already been said with regard to peculiarities of cell-membrane producing the phænomena of endosmose (§ 70.), it will readily be seen how perfectly the structure of the fibrillæ of the roots (§ 129.) is adapted to the absorption of the fluids around them. The nature of the development too of the radical tissues, the root always growing by its extremity (§ 136.), continually furnishes fresh cells in the most favourable condition for absorption. The absence of epidermis, that denser and more impermeable layer of tissue which is produced in other parts to moderate the transmission of fluids, is another important condition in the absorbing extremities; the delicate *epiblema* (§ 65.) by which young roots are clothed being composed of cells which have lost none of their absorbent power, while their apposition as a continuous layer guards against the entrance of solid matter into the cavities of the internal parenchyma. The roots absorb only fluid, and all substances which afterwards present themselves in a solid form within the cells, such as crystals, &c., must have entered the plant in a state of solution. Experiments have been made, placing the roots of plants in water containing finely powdered solids, such as charcoal and colouring matters; these were always found to accumulate upon the surface of the root, but never to penetrate the tissues.

196. Although roots thus reject all solid matter (and this is most probably a simple mechanical necessity), they do not appear to have any power of selection; they absorb poisons as readily as innocuous or beneficial fluids. Difference of the relative densities of fluids, as would follow from the recognition of endosmosis as the agent of absorption, is the only circumstance which requires any manifestation of preference by the absorbing surfaces.

CIRCULATION.

197. The processes which have received the name of *circulations* in plants are of two kinds; to these a third is added by

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mentary tissues, but to those assemblages of structures for a special function commonly known as *organs*.

some physiologists ; but the existence of this, as I have already had occasion to remark (§ 80.), appears to be a hypothesis based upon imperfect observation.

The simplest kind of circulation is that which has been described as the motion of the cell-contents (§ 77.). This has received the name of *rotation*, and little more is known concerning it than the simple fact of its existence. M. Dutrochet has shown that it is evidently independent of the mere physical forces, such as electricity, heat, &c., and that these only affect it as stimulants. He has recently shown that the currents in the circulation of *Chara* have nothing in common with electric currents, since they remain unaltered within the influence of electro-magnets of enormous power.

198. The circulation more particularly to be examined in this chapter is that motion of the fluids absorbed by the roots, by which the food of plants is conveyed to the organs of respiration and development, and which is called the *circulation of the sap*. This name is objectionable in some respects, as it indicates a kind of analogy to the circulation of the fluids in animals. Plants possess no proper vessels within which a true circulation, maintained by a propelling organ or heart, takes place. The motion of their fluids must be looked upon rather as a process of distribution, and the immediate cause consists in the tendency to equilibrium of density involved by the laws of endosmosis and exosmosis. In the higher classes, those plants which possess ducts and vessels (§§ 56–60.), another physical agency comes into play, which is the force called *capillary attraction*. It is known that in delicate tubes which have their extremities immersed in a fluid, the level of the fluid within the tube becomes raised above that of the fluid without, and this in a ratio proportionate to the calibre of the tubes. In the capillarity of the ducts, and in the endosmose consequent on the increased density of the fluids as they approach toward the seat of the evaporative process, we have sufficient causes to produce the rise of the sap; and the existence of these two causes is capable of direct experimental proof.

199. But we have not here an explanation of the impulse which causes the great acceleration of the movement of the sap in spring. During the winter the fluids remain to a great extent in a state of

equilibrium, and the vitality of the plant is comparatively dormant. Why is this? An inquiry into the condition of the organs and the contents clearly brings all into relation with the laws of capillary attraction and endosmosis.

In the winter all the evaporating surfaces are carefully closed up and protected by organs, often containing secretions peculiarly adapted for the purpose (§ 171.), which effectually seal them up, as it were, and defend them from the influence of external circumstances. Here capillarity clearly cannot act until the upper extremities of the tubes be put in relation to the atmosphere. Fluids do not rise in capillary tubes closed at the top.

The cells however of the buds, of the pith in the neighbourhood of the buds and in other situations, are not then filled with dense fluids, but with watery juices containing *insoluble* secretions, such as starch, fixed oils, &c., which are stored-up nutriment. The heat and moisture of spring produce the decomposition of these secretions, and the starch, oil or other substance becoming converted into dextrine and sugar, the cells are thus filled with dense mucilage and syrup. Here then is a sufficient cause for a strong endosmotic action to be set up, since this is not subject to the same statical laws as capillarity. Development is almost simultaneous, and evaporation quickly follows; the capillarity is then free to act, and the two forces are kept in vigorous action by the rapid development of structures and consequent evaporation of water and liberation of oxygen which take place.

A striking instance of this influence of the buds over the movement of the sap is seen in cases where a single branch of a vine is introduced into a hothouse, where development, taking place in the buds of that branch alone, produces a current from the root. The revival of drooping cut-flowers, when placed in water, exemplifies the action of the capillary tubes in the stem; the evidence of this, as opposed to the notion of the effect being produced by mere endosmosis, is given by the fact that it is so advantageous to make a *clean* cut across the end of the stem, so that the extremities of the vessels may be opened without laceration.

The effect of heat, the hygroscopic state of the atmosphere, and the sun's light, upon the circulation, will be most conveniently treated in speaking of the respiration and assimilation, since it is through these processes, added to evaporation, that the effect of the above agents becomes indirectly exerted in the circulation.

200. We have hitherto regarded the sap merely as moving in an ascending current, rising from the roots and making its way, which it does chiefly through the *alburnum* (§ 116.), to the buds and leaves. But the movement does not cease here; this is merely a critical point in its course, and subsequently it passes down again, particularly in that layer of developing tissue which is called the *cambium* (§§ 60, 108.), as the material out of which all new structures are to be formed. It is difficult to define clearly the nature of this descent of the elaborated juices. It is probable merely by the force of gravity that it supplies the material for the filling up of old ducts and cells, such as those of *heart-wood* (§ 116.), since these are closed at their base by new enveloping layers (§ 129.), and are no longer in a position to be concerned in the capillary attraction. In the cambium it is probable that gravity exerts considerable influence; the connection of the phænomenon with endosmosis is not so evident, since it is not in accordance with the laws of that force that a prevailing current should take place into cells the contents of which are continually becoming *thinner*, by the deposition of solid matter from the protoplasma, until this last almost entirely loses its mucilaginous character and remains as an investment of the cell-wall. That the descending current does take place all evidence shows, and it is a necessary consequence of the situation of the organs of respiration. How, and why it does so, we must be content to admit our ignorance of at present.

201. The so-called cyclosis or circulation of the latex has already been alluded to as a fallacious hypothesis. The grounds on which I take this view of it are, an elaborate examination of the subject by Mohl, who came to the conclusion that the motion was a mere result of fluids gravitating in the reservoirs, running out when the ends were cut. I have carefully repeated the observations in several plants which have been stated to exhibit this phænomenon, with the same results.

RESPIRATION AND ASSIMILATION.

202. The respiration of plants, like that of animals, is accom-

panied by a large amount of exhalation. This exhalation, the evaporation of water, which has been alluded to as one of the chief agents in maintaining and regulating the absorption of nutriment by the roots, is of course subject to great modification, from its close relation to and dependence on external conditions, such as the dryness or humidity of the surrounding atmosphere. The most important influence however is exerted by light. It has been ascertained that the amount of exhalation taking place in the shade, at a given temperature, is very much less than that occurring at an equal or even much lower temperature in the sunlight. The vapour exhaled is not always that of pure water, but may contain various proportions of the gases present in or liberated from the tissues of the plant.

203. Evaporation takes place almost entirely through the stomata (§ 66.); the epidermis, excepting in its earliest condition, being evidently designed to prevent general exhalation from the surface. Exhalation is therefore most abundant from the lower surfaces of leaves.

It has been sometimes imagined that leaves also possess the power of absorbing fluid, especially in those plants which live for a long time without roots. But these plants are always very succulent, and at the same time are provided with very few stomata; the juices being retained within their tissues are sufficient to support them for a considerable period. The cases of plants furnished with numerous stomates living a long time immersed in water are explained by the fact that evaporation is prevented, and thus again absorption is not so immediately necessary. It may be assumed that absorption is never, or at least but seldom, exercised by leaves in a normal condition.

204. The structure of the so-called spiral vessels of plants (§ 54.), so closely resembling in a cursory examination the respiratory tubes of insects, led the earlier physiologists to suppose that they were the organs chiefly concerned in the respiration of plants; hence their name, *tracheæ*. If this cannot be proved to be a mistaken view, it may at least be shown that it is very improbable.

In the first place, true spiral vessels have closed conical extremities, and their position in the stem is such as to remove them as far as possible from the influence of the air, as is the case in the leaves, where they are in the neighbourhood of the *upper* face, which is provided with the fewest stomates. In their earlier, developing condition they are filled with fluid, and subsequently their analogy to the other modifications of vessels forbids our attributing any special function to them. It appears most probable therefore that their office, like that of the other vascular and fibrous tissue, is to give strength to the parenchyma, and they are peculiarly adapted to the requirements of the tissue in which they are found. Their structure is that which gives the greatest strength and elasticity consistent with lightness. This is a sufficient explanation of their predominance in those parts where the tissue is most delicate and the growth most rapid. The medullary sheath is of course, in this view, regarded as adapted peculiarly to the early, developing condition of the pith.

The statement that the spiral vessels contain a larger proportion of oxygen than is present in atmospheric air, if founded on fact, is evidence that they are *not* concerned in respiration, since it would show that the law of diffusion of gases is interfered with in some degree, and that the oxygen liberated in the more internal portions does not pass freely out and become mixed with the atmosphere.

The analogy attempted to be drawn from the resemblances between spiral vessels and animal tracheæ becomes still less worthy of consideration when we find one so much clearer in the apparatus connected with the stomata. These orifices are not in any relation with the spiral vessels; on the contrary, they are invariably developed in the areolæ or interspaces between the nerves of leaves, and open an ample system of communication between the parenchyma and the external air. The passages from the stomata are continuous with large lacunæ in the leaves (§ 139.), and these again communicate with the general intercellular system of the plant. The law of the diffusion of gases, so graphically stated by Dalton,—" One gas acts as a vacuum with respect to another,"—is fully sufficient to explain the physical portion of the respiratory process.

205. The respiratory process must at the same time be regarded as a process of digestion, and consists of a chemical decomposition of the substances absorbed by the plant, in which these substances lose a certain portion of their oxygen, which is sepa-

rated in a free condition, while the remaining elements being in what chemists term a "nascent" state, combine to form new compounds of a very peculiar character. The production of these compounds differs from all other chemical phænomena we are acquainted with, in the fact that they can only be formed in living tissues, and they are therefore called *organic compounds*.

206. Respiration takes place chiefly in the leaves, but is also participated in by the herbaceous stems and all green parts. The stimulus upon which its activity is immediately dependent is light. The disengagement of oxygen takes place most rapidly in the full light of the sun, and this agent therefore regulates the intensity of the green colour of the tissues, as well as the development of all those structures and secretions which are dependent on the assimilation of carbon for their production.

207. The importance of the respiration of plants may be estimated from the statement that it is the only known process by which the oxygen continually abstracted from the atmosphere by the animal world by their respiration, and by the mineral world in the constant processes of oxidation which are there going on, is restored in a free condition. Even plants after their death are continually abstracting oxygen from the air, to be restored by their successors.

Again, it is in the tissues of plants alone that inorganic or mineral substances can be combined into those products which are called organic substances; therefore animals are wholly dependent upon plants for their subsistence. It is in the process of respiration that the *assimilation* (as the production of these organic substances is called) takes place, and the immediate product appears to be that mucilaginous matter or protoplasma (§§ 13, 71.) from which all the tissues and secretions are elaborated. It has been asserted that plants cannot be sustained by organic nutriment. This is stating the question too broadly, as is evident when we regard the nature of the growth of the various parasitic and infusory Fungi, and even that of the parasitic plants of the higher orders, as *Monotropa, Cuscuta*, &c. These plants exhibit little or no trace of a respiration like that of the green plants. Their food is the already assimilated matter with which their tissues come in contact, and they must be regarded as deriving their support from the organic matter surrounding their absorbing surfaces, precisely in the same way as in the higher plants the embryo or the bud is nourished by the secretions stored up in the cells of the cotyledon or analogous parts until it has become furnished with respiratory organs, and can itself fix carbon. In the development of the Yeast Fungus, carbonic acid is given off exactly as in the germination of a seed, and this not a process of respiration, but of development.

A distinction therefore must be taken between the process of respiration, in which the liberation of superfluous oxygen takes place, leaving the other elements combined in an *organic* or assimilated condition, and that process in which the assimilated matter is again chemically altered by the oxidation of a certain amount of carbon, which is liberated as free carbonic acid in plants unprovided with leaves, but under most circumstances decomposed again by green plants.

208. Green plants which fix carbon in their chlorophylle are said to be the only agents by which inorganic can be converted into organic substances, but the organic matter which is thus obtained is not immediately available for development; it is oxidized and converted into sugar, dextrine, &c., which again must combine with nitrogen and pass through the condition of protoplasma, the proteine compound which secretes or separates from itself all new structure (§§ 40, 41.). It appears more probable, especially when we consider the development of the chlorophylle granules (§ 37.), that the production of that highly carbonized substance is the result of a very high development of the respiratory process. For we are led from observation to believe that chlorophylle granules are produced from starch granules, while the latter are apparently developed by the protoplasma or mucilage. The process of respiration or assimilation therefore will, in this view, consist of the production of a proteine compound, by the agency of light, from the crude juice consisting of water holding in solution carbonic acid and ammonia. When the light is freely admitted to act, as is the case in the usual condition of plants, the assimilating process preponderates in activity over the developing power, and the excess of nutriment not being required for immediate use is deposited as starch instead of cellulose; the deoxidating process still continuing, this starch, also receiving in the process a small quantity of nitrogen, becomes

chlorophylle. Should the light be intercepted now, we shall have a retrogressive series of processes; the chlorophylle will disappear, since the respiration is reduced to such a low degree that all the carbon is required for development; the plant continues to grow for a time, its tissues weak and succulent, till all the assimilated carbon having been consumed in the production of new structures, the plant dies of starvation. This is the case when light is *totally* excluded, but a very small quantity of light is sometimes sufficient to produce sufficient respiration to maintain a low degree of vitality. Under such circumstances the per centage of solid matter in the structures is very small, and little or no chlorophylle is formed. The peculiar secretions, usually rich in carbon, such as oils or resinous matters, are but very sparingly produced. An example of this is offered in the etiolation of kitchen herbs by gardeners.

The production of the green matter is therefore a mere result of the liberation of oxygen, and not the cause of it. The degree of its development is in direct relation to the intensity of the light, which governs the activity of the respiratory process; and if we cannot explain why plants grow toward the light, we can see the purpose for which they are so constituted as to do so, since it is absolutely necessary to the continuation of their existence; without light they die of starvation.

209. In germination and in the development of a bud of any kind, whether from a bulb, a tuber, or the growing points of a stem, the young plant at first depends on the nutriment stored up in the neighbouring parts for its support. The ternary compound, starch, fixed oil, or whatever it may be which has been there secreted in an insoluble form, becomes soluble, as dextrine or sugar, and combining with the proteine compound (§ 13.) which is always present in cells capable of reproduction (§ 34.), forms the protoplasma which deposits it again in the form of cellulose. The permanent tissues being thus composed of the ternary compound, the nitrogenous matter is not exhausted by development, but continually passes onward with the growing tissue, combining with fresh carbon and water which, after the development of the roots and leaves, are supplied by the process of absorption, the oxygen of the absorbed carbonic acid being liberated in the process of respiration.

210. It is not clear under what circumstances the secondary layers of old tissue are deposited. We no longer find in them the dense protoplasma which secreted the primary layers. It is probable however that they receive their additional layers from a proteinous fluid of the same kind, which being in a more dilute condition is not so readily recognized.

SECRETION.

211. The formation of the peculiar secretions, such as the essential oils, resins, &c., the alkaloids, acids and saline compounds, are, as was stated in a preceding chapter, little understood. The production of wax upon the epidermis frequently takes place, and this is evidently analogous to the production of chlorophylle. In the latter case we have seen that most probably wax is produced from starch by the liberation of oxygen; to explain the former, it is only necessary to substitute cellulose for starch.

212. That peculiar secretion so abundant on the surface of such Confervæ as *Nostoc* and many filamentous genera, investing them with a kind of slimy coating, is nothing more than the dead and decomposing outer layers of the cell-membrane*, and is therefore represented in the higher plants by the intercellular substance (§ 83.).

213. It does not appear that plants produce any other secretions besides those required for the various processes connected with their own vegetation or reproduction. The opinion that plants excrete substances by their roots appears totally without foundation, and is now generally rejected. The real reason why a particular plant cannot be grown in the same spot for an indefinite period is, that the soluble portion of the mineral constituents required by the plant are all removed. Certain mineral substances are necessary to the growth of plants, the phosphates to the Cerealia, silica also for their epidermis; salt to all the sea-shore plants (which are found also about salt-springs); and if the soil be exhausted of these matters, it is evident that the plants will not flourish.

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* Like the mucus of animals produced by the debris of epithelium cells.

CHAP. VIII. REPRODUCTIVE SYSTEM OF FLOWERLESS PLANTS.

Sect I. THALLOPHYTES.

* ALGÆ.

214. In the simplest form of the reproduction of plants, we find an illustration of the general fact, that the lower we descend in the scale of organization the more independence does the individual cell possess, and the greater number of functions does it exercise.

The *Chlorococcus*, which has already been alluded to (§ 32.) as consisting merely of a single cell, affords us an example of the multiplication of the number of individuals of a species by the direct division of the parent-cell into four new cells. Each of these, like the parent, is at once endowed with the power of vegetation, growing by the assimilation of the nutriment in contact with the exterior of its walls, and capable of producing a new generation of individuals by the process of self-division. The actual nature of the process of the formation of the septa which constitute the walls of the new cells is at present involved in obscurity; the minute size of the plant and the dense mass of granular matter which it contains rendering it exceedingly difficult to draw a satisfactory conclusion from direct observation of the phænomena presented. In Plate I. fig. 8. is represented the *Chlorococcus* in various stages of its existence, and from analogy I am inclined to interpret these appearances as indicating the production of septa in the manner I described in speaking of cell-formation (§ 41.). If this be really the true view, it is probable that a layer of membrane is formed all over the interior surface of the parent-cell contemporaneously and continuously with the membranes forming the septa, and that the separation ensues upon the subsequent destruction of the external layers of the membrane of the parent-cell by decomposition. In many of the Nostochineæ these decomposing membranes becoming blended, persist as gelatinous envelopes enclosing a number of individual cells (IX. fig. 1.). In the Diatomaceæ, however, there is no indication of a destruction of the cell-membrane, or of the siliceous lorica of the parent; here a septum is produced which divides the parent-cell into two halves, these subsequently becoming wholly or almost wholly detached by a direct fissure, in either case constituting distinct individuals (IX. fig. 2.).

215. In the Confervæ we find an advance in organization, these plants consisting of filaments composed of cylindrical cells applied end to end. The mode of growth is an elongation of the filament by the indefinite division of the cylindrical cells, either by simple transverse septa, or as in the branching kinds, by the formation of lateral branches, which in like manner subsequently become distinct cells by the production of septa (IX. fig. 3.). In the first case this growth may be confined to the terminal cell or may be interstitial. The reproduction is effected by means of spores, which are cells developed within the cavity of the cells of the parent plant, subsequently becoming free and producing new individuals.

216. In *Vaucheria* the production of the spores takes place in cells situated at free extremities of the filaments ; in *Prolifera* any of the cells may serve the office, but the process is apparently identical in the two cases.

When a spore is about to be formed in *Vaucheria,* the terminal cell undergoes division in the usual manner; the new terminal cell however soon becomes swollen so as to acquire a clavate form, is densely filled with granular matter, and finally it bursts at the apex and discharges the spore (IX. fig. 4.). The spores of *Prolifera* appear to be formed in the same manner, but are produced in cells situated at various distances along the filament; the growth therefore is in this case interstitial, and the filament necessarily becomes broken across at the articulation to allow of the escape of the spore (IX. fig. 5.).

It is in the spores thus formed we are presented with those remarkable phænomena of motion which have been alluded to in a former chapter (§ 78.). In Plate II. fig. 25. are represented ciliated spores from *Vaucheria* and *Prolifera,* which after (and, it is said, before) making their escape from the parent-cell have an active spontaneous motion; in the course of a few hours this ceases and they begin to germinate, elongating and undergoing division by septa in the usual manner.

217. In *Zygnema* we meet with another singular fact, which as yet remains unexplained. This plant consists of filaments composed of rows of cells, which cells at a certain period bud out laterally, and coming in contact with similar buds on contiguous filaments, unite with them and the septa become absorbed, so as to open a free communication between the cells of the two filaments. The granular contents of the cells then pass across from one cell to another, and accumulate in masses which form the spores (IX. fig. 6.). This conjugation, as it is called, has been supposed by some authors to be a process of impregnation, and indicative of sexes in these plants; but this is shown to be groundless by the fact, that the conjugation is not essential to the production of spores, since these may be formed in the papillæ or lateral branches which have not united with others, and even in cells on which no papillæ have been developed.

218. It has been stated (§ 214.) that Nostochineæ become free by the decomposition of the external layers of membrane, that is, the membrane of the parent-cell. But in the case of free spores formed within, and becoming discharged from the cavity of the parent-cell, it is evident that there must be some difference in the nature of the processes of development. This is a point which presents very considerable difficulty and which requires much further investigation. The only explanation which meets all the facts respecting this formation of free spores is, that the primordial utricle (§ 34.) enclosing the cell-contents, after the production of a septum, in the usual manner (§ 41.), by which the cavity of the parent-cell is isolated, becomes detached from the cell-wall. This external cell-wall then receives no new deposits of thickening layers, but grows by intus-susception; layers of cell-membrane are at the same time produced on the outer free surface of the primordial utricle. The parent-cell frequently enlarges more rapidly than the spore, so that a perceptible interval becomes visible between their membranes. This view corresponds with that of Nägeli (§ 40.) in the main, but I believe

that the division of the primordial utricle, where two or more spores are produced, takes place gradually by a folding inward.

219. In *Achlya prolifera,* Unger has described an instance of the formation of a large number of spores in the terminal cell (IX. fig. 7.). Here the first sign of the production of spores is a reticulated appearance of the granular cell-contents, the areolæ of which correspond to the cavities of the future spores. Subsequently these become evident as distinct cells of irregular form, resulting from their mutual pressure in the confined space of the parent-cell. The parent-cell afterwards expands more rapidly than the spores, and thus affords space for the latter to acquire the spherical form and freely to manifest spontaneous motion like that of the spore of *Vaucheria.* When mature they burst through the wall of the parent-cell at its apex, and "swim" about actively in the water for some hours.

220. The fructification of those Algæ which consist of a frondose cellular expansion appears at first sight to be much more complicated than those we have hitherto considered; but when its various forms are examined in relation to each other, it becomes apparent that they may be resolved into modifications of the primitive type; the apparent complexity resulting from a multiplication of parts more than from a higher degree of development.

In the Ulvaceæ, which consist of a flat expanded layer of cells, the reproduction is effected, as far as it has been hitherto made out, in certain of the common cells of the frond which produce four cellules or spores in their interior (IX. fig. 8.); these probably escaping by the decomposition of the wall of the parent-cell, since the frond in general has a coating of that gelatinous matter already alluded to (§ 212).

221. The Florideæ, which otherwise manifest characters of a higher rank, for instance, in the diversity of form, and consistence and permanence of their structure, have the reproductive office restricted to particular portions of the frond. The *sporocarps* or cells in which the reproductive cellules or spores are developed, are aggregated in groups in the interior of certain organs called *conceptacles.* These consist in some cases of ca-

vities in the parenchyma of the frond subsequently communicating with the external surface, and in others of capsules borne upon one of the faces of the frond, or at the apex of certain of its branches (IX. fig. 10.). The sporocarps consist of elongated cells in which are formed the spores, varying in number, sometimes two, most frequently four, and occasionally some multiple of that number. These spores are apparently developed exactly in the same manner as those of the Confervaceous Algæ, but in many cases we find, intermingled with the true sporocarps, peculiar bodies which have been called *antheridia*. The nature of the antheridia, which we shall meet with again in the higher Cryptogamia, is at present quite unknown. From the researches of Decaisne and Thuret however, we have the assurance that they do not produce reproductive bodies. They consist of filaments composed of rows of cells, of which the terminal one expands so as to acquire a clavate form, subsequently bursts and discharges a number of those spiral filaments (§ 45.) which have been called spermatozoa by some writers. Since these are not zoospores (§ 216.), there is a foundation to the opinion of Schleiden, that they are mere mucilaginous secondary deposits, and that their apparently spontaneous activity is mere molecular motion; and if the description above given of the zoospores of the Confervaceæ (§ 216.) be correct, there is no analogical connection with them, although both require much further investigation.

In *Ctenodus Billardierii* (Florideæ), according to M. Montagne, the sporocarps are produced on the walls of cavities excavated in the branches of the frond (IX. fig. 9.), being the terminal cells of the filaments forming the general parenchyma. In *Delisea*, the same author represents some individuals with conceptacles (IX. fig. 10, *a*) bearing only organs resembling antheridia, others with what he calls tetrasporophores (IX. fig. 10, *b*), which consist of expansions of cellular tissue clothing papillæ, occurring in the same situations upon the frond as the conceptacles; some of these cells become sporocarps, others remaining sterile. The sporocarps vary in form from spherical to clavate. The spores of the former separate crucially like the spores of the Hepaticæ, &c.; in the clavate sporocarps the spores are arranged in a linear series. In *Lenormandia*, conceptacles resembling those of *Delisea* (IX. fig. 11.) produce sporophores.

222. The fructification of the Fucaceæ exhibits a close analogy to the above, and is contained in large clavate expansions (*receptacles*) at the extremities or borders of the branches of the frond. The conceptacles are cavities in the substance of these receptacles, and communicate with the exterior when mature; they contain both sporocarps and antheridia (IX. fig. 12.).

223. I am inclined to doubt the validity of the distinction between the antheridia and sporocarps, regarding the former merely as examples of that exceedingly common occurrence among plants, namely arrest of *special* development.

224. The Characeæ, which are now generally referred to this order, present a very peculiar form of reproductive organs. They are of two kinds; one which is called the nucule, and is definitely ascertained to germinate and produce new individuals; the other, the globule, as to the nature of which we are quite in the dark. According to the researches of K. Müller, the nucule (IX. fig. 13, *a*) is essentially a bud, developed in the axil of a pair of cells upon a lateral branch, and consists of a large central cell containing granular matter, surrounded by five elongated cells wound spirally round it; its summit is crowned by five other cells. The central cell, which is called the spore, is filled with granular matter and invested by a dense membrane, the spore-case; in germination the spiral and terminal cells decay, leaving the spore free; the latter then elongates and grows by the formation of a succession of cells at the apex.

The globule is a spherical organ, generally situated closely beneath the nucule, consisting of eight valves, enclosing a cavity, within which are found bodies of a very peculiar character. Each valve is composed of a number of flattened cells radiating from a centre and angular at the circumference, where they correspond to the cells of the other valves, forming a dentate suture (IX. fig. 13, c). In the interior of the cavity a conical cell is found, projecting from the base, and a cylindrical cell proceeds from the centre of each of the valves. These, like the cells composing the flat expanded portion of the valves, are filled with red granules.

Situated on the summits of the cells projecting internally, occur the peculiar bodies above alluded to; they consist each of a cylindrical or rather campanulate cell, bearing on its free extremity a number of filaments composed of rows of minute cells (IX. fig. 13, *d*); each cell contains a free spiral fibre of two or three coils, which, when it escapes from the cell under water, manifests an apparently spontaneous motion; it is developed out of a mucilaginous granular matter, as is shown in the figures (II. fig. 28, *a*, *b*, *c*, *d*, *e*). The globule is called the anther by some authors, but there is no apparent analogy; indeed the import of this organ is altogether unknown.

** FUNGI.

225. The spores of the Fungi are cellules developed in or on certain portions of the Thallus, and in their nature essentially like those of the other Thallophytes. The lowest forms of Fungi so closely resemble the Confervoid Algæ, that much confusion exists with respect to them in systematic works; the *mycelium* of these simpler forms consisting merely of cellular filaments, they frequently can only be identified as Fungi when they produce their fruit. In that case, though the mycelium may grow in water or other fluid, the filaments bearing spores are aërial, and stand erect above the surface of the fluid.

226. The spores of the Hyphomycetes or filamentous Fungi are produced as little spherical cells developed at the extremities of the filaments (*Botrytis*, IX. fig. 14.), sometimes in large numbers, so as to form a spherical head (*Mucor*, IX. fig. 15.).

227. The arrangement of the sporangia of the Gasteromycetes is somewhat more complicated. The filaments upon which they are borne are variously branched and convoluted, forming sometimes a reticulated expansion, as in *Stemonitis* (IX. fig. 16.), or constituting a kind of medulla enclosed in an envelope of denser texture, as in the Truffle (IX. fig. 17.) and Lycoperdon or Puffball (IX. fig. 18.). The spores are sometimes borne on the apex of filaments, at others in the cavities of thecæ or cystidia.

228. The Hymenomycetes include all those Fungi in which the reproductive bodies are borne upon a kind of membranous expansion, formed of a flattened layer of the interwoven filamentous cellular tissue (§ 51.). In these plants the sporangia are not

borne immediately upon the *mycelium*, but on peculiar organs which differ considerably in their structure in different species; that of the Agarics, as the best known, may serve as an example of the general arrangement of parts and the course of their development (X. fig. 1.). From a point on the *mycelium* a small, hollow, round body is developed, called the *volva*, which rapidly increases in size; within the cavity appears a somewhat spherical body, attached to the base by a short stalk; the under portion of this spherical body becomes hollowed, so as to enclose a horizontal annular cavity, within which the reproductive organs are produced. The lower wall of this cavity finally consists only of a membrane (*indusium*), which is torn by the subsequent growth of the organ; the upper wall, bearing the fructification on its inferior surface, becomes much thickened and developes into the expanded flat or conical summit, which is called the *pileus* or hat of the fungus. When the *indusium* is torn by the expansion of the *pileus* and the elongation of the *stipes* or stem, it is either completely detached from the latter, or giving way at the margin of the *pileus*, it remains attached as a membranous ring (*annulus*) encircling the stipes. In the course of the development of these various parts, they break through the *volva* in which they were originally contained, and which generally decays very speedily.

The *hymenium*, on which the organs of reproduction are borne, differs both in its arrangement and its situation upon the *pileus* in different tribes. In some cases it consists of vertical plates radiating from a centre, as in *Agaricus* (X. fig. 1.); in others it forms tubes, as in *Polyporus* (X. fig. 2.), or solid columns, in *Hydnum* (X. fig. 3.). In other tribes of this order the sporangia are borne on vertical, simple or branched, clavate or cylindrical bodies or receptacles, as in *Clavaria* or *Geoglossum* (X. figs. 4, 5.); in these the hymenium is superior. In what are called the Mitrati, the somewhat pileate receptacle has a superior hymenium which is never covered by an indusium (*Helvella*, X. fig. 6.). The Cupulati, for instance *Peziza* (X. fig. 7.), possess a cup-like receptacle, with the hymenium on its upper concave surface; this hymenium being originally more or less closed, before the margin of the cup expands. The Tremellini and Sclerotiacei vary as to the form of the receptacle; in the former it is more or less gelatinous, in the latter compact and fleshy. The Hymenomycetes have also been divided into two great tribes, according to the nature of the reproductive organs themselves, viz. the Thecaspori and the Basidiospori; the former producing *thecæ* or *cystidia* (X. fig. 8.), elongated cells containing generally eight free spores, often accompanied by those organs which have been called antheridia; while the latter more resemble the Hyphomycetes, since they do not appear to produce free spores in the cavities of *thecæ*, but bear them upon the apex of peculiar enlarged cells called *basidia* (X. fig. 9.), the outer envelope of the spore being apparently continuous with the membrane of the basidium. The basidia usually bear four of these basidiospores. The Thecaspori include the Cupulati, Mitrati, and perhaps a portion of the genus *Clavaria*. The Basidiospores are found in *Tremella*, &c., and also in the higher forms, such as *Hydnum*, *Polyporus*, *Agaricus*, &c.

229. According to Schleiden's views this division is false. He states that the spores are always free, that is always basidiospores, in the Fungi, and makes this the distinctive character of the order; consequently he includes the Thecasporous Fungi of other authors among the Lichens.

*** LICHENES.

230. The spores of Lichens are produced in the cavities of special parent-cells, which are called thecæ or sporangia. These are accompanied by a number of filiform cells (*paraphyses*) resembling those occurring with the sporangia of the Fuci, &c., and are collected together in groups of a definite form on the upper surface of the thallus, generally more or less immersed in its substance. The young thecæ contain a variable number of spores, usually eight to twelve, but seldom perfect more than one or two.

The reproductive organs are apparently developed indifferently on any part of the frond, and present the following characters in the course of their growth. A protuberance first appears, of various shapes in various genera, formed of a number of thick-walled roundish cells, much more densely packed than the general tissue of the thallus, and frequently of a different colour. Beneath this layer is produced another, composed of paraphyses and sporangia intermingled, but all perpendicular to the first layer (X. fig. 10.). The whole fruit growing, gradually projects more and more from the surface of the thallus, clothed by the external layer, which in the greater number of Lichens is subsequently broken through. In those in which the fruit remains closed it contains a *nucleus* in the centre, and it is among these that Schleiden includes the Pyrenomycetous Fungi. When the fruit breaks through the cortical layer, it extends itself into a shield-like, cup-shaped or linear expansion, called, when circular, *apothecium, patella* (X. fig. 11.), when linear, *lirella.* Sometimes these raise a portion of the cortical layer with them, so as to form an elevated border; at others, a portion of the upper surface grows up and elevates the fruit upon a footstalk (*podetium,* X. fig. 12.).

231. The sporangia remain closed for a long time in most Lichens, but in what are called the Coniothalami (*Calycium*) they burst very early, and the spores lie free in the fruit.

The Lichens have been divided into four tribes, according to the conditions of the fruit. In the Coniothalami the shields are open and contain no nucleus, the cavity being filled with free spores (X. fig. 13.). The Idiothalami have the shields closed at first and opening afterwards, containing free spores in a nucleus composed of the gelatinous remains of the paraphyses and sporangia (X. fig. 14.). In the Gasterothalami the shields are either always closed, or open by bursting through the cortical layer of the thallus, the nucleus containing the deliquescing or shrivelled sporangia (X. fig. 15.). In the Hymenothalami the shields are open, and the discoid permanent nucleus bears the sporangia on its surface (X. fig. 16.).

232. When only one or two of the spores are perfected, the abortive ones frequently adhere to those which are ripened, forming processes of various shapes upon their surface. In *Borrera ciliaris* it has been made out that the simple spore first formed in the theca gradually divides into two portions, presenting two nuclei; these portions remain attached, and from their peculiar appearance are called double spores (X. fig. 17.).

Sect. II. ACOTYLEDONOUS CORMOPHYTES.

* HEPATICÆ.

233. Among the Hepaticæ we meet with two modes in which the plant is multiplied, namely a production of reproductive bodies or spores, and that form in which the number of individuals is increased by buds or *gemmæ*, which become detached from the parent and are analogous to the bulbels of higher plants.

The formation of the spores presents the following characteristics. In those genera where the plant consists of an expanded stem, the capsules are often collected in heads, as in *Marchantia*; in *Jungermannia*, where there is a distinction of stem and leaf, they are solitary, as is the case also in *Riccia*.

234. As *Riccia* presents us with the simplest form, being in fact but little raised above the Algæ, it may be described first. The *pistillidia*, which in this genus have no involucre, or merely a few scales, are somewhat flask-shaped bodies more or less immersed in the substance of the frond (X. fig. 18.), the elongated apex projecting above. The pistillidium contains a nucleus which subsequently developes into a capsule containing the spores, and as this capsule does not elongate upward during its maturation, it is enveloped by the outer layer or membrane of the pistillidium, which then receives the name of *calyptra*. The spores are developed in what are called mother-cells; that is, primary cells are produced in the parenchyma of the nucleus, and each of these becomes again divided into four, which are the spores. In *Riccia* the capsule does not burst, but is absorbed, leaving the spores free in the cavity of the calyptra (*involucel*), from which they escape by its decay.

235. *Marchantia* (X. fig. 19.) exhibits a more complex organization. The capsules are collected in heads elevated on footstalks. The pistillidia are produced within involucres situated on the underside of the peltate expansions at the summit of the footstalks, these expanded portions being often stellate. The spore-cases formed from the nuclei are slightly stalked, and tearing the calyptra, burst either with distinct teeth or irregular fissures, and discharge the spores. In addition to the spores we here first meet with peculiar organs intermingled with them,

which are called *elaters*: they consist of delicate cylindrical cells, within which are coiled one or more elastic spiral fibres (I. fig. 22, X. fig. 19, *c*).

236. In *Jungermannia* (X. fig. 20.) the pistillidia are numerous, but only one becomes matured, they usually make their appearance in the centre of a bud or rosette of leaves, in an involucre called the *perichætium*; on bursting through this and the calyptra or involucel, the capsule is carried up on a delicate footstalk. The capsule in some instances (*J. pusilla*) bursts irregularly, but in most instances separates with elasticity into four valves and discharges its spores and elaters.

In *Anthoceros* (X. fig. 21.) the capsule is filiform and carries up the calyptra in its elongation; it is also two-valved and contains a central columella. *Monoclea* (X. fig. 22.) has a filiform capsule which bursts by a longitudinal slit, and also possesses a columella.

The development of the spores from the parent-cells has been traced in *Anthoceros* by Mohl. The elaters sometimes lie loose among the spores, sometimes adhere to the central columella (*Pellia epiphylla*), or to the border, apex, or inner surface of the valves.

237. The Hepaticæ also bear peculiar organs which have received the name of *antheridia*. These bodies are found in various situations; in some cases they are contained in irregularly scattered cavities excavated in the substance of the expanded stem (*Pellia epiphylla*, X. fig. 23.), or they may be borne on elevated receptacles (*Fegatella conica*, X. fig. 24.). In *Marchantia* they occur on receptacles resembling those bearing the capsules, but are situated on the upper side of the lobes (X. fig. 19, *b*). In some species of *Jungermannia* they are developed in the axils of leaves collected into a kind of catkin (X. fig. 25.). The antheridia are little ovate bodies, generally shortly stalked, and consist of a cellular external wall enclosing a large cavity. When they are imbedded in the substance of the stem, the cavity in which they lie is lined by a layer of epidermis continued in through the orifice situated over the summit of the antheridium (X. fig. 23.); the borders of this orifice are frequently elevated slightly above the surrounding surface.

238. The *gemmæ* are produced in cup-shaped receptacles developed upon the frond; they are minute lenticular bodies, which, when perfect, separate, fall off, and become distinct plants; they often emit roots before they become detached from the parent.

** Musci.

239. The capsules of the Mosses are either terminal or lateral, and arise from a little rosette of leaves, usually narrower than those distributed over the stem. In the earliest condition we find these rosettes or buds closed and containing within them the germina or rudimentary capsules, which closely resemble the pistillidia of the Hepaticæ, consisting of a somewhat flask-shaped external cellular envelope, and a nucleus attached to the base of the cavity by a short stalk (X. fig. 26, *a*). Intermixed with these bodies are also found *paraphyses*, those filamentous bodies consisting of rows of cells, which are regarded by some authors as undeveloped germina (X. fig. 26, *b*). By the growth of the nucleus, the external layer or *calyptra* of the germen is torn away at the base and carried up by the elongation; the lateral expansion of the nucleus frequently splits the calyptra at the side, but it most commonly remains for a long period as a kind of cap upon the summit of the fruit. When the calyptra is torn away from the base, a small portion of it generally remains, forming a kind of sheath (*vaginula*) round the bottom of the fruit-stalk (X. fig. 27.).

In its ulterior development the nucleus admits of a division into three separate regions. The lowest expands most in the longitudinal direction, and forms the *seta* or fruit-stalk; the distinction between this region and the central is sometimes rendered less evident by an expansion of the upper part of the seta, so that it passes gradually into the capsule; this thickened point of junction is called the *collum*; sometimes the thickening takes the form of a projection of variable form, and is called the *apophysis* (X. fig. 28.).

The central portion forms a cup-shaped, cylindrical, square or urn-shaped organ, and in the course of development exhibits the following anatomical characters (X. fig. 29.). A portion of the cells take the form of a central cylindrical or fusiform column (*columella*), the outermost become the walls of the capsule, while between these a portion of tissue of a more delicate texture is developed into spherical cells (*sporangia*), each of which produces four spores. Each spore while still within the sporangium or mother-cell becomes clothed with a peculiar external layer, which usually presents a definite arrangement of wart-like projections and areolæ upon its surface. The walls of the capsule are double, and composed of a tissue made up of densely-packed cells. Between these two layers (*membrana interna* et *externa*) there is a layer of loose spongiform tissue which is often absorbed previously to the full maturation of the fruit.

At the summit of the nucleus the layer of tissue continuous with the external wall forms a kind of lid (*operculum*, X. fig. 30, *a*), of a flat, convex, or apiculate form. Beneath this, between the capsule and the operculum, there is in most Mosses an annular layer of cells, made up of three or four rows (*annulus*). The columella is continued up to the point of the operculum, and when the latter falls off, which it does by a circumscissile dehiscence, the upper extremity of the former appears in the centre of the membrane closing the mouth (*stoma*) of the capsule. This tissue between the operculum and the columella developes into a very peculiar structure. It splits into a number of teeth (4–64) lying side by side in one plane (*dentes*), or again splitting, forms two rows one within the other. The inner row consists of broad teeth (*processus*) alternating with the teeth of the outer row, and between the processes more delicate teeth (*cilia*); the teeth of the inner row sometimes remain partly or wholly undivided, so as to form a kind of membrane (X. fig. 31.). The cells of the teeth of the outer row are almost universally irregularly thickened on the upper and under walls, so that the horizontal septa formed by these, when the cells become dry, project laterally as well as externally and internally, giving the teeth the appearance of being articulated. These projections are called *trabeculæ* (X. fig. 31, *d*).

240. The antheridia of Mosses are produced in little buds like those in which the capsules make their appearance, in some cases however having more of a flattened, discoid form; or they may be intermingled with the germina in the same bud. They present the appearance of little ellipsoidal cellular bodies,

having a stalk of variable length. The microscope detects a dense opake mass in the interior of the expanded portion (X. fig. 32, *a*). At a later period an external pellicle composed of one layer of cells may be distinguished surrounding a cavity which is at first filled with mucilage, but afterwards is occupied by a closely-packed but very delicate cellular tissue. In each of the cells of this tissue occurs one of the spiral fibres (§ 49. Pl. II. fig. 29) of two or three turns, exhibiting an active movement in water. Along with these are found the *paraphyses* or filiform cellular bodies (X. fig. 32, *b*); apparently abortive antheridia.

*** FILICES.

241. The reproductive organs of this class are always developed from the parenchyma of the leaf and are borne upon the posterior surface. They are situated upon the nervures, and in some cases the whole of the surrounding parenchyma disappears, so that the leaf is metamorphosed into a spike bearing capsules. Where the fertile frond is little altered in its form, the fruit is found in the shape of little collections of capsules called *sori*, upon the posterior face, often at the margin, and generally covered by what is called an *indusium*, which consists of a little membranous process continuous with the epidermis (XI. fig. 1.). The shape of the sori as well as that of the indusium, and the point of attachment of the latter to the leaf, vary in different genera. Sometimes the indusium is a mere fold (XI. fig. 2.), or a shield-like, stalked body, or it may be united at its margins with a production of the frond so as to form a cup. The capsules are attached to the frond beneath the indusium, this portion of frond being generally a little elevated, so as to present the appearance of a little stem or ridge; in *Hymenophyllum* and allied genera this stem is much elongated, and the capsules are then borne upon this, which is free in the interior of the cup formed by the frond and indusium (XI. fig. 3.). The capsules or *thecæ* are developed from cells budding from the parenchyma, which each divide into two, one cylindrical, the other spherical; the former becomes the stalk of the theca, while the latter produces a large number of cells, part of which, the interior, are the mother-cells or sporangia in which the spores are formed; the

outer cells unite to form the membrane of the capsule. Some of the cells of this membrane have a special structure; a zone of cells, either vertical and attached to the base, or oblique and free, become much thicker in their inner and contiguous walls than in the outer, so that when the capsule is ripe, the unequal contraction tears the delicate membrane enclosing the spores (XI. fig. 4.): this zone is called the *annulus*. The spores, produced in the sporangia, are clothed with a peculiarly-marked outer membrane (XI. fig. 4, *a*).

In the spiked fructification, the spores are formed from the parenchyma upon the nervures, which expands so as to form large capsules arranged upon the simple or pinnately-branched rachis; these sporangia burst by a vertical fissure at the summit, and are sometimes provided with an imperfect *annulus* (XI. fig. 5.).

242. The only organs resembling the antheridia of the preceding classes are bodies found upon the primary leaf of the germinating spores. They are cellular papillæ seated on the border or upper surface of the leaves, and the cells each contain a spiral fibre (IX. fig. 6; II. 26, *b b*).

243. Bulbels or gemmæ are often formed from the tissue of the leaves, either on the surface or in the angles of the lobes; these drop off and become independent plants. In germination the spores of Ferns first produce a parenchymatous expansion which appears to be analogous to the cotyledons of the higher orders.

**** EQUISETACEÆ.

244. This order differs from the rhizomatous Ferns in sending up erect branches instead of leaves from the rhizoma, at the summit of which primary branches (and in some cases only on special simple branches) an ovate or more elongated fructification is produced. It consists of a large number of whorls of leaflets closely approximated and converted into organs closely resembling the anthers of the Yew. They are shield-like, usually hexagonal bodies supported on a stalk inserted in the centre of the under-surface. The spores are produced in capsules situated beneath the shield and surrounding the stalk, and are

from five to seven in number (XI. fig. 7). Within these, the mother-cells (sporangia) each produce one spore, which is provided with two elastic spiral appendages (XI. fig. 8). The spiral fibres at first completely cover the wall of the mother-cell and enclose the spore; in the course of the growth of the latter the turns of the spirals become separated, and finally they burst through the delicate outer wall of the sporangium, and the capsule splitting longitudinally, the spores are emitted. The spiral fibres or elaters remain attached to the middle of the spore, and by their elasticity facilitate its escape from the capsule.

***** LYCOPODIACEÆ.

245. The capsules of this Order are generally situated in the axils of the leaves, the fertile leaves being often collected into a long clavate spike. Müller states that the *thecæ* are always productions of the stem and not of the leaf; and indeed in *Bernhardia* they are arranged in twos and threes at the apex of short branches.

The capsules are of two kinds; the first (XI. fig. 9), which are round, reniform or crescentic, are analogous to the thecæ of such ferns as *Ophioglossum*, and originate from a papilla of cellular tissue, the external layer of which forms the wall, while the contained cells become sporangia, and produce each four spores in its interior. The mother-cells are subsequently absorbed, and the free spores escape by a slit, vertical or horizontal, from the external capsule. Spring calls these organs *antheridia*, but they clearly are not analogous to the *antheridia* we have hitherto mentioned. The germination of these spores has not been observed.

246. Müller minutely describes the second kind of capsule, which has also been noticed by other authors. This is of a roundish tetrahedral form, and is met with in the same situations as the above. According to Müller it consists of a cellular membranous wall, forming a cavity, from the base of which, at the point corresponding to the apex of the branch, a cell is developed, quite independent of the wall and a production of the axis (XI. fig. 10). This mother-cell produces four spores in its interior. The capsule bursts with two valves, emitting these four spores, which are much larger than the other kind, and have been ex-

amined in germination. This process exactly resembles the germination of a dicotyledonous embryo, except that the cotyledons are *produced* during germination (XI. fig. 11). Since these spores are direct productions from the axis, Müller regards them as analogous to ovules, and the capsules thus representing ovaria are called *oophoridia*. No impregnation takes place. He regards the Order as intermediate between the Filices and the Marsileaceæ, where there is the first occurrence of pollen and ovules.

247. *Isoëtes* presents two kinds of capsules, which are imbedded in the substance of the base of the leaf (XI. fig. 12). The structure of these is essentially the same as of those of *Lycopodium*; and if Müller's observations are correct as to the mode of development of the large spores in the latter genus, those of the former will probably be found to resemble them.

248. The Lycopodiaceæ sometimes produce fleshy axillary bulbels.

****** RHIZOCARPEÆ.

249. The reproductive organs of this Order have long afforded a subject for great difference of opinion among botanists, since although the descriptions of the various parts given by different authors agree very closely, scarcely two writers have agreed as to their nature. If the later observations of Schleiden prove to be correct (and there is every reason to depend upon them), they are of exceeding interest, as offering an example of the production of a new individual through the impregnation of an ovule by pollen, such as occurs in the phanerogamous plants; this difference alone existing, denoting their inferiority of organization, that the process of impregnation, and consequently the development of the embryo, takes place after *both* ovule and pollen have become detached from the parent plant. Since this Order thus acquires so much importance in a physiological point of view, it will be quite worth while to consider the different forms somewhat minutely.

250. In *Pilularia* the reproductive bodies are produced in little roundish capsules, situated at the base of the leaf-stalk (XI. fig. 13). The outer envelope consists of a dense coriaceous coat,

which subsequently dehisces by four valves; the cavity is divided into four chambers by vertical partitions; from the interior of the external wall of each cavity proceeds a gelatinous process of cellular tissue, which bears the two kinds of organs called by Schleiden anthers and ovule-sacs.

The anthers appear to be identical in their development with the thecæ of the Ferns, and are pyriform sacs originating from little papillæ of cellular tissue, which subsequently form the two regions, the outer cellular envelope and the contained parenchyma, the cells of which become mother-cells, and each produce what have been called spores, but which are in fact pollen grains (XI. fig. 14). The ovule-sacs closely resemble the anthers in their original condition, and according to Valentine, even up to the point of the production of the four cells in each mother-cell; but then a change takes place; the cells in fours are ruptured, their contents extravasated, and this occurs to all but one group; in that group three out of the four burst; the remaining cell takes up a central position in the sac, and becomes developed into the ovule, which in its perfect state is solitary, and presents the following characters. It possesses a central sac (the embryo-sac), consisting of a simple cell filled with starch, oil, etc. (XI. fig. 15); this is surrounded by a dense white leathery coat, composed of cells almost undistinguishable, and at the apex of the ovule presents an orifice through which projects a papilla (the nucleus), which is in contact with the embryo-sac. The whole is enclosed in an envelope of gelatinous, almost confluent cells, which contains the remains of the ruptured abortive quaternary groups of cells. The nucleus is at that end of the ovule most distant from the point of attachment.

According to Schleiden, the anthers and ovule-sacs, when discharged from the bursting capsule and swimming in the water, exhibit the following phænomena:—A grain of pollen comes in contact with the nucleus (XI. fig. 16), becomes imbedded in its substance, and there expands and forms the embryo, with cotyledon, radicle and axillary bud or plumule (XI. fig. 17).

251. The fruit of *Marsilea* is somewhat more complicated in its arrangement. It is contained in an ovate flattened capsule, situated, like that of *Pilularia*, at the base of the petiole (as in

M. pubescens) or on the lower part of that organ (*M. quadrifolia*); the coat is dense and coriaceous, and dehisces by two valves. The cavity is divided first by an imperfect longitudinal septum into two compartments, which are again divided by cross partitions into from five to twelve chambers (XI. fig. 19). At the region opposite the point of attachment of the capsule arises a cord of cellular tissue of a gelatinous character, which lies free in the space where the longitudinal septum is deficient along the upper side from the base to the apex of the capsule, and on the dehiscence of the latter is protruded, bearing the ripe sacs: to this are attached a double row of little sacs of a similar tissue, corresponding in number to the chambers and lying within them. Within each sac is a kind of placenta of gelatinous cellular tissue, to which the organs of reproduction are attached, the ovule-sacs, least numerous, occurring chiefly in the centre of that part turned towards the longitudinal septum (XI. fig. 19, *a*). The stalked ovule-sacs enclose a single ovule, the nucleus of which is turned toward the peduncle; they are subsequently ruptured. The anthers, irregularly pyriform, contain a large quantity of pollen grains, which possess a peculiar gelatinous envelope in addition to the usual external membrane. Esprit Fabre, who considers these bodies anthers and ovules, states that he has observed that if they are left apart in water they putrefy, while if mixed in water the anthers burst and the grains of pollen collect about the nipple (*nucleus*) at the surface of the water, after which the ovules fall to the bottom, where, at the end of seven or eight days, germination commences.

252. *Salvinia* bears the anthers and ovules in distinct capsules, which are collected on little branches originating from the base of the petiole and hanging like catkins in the water. Each catkin has one capsule rather removed from the rest, and nearer the base of the branch; this alone contains ovule-sacs (XI. fig. 20). The capsules in *S. natans* are somewhat globular, compressed vertically and marked by deep furrows like a melon; each projecting ridge is hollowed into a cavity (XI. fig. 20, *b*) divided by a horizontal septum. The capsule does not burst regularly, but the delicate cellular tissue of which its walls are composed becomes decomposed; in *S. verticillata* the capsules are clothed

with rigid hairs. From the base of the cavity arises a cellular column, somewhat swollen at its upper extremity (XI. fig. 21, *a*, *b*), which bears in the one capsule ovule-sacs; in the others, anthers. The peduncle of the ovule-sacs is composed of several rows of cells; the sacs which are ovate consist of a single layer of cells, and enclose an ovule the nucleus of which has the same direction as that of *Pilularia*. The peduncle of the anthers is a single string of cells; the anthers are globular, and the pollen has a thin smooth outer membrane.

Savi experimented on the germination of *Salvinia*; he relates that he placed in separate vessels, anthers alone, ovules alone, and both together; in the first two experiments there was no development; in the third the ovules rose to the surface and germinated. Duverney questions these results, and states that with him the ovules germinated when separate from the anthers, but it is very possible that the ovules were accidentally fertilized. Mr. Griffith regarded certain moniliform filaments occurring on the stalks of the ovules as the male organs, but this can hardly be correct; these hairs are more probably analogous to the paraphyses (§ 240.) of the lower plants.

253. From the observations of the last observer, it appears that *Azolla* has a structure somewhat similar to the preceding genus. The capsules are attached in pairs to stem and branches, with a membranous involucre; the capsules are of two kinds, the globose and oblong-ovate. The oblong-ovate capsule opens by circumscission (XI. fig. 22), and contains a large yellow sac composed of a fine membrane, filled with oleaginous granular fluid, and surmounted by a mass of fibrous tissue, by which it adheres slightly to the calyptra. On the surface of the fibrous tissue are nine cellular lobes (XI. fig. 23), the three upper the largest. This is probably an ovule resembling those of the other genera, the lobes representing the nucleus. The globose capsule has a rugose surface (XI. fig. 22) from the pressure of the secondary capsules (anthers) within; these are numerous, spherical, and attached by long capilliform pedicels to a much-branched central receptacle (XI. fig. 24). It seems most probable that Griffith observed these in an immature condition, since he describes them as each containing two or three cellular masses presenting radi-

ciform prolongations on their contiguous surfaces, and containing numerous yellow grains (pollen) which he calls spores in their interior.

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254. With this Order we have arrived at a stage of development which is very closely approximated to that of the Cotyledonous orders; and in the various forms we have traced we see all the members of a graduated series. In the consideration of the reproduction of the higher classes a somewhat different plan must be adopted; the embryo being perfected while in connection with the parent in all the orders, it is found more convenient to take the descriptions of the various modifications of parts under the heads of organs rather than of families, as has been hitherto done.

CHAP. IX. REPRODUCTIVE SYSTEM OF FLOWERING PLANTS.

Sect. I. INFLORESCENCE.

255. Flowers are to be regarded as composed of a number of whorls of modified leaves, collected together in consequence of the non-development of the internodes of the axis; flower-buds are therefore analogous to leaf-buds from which branches are produced, and we may expect them to be subject to similar laws of arrangement. That portion of the stem which is especially devoted to the production of flowers is called the *inflorescence*, and the leaves borne upon it being generally modified in their form, are distinguished by the name of *bracts*. The flower may either be terminal (§ 175.), thus arresting the further growth of the axis upon which it is seated, or axillary (§ 170.), and in this case the form of the inflorescence is regulated by special laws analogous to those which I have already alluded to as affecting the distribution of the leaves and branches.

256. The stalk of a solitary flower, whether terminal or axillary, is called the *peduncle*; in the latter case the floral leaf is the *bract*: where lateral branches are again produced in the axils of *bracteoles* seated on the peduncle, that portion of the stem between the flower and the bracteole is called a *pedicel*.

257. When the inflorescence is enclosed in a single large bract, as in Aroideæ, this is called the *spathe* (XII. fig. 1); where a number of bracts are collected into one or more circles surrounding the inflorescence, these are collectively named an *involucre* (XII. fig. 2). It is often difficult to define any line of demarcation between the leaves and bracts upon a stem, the change of form occurs in a gradual series from below upward, and consequently there is frequently great uncertainty in distinguishing between a stem bearing many solitary axillary flowers and a spike or raceme.

On the other hand, the bracts, in some orders especially, gradually lose their foliaceous character, become mere scales, as in those bracts called the *paleæ* of the Compositæ, and even disappear altogether, leaving the receptacle naked. In the Umbelliferæ we find a *partial involucre* at the base of each umbel, and an *universal involucre* at the base of the peduncles of a compound umbel; among these involucres bracts sometimes occur possessing the true foliaceous character, sometimes becoming gradually metamorphosed into leaves, or the bracts are very little developed or wanting, either to the simple umbel or the compound, or altogether absent. In the Boragineæ also, cases occur where the floral leaves pass gradually into bracts, and the bracts become smaller upwards, or, as in *Symphytum*, are wanting.

On the other hand, some of the general involucres are to be looked upon as bracts which have become developed at the expense of the flowers; as in the involucre or general calyx of Compositæ, the *glumes* of Grasses which are often barren. It may then be assumed as a general law, that with the exception of the terminal flower, every flower is situated in the axil of a bract, or at the point corresponding to the axil of an undeveloped bract.

258. Both peduncle and pedicel vary as to the length of time they remain attached to the stem. They are called *caducous* when they fall off soon after the opening of the flower, as in the male flowers of Amentaceæ; those falling off with the ripe fruit, like the Cherry, are *deciduous*. In many cases they remain attached after the ripening of the fruit and the scattering of the seed, and then are *persistent*; if they acquire peculiar development during the maturation of the fruit, as is the case in *Anarcardium* and other plants, they are named *excrescent*.

259. The general form of the inflorescence is frequently much altered during the flowering period, by the order in which the flowers successively expand.

When the opening of the flowers follows the order of age, first becoming perfect in the lowest, or in an umbel or capitulum, in the most external, the inflorescence is called *centripetal*.

The reverse order of course will be the *centrifugal*, and is found where the growth of the rachis is arrested or *defined* by the expansion of the terminal bud first; whence it follows that all additional development of flowers must be axillary.

Occasionally the flowers follow no definite order of unfolding; for instance, in *Dipsacus sylvestris* the flowers situated in the middle of the cylindrical capitulum open first, and from thence both upward and downward. This is the indefinite inflorescence (*inf. vaga*). In the compound forms of inflorescence the order of succession is regulated by similar laws; but it is not necessary that the individual heads should follow the same law as the primary ramifications. For instance, in most of the Compositæ the capitula have a centripetal inflorescence, but the terminal capitulum generally expands first, consequently all the others must be axillary, and be perfected in a centrifugal order. In *Sanguisorba* both have the centrifugal inflorescence; while in the majority of the Labiatæ, the flowering branches are developed centripetally and the inflorescence of each is centrifugal.

The following are the principal forms of the inflorescence:—

260. Where the axis terminates in a single flower-bud, this the simplest form of inflorescence is called a *solitary terminal flower*, as in the Tulip and many other bulbous plants. A similar solitary flower may terminate an axillary branch bearing leaves, an example of which is found in some of the Caryophylleæ.

261. *Solitary axillary flowers* are borne on peduncles situated in the axils of leaves, as in *Lysimachia nemorum*.

262. When the leaves borne on the upper portion of the axis are crowded together and altered in form so as to be distinguishable as bracts, with axillary flowers, we have a *Raceme* (XII. fig. 3). Several modifications of this kind of inflorescence have received particular names.

a. The *Spike*, where the axillary flowers are sessile (XII. fig. 4).

b. The *Spadix*, which is a spike where the flowers have no special bracts, but are enclosed in a *spathe* (§ 257.), and densely crowded upon a fleshy axis (XII. fig. 5), which is often prolonged beyond them as in *Arum* (XII. fig. 2), or even branched as among the Palms (*spadix racemosus*).

c. The *Amentum* or *Catkin*, a spike with large scale-like bracts and the flowers closely aggregated; usually caducous in a single piece, as in the male flowers of Cupuliferæ, &c. (XII. fig. 6).

d. The *Strobilus* or *Cone* is a kind of spike found chiefly among the Coniferæ, where the foliaceous organs are persistent and become woody (XII. fig. 7). The female inflorescence of the Hop is generally called a Strobile, but differs only in form from the other catkins.

e. The *Panicle* is formed by the branching of the peduncles of a raceme, so that the flowers are borne on pedicels.

f. The *Spikelet* is the simple peduncle of the Grasses and Cyperaceous plants, which bears few flowers, destitute of special bracts, the whole being enclosed at the base in two sterile bracts or *glumes.*

g. The *Corymb,* a raceme where the peduncles have grown unequally, so that the flowers of the inflorescence are nearly all in the same plane at the summit (XII. fig. 8).

h. The *Thyrse* consists of a panicle where the flowers have very short pedicels.

263. When the upper portion of the axis, instead of extending upwards, as in the spike, becomes thickened and expanded laterally, the flowers are borne upon this terminal head, which is called a *Capitulum.* The varieties of this type are—

a. The *Anthodium* or true Capitulum, the *Flos compositus* of Linnæus, consists of a dense head of flowers which are respectively situated in the axes of bracts (more or less arrested in their development or even wanting), and surrounded by one or more circles of sterile bracts, forming an involucre (XII. fig. 9).

b. The *Hypanthodium,* a term applied to the flowers of some of the Urticaceæ, such as *Ficus* and *Dorstenia,* but scarcely to be distinguished by a general definition in words from the foregoing. In the Fig the peduncle is fleshy and excavated, bearing the flowers, provided with bracteoles in its interior (XII. fig. 10); in *Dorstenia* the peduncle is expanded into a large flattened receptacle (XII. fig. 11).

264. The *Umbel* may be looked upon as a kind of capitulum where the flowers are elevated upon pedicels, their bracteoles forming a whorled involucre (XII. fig. 12). The *Compound* Umbel is formed by the branching of the peduncles in an umbellate manner, and sending off the pedicels forming simple umbels (XII. fig. 13).

265. All these forms of inflorescence are developed in the centripetal direction, and are said to be *indefinite*. Those which blossom downward from the summit have been included by most authors under the general name of *Cyme*. This is, generally speaking, a kind of Corymb, where the terminal flower is developed first, and where, consequently, all new growth must take place in the axils of the leaves below; but as this new growth frequently takes the form of leafy branches, the relative position in the inflorescence is continually becoming altered. Among the Caryophylleæ are found striking examples of this: in *Arenaria lateriflora* an axillary branch is developed below the terminal flower; the growth of the branch beyond the flower soon renders this lateral and apparently axillary; when two axillary branches are produced, the terminal flower is left in the fork. These branches terminate in flowers in a similar manner, and again produce either branches or flowers in the axils of their bracts. The central flower in a head of this kind therefore is always the oldest. All these forms are included under the general head of the *cymose* or *centrifugal* inflorescence; several of them have been particularized :—

a. The true *Cyme,* found in all species of *Viburnum, Sambucus,* &c., which has the structure first described, but in which the flower-buds are *all* perfect before *any* of them open. The general form is the same as that of a corymb, but it may be distinguished by the three-forked division of the peduncles, also by the fact that the central flowers of each cluster open first; and since the central clusters represent the apex of the stem, the expansion of the whole is centrifugal.

b. The *Fascicle* is a cyme with the flowers closely aggregated and nearly sessile, as in the Sweet-William.

c. A *Glomerule,* the crowded heads of flowers in the centrifugal inflorescence of some Urticeæ, Chenopodiaceæ and Junceæ.

d. Scorpioid or *Helicoid Cyme* is the term applied by most authors to one-sided racemes like those of the Boragineæ, which are usually coiled up spirally or in a circinate manner at the undeveloped upper extremity.

It is stated that this curling of the axis is consequent on the peculiar nature of the growth. Each flower is said to be terminal, the first to the stem, the second to the primary axillary branch on which it is borne, and so on, the direction of the growth of the whole being thus altered and turned aside at each node. Thus in alternate-leaved plants the apparent axis will always appear to be between the flower and the bract (XII. figs. 14, 15). In opposite-leaved plants, on the other hand, plants having this structure possess a terminal flower and an axillary branch continuing the growth, the other axillary branch being abortive. Schleiden however denies the truth of these statements altogether, and declares that we have here nothing more than an unilateral raceme or spike, consequently that the inflorescence is not centrifugal but centripetal.

266. All these forms—the spike, raceme, head, &c.—may be situated at the extremities of branches as well as at the apex of a stem, and also in the axils of leaves. A peduncle arising below the ground, as in *Primula* and many bulbous plants, is called a *Scape* or *radicle peduncle*. In some of the species of *Solanum* the axillary peduncles adhere to the stem for a short distance, so as to appear to arise above the axil. In *Tilia* the peduncle is adherent to the midrib of the bract to a considerable extent. The clusters of flowers of the Labiatæ are frequently called whorls, but they are in fact cymes, and are axillary to the two opposite leaves. They have been called *Verticillasters* (XII. fig. 16).

267. Fasciation.—In some cases the stem seems to undergo a peculiar metamorphosis and to enlarge into a kind of phyllode, for instance in *Xylophylla*, bearing fascicles of flowers upon its borders. Some of the cases have been cited as presenting an example of the production of flowers upon leaves, as in the case of *Ruscus*, but the more general opinion is that they are phylloid branches.

The Cockscomb is another curious example of fasciation, where the branches are expanded laterally in one plane, bearing the flowers in a sort of crest on their dilated extremities.

Sect. II. The Flower in general.

268. Flowers have hitherto been spoken of as consisting of a number of whorls of modified leaves arranged on the extremity of an axis or branch; but since the organs of which they are

made up differ so much from leaves, properly so called, both in appearance and function, we must now proceed to examine the grounds upon which this theoretical notion of a flower is based. The generality of cultivated, partially double flowers will afford an example of a graduated series of forms in evidence of the possibility of the conversion of the organs one into another, or rather the possible production of any one of them from any of the little cellular papillæ under which they all make their first appearance; but no better instance of the normal existence of a series of this kind can be found than the common white Water-Lily. At the circumference of this flower the leaf-like bodies are green exteriorly and white within; next to these are a number of circles of white leaf-like expansions, longer than the green bodies in the outer whorls, and gradually becoming smaller inwards, until they acquire a narrow ovate form and a yellow colour. These gradually become narrower as we proceed inward and exhibit two thicker prominences at their apex, like longitudinal folds; in those situated more internally these folds come to occupy more than half the length of the organ, and, lying in contact, form the whole of the upper part of it, supported by the narrow strap-like base. In the centre are a number of yellow thickened bodies which are single and much shorter than the preceding, and they form a kind of crown to a large central body, which on being cut across displays cavities radiating from the centre and equalling in number the crowning bodies. These cavities are filled with minute bodies, the ovules, attached to the radiating septa.

If we take now a flower of the *Ranunculus aquatilis*, we find it to be composed of four very distinct kinds of bodies; the most external green, resembling leaves as closely as the majority of bracts, which we have seen (§ 257.) are often undistinguishable from true leaves; within these are five white leafy expansions, surrounding a number of thread-like filaments bearing two-lobed yellow bodies on their summits. The centre is occupied by hollow green organs which are distinct from one another, and each contains an ovule. In this flower therefore we have four distinct kinds of organs, and on looking at the *Nymphæa* we readily recognize the three outer series to be represented among the numerous modifications existing there; the central organs of the *Ranunculus* represent the cavities of the central body of the *Nymphæa,* separated from each other. A more direct proof of the leafy nature of these central organs is offered by double garden flowers, where they are often replaced by leaves, as in the double Cherry, and it is shown even in a normal condition by many of the Magnoliaceæ; in *Liriodendron tulipifera* the foliaceous character is possessed in a great degree by the central organs. These organs are divided into two sets, namely the *floral envelopes* and the *essential organs* (XII. fig. 18).

269. The former include the two outer or lower kinds possessing the leafy character; they receive this name since they do not appear to serve any special office in the peculiar processes belonging to the reproductive function of the flower, and are often wanting. The two kinds are called respectively the *Sepals,* which are the most external and generally green, forming collectively the *Calyx* (*a*); and the *Petals,* the more delicate and generally more brightly coloured rows, which compose the most conspicuous part of the blossom called the *Corolla* (*b*). In many instances it happens that only one whorl or circle of envelopes is present; this is then generally called the calyx, whatever its colour may be, since the calyx is often coloured and *petaloid,* and the corolla, on the other hand, sometimes greenish and resembling a circle of sepals; the chief point of distinction is founded upon position.

In the Monocotyledonous families the floral envelopes are very commonly all petaloid, and the term *Perianth* is generally applied to such a structure; it is also sometimes called a *Perigone.*

270. The essential organs are the two other kinds. The external row next the petals are the *Stamens,* which consist of two distinct parts—the *Filament* supporting the *Anther* (*c, d*), the thickened body or case which contains dust-like substance called the *Pollen.* A collective term is applied to these organs, and this, *Andræcium,* therefore expresses the whorl or whorls of leaves developed into stamens.

The central organs, constituting the fourth kind, are called the *Pistils,* with the collective name of *Gynæcium.* The *pistils* are quite as often united together in one mass as distinct; the terminal portion only is commonly free. Each metamorphosed leaf, bearing ovules, whether forming a simple ovary, or one portion of a compound, is called a *Carpel.* Whether distinct or united with the rest, the pistil is divided into three regions: the lowest inflated portion at the base, containing the seeds in its *cell,* is called the *Ovary*; the slender prolongation upward is the *Style*; and the apex of this, which terminates in a great variety of forms, is called the *Stigma* (*e, f, g*).

These are called the *essential organs,* because the presence of both kinds is necessary for the production of fertile seeds; but even one of these kinds may be absent in a flower, or even in all the flowers of a single plant, which in such circumstances are called *staminal* or *pistillate,* as the case may be; they are very frequently called *male* or *female* flowers, but such a term involves at least a hasty generalization in the present state of our knowledge of the physiology of the development of ovules.

271. The apex of the peduncle on which all these organs are situated is called the *Receptacle,* which by the modifications of its form, both in lateral expansion and longitudinal development of its internodes, exerts considerable influence on the form of the flower. The organs of the flower are attached to it like the leaves on a stem, in a spiral (§ 165.) arrangement, but by the non-development of the internodes they often become approximated so closely as to appear like whorls situated one above another; or as in many cases, by the radial extension of the receptacle, they come to be all nearly on one plane, in circles one within another, in the order—1. Calyx; 2. Corolla; 3. Andræcium; 4. Gynæcium.

If we accept the views of Schleiden with respect to placentation, the receptacle also includes an additional system of prolongations, since he regards the ovules as arising from the axis and not from the margins of the carpellary leaves. This subject will be more fully considered when we come to describe the structure of ovaries.

272. Many plants possess bracts arising immediately below the sepals and alternating with them; some authors include them as parts of the flower, under the name of *epi-calyx,* but they are generally described as an involucre (XII. fig. 19).

273. When a flower is made up of all the four systems of

organs, viz. sepals, petals, stamens and pistils, it is what is called *complete*. Complete flowers may be *simple* and contain only one row of each kind, and they are then *regular* when the whorls possess equal numbers of organs; if the members of each series are uniform in *size* and *shape*, they are *symmetrical*, and *vice versâ*. Flowers possessing all these qualities may be found and can be taken as types; for instance, among the dicotyledons we see a tendency to produce regular flowers with symmetrical whorls of five organs; again, in the monocotyledons the number three appears to predominate. In typical flowers of this kind the organs of each whorl will be found to alternate with those of the whorls external and internal to it, and this is regarded as an universal law. But among the innumerable diversities of form and structure existing in the flowering classes, this primitive simplicity is sometimes very difficult to detect; a number of interfering causes produce deviations from the type, affecting each or all the qualities above enumerated.

274. Thus the fundamental structure of a flower may be disguised by—

1. Adhesions of the parts of the flower to each other, and this may take place both between the members of one or of different whorls.

2. Alterations of the number of parts, either augmentation or diminution; the former arising from the production of additional whorls of any kind of organ, and also from what is called *deduplication* (§ 280.); the reduction results from the suppression or abortion of certain whorls or parts of whorls.

3. Less important differences arise from the inequality of the size of or union between the parts of the flower, and from peculiar development of the axis or receptacle altering the situation of the attachment or *insertion* of the organs.

275. When the parts of the flower occur in a state of cohesion, the leafy character is more or less disguised according to the extent to which they are connected with each other. The union of all the members of a whorl into a single piece takes place indifferently in all the four kinds of organs. Thus we have the sepals or the petals united together by their edges, so as to form tubular or similar bodies, which receive the respective names

of *mono*-sepalous calyx and *mono*-petalous corolla. This prefix is objectionable for etymological reasons, but long use makes it the most convenient we can employ, since the sense in which it is used is clearly defined. The fusion of the component parts generally takes place only to a certain extent, the number of organs in the whorl being most frequently indicated by lobes or prominences on the upper border of the tube. In some instances however they are undistinguishable, as in the caducous calyx of *Eschscholtzia*, which consists of two sepals united into a kind of conical cap, falling off by a circumscissile dehiscence at its base. In the case of cohering stamens a different term is used, the number of the groups being indicated by the prefix *mon-*, *di-*, &c., to which is added the adjective term *-adelphous*; thus as in *Malva*, when the filaments are all united into one tubular parcel, the stamens are called *monadelphous*, in those leguminous plants which have two parcels, *diadelphous*, &c. It is evident that the coherence of the filaments of the stamens will take place most frequently where they have a dilated character, and from their much narrower form they contract this adhesion less frequently than the petals which press more closely upon each other. In the case of the carpels the union acquires a somewhat different character; they are not only in contact at their lateral borders, but, occupying the centre of the flower, they unite by the whole extent of their margins, and thus the resulting body loses externally all traces of its compound origin, unless it be marked by furrows or projecting angles, &c. The cohesion of the carpels is so much the more frequent than that of any other whorl, that they are more closely approximated, by being situated upon the short and slender extremity of the receptacle, and by being more thickened and fleshy in their nature. Examples of the simple carpels and the compound ovary may be seen, in *Ranunculus*, where the former are seated on the elevated conical receptacle, and in *Nymphæa*, where they are blended into one mass.

276. The parts of different whorls also may become adherent, for instance, corolla with calyx or stamens, or with both, or all three with the ovary; this is the case where the calyx is what is called *superior*, that is, arising apparently from the summit of the ovary, but in fact adhering to it up to that point, when of

course the intervening whorls, petals and stamens must be included in the fusion. There are but few examples of adherence of the pistils to other whorls with the exclusion of the calyx.

From the law of alternation of the organs of contiguous whorls, we might expect that where the members of one are adherent to those of another, they must also adhere among themselves; thus if a stamen is situated opposite the interval between two petals, the two latter in a case of adherence of this kind must be united either directly or with the intervention of the filament; if the fusion of the parts is perfect we get a tube on the borders of which anthers alternate with the lobes of the corolla, as in *Cuscuta* (XIII. fig. 1.). In some Oleaceæ having four petals and two stamens, the former are united into pairs by cohering with the intervening filament. Where the law of alternation does not hold, or rather is not apparent from causes which will be subsequently alluded to, adhesions may take place between petals and stamens placed *opposite* to them without any lateral union, as in Statice and some of the Caryophyllaceæ. The degree of union between the stamens and petals varies much; sometimes the adhering filament is perfect, projecting on the face of the petal down to its base (XIII. fig. 2.); at others it appears to arise at once from the point where it becomes free, and all traces of two organs are quite undistinguishable below.

277. The union of the different parts also takes place through the medium of another structure which has not yet been spoken of. That portion of the receptacle (§ 271.) situated between the calyx and the pistils, commonly called the *torus*, is often clothed by a layer of tissue of a glandular character, which in particular cases acquires a greater development and forms a prominent thickened ring or collar. The whorls of floral organs may arise either from the border or the outer or inner face of this projecting ring. According as the collar is larger or smaller, the organs which it supports are removed from the receptacle, while on its thickness depends the distance between the succeeding whorls. This structure is the most frequent bond of union between cohering whorls, and in such cases we find calyx, corolla, stamens and carpels not directly in contact, but arising from this *torus*,

in the substance of which their inferior extremities are lost. Members of a whorl when not cohering with their fellows, are said to be *distinct*; when not adhering to other whorls, *free*.

278. The apparently different relative points of origin of the whorls in different flowers, arising from these phænomena of adherence, affording what are called character of *insertion*, are important for the distinction of flowers in classification. Various terms are employed to express the relations of the essential organs, that is, the stamens and pistils. When the stamens with the floral envelopes are *inserted* upon the receptacle and *free*, that is, with none of the whorls adherent, they are said to be *hypogynous* (XII. fig. 20.), or situated beneath the ovary; when the stamens or petals appear to arise from the calyx, their position becomes somewhat lateral in relation to the ovary, and they are called *perigynous* (XII. fig. 21.); the same term is sometimes applied to the calyx when it adheres to the base of the ovary (XII. fig. 22.); the calyx very frequently adheres to the whole surface of the ovary, and thus clothing it with another coat, which becomes intimately blended with it, appears to arise, together with the stamens, &c., from its summit (§ 276.); in this case all the parts are termed *epigynous* (XII. fig. 23.), and the ovary in this condition was said by the older botanists to be *inferior*; in the former cases the ovary is of course *superior*. Of the terms employed by De Candolle, *thalamiflorous* flowers include the hypogynous forms of insertion, the term *thalamus* being synonymous with the torus; the *corolliflorous* are those in which the stamens are adherent to the petals; the *calyciflorous* confound together the epigynous forms with those in which the stamens adhere to a free calyx.

In the Orchis tribe we have an example of stamens and pistils adherent to such an extent as to form one columnar body, the stamens being then *gynandrous* (XIII. fig. 3.). In Asclepiadaceæ the anthers borne upon a tube composed of the confluent filaments, adhere to the stigma, and in some instances, as in Compositæ, the anthers are united together (XIII. fig. 4.).

279. The typical form of a flower contains four whorls, each consisting of five organs in the dicotyledons, of three organs in the monocotyledons. We meet with innumerable deviations

from these types, and these will be conveniently studied under the two heads of *augmentation* and *diminution*. The augmentation of the number of parts arises in most cases from the production of additional whorls, of which an example is offered in the flowers of the genus *Sedum*, which possesses ten stamens (XIII. fig. 5.), while *Crassula*, belonging to the same Order, has the normal number five (XIII. fig. 6.). In Ranunculaceæ many of the plants possess several whorls of stamens and pistils (XIII. fig. 7.); *Nymphæa* has several rows of floral envelopes and stamens. In Magnoliaceæ the carpels are multiplied, and in most of the cases, where the additional organs are very numerous, these insertions follow a spiral line upon the enlarged receptacle. But it is among the stamens that we find this multiplication most commonly occurring.

280. At the base of the petals of *Ranunculus* is found a little scale-like body (XIII. fig. 8.); an analogous greenish scale occurs at the base, outside the carpels of various Crassulaceæ; and in *Erythroxylon* this accessory structure becomes developed on the face of the petals into an additional petal, almost as large as the one to which it is attached. In *Lychnis* and other Caryophyllaceæ, a somewhat similar appearance is offered by projecting folds upon the internal face of the petals (XIII. fig. 9.). This is regarded as a *deduplication** of the original organ, and is looked upon by Jussieu, Duchartre and others, as one of the most important phænomena bearing upon the multiplication of stamens. It is considered by these authors that this tendency to divide into a number of parts is the most marked distinction between the floral envelopes and true leaves.

In *Butomus umbellatus*, which has three sepals and three petals, six stamens occur opposed in pairs to the sepals (XIII. fig. 10.); this is regarded as a collateral deduplication of three staminal organs, but since there are six carpels also, following the regular alternating arrangement, and consequently resulting from the production of an additional whorl, this explanation is somewhat questionable. The deduplication does not always take place upon one plane; in fact most of the examples exhibit the additional organs situated in one or many rows, either in the place of or upon the face of the fundamental organ. In *Lühea*, one of the

* In the French *dédoublement*, an un-lining.

Tiliaceæ, five distinct bundles of hypogynous stamens are found alternating with the petals, and are said to arise from the deduplication of five original organs. In some Myrtaceæ again there are only five stamens, while in *Melaleuca* these are replaced by five groups (XIII. fig. 11.).

In the Malvaceæ, Duchartre states, the bundles of stamens belong, not to the staminal whorl, but to the petals, from which they are produced by deduplication; and he has followed the development of the five groups, by subdivision, from five simple papillæ *opposite* the petals. He believes that the staminal whorl is represented by the five lobes in the inside of the tube to which all the filaments adhere.

These statements are much at variance with the common opinion of regular alternation of whorls of organs, according to which, opposition of succeeding whorls, as in the stamens opposite the petals of Primulaceæ, is explained by the supposition of the abortion of an intervening whorl.

281. Diminution or reduction of the parts of a flower appears either in the absence of entire whorls or only of parts of them. In the former case the flowers are *incomplete*.

Since the most external whorl of floral envelopes is always considered as the calyx (§ 269.), this can never be wanting where there is a corolla*; it is often only apparently absent, as in certain Umbelliferæ, &c., where it is reduced to a mere ring or projecting border, or to a circle of hairy or feathery processes, called a *pappus* in the Compositæ. Flowers are often *apetalous*, and those orders where only one whorl of envelopes, a calyx, is found, are called *monochlamydeous*, *e. g.* in the Aristolochiaceæ, &c. Sometimes floral envelopes are altogether wanting, as in *Callitriche* (XIII. fig. 12.).

Where this kind of reduction affects the whorls of essential organs (§ 270.) the flowers become *imperfect*, and it may occur when the floral envelopes are present. Many plants produce some flowers having only stamens, others only pistils, termed *diclinous* flowers, respectively *staminate* or *sterile* and *pistillate* or *fertile*. These forms are found especially among the Amentaceæ

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* There appears to be an exception to this rule in some of the Rutaceæ, where the only whorl of envelopes consists of true petals.

and allied orders. Where both kinds occur on the same plant, as in the Oak, they are called *monœcious*; when the flowers of one kind alone are found upon individual plants, as in the Willow, Hop, &c., they are *diœcious*. In the Palms, some Aceraceæ, &c., are found examples of the *polygamous* character, where staminate and perfect flowers are present in the same plant or different plants of the same species.

282. The suppression of parts of a whorl is one of the most extensive causes of the variations of the structure of flowers, and it would occupy too much space to go into minute details of the examples of it. The most important of the general facts alone can be here alluded to.

In the first place, the number of organs in all the whorls may be reduced in the same extent; in *Ruta graveolens* are found only *four* organs in each whorl, the flower remaining regular and symmetrical (XIII. fig. 13.); *Circæa lutetiana* has only two organs in each verticil (XIII. fig. 14.).

The number of organs in some of the whorls may be smaller. This occurs most frequently in the reduction of the number of carpels, as in *Solanum*, with a pentamerous arrangement of the envelopes and stamens and but two carpels (XIII. fig. 15.); but it extends also to the remainder of the whorls; thus in regard to the stamens, the Scrophulariaceæ offer a striking example of the reduction of the number. The numbers of the sepals and petals (combined in single pieces) are five; in *Verbascum* we find five perfect stamens; in *Penstemon* four perfect stamens and one sterile filament, the latter being rudimentary in *Antirrhinum*, while two of these perfect stamens disappear in *Gratiola virginica*; in *Salvia* and other genera of the Labiatæ, we have other examples of two stamens reduced from the four possessed by *Stachys*, &c.

Tropæolum pentaphyllum, with five sepals, has only two petals; *Amorpha* only one. *Impatiens* with five petals, stamens and carpels, has a tri-sepalous calyx; and in Plate XIII. fig. 16. *a, b, c,* &c. is represented a series of plans showing the gradual degradations of structure to be met with in examining a number of flowers of different orders.

283. Inequality of size or degree of union of the parts of the flower produces what are called irregular flowers. In the corollas

of the Labiatæ an irregular form is produced by the different form and unequal adhesion of the petals, the two upper being generally combined into an upper lip, overhanging the usually more expanded lower lip formed by the other three. In some genera the two superior petals do not cohere with each other to so great an extent as they do with the lateral divisions of the lower lip; in such cases the corolla appears ajugous, that is, wanting the upper lip. The flowers of the Orchidaceæ present a great diversity of form, arising from the irregular form and adhesion of the petals and sepals. The ligulate florets of Compositæ only differ from the regular tubular florets of the same Order in being split down at one of the sutures. *Lobelia* differs from the bilabiate form by the two upper petals being distinct down to the base; *Caprifolium* has a two-lipped corolla, with four petals in the upper lip and one in the lower.

In some cases the inequality of size in the parts of a flower appears to be dependent to some extent upon their position; thus in the Umbelliferæ we often see the outer petals much larger than those turned toward the centre of the umbel. In some species of *Scabiosa* this is still more striking; the flowers are densely crowded upon the capitulum, and those situated most externally having more space to expand, have irregular and much larger corollas, while the small closely-packed central florets are regular.

Difference of size and form of the component organs of the whorls render irregular the flowers of the Papilionaceous group of the Leguminosæ, certain of the Ranunculaceæ, &c. In the former the uppermost petal is usually much larger than the others, the two lowest united more or less together along their anterior borders, while the two intermediate petals spread out laterally. The relative size of these petals varies much in different genera; the single petal of *Amorpha* is the vexillum or superior petal of a papilionaceous corolla, the other four being suppressed. In *Cassia* the five petals differ little from each other, either in shape or size. In *Delphinium* one of the sepals is prolonged back into a spur or pouch, and the irregular asymmetrical corolla consists only of four petals, two of which are elevated on narrow stalks, the other two prolonged into spur-like processes received into the pouch of the spurred sepal. In *Aconitum* two of the petals are elongated bodies of a peculiar form contained in the hood formed by the two upper sepals of the irregular calyx; the other three petals are very small, and in some instances converted into stamens. In *Viola* one of the petals is larger and usually provided with a spur; *Impatiens* has irregular and asymmetrical flowers, one of the five sepals being spurred, while the four petals are united in pairs so as to appear like two.

284. The irregularity of flowers appears to depend in some measure upon the condition of the torus, the axis of which is often somewhat oblique in relation to the pedicel, and thus the members of the whorls situated on one side become elevated to a certain extent, while those opposite to them are depressed in an equal degree. In regular flowers the axis of the torus is perpendicular to the pedicel.

The form of the receptacle considerably influences the arrangement of the floral organs. Thus in *Ranunculus* it is an elevated body, bearing the carpels on a sort of cone (XIII. fig. 17.); in *Rosa*, on the contrary, it lines the hollow tube of the calyx, within which the carpels are attached (XIII. fig. 18.) upon the concave walls. In the Umbelliferæ and Geraniaceæ it is prolonged upward as a sort of column, to which the styles are at first united (XIII. fig. 19.). In *Dianthus* and *Silene*, the petals, stamens and pistils are elevated upon a stalk above the calyx. In certain of the Gentians the internode between the stamens and the ovaries is considerably developed, while in *Gynandropsis* the axis is apparent, both between the petals and stamens and between the stamens and ovary (XIII. figs. 20, 21.).

ÆSTIVATION OR PRÆFLORATION.

285. Like the leaves in a leaf-bud (§ 172.), the organs of the flower are variously arranged within the unopened flower-bud; and as the summit of the peduncle in this condition exhibits a close resemblance to the nascent branch, the relative position of the different floral whorls can often be determined more accurately in the bud than in the expanded flower. They are situated higher or lower or more or less exteriorly upon the receptacle; and since the petals and sepals already possess somewhat of their expanded foliaceous form, they must inclose one another to some

extent, and thus clearly indicate the order of their succession. The process of the development of flower-buds is called the *æstivation* or *prefloration,* and the various modes of arrangement of the parts may be divided into two classes, namely that in which the organs succeed one another at unequal heights or in a spiral course around the receptacle, and that in which circles of organs situated in one plane are arranged one above and within another.

286. The *spiral* æstivation is also called the *imbricated* (XIII. fig. 22.), since the organs overlap one another; but where they completely envelope one another, the term *enveloping* or *convolutive* is sometimes substituted. Occasionally the organs are long enough to project beyond those situated more interiorly, but not sufficiently broad to inclose them, and then the organs succeeding one another spirally, alternate in pairs, three and three or five and five, &c. Five is the most common number of organs in a whorl; and if in the spiral arrangement they are not broad enough to allow two succeeding organs to meet at their borders, the five organs generally take a *quincuncial* arrangement (XIII. fig. 23.). In some irregular flowers, as in the Papilionaceæ, the regularity of the quincunx is interrupted by the alteration of the point of insertion of one of the organs, which becomes situated more internally or higher up (XIII. fig. 24.); this is here called the *vexillary* prefloration.

287. In the *circular* æstivation the form may be *valvate* (XIII. fig. 25.), *induplicative* (XIII. fig. 26.) or *reduplicative* (XIII. fig. 27.), &c., all modifications of one type, dependent chiefly on the size of the organs. Sometimes each of the organs may be situated a little obliquely, so that it overlaps its neighbour on one side and is overlapped in an equal degree on the other; the upper parts of these are then generally imbricated in a circle, forming what is called the *contorted* æstivation (XIII. fig. 28.). A slight alteration of the position of one organ converts this into a spiral arrangement of one turn (XIII. fig. 29.).

As in the case of the leaf-bud (§ 172.), the separate organs may present peculiar modifications of folding within the flower-bud; in the Poppy the petals are contracted into a multitude of wrinkled folds.

288. The relations of the succeeding whorls of floral organs to each other present many peculiarities. In *Nymphæa* the organs

pass imperceptibly one into another in a spiral course; the same holds good as to the calyx and corolla in *Magnolia*; otherwise the different colours and forms of the organs of the calyx and corolla generally mark the distinction, even where the regular spiral course is followed through both. But this spiral arrangement is frequently interrupted by the suppression of some organs between the last of the calyx and the first of the corolla; and in some instances the spiral described by the organs of the corolla is turned in the opposite direction to that of the calyx.

Again, the calyx may be valvate while the corolla is contorted, as in Malvaceæ (XIII. fig. 30.); or the calyx imbricated and the corolla contorted, as in *Agrostemma Githago*. In general the valvate and contorted æstivations are characteristic of a regular calyx or corolla; the spiral arrangement is common to the regular and irregular forms.

Most flowers lose these peculiar relations of position in the course of their expansion, but this is not the case with all; the condition of the margins of the sepals will generally indicate the character of its æstivation; where it has been valvate, they are usually found to be thickened, while in the imbricated forms the overlapping borders are usually thinner.

289. The stamens and pistils can of course afford no evidence of their relative position by enveloping one another, but the unequal degrees of development give some evidence. The different members of one whorl often exhibit a considerable difference of perfection of structure, and in many instances, where the flower possesses numerous stamens, the component whorls are distinct in the early condition of the bud. The position of the stamens in æstivation in some Malpighiaceæ affords some evidence in favour of the theory of deduplication (§ 280.), the petals which enclose one another containing each a stamen in its axil (XIII. fig. 31.).

290. The terms *anterior* and *posterior*, &c. are applied to the organs of the flower in describing their position.

That organ of a whorl which is directed toward the axis of the plant whence the pedicel arises is called *posterior* or *superior*; that next the bract or leaf in the axil of which the pedicel is produced is *anterior* or *inferior*. When there are four organs in a whorl there will be an *anterior*, *posterior* and two *lateral*. If five, there will be one sepal posterior, two anterior and two lateral, as in Rosaceæ, Labiatæ, &c., the reverse being the case with the alternating petals, and thus in Labiatæ the bilabiate corolla has two lobes in the upper lip and three in the lower. In Leguminosæ the odd sepal is anterior or inferior, and thus in papilionaceous corollas the odd petal or *vexillum* is superior or posterior.

These relations are generally constant in the same plant, and often throughout whole families, as in the case of the sepals of Rosaceæ and Leguminosæ. In the Scrophulariaceæ one of the two carpels is always posterior, the other anterior.

Again, in Zingiberaceæ it is always the posterior stamen which is fertile; in Marantaceæ one of the lateral; in Orchidaceæ the fertile stamen is anterior, although apparently posterior, the true position being disguised by the twisting of the ovary.

Sect. III. The Floral Envelopes.

291. The envelopes of the flower already alluded to (§ 269.) require some special description, and here there is some little difficulty in avoiding an arbitrary division of these parts. It has been stated that the outer whorl is called the calyx, the inner the corolla; but that when, as is frequently the case, the latter is wanting, that whorl which is present is considered as a calyx, and the flower is called apetalous: there are some few exceptions to this rule, in which the members have the distinct petaloid character and the corolline nature is evident.

Among dicotyledons the calyx and corolla are usually distinguishable by their difference of colour and form, but in the monocotyledonous orders we find the envelopes to consist of two concentric whorls of organs, often all exactly alike, and usually petaloid in their nature, but sometimes, as in *Asparagus*, all green. In other families the three outer organs are green, like a calyx, and the three inner coloured and petaloid, as in *Tradescantia*, *Alisma*, &c. Now all these forms of structure are so closely allied together and so plainly identical in their essential nature, that it would be extremely artificial to arrange them under separate heads of calyx and corolla. To meet this difficulty, the collective terms *perianth* and *perigone* were invented (§ 269.), which have been applied indiscriminately by various authors to the envelopes of dicotyledons and monocotyledons, where the floral organs are all alike. The most convenient method, however, is to restrict the term perianth to the monocotyledons and to use the term calyx in the case of the dicotyledons, whether applied to outer or the only existing whorl.

* The Calyx.

292. The calyx is composed of the whorl of sepals, which may be distinct or adherent by their contiguous margins. In the first case it is called *poly-sepalous*; in the second, where the component parts are united into a single piece, it is termed *mono-sepalous*. The sepals possess a distinct foliaceous character, generally resembling the bracts rather more than true leaves. Their structure, nervation, &c. resembles that of leaves, and the epidermis of the outer or inferior surface is provided with stomates (§ 66.), and sometimes clothed with hairs, or even glandular. The nerves are chiefly composed of unrollable spiral vessels (§ 54.), and are parallel in the monocotyledons, reticulated in the dicotyledons, the mid-nerve indicating the centre of each sepal in the monosepalous calyx; in this latter, distinct nerves are often found running up the line of union between contiguous sepals, forking at the top and branching off in the body of the sepals. These intermediate nerves are composed of the lateral nerves of the two adherent sepals, united together. The sepals are seldom narrowed below, so as to appear petiolated; neither are they often lobed or otherwise incised at their margins. In the Rose is an example of divided sepals, and in the species *Rumex* we find sepals both toothed at the margin and with the outer face tuberculated and provided with hook-like processes. In *Phlomis tuberosa* there are two teeth between each of the five points of the calyx; the latter answer to the mid-nerves; the others are lateral teeth, each sepal being trifid. In *Chamælaucium plumosum* the calyx appears to consist of twenty-five parts, but in reality it has only five deeply five-lobed sepals.

Their usual form is ovate, either obtuse or acute; the direction is either upward, *erect*; inward, *connivent*; inclined outward in different degrees, *divergent, patulous* or *reflexed*; in the last the apex is turned downward.

293. The calyx, taken as a single organ, as has been stated, may be polysepalous or monosepalous. In the latter case various terms are employed to indicate the degree of union, &c. of the component parts; the words which characterize the condition of the margins of leaves (§ 146.) are again brought into use here to describe the condition of the border of the calyx, and this is *partite, fid* or *dentate,* according to the depth of the fissures between the contiguous sepals, and *entire* when they are united up to their apex. In a calyx thus consisting of a single piece, that part where the sepals are united is called the *tube*; where they are free, the *limb*; the point of junction between the limb and the tube is the *throat*; the segments of the limb (indicating the component sepals) receive the name of *lobes.*

The sepals are generally indissolubly united in the tube of the monosepalous calyx, but in some cases the adherence is but slight and *Œnothera* very clearly shows the real composition of such a calyx, since its sepals have *lacunæ* at intervals along the line of adhesion.

294. When the sepals are of equal size and like form, or, if united, all of the same height; again, when unequal in size their number is *even,* and they are arranged symmetrically, the calyx is called *regular.* If these conditions are not fulfilled, of course it is *irregular,* and this must always be the case when the number is uneven and they are of unequal size: a secondary kind of irregularity ensues from the unequal adhesion when the parts are alike, but generally speaking regularity depends upon equality and symmetry, and although unequal adherence interferes with these in appearance, it does not in reference to the essential structure.

It will be evident from the foregoing that all possible intermediate stages may exist between perfect regularity and the most distinct irregularity. The most common form of irregularity arising from adhesion is that of what is called a *bilabiate* calyx, where the sepals are more or less separated into two lips by two fissures deeper than the other three (XIV. fig. 1.).

295. The calyx is often *angular* or *prismatic,* and at the angles will be found the mid-nerves of the component sepals, as in *Lamium, Primula,* &c. This mid-nerve may extend beyond the

parenchyma, as in true leaves (§ 158.), producing projecting points; the sepals are then called *apiculate, mucronate* or *spinose*, according to the length, acuteness or rigidity of the point. These points indicate a want of proportionate development of parenchyma; sometimes it is altogether absent, as in some Acanthaceous plants. Among the Compositæ, the free portion of the calyx called the *pappus*, presents a great variety of modifications of this structure. Sometimes the lobes consist of membranous scales called *paleæ*; where there is nothing but the nerves, the pappus is *plumose* when it consists of mid-nerves having pinnate lateral nerves (XIV. fig. 2.); *pilose* when the mid-nerve alone remains (XIV. fig. 3.); and *aristate* when only two or three more or less rigid and spiny processes exist (XIV. fig. 4.). A *membranous* pappus is formed by the union of all the parts into a narrow crown, and in some cases the free portion of the calyx disappears altogether. In *Centranthus ruber* (XIV. fig. 5.), the free portion of the calyx is rolled inward upon itself until the corolla has fallen, but during the ripening of the fruit it unfolds, and extends into a feathery pappus.

296. The form of the calyx varies much, more especially in the monosepalous kind. It is called *tubular* when of the shape of a tube; but this is a general term, not indicating any particular modification of a tube. Among the most striking forms are the *cupuliform*, when it is cup-shaped (XIV. fig. 6, *a*); *globose* (XIV. fig. 6, *b*); *conical* (XIV. fig. 6, *c*); *urceolate*, when inflated below and contracted at the throat; *turbinate*, somewhat of the shape of a top (XIV. fig. 6, *d, e*); *campanulate* (XIV. fig. 6, *f*); *infundibuliform* or funnel-shaped (XIV. fig. 6, *g*); *clavate* (XIV. fig. 6, *h*); *cylindrical* (XIV. fig. 6, *i*); *inflated* (XIV. fig. 6, *k*).

They may be further complicated by being *compressed* at two or more sides, causing the section to become ovate or angular; or having the base *intruded*, when the tube of the calyx curves downward from the peduncle slightly before it takes the regular ascending direction; *truncate* when it passes off at right angles; and *attenuated* when it at once takes an ascending direction, expanding gradually from the summit of the peduncle. The intruded base is a transitional form, leading us to the irregularities caused by the expansion of the sepals into appendices of various kinds where the calyx or individual sepals become *gibbous* or enlarged at one side; *saccate* where a portion of the sepal or calyx is protruded outward in a sac-like form; or *spurred* where this protrusion is very long (XIV. fig. 7.); *appendiculate* where, as in *Campanula media,* the sinuses of the calyx are furnished with an appendage formed by elongation downward of the connivent margins of the sepals (XIV. fig. 8.). The spur of the calyx of *Delphinium* is a prolongation of its superior sepal; that of *Tropæolum* formed by the cohering prolongations of three sepals; in *Pelargonium* the tube is a prolongation of the upper sepal, adherent to the peduncle. In *Aconitum* the upper sepals are enlarged and curved into the form of a hood. The sacs formed by these enlargements of the sepals frequently receive within them the processes of the irregular petals which accompany them.

297. The small intermediate teeth found between the principa divisions of certain calyces, as in some of the Rosaceæ, result from a different cause from any of those yet spoken of; the leaves of the plant on which such a structure is observed are accompanied by stipules (§ 156.), as in the case of *Potentilla,* &c.; the analogy between sepals and leaves at once explains the nature of the intermediate teeth, which consist of the coherent stipules of the two calycine leaves between which each of these occurs.

298. The *exterior* or *epi-calyx,* which is outside the regular calyx in the Malvaceæ (XII. fig. 19.), is regarded by some authors as really an additional calyx (§ 272.), but more generally it is considered to be an involucre. Since the essential nature of both bracts and sepals, and therefore of involucre and calyx, is the same, this question seems to be a mere question of names, only important in relation to the definition of the terms used in organography; it would appear however to be a special modification more allied to the calyx than the involucre, on account of the definite number of its component parts.

299. The duration of the calyx is variable in different plants. In the Poppy it falls before the expansion of the flower, and is said to be *caducous*; where it falls with the corolla, or soon after fecundation, it is *deciduous*; it is *persistent* where it remains attached during the maturation of the fruit, or it may be persist-

ent at the base only, as in *Datura Stramonium*, where the upper part separates by a horizontal fission. The persistent calyx may dry up and become hardened during the maturation of the fruit, and is then called *marcescent*; if it grows during the same period it is *accrescent*, as in *Physalis* and *Belladonna*. It sometimes becomes membranous during this expansion, forming a kind of bladder, as in the Trefoils; in *T. fragiferum* the inflated or *vesicular* calyces crowded together, acquire somewhat of the form of the fruit of the Strawberry.

The persistence of the calyx affords protection to the fruit during the process of ripening, and the peculiarities of its form frequently assist in the dissemination of the seeds, for instance in the case of the feathery pappus of certain Compositæ, or in the calyces provided with hook-like processes, inclosing the fruit of *Galium*, &c.

** The Corolla.

300. The corolla consists of the whorl or whorls of organs situated between the calyx and the stamens; these organs, the petals, are generally distinguished by their more delicate structure and brighter colours from the sepals, but, as has been stated already, they occur in some cases in a condition where these characters are wholly wanting, while the occasionally petaloid structure of the calyx increases the confusion. From the stamens they differ both in form and function, since the former are *essentially* organs of reproduction, while the petals do but form part of the envelopes; but here again we meet with transitional forms, as for instance in *Nymphæa*, already alluded to (§ 268.). The petals present a system of nervation (§ 143.) analogous to that of the sepals and leaves. The petals have one character in which they resemble leaves more than sepals do, namely, they are sometimes furnished with a petiole, or what is analogous to one. The base of the petal is attenuated in these cases into a narrow base called the *claw*; the upper expanded portion is termed the *limb* (XIV. fig. 9, *a*, *b*).

301. Form of Petals.—They exhibit a much greater variety of forms than the sepals. They are *regular* when they may be divided into two exactly corresponding portions by a vertical line

down the centre; in the contrary case they are *irregular* (XIV. fig. 10.). The figures of the outline in various petals have received a multitude of distinctive names, of which may be enumerated the following:—*linear, oblong, elliptic, lanceolate, ovate, orbiculate, cordate, cuneate, spathulate,* &c., which need no explanation; but the general form assumes such a multitude of strange characters, that it is impossible to describe them by adjective terms which would be readily intelligible; among the shapes arising from mere curvature of the limb may be cited the *concave*, the *navicular* or boat-shaped, and the spoon-shaped or *cochleariform*.

They also present great diversity in the condition of their borders, the division however never extends beyond that of the first degree of that which we have met with in leaves (§ 146.); thus we have them *emarginate, crenate, serrate, bifid, trifid, pinnatifid,* &c., but never bi-pinnatifid, &c. They are sometimes *fimbriate* or fringed, as in *Dianthus alpestris,* and *laciniate,* as in *Lychnis flos-cuculi*. *Entire* petals are met with universally in some orders; certain incisures of the margin distinguish some genera; in other cases the species of a genus all differ.

The petals are as it were squeezed up in an irregular manner in one kind of æstivation, as in the Poppy (§ 287.): as the petal is here of very delicate consistence, it retains traces of the wrinkles and is termed *corrugated*. In certain plants they are furnished with appendages of various kinds, like the spur of *Viola* peculiar to one petal, or of the *Aquilegia,* where all are spurred. Others have a kind of duplicature (§ 280.) projecting at the point of junction between the claw and the limb, as in *Reseda*; sometimes this is fringed or laciniate, as in *Lychnis* (XIII. fig. 9.), while the Umbelliferæ often have the summit inflected and bound down by a kind of strap arising from the middle of the petal; in several species of *Polygala* one of the petals terminates in a delicately-fringed crest.

302. Polypetalous Corolla.—A polypetalous corolla consists of one or more whorls of petals which are not coherent; or by reduction (§ 281.) it may contain less than a whorl, the number of members being indicated by the terms *di-, tri-, tetrapetalous,* &c. Thus the typical number of organs in a whorl is

five (§ 273.) among the Dicotyledons, but *Circæa* has only two petals, the Cruciferæ but four, &c.

It is called regular when made up of petals of like form and size, as in the pentapetalous corolla of the *Ranunculus*; where the petals are unlike, as in *Aconitum*, it is irregular. A regular corolla may be formed of irregular petals (§ 301.), provided that these are all exactly similar.

Certain forms of irregularity are distinguished by special names, as the *papilionaceous* corolla of a large number of Leguminosæ. This is composed of five petals, one only of which is regular, namely that situated posteriorly (§ 290.), which is larger than the others and is called the *vexillum* (XIV. fig. 11, *a*) or standard; anteriorly are found two petals of irregular shape but corresponding to one another, so as to produce a symmetry of the two lateral halves of the flower; their faces are perpendicular to that of the vexillum, and they combine together below to form a boat-shaped cavity enclosing the *essential organs* (§ 270.); these two receive the collective name of the *carina* or keel (XIV. fig. 11, *b b*). On each side, between the vexillum and the carina, occur the *alæ* (XIV. fig. 11, *c c*), also irregular in form but corresponding to each other. The shape of the petals and the mode of attachment to the receptacle varies very much, and a series of forms of papilionaceous corollas is thus presented from extreme irregularity to perfect regularity.

303. Monopetalous Corolla is the term applied, as in the case of the calyx, to the condition where the petals are coherent into a single piece, and this cohesion is found to exist in all possible degrees from the mere union at the base to complete fusion. The older botanists regarded the monopetalous corolla as formed of a single piece, and hence is derived the host of names relating to the condition of the border resulting from the various degrees of union. The free portion of each petal is denominated a *tooth*, *lobe*, &c,, according to its size and the number indicated by the prefix *bi-*, *tri-*, &c.; the adjective term thus obtained is applied to the corolla exactly in the same manner as to the calyx (§ 293.).

304. The monopetalous corolla is regular or irregular according to the equality or difference of the size, form and adhesion

of its component petals. The parts may even be irregular, as in polypetalous corollas, provided they are all alike and symmetrically arranged, as in *Vinca*, &c.

The regular forms are very various like those of the monosepalous calyx, and they are for the most part described by similar terms, *e.g. tubular, globose*, &c. (§ 296.). The corolla is also divided like the calyx into *tube* and *limb*, meeting at the *throat* or *faux* (§ 293.). The two extreme forms perhaps are the *tubular* (XIV. fig. 12.), which has scarcely any limb, and the *rotate* (XIV. fig. 13.), in which the limb is horizontal and provided with scarcely any tube.

305. Irregular monopetalous corollas present themselves in a great diversity of forms. Of these the most important are the *labiate*, the *personate*, and the *ligulate*. The *labiate* (XIV. fig. 14.) takes its name from the condition of the limb, which by the unequal adhesion of the lobes or component petals, becomes divided into two principal divisions, which being situated anteriorly and posteriorly, and the posterior generally overhanging the anterior, bear some resemblance to a mouth, and are called the *upper* and *lower* lips; the tube remains open. The upper lip generally presents two secondary divisions and the lower three, indicating the five component petals. The upper lip takes various directions, being sometimes straight, at others spreading, or curved in a sort of arch or vault over the mouth of the tube; the lower lip is sometimes entire, at others variously *lobed, dentate*, &c., and its lobes are either *flat, concave*, or *reflexed*. This form characterizes the Labiatæ and certain genera belonging to other orders. The *personate* (XIV. fig. 15.) differs from the labiate chiefly in the form of the mouth. The lower lip is, as it were, everted and the mouth of the tube closed by the large convex base of the lower lip, called the *palate*, extending inward toward the upper side of the tube; this corolla is found among Scrophulariaceæ and Lentibulariaceæ.

It has just been stated that the lips of a labiate corolla are variously lobed according to the condition of adhesion of its parts; in *Lobelia* the upper lip is divided nearly down to the base. In *Scævola* (XIV. fig. 16.) there is no cohesion whatever between the two superior petals, while their union with the inferior, and of the latter with each other, is equal, and thus is formed a regular corolla split down to its base and expanded like a fan. This form is closely related to what is called the ligulate corolla. The flowers of the Compositæ are usually denominated *florets*, from their small size, and the corollas present themselves under three forms, the *labiate*, the *tubular* and the *ligulate*; the latter only differing from the tubular in the fact of its being split down at one of the sutures and expanded in a flat ribbon-like form, the border of which exhibits five teeth, corresponding to the five component petals (XIV. fig. 17.).

From what has been said (§ 301.) respecting the appendages or processes of irregular petals, it will readily be conceived that similar structures should present themselves in monopetalous corollas. Thus in *Linaria* the base is *spurred* by the sac-like prolongation backward of the intermediate petal of the lower lip. In *Antirrhinum* this projection is a mere sac and the corolla is called *gibbous*. In a few cases the petals are found united at their apices, as in *Phyteuma* among the monopetalous forms, while the polypetalous corolla of the Vine has its petals coherent at their summits.

306. Corona.—I have already mentioned (§ 301.) that many petals are provided with a kind of appendix at the junction of the claw with the limb; in a monopetalous corolla these may also be coherent, forming a kind of ring at the throat, which is often fringed, as in *Nerium Oleander*.

307. Scales.—Many corollas bear scales at the mouth of the tube, often covering up the parts contained within it. They are often of greater consistence than the petals, and are found either beneath the divisions of the lobes (XIII. fig. 1.), or between them (XIV. fig. 18.); the first case is evidently analogous to the *corona* (§ 306.); these scales are common among the Boragineæ, *Cuscuta*, &c.

308. The duration of the corolla is expressed by the terms *caducous*, *deciduous* and *persistent*, in the same sense as they are applied to the calyx (§ 299.); here again too we occasionally have the base alone persisting, as in *Orobanche* and *Rhinanthus*,

where it remains and surrounds the ovary. The corolla of *Mirabilis* is fleshy at its base, and this part persists, becomes hardened and wrinkled, resembling a reed.

309. Development of the Floral Envelopes.—According to Schleiden the floral envelopes make their first appearance, in *Lupinus*, under the form of small distinct cellular papillæ of equal size; those of the calycine whorl first and those of the corolline whorl next. In this plant the corolla is polypetalous, and the petals of unequal size when they have attained their full development. In Malvaceæ, which have the sepals more or less united at the base, and in Primulaceæ, where the calyx is tubular, Duchartre states that the first appearance of the calyx is a little projecting ring, which subsequently presents the five prominences indicating the quinary structure; hence the monosepalous form does not arise from actual fusion of the parts. In the same orders also he found that the stamens always appeared next in order after the calyx, and that the petals afterwards presented themselves between the two first-formed whorls; this he considers as a strong evidence of the truth of the view which assumes that where the stamens are placed opposite the petals, they all belong to one whorl and result from deduplication (§ 280.), consequently that this structure does not arise from the abortion of an intermediate whorl. Barneoud says that he has observed the development of the irregular corolla in the Orchideæ, Labiatæ, Scrophulariaceæ, Aristolochiaceæ, Verbenaceæ, Leguminosæ and Polygalaceæ, and that in all cases the papillæ indicating the lobes were equal at the time of their first appearance.

Sect. IV. The Essential Organs.

* Stamens.

310. The third system of organs, counting from without inwards, is called the *Andrœcium* (§ 271.), as the stamens of which it is composed are supposed to represent the male organs of the plant. In its most highly developed condition the stamen consists of two parts, the *filament* (XII. fig. 18, *c*), the thread-like stalk supporting the *Anther* (XII. fig. 18, *d*), which is a thickened body, comprehending a variable number of pouches or cells containing

the *pollen* (§ 333 *et seq.*) or fertilizing powder. The anther alone is essential in the stamen, and when the filament is wanting, it is said to be *sessile*; where the anther is imperfect or undeveloped, the organ is called an *abortive* or *sterile* stamen.

THE FILAMENT.

311. The form of the filament is very variable; commonly it is *filiform* and slender, as in *Dianthus*; in the Grasses it is *capillary*, while in *Butomus umbellatus* it is *subulate*. Generally speaking it is *cylindrical*, but it is also found more or less flattened. In *Erodium* it is *flat* and *membranous*; in *Campanula dilated at the base*, forming a kind of arch over the ovary. *Ornithogalum* has the filament *dilated* throughout, a transitional form between the foregoing and that of *Canna*, where the anther is borne upon a *petaloid* filament.

Occasionally the dilated filament is divided into three teeth at its apex, the central one, either longer or shorter than the others, bearing the anther, as in *Allium* (XIV. fig. 19.), *Alyssum calycinum*, *Ornithogalum nutans*, &c.; in *Allium sativum* one of the teeth is elongated like a tendril (XIV. fig. 20.). Filaments are sometimes furnished with little branches or teeth when not dilated, either at the base, as in *Rosmarinus officinalis*, where the filament is *spurred*, or at the summit, as in *Crambe*, where it is *forked*.

In certain cases they are accompanied by a different kind of appendix, the filament not arising immediately from the receptacle, but from the anterior or posterior (§ 290.) face of a kind of scale. In *Simaba* (XIV. fig. 21.) the filament proceeds from the back of the scale, which is consequently interposed between it and the ovary; in *Borago* (XIV. fig. 22.) it arises from the face of the scale which is prolonged upward in the form of a beak. In a few cases the filament is merely toothed throughout its whole length (XIV. fig. 23.) or alternately expanded and contracted, giving it a *nodose* or *moniliform* appearance (XIV. fig. 24.).

312. It is stated by some authors that filaments are occasionally *articulated*, but we must not confound the stamens of *Euphorbia* with such cases, since in these each stamen constitutes a flower, and the apparent *articulation* is the node indicating the suppressed calyx (XIV. fig. 25.). In a few cases the fila-

ments are *geniculate*, that is, inclined at a sharp angle near their apex, without any articulation. The direction taken by filaments varies much, as does also their length. They are frequently *erect, incurved, recurved, pendulous,* &c., and are very long in *Fuchsia, Lilium,* &c., short in Primulaceæ, Boragineæ, &c. They may be so small that the anther appears sessile; *Viola* is an example of the difficulty of distinguishing a sessile anther from one with a short filament, the stamens having been described under both characters.

313. Filaments are generally of a more or less pure white colour, but they often occur vividly tinged with some of the colours of the envelopes; they are red in *Fuchsia*, blue in *Tradescantia virginica*, yellow in *Ranunculus acris*, &c.

THE ANTHER.

314. The anther generally consists of two lateral and parallel chambers called *loculi* (XIV. fig. 29, *a, a*) separated by a third portion, more or less continuous with the filament, the *connective* (XIV, fig. 29, *b*). The chambers or *loculi* are each composed of two unequal valves, the point of junction of the valves being the *suture* (XIV. fig. 29, *c, c*). At the dehiscence of the valves is exposed a kind of partition extending across the *loculus* on each side from the connective toward the suture, which it sometimes reaches; this is the *septum* (XIV. fig. 29, *d, d*). That surface of the anther generally looking toward the petals, to which the filament is attached, is the *back*; it is in most cases more even than the face and bears no indications of the chambers. The *face*, the opposite side, commonly looking toward the ovary, has the chambers projecting from it and leaving between them a furrow; the sutures also look inward, and thus the inner valve of each chamber is narrower than the outer (XIV. fig. 29, *e, e*). The sides are of course those portions intervening between the face and the back, and the breadth is the distance between the point of attachment and these sides; the length, the dimension at right angles to the breadth.

315. STRUCTURE.—Since the stamen in common with the other floral organs is regarded as a modified typical leaf, we have to inquire what are the special conditions under which the leaf is

here to be recognized. The filament may clearly be regarded as analogous to the petiole, both from its shape and position, and from its anatomical structure; the little vascular bundle it contains being continued unbranched throughout the filament. The anther presents greater difficulty at first sight. On making a transverse section of an unopened anther of the usual form (XVI. fig. 1.), we see four pollen chambers (*d, d*) disposed in two pairs, each pair being contained in one lobe of the anther and separated from the other by the connective (*a*). The two chambers of each lobe are separated by the cellular mass (*f*), which is the septum.

Now if we imagine that the pollen is produced out of the cellular tissue of the leaf, that is, from the *diachyma* or *mesophyllum* (§ 139.), it will be seen that such a structure as that represented in figure 1. Plate XVI. may result from the folding inward of the lateral halves of the lamina of the leaf upon themselves; the outer coat (*e*) then represents the epidermis of the inferior face of the leaf, the septa (*f*) that of the upper face blended where it is folded upon itself and considerably thickened; *a*, the vascular bundle of the connective representing the midrib.

In *Nymphæa* the gradual conversion of the petal into a stamen has been described, and in *Canna* (XIV. fig. 26.) the organ is found in a transitional condition; one side is regularly petaloid, while the other consists of a simple unilocular anther. In double Roses a yellow substance like imperfect pollen is often found in thickened borders of the inner petals (XIV. fig. 27.). In *Viscum album* there is apparently no folding of the fundamental organ upon itself; the whorl consists of an apparent corolla, the lobes of which bear pollen, which appears to be developed in their substance and discharged at the inner face (XIV. fig. 28.).

316. At their first appearance the stamens are composed of a delicate homogeneous cellular tissue; by the time the *loculi* begin to appear, the internal tissue has become divided into two kinds, one of which goes to form the walls of the *loculi*, the other developes into pollen (analogous to what we have seen taking place in the thecæ of the flowerless plants); the outermost layer forms on its outer surface a kind of epithelium (§ 65.), which in some plants (*Gladiolus, Passiflora*) is formed of cells

elongated in a direction perpendicular to the surface, near the *sulcus*. Between the cellular tissue of the walls of the *loculi* and that which produces the pollen is a layer of cells which subsequently become absorbed, and thus leave the central mass free. In most aërial plants are found layers of spiral-fibrous cells (§ 47.); usually there are but two (XVI. fig. 2.), situated beneath the epithelium of the substance of the walls; but in a few instances only the epithelium, or even the whole parenchyma of the anther with the exception of the epithelium and the vascular bundle of the connective, acquires this character.

The structure of the contents of the *loculi* will be considered under the head of the development of pollen (§ 333.).

317. The distinction into filament and anther which has been adopted for the convenience of description is to be regarded as artificial, since the parts are indeed representative of the petiole and lamina (§ 315.) of true leaves. The connective (§ 314.) is the part of the anther most directly continuous with the filament, and where they pass at once into one another without any sensible contraction the anther is *immoveable*; it is moveable or *versatile* when there is an articulation, or the filament is much attenuated at the point of attachment. When the anther is immediately continuous with the filament, the latter is of course *attached to its base* (XV. fig. 1.); sometimes it is *attached at the back* at various heights. The cases where it is attached to the back must not be confounded with those where the filament is really attached to the base of the *connective*, but the chambers or *loculi* are elongated downward, either separate and resembling a *bifid* base, or in contact so as to make the filament appear as if attached to the back. In *Tulipa Gesneriana* (XV. fig. 2.) the attenuated point of the filament is received into a cavity in the base of the connective.

318. Where the filament is attached to the back of the connective, the latter is prolonged downward, and in certain cases it extends beyond the loculi of the anther, in *Ticorea febrifuga* (XV. fig. 3.) into a fleshy appendage; in *Melastoma heterophylla* the filament is actually attached to the filiform appendage at the base of the connective.

On the other hand, the connective is sometimes prolonged upward beyond the summits of the *loculi*; most frequently in *sessile* anthers. In *Xylopia grandiflora* the prolonged apex of the connective is fleshy and truncated (XV. fig. 4.). Among the Violets (XV. fig. 5.) it is a coloured petaloid membrane. Each of the five stamens of Compositæ presents a membranous expansion on the apex of the connective, which in the bud combine to cover up the style. Again, the connective may not extend to the summit of the anther, which thus becomes *emarginate* (XV. fig. 6.) or *bi-fid* (XV. fig. 7.), and by the occurrence of this character at both extremities, both apex and base may be *emarginate* or *bifid*.

319. In the foregoing instances the enlargement of the connective takes place in the longitudinal direction, being generally narrow, and thus but slightly separating the loculi; but this enlargement also occurs in the opposite direction. The connective in such case becomes broader, and consequently removes the loculi to a greater distance from each other, as in *Melissa grandiflora* (XV. fig. 8.) and *Thymus Patavinus* (XV. fig. 9.). In *Salvia pratensis* the connective is a curved filiform body (XV. fig. 10.) articulated on the summit of the filament, one extremity bearing a chamber containing pollen, the other an abortive pollen-cell. In *Stachys* the connective is sufficiently expanded laterally and inferiorly to bring the two chambers into a horizontal line (XV. fig. 11.), as also in *Prunella* (XV. fig. 12.); in *Stemodia trifoliata* it gives the appearance of a bifurcate filament (XV. fig. 13.).

These anthers rendered horizontal by the enlargement of the connective are quite distinct from those rendered almost horizontal by the curvature of the filament, as in many Scrophulariaceæ and Orobanchaceæ (XV. fig. 14.).

320. In *Viola* we find two of the anthers *spurred* (XV. fig. 15.): this appendix is an enlargement of the connective in some cases, in others it arises from the point of junction of the connective with the filament.

The connective, although commonly linear and narrow, attains a much greater size in many cases and assumes a variety of forms, such as *ovate, orbicular, lunulate,* &c. In the *unilocular* anthers it is sometimes wanting; but in these cases, where that part of the filament by which it is attached to the anther is dilated, it is considered to be the rudiment of a connective.

321. The *loculi* also take a variety of forms, which, together with those of the connective, determine the shape of the anther. In Cucurbitaceæ they are linear but *convoluted* (XV. fig. 16.). In *Solanum* (fig. 17.) the *sides* are as broad as the *face* or the *back* (§ 314.), and then the anther is *tetragonous*.

The loculi also are furnished with appendages in certain cases; in a great many Compositæ, *Orobanche* and *Euphrasia*, each *loculus* exhibits a point at its apex. Among the Ericaceæ occur a variety of forms of appendix; in *Vaccinium Vitis-idæa* (XV. fig. 18.) each loculus is prolonged upward into a narrow tube. In the Melastomaceæ the two *loculi* unite into a single tube at the apex. They are generally parallel with each other, but by peculiar conditions of the connective they assume all degrees of divergence, as may be seen in Scrophulariaceæ; sometimes even they are arranged in a horizontal line, as in *Stachys* (XV. fig. 19.), so that after the opening of the sutures (§ 314.) it is difficult to ascertain whether there are two loculi or only one. In the Lentibulariaceæ there is actually but one, the point of junction being indicated by a slight contraction. In Polygalaceæ (XV. fig. 20.) and Amarantaceæ (XV. fig. 21.), also in some Coniferæ, only one chamber exists, and there is no contraction.

The unilocular anthers resulting from the suppression of one *loculus* must not be regarded as analogous to those just described, since the former are evidently incomplete and irregular, while the latter represent a *more complete* stage of the metamorphosis of the leaf.

In the Laurineæ we meet with quadri-locular anthers, resulting from the greater development of the *septum* (§ 314.), which here extends quite to the border and unites with it. The parts of these anthers however are not exactly in the same relation to each other as those of the bilocular anthers; in *Persea gratissima* for instance, the situation of each single chamber of a bilocular anther is occupied by two placed obliquely one over the other.

The anthers of the Coniferæ and Cycadeæ deviate to a great extent from the usual forms, particularly that of *Taxus* (XV. fig. 22.). The morphology of these organs will be examined hereafter (§ 330.).

322. The face of the anther is generally turned toward the ovary (§ 314.), in which case it is called *introrse*; where it is reversely directed, looking to the petals, it is *extrorse*. The really extrorse anthers must be distinguished from such as those of *Passiflora* and *Oxalis*, which, really introrse, become, subsequently to the expansion of the flower, extrorse, by their weight bending down the slender filament so as to reverse the position of the faces of the anther.

323. DEHISCENCE.—The *loculi* of the mature anther open to emit the pollen contained within them. Usually the dehiscence consists of a longitudinal splitting down in the line of the suture (§ 314.), by which the two valves of each *loculus* become free from each other. Sometimes the slit does not extend all down the suture, it may be arrested at any point of it, and often no trace of suture is visible beyond such point. In Ericaceæ the *loculi* open by oblong lateral *pores* (XV. fig. 23.); in *Solanum*, by terminal *pores* (XV. fig. 24.). The long tube which terminates the anthers of Melastomaceæ (§ 321.) presents a single aperture at its apex. In *Berberis* (XV. fig. 25.) and *Laurus nobilis* (XV. fig. 26.) the anterior valve separates with elasticity like the lid of a box, being only retained by a small portion of its border at the summit. The quadrilocular anther of *Persea gratissima* opens by four such valves (XV. fig. 27.).

All these cases may be included under the head of longitudinal dehiscence, and in like manner must we regard the dehiscence of the anthers, rendered horizontal by the enlargement of the connective (§ 319.), since in these the loculus is situated transversely. But cases occur of true transverse dehiscence taking place across the anther, by a slit extending from the connective to the side, as in *Alchemilla*, *Lavandula* (XV. fig. 28.), *Lemna*, &c.

324. The anthers dehisce at various stages of the existence of the flower; sometimes in the bud, sometimes after the flower has expanded. Many open at the period when the pistils have attained their full development, others before that epoch. In some flowers all the anthers open at once. According to Vaucher, the stamens nearest the centre open first in *Glaucium*, those nearest the circumference in *Helleborus*. In *Parnassia palustris* each anther inclines successively toward the pistil, dis-

charges the pollen, and returns to its former position. These cases of *irritability* will be more fully spoken of hereafter. The anthers take various forms after the discharge of the pollen, which it would be needless to enumerate; it must be remarked however that this renders it necessary to examine the unopened anther to ascertain the true form.

325. Anthers are of various colours, usually yellow, black in many Poppies, red in the Peach, &c.

326. Sterile stamens have already been spoken of (§ 310.). Among the Scrophulariaceæ sterile filaments are often found indicating *reduction* (§ 282.) of the flower from the typical regularity. Again, in *Geranium* there are ten fertile anthers with flattened filaments; in *Erodium*, an allied genus, five similar fertile anthers alternating with five filaments destitute of anthers.

Abortive stamens sometimes appear in incomplete flowers, as in the female flowers of *Xanthoxylum*, where there are even anthers containing no pollen. The expanded sterile filaments have an important share in the formation of the *androphores* (§ 329.).

THE ANDRŒCIUM.

327. Under this collective head we have to examine three kinds of relation in which the stamens stand to each other and to the adjacent floral whorls—of *number*, of *position*, and of *adhesion*. The number of stamens contained in a flower may equal that of the petals and sepals, the flower is then *isostemonous*; inequality in this respect renders it *anisostemonous*. In the latter case the number may be less than that of the outer whorls, *meiostemonous*; double, *diplostemonous*; or more than double, *polystemonous*. It has already been shown how these conditions may result either from reduction (§ 282.), from the presence of an additional whorl or whorls (§ 279.), or from deduplication (§ 280.). The relative position of the stamens as regards the petals, &c., whether opposite or alternate, &c., has also been investigated (§ 273.).

Their adhesions with these whorls, and the consequent apparent insertion relatively to them, and more particularly the calyx, are explained in the definition of the terms *hypogynous*, *peri-*

gynous, and *epigynous* (§ 278.). Where the stamens are shorter than the tube of the corolla they are said to be *included*, in the contrary case they are *exserted*.

328. A few considerations remain as to their relations with each other. They may all be perfectly *distinct* and independent (*free*); or coherent (*connate*).

The cohesion may be confined to the anthers, as in Compositæ, *Lobelia*, &c. (XIII. fig. 4.), when they are said to be *syngenesious* or *synantherous*. But it is most frequently by their filaments alone that stamens are united, the union taking place in various conditions; where they are combined either into a single piece bearing the anthers, elevated on portions of the filaments of variable length upon its upper free border, *monadelphous* stamens (XV. fig. 29.); or into two, three, or many groups, these arrangements being respectively termed *diadelphous*, *triadelphous*, and *polyadelphous* (XV. fig. 30.).

In the first case, in a *complete* flower (§ 273.) the filaments must necessarily form a tube surrounding the pistil, as in *Malva*; but in incomplete, that is male flowers, where no pistil exists, the filaments may form a central column. Where there are several groups, they may each have the form of a segment of a circle or of a column; both forms occur in the genus *Hypericum* (XV. fig. 31.). The stamens of *Fumaria* are diadelphous, as also are most of those of Papilionaceous Leguminosæ; in the latter case the ten stamens are distributed into a bundle containing nine and one remaining solitary and free (XV. fig. 32.).

In the bundles or groups of stamens again, the filaments may be united in their whole extent or only at the base; in the first case forming a column, in the second and commoner condition the filaments often branching off at different heights.

These groups of stamens are also furnished with peculiar appendages in some instances; these probably depend upon the nature of the deduplication (§ 280.); for instance in *Lühea* (XV. fig. 33.), already spoken of, the group of perfect stamens is united to a peculiar expansion, bearing at its summit a number of thread-like bodies resembling sterile filaments. In *Loasa*, again, the petals are succeeded by an alternating whorl of petaloid bodies, each bearing several anthers.

329. The term *androphore* is applied to the piece formed by the coherence of a number of filaments. The androphore is occasionally of considerable size in proportion to the number of anthers, since sterile intermediate filaments may enter into the combination.

330. In Cucurbitaceæ and in *Lobelia fulgens*, the adhesion extends throughout the whole stamen, anther and filament. It has just been stated, that in *male incomplete* flowers the coherent stamens may form a central column; in Cucurbitaceæ they are often thus united; in *Phyllanthus* and *Cissampelos* the four stamens are united so as to present a slender filament terminating in a disc, around which are arranged four unilocular anthers. St. Hilaire found in the male flower of *Fragariopsis scandens* (one of the Euphorbiaceæ) seven unilocular anthers situated upon a common peduncle, fleshy and rounded like a minute strawberry. It is not improbable therefore that the idea thrown out by Zuccarini as to the nature of the so-called stamens of the Coniferæ and Cycadeæ is correct, viz. that each body commonly regarded as a stamen in *Taxus* (XV. fig. 22.) is in fact a male flower, each cell of the anther indicating a distinct fundamental organ answering to a leaf; each peduncle would then be regarded as analogous to a branch. Various intermediate forms reduce this to the simple two-celled or bilocular anther of *Pinus* (XV. fig. 34.), while in *Abies* (XV. fig. 35.) this is still further simplified and becomes unilocular, and corresponds to a single cell of the anther of *Taxus*. In the Cycadeæ we find the anthers (or according to this view, the male flowers) arranged all over the under surface of a common scale (XV. fig. 36.), instead of possessing each a special scale, as in Coniferæ.

331. The relative length of stamens gives rise to certain peculiarities. In the *diplostemonous* flowers (§ 327.), the stamens opposite the petals are generally shorter than those alternating with them. Where the stamens are numerous, the length may increase in the whorls from the centre to the circumference, as in many Rosaceæ, or in the reverse direction.

The stamens of the Cruciferæ, of which four are long and arranged in pairs alternating with two solitary shorter ones (XV. fig. 37.), are called *tetradynamous*. The stamens of the Labiatæ, Personatæ, &c. are normally five in number, but one is usually more or less suppressed, and the remaining four are arranged so that the two upper are longer and correspond to the upper lip of the corolla, while the others, shorter, are lateral; this condition is termed *didynamous* (XV. fig. 38.).

332. The directions taken by the stamens have been spoken of in the description of the filament (§ 312.). One alone remains to be mentioned, namely the *declinate*, where all the stamens are curved towards one side of the flower, as in the Horse-chestnut, &c.

POLLEN.

333. STRUCTURE.—The central portion of the parenchyma of the young anther (§ 316.) gives origin to the pollen granules. A single row of these interior cells gradually develope into a cylindrical assemblage, composed of a variable number of what are called *mother-cells*. Within these mother-cells a new generation speedily makes its appearance, each containing in most cases four, but sometimes only two, under which latter circumstances each of these two at once produces another pair. The four cells thus produced from the mother-cells are called the *special-mother-cells*, and within each of these is developed a single *pollen-cell*. In all, except aquatic plants, the pollen-cells are soon clothed by the deposition of one or more layers forming the outer pollen membrane which exhibits peculiar markings, always constant in the pollen grains of particular species. The mother-cells, and subsequently the special-mother-cells, are usually dissolved and absorbed during the perfecting of the pollen, but this does not always take place wholly; in many Monocotyledons the dissolved substance of the mother-cells acquires the character of a viscous or perhaps oily fluid which adheres to the outer pollen membrane; in Onagraceæ long viscous filaments are found among the pollen grains, connecting them in chaplets; these are probably secondary spiral deposits formed within the primary or secondary parent-cells. What is called *quaternary* pollen arises from the gluing together as it were of the four pollen grains of a mother-cell by the viscous matter resulting from its dissolution. Sometimes two pollen grains are

united in this manner, sometimes eight or a greater number (XV. fig. 39.). In the Orchidaceæ the parent-cells are wholly resolved into a viscid matter which connects all the pollen-grains into one mass, and may easily be perceived among them as a tenacious substance which may be drawn out in threads (XV. fig. 40.). In the Asclepiadaceæ it seems as if the mother-cells alone are absorbed, and this at an early period; the special-mother-cells remain, and the whole of the outer layer of these produces no pollen-grains, so that the coherent mass of pollen of each *loculus* appears to be enclosed in a special cellular envelope (XV. fig. 41.).

334. During the maturation of the pollen, its component structures not only increase in number but in size, consequently the outer layers of tissue (§ 316.) forming the walls of the *loculi* are gradually broken down and absorbed to make room for the internal expansion, until the walls of the anther at last frequently consist of but two or three layers of cells; the septa (§ 315.) also, which originally divide the polliniferous tissue into four compartments, are by degrees absorbed, appearing only as thin walls in quadrilocular (§ 321.), as imperfect partitions in some bilocular (§ 314.), and wholly removed, together with the connective, in perfect unilocular anthers (§ 321.). The external walls always become thinnest at the places corresponding to the lines or pores of dehiscence (§ 323.).

335. A peculiar structure is connected with the pollen masses of the Orchidaceæ. The polliniferous tissue is sometimes continued downward to a little projection at the base of the anther, called the *rostellum*; in other cases the prolongation is at first independent of the *rostellum*, but before the opening of the valves they become united by the absorption of the intervening tissue. This prolongation becoming converted into a tenacious substance, appears at the period of dehiscence as a stalk (*caudiculus*) upon which the pollen mass is supported, the stalk itself adhering to a similar viscous matter produced by one or two little cellular masses (*retinacula*) on the upper surface of the *rostellum* (XV. fig. 42.).

336. A perfect pollen-grain consists of the essential pollen-cell, which in all but certain aquatic plants is invested by an external coat. In the exceptional cases, occurring in certain

Zosteraceæ, the simple pollen-cell has a tubular form. The internal envelope is formed first, and the external, which occasionally contains more than one layer, is deposited upon it while within the *special-parent-cell*. It exhibits peculiar prominences upon its outer surface, which, since they frequently have the form of anastomosing ridges, give it a reticulated appearance, which has led some observers to the erroneous conclusion that it is made up of numerous minute cells. The interspaces of the reticulations are frequently filled up with a gelatinous matter. These regular reticulations often give the pollen-grains a beautiful appearance, as especially in the Passifloreæ. The projections occur also as points, cones, papillæ, nodules, &c., either regularly arranged or scattered without order upon the surface. The colour of this external layer is generally yellow, rarely green, blue or red. The granular or otherwise marked external coat is generally covered by an oily matter, which gives the colour to it and renders it opake; the smooth varieties are usually without it, and transparent.

337. FORM.—The most common form of the pollen-grains is oval or ellipsoidal, more or less attenuated at the ends; in a few cases it is spheroidal, or it may have the appearance of an assemblage of segments of a sphere, frequently three, forming a trigone (XV. fig. 43.). Other grains are polyhedral, and the plane or slightly convex faces sometimes present ridges at their solid angles (XV. fig. 44.). These faces are not always equal, two of them (which may be called the poles) usually exceeding the rest in size. The form varies considerably according to the degree of humidity; thus when dry the angles are sharper, or the poles of the ellipsoid forms more prominent, while if wet they are unnaturally distended.

338. Almost all pollen-grains exhibit on their surface certain places either resembling slits or sharply-defined circles, at which points the outer membrane is either wanting or is so thin as to be invisible. Some grains have only the slits, some only pores, others both together.

Most of the Monocotyledons have a single longitudinal slit, as in *Gladiolus* (XV. fig. 45.), extending from one poleof the ellipse to the other; in some cases the slits are shorter and equidistant from the extremities. Dicotyledons have usually three slits (XV. fig. 46.); there are a few instances of two, still fewer of four; but six occur much more frequently, and twelve and even more have been observed. They are usually straight, but *Mimulus moschatus* presents an example of spirally curved slits.

The pores present similar modifications, one being the common number in Monocotyledons, as in the Grasses (XV. fig. 47.); three most frequent among Dicotyledons (XV. fig. 48.). When there are many pores, they are frequently arranged in a circle around what may be called the equator of the pollen grain; or they may be scattered regularly or without order over the surface (XV. fig. 49.).

The slits usually appear, in their natural condition, like little folds projecting inward, which, when the pollen is moistened, become distended and project outward. The pores are at first merely thinner circular spaces, which when the grain is wetted swell out like a little globule formed of a transparent membrane, which is the internal coat, or, as some authors state, the outer in a condition of extreme attenuation. The latter statement has probably arisen from the fact, that in some cases, as in *Passiflora* (XV. fig. 50.), the pores are reticulated like the rest of the surface, and are only indicated by a circular line; but when the grain is wetted, these pieces become detached in this line (XV. fig. 51.) and fall off like lids, whence this kind of pollen has been called *operculated.* In some instances the pores occupy the projecting angles of the pollen-grain, as in the trigonal pollen of the Onagraceæ (XV. fig. 52.). In a large number of Dicotyledons both pores and slits are present, combined in various proportions. The polyhedral grains, which occur in many Compositæ, have the pores either at the angles or in the midst of the faces.

339. When the pollen is enclosed only in a single delicate membrane, if it be wetted at any point, the absorption of the water by endosmose tends to expand the pollen vesicle, and it extends itself at the place where it has been wetted, finally bursting. In most kinds of pollen where there is an external denser coat, the expansion, under similar circumstances, is limited to the pores or slits, and this operation may be hastened by the

addition of nitric acid; the internal membrane is protruded in these situations and finally bursts, emitting the contents (*fovilla*).

340. THE POLLEN-TUBE.—Under the natural conditions the pollen does not present the same phænomena. When it falls upon the *stigma* (§ 348.), it has only certain points in contact with the fluid secreted upon that organ, the expansion takes place more slowly, and since it is confined to one (or very rarely two) points, the prolongation of the internal membrane may become extended to a considerable length without bursting. These conditions may be imitated by a *slightly* moistened surface. When this elongation takes place upon the stigma, it produces a tubular process, within which the contents of the pollen-grain may be detected, and occasionally moving in regular currents of circulation (§ 77.). This tubular process is called the *pollen-tube* or *utricle*; its functions will be alluded to hereafter.

The contents of the pollen-grains at first consist chiefly of a granular matter (protoplasma, § 13.), which is afterwards resolved into a more watery fluid. The remaining granules are mucilaginous; toward the period of maturation these increase in number, and among them are mingled oil globules, and frequently a greater or less proportion of starch granules. The fluid thus becomes more concentrated and contains less water, and toward the completion of the development of the pollen-grain the contents become somewhat contracted, producing the appearance of infolding at the slits; this concentration of the fluid of course renders its endosmotic power stronger. The reticular circulation (§ 77.) ceases within the pollen-cell long before its maturation in all known cases except *Zostera marina*, but the granules of the contents exhibit an active molecular motion, often in the pollen-cell, always after their expulsion, even in pollen taken from dried specimens or after the application of tincture of iodine.

** THE DISK.

341. The term *disk* is here used in a restricted sense and applied to a certain class of those accessory organs which have been included under the general term of *nectaries*. By the *disk* I mean the appendicular organs, of whatsoever shape, which are found between the stamens and the pistils.

The disk is probably composed of a distinct whorl of organs in those cases where its lobes alternate with the stamens; where they are opposite, it may be a result of deduplication (§ 280.).

It appears in various conditions; most frequently petaloid, but often reduced to small glandular bodies. In some cases the petaloid expansions are large, as in *Helicteres* (XVI. fig. 1.), or small, as in *Aquilegia*. In *Biscutella auriculata* the disk is composed of four small scales. *Sedum* has five glands, and many Cruciferæ, *e.g. Cheiranthus Cheiri* (XVI. fig. 2.), only four.

The constituent parts may cohere, and they are then usually in the glandular condition. In *Cobæa* there is a disk with five lobes (XVI. fig. 3.); in *Veronica* it is entire (XVI. fig. 4.). The height also is variable, and it may present itself either as a little raised ring, a cup of greater or less depth, a tube, or even, as in *Pæonia Moutan*, as an envelope completely enclosing the ovaries (XVI. fig. 5.).

Some portions of the disk may be suppressed (§ 282.) and but one or two glands remain to represent it, as in *Melampyrum cristatum*, some Cruciferæ, &c.; or it may consist of two whorls, as in *Arbutus*. These cases are evidently conformable with the phænomena of suppression and multiplication which we have met with in the exterior whorls.

342. It would be well to limit the use of the term *nectary* to the glandular bodies which secrete the sweet viscous fluid whence the name originated. These bodies occur indiscriminately on all the floral organs, very frequently as little scale-like bodies at the base of the petals, as in *Ranunculus*, but also in other situations, mostly on the inner surface and often at the apex, as in the stamens of many Rutaceæ. The disk is very frequently nectariferous.

*** The Pistil.

343. The pistil, the central terminal organ of the flower, being, as we have already seen (§ 270.), composed like the stamens &c., of a whorl of accessory organs, is of course subject to similar modifying laws, and we meet with reductions of the number of parts, various degrees of adherence, &c., exactly analogous to those occurring in the outer whorls (§ 274 *et seq.*). Its relations of position and adherence to these outer verticils have been already

examined (§§ 273–8.), and we have now therefore only to consider its own peculiar structure and the relations of its individual parts to each other. To this end, it will be most convenient to proceed as in the case of the stamens, and in the first instance to investigate the nature of a single carpel.

The Carpel.

344. In a former section (§ 270.), it was stated that the carpel consists of three parts, the *ovary*, the *style*, and the *stigma* ; this is the case in a highly-developed carpel, but the intermediate portion, the style, may be absent, and the stigma under these circumstances is *sessile* upon the ovary.

The *ovary*, the lowest part of the carpel, as seen in plants where they are distinct, *e. g. Crassula rubens*, is a chamber enclosed by rather fleshy walls which arise, below, from the summit of the receptacle, and are continued upward, gradually becoming attenuated, into the style. Within the cavity or *cell* are found little oval projecting bodies, the *ovules*, attached by a delicate tissue, the *placenta*, to the walls.

The *style*, which is continuous with the upper part of the ovary, is usually an elongated cylindrical body, and terminates in an expanded apex which is the *stigma*.

That surface of the carpel turned toward the floral envelopes is called the back or *dorsum* ; opposite to this are two surfaces meeting at an angle, which angle looks toward the centre of the flower, the two *faces* toward the contiguous carpels.

345. The proof of the real nature of the carpel is to be obtained by tracing its development in the bud and by examining the anomalous conditions which it exhibits in many cultivated flowers.

In a very young condition of the flower-bud the carpels may be detected as little greenish concave bodies, scarcely distinguishable from nascent leaves (XVI. fig. 6, *a*) ; a little later they become more concave, and finally their borders meet and become united (XVI. fig. 6, *c*). A hollow body is thus formed by each carpel, within which the ovules speedily make their appearance, springing from the inner surface of the walls.

In the double Cherry, the central organs appear as leaflets, the lower portion consisting of an expanded lamina, while the upper portion is elongated into an attenuated body, terminating in an expansion resembling the stigma of the normal carpel (XVI. fig. 7.).

346. STRUCTURE.—The ovary is composed of parenchymatous tissue, which is generally more succulent than that of the leaves. The vascular bundles which ramify through this consisting of unrollable spiral vessels (§§ 47, 54.), run upward, converging toward the style; they vary in number, and are sometimes simple, sometimes ramified. The cellular tissue of the walls does not present distinct layers like those of the leaves (§ 139.), but is bounded externally by an epidermal layer (§ 66.), and gradually becomes more lax and delicate toward the interior, which is clothed by a layer of epithelium (§ 65.).

347. The style is not a prolongation of the midrib of the leaf, but rather a continuation of the infolded lamina, for it is a parenchymatous cylinder with the vascular bundles distinct and arranged in a circle near the circumference, passing upward in a straight line, and terminating at various distances below the summit. When we examine a section of the style with sufficient magnifying power we always find it hollow; a canal in fact extends from the cavity of the ovary to the stigma. In certain cases (XVI. fig. 8.) this canal is freely open; in other instances it is somewhat obstructed by cellular tissue which is often very lax, and having many gaps between its cells. This tissue always differs very much from the general parenchyma of the style, and even when somewhat dense, it is clothed by a layer of filiform projecting cells (XVI. fig. 9.).

At the period of fecundation the canal of the style is occupied by a quantity of elongated cells of soft and humid nature, almost like a lining of mucous filaments; these form what is called the *conducting tissue* of the style.

348. The *stigma* appears to be a continuation of the lax tissue which is expanded at whatever point the canal of the style opens externally. The stigma is terminal when the canal extends to the apex; lateral, and of varying length, when the orifice is on one or even both sides (XVI. fig. 10.). The outer cells of the stigma are often developed into papillæ (XVI. fig. 11.) or hairs, in other cases they are more compact and closely united at the surface. At the period of fecundation, all the cells of the stigma

as well as of the conducting tissue become filled with fluid, which is generally viscous, and exuding upon the surface of the stigma, renders it moist and glutinous. It is this fluid which causes the dehiscence of the pollen-grains (§ 339.) in the process of fertilization.

The Gynæcium.

349. This central system may be composed of one or many carpels, either distinct or more or less united together. When each carpel constitutes a distinct ovary, it is *simple*; when several unite to form one body, this is called a *compound* ovary; this term compound, it must be borne in mind, does not refer to the number of cavities, but to the number of carpels entering into the composition of the ovary.

350. Where the ovaries are numerous they may be situated in one plane, arranged in a single verticil (XVI. fig. 12.), or at unequal heights, arranged spirally upon the receptacle or summit of the axis. The receptacle under these circumstances is produced into an elongated cylinder as in *Magnolia*, a cone as in the Raspberry, &c. and *Ranunculus*, or it may form an excavated cup clothed externally by the adherent envelopes (§§ 278, 356.), and bearing the carpels on its inner walls, as in the Rose (XIII. fig. 18.). I have already mentioned that the axis is sometimes developed considerably between the stamens and the ovary, as in *Gentiana*, *Gynandropsis*, &c., this stalk-like body being called the *gynophore* (XIII. figs. 20, 21.).

In certain modifications of the gynæcium, composed of a number of simple ovaries, the style appears to arise from the receptacle and not from the summit of the ovary, as above described (§ 344.). This is explained in the following way:—In the carpel which was described in that paragraph (§ 344.), the style was terminal or at the apex of the ovary; but if we imagine the point of the carpellary leaf to be inflected to some extent, the style will have a *lateral* position (XVI. fig. 13.); a further degree of inflection bringing the apex of the leaf down to a level with its base, would render the style *basilar* (XVI. fig. 14.). Now all these conditions are met with; the pistil of the Strawberry is basilar, while in many allied plants it is lateral.

If then the ovary be sessile, and still more, if it be slightly sunk in the surface of the receptacle, the basilar style will appear to arise from that organ rather than from the ovary; this is what is called a *gynobase*. When several gynobasic ovaries are situated in one plane, the styles usually become blended, forming a central column around which the ovaries are arranged; these then appear to be devoid of styles, as in Labiatæ, Boragineæ, &c. (XVI. fig. 15.).

This is quite different from what is found in Geraniaceæ, Umbelliferæ, &c., where the axis or receptacle is elongated into a central column beyond the carpel and the styles attached to it. This is called a *carpophore* (XIII. fig. 19.).

The simple ovaries are sometimes united together, either wholly or only in part: in the Labiatæ, &c., as we have just said, the styles alone are coherent; in the Apocynaceæ and Asclepiadaceæ the stigmas alone are united together (XVI. fig. 16.). But it is at the lower part that the cohesion is most frequently met with.

351. When the coherence extends to an actual blending together of constituent carpels, these lose their individual title of ovary and are called the carpels of a compound ovary. Among the Ranunculaceæ, those genera having a follicular fruit present all the stages of a transition from simple to compound ovaries.

As the separate ovaries each present a cavity, so the compound ovary may present a cavity corresponding to each carpel. Each cavity will then be separated from its neighbours by a *double* wall, that is, by one of its own lateral walls in contact with one wall of each contiguous cell. These partitions are called *dissepiments*, and divide the interior of the compound ovary into as many compartments as there are carpels. False dissepiments are sometimes met with, generally composed of loose cellular tissue. Where the carpels are placed side by side, true dissepiments must always be vertical, and all horizontal partitions be regarded as *spurious dissepiments*, as in *Cathartocarpus*; but they are also often vertical, as in *Nymphæa* (XVI. fig. 17.) and in *Datura*, where the ovary, though four-celled, is composed of two carpels only. Horizontal *true* dissepiments occur in the

Pomegranate, where the ovary is composed of several whorls of carpels.

The *cells* of the ovary are also called *loculi*, whence the terms *uni-locular, bi-locular, multi-locular ovaries*, are employed to indicate the number of cavities. They are however a remnant of the old terminology which was founded on the mistaken view that the compound pistils were single organs; it is better always to express the number of carpels and cells, and the degree of cohesion.

It will be evident on consideration that the dissepiments must alternate with the styles where these latter are free.

352. In the compound ovaries just described, the carpels are found in a condition resembling that in which they present themselves when distinct, that is to say, with their lateral portions folded inward and their borders in contact at the inner or *ventral suture*, looking toward the axis of the plant.

A large number of compound ovaries are formed in a different manner. The carpels, instead of folding inward toward the centre, merely adhere by their margins to their neighbours on each side, and thus present themselves as the external walls of a single large cavity. Here the ovules must be differently attached, since in the many-celled as well as the simple ovary they are attached to the *ventral suture*, which in this case does not exist. This question involves an inquiry into the relation of the ovules with the carpels generally, and we must now examine the different kinds of *placentation* or mode of attachment of the ovules, and briefly consider the views which are entertained as to their morphological import.

PLACENTATION.

353. The name of *placenta* is usually applied to the line or ridge projecting into the cavity of the ovary, upon which the ovules are borne. Some authors restrict the term *placenta* to the attachment of each individual ovule, and include the rows under the general name of *placentaries* or pistillary cords. The placenta may extend from the base of the carpel to the origin of the style, or may be confined either to the base or apex; where there is

more than one ovule, the placenta is a line which projects from the ventral suture in simple and many-celled ovaries (XVI. fig. 18, *a*, *b*); from the confluent margins of the carpels of some one-celled, compound ovaries (fig. 18, *c*), and around a free central axis in others. The first form is called *axile* placentation, the second *parietal*, and the third *central*. The *axile* and the *parietal* placentas pass gradually into one another, through a multitude of transitional forms resulting from the varying extent to which the margins of the carpels are inflected (fig. 18, *d*, *e*).

Each placental line is essentially double, one half corresponding to each margin of every carpellary leaf; thus in the axile placentation each placenta belongs to a single carpel; in the parietal, on the contrary, the placenta is composed of two halves furnished by contiguous carpels (XVI. fig. 18.). But in certain instances, as in *Butomus* (XVI. fig. 6, *d*) and *Nymphæa*, the ovules are attached all over the *dissepiments*, in *Cabomba* to the dorsal suture, and in some cases the whole internal surface of the carpels is ovuliferous.

The *free central placenta* is apparently very distinct from all these, and presents some peculiarities which render it necessary to state, in the first place, the theories which are entertained of the origin of the placenta.

354. The prevalent view is that the placentas are productions of the carpellary leaves, from the margins of which the ovules are developed. This opinion is supported by the natural condition of axile and parietal placentas (XVI. fig. 18, *b*, *c*), and by monstrosities which are frequently met with, where open carpellary leaves bear ovules upon their free margins; it applies also to some forms of central placentation, as in the Caryophyllaceæ, where imperfect septa are found at the lower part of the ovary. It has therefore been assumed that other perfectly free central placentas, like those of Primulaceæ, result from the disruption and absorption of the dissepiments at a very early period.

355. This last statement, however, is not borne out by the history of the development of the ovary, which has been traced by several observers. The placenta in *Primula* is free at the earliest epoch of its existence, and originates, according to Duchartre, as a distinct *papilla* upon the apex of the axis, surrounded by a

little ring, indicating the future carpels, which grow up independently to form the walls of the ovary.

This and similar facts bear out the theory of Schleiden, Endlicher, &c., that the placentas are not portions of the carpellary leaves, but prolongations of the axis of the plant, bearing ovules exactly as the other branches bear buds. This hypothesis clearly explains the case of *Primula*, but it does not accommodate itself so naturally to the axile or parietal form of placentation, the latter of which would require that a double branch should be given off and adhere to each suture; in regard to the former, however, it is possible to imagine the margins of the carpels united to the ovuliferous axis.

In the usual condition of buds which we examined in an earlier chapter (§ 169 *et seq.*), we have seen that they are terminal or axillary to a leaf. Now in the single-seeded ovaries of Compositæ (XVI. fig. 19.), Graminaceæ (XVI. fig. 20.), Plumbaginaceæ (XVI. fig. 21.), &c., we may regard the ovule as a terminal bud, surrounded by a whorl of cohering carpels, and axillary to *one* of them, the buds of the remaining carpels being suppressed. The ovules of *Ranunculus* (XVI. fig. 22.), *Rosa*, &c. may also be included among axillary buds according to this hypothesis. Again, the free central placenta of Primulaceæ may be compared to those forms of inflorescence (§ 257.) where the bracts to which the flower-buds are axillary are suppressed, a view which is borne out by the production of flower-buds from these free central axes, as in the case of *Cortusa Matthioli*, related by Duchartre. The development of *Pavonia*, a Malvaceous plant, as described by the same author, also speaks in favour of an independent origin of the ovules; he states that the carpels originally present themselves as a raised ring upon the summit of the peduncle, displaying ten papillæ on its superior border; these papillæ are the commencements of the ten styles, but the ovarian cavities are only five in number, and alternate with each pair of styles (XVI. fig. 23.). When ripe, these cavities dehisce by two valves; the placenta would thus appear to be a production of the axis, enclosed by two carpellary leaves. The bi-linear parietal placenta is the great difficulty which cannot be satisfactorily explained; Schleiden concludes that it is produced by a flattened branch folded upon itself; the instance which he cites to support the assumption of the possibility of such branches is the inflorescence of *Phyllanthus.*

As the question stands at present, we are led to prefer the theory of carpellary placentation by the evidence afforded by the *parietal* form as occurring in Violaceæ, Papaveraceæ, Orobanchaceæ; the *axile* placentas of Scrophulariaceæ, Ericaceæ, &c. appear to admit of an explanation by both views, as do also the *central* placentas of Caryophyllaceæ. The central placenta of Primulaceæ and Santalaceæ favours the idea that the placenta is a prolongation of the axis, and can only be explained by the carpellary hypothesis, by supposing that the central placental column is a *confluent whorl of placental processes developed separately from the carpels through a process of deduplication* (§ 280.).

THE OVARY.

356. In the explanation of the terms *hypogynous,* &c. (§ 278.) it was stated that in some cases the whole of the exterior floral whorls are more or less adherent to the ovary; the *calyx,* for instance, being *inferior, half-superior,* or *superior.* In these cases the *ovary* is said to be *superior, half-superior,* or *inferior.* The terms "*calyx adherent* or *free,*" or "*ovary adherent* or *free,*" are now usually preferred, but they indicate a different structural relation of the parts which is not admitted by all authors. Thus Schleiden, who contends that the ovary, with the style and stigma, is not a definitely originating organ, but is sometimes formed of carpels, sometimes of the stem, and sometimes of the two combined. He makes five kinds of ovaries, viz.—1. The *superior* ovary, which is composed of carpellary leaves, according to the commonly received notion. 2. The *pseudo-inferior* ovary, where the expanded cup-like receptacle bears the true carpellary ovaries in its interior and the other floral envelopes on its summit, as in Pomaceæ and Puniceæ. 3. The *inferior* ovary, where the ovary or *germen* is partly excavated on the summit of the peduncle, and closed in above by the carpels, as in Saxifrageæ and Myrtaceæ; where the germen is contained in the stem, as in Onagraceæ, and the carpels only form the style and stigmas; or the axis is

continued still higher and bears the anthers, as in Orchidaceæ, where the carpels are represented merely by the little scales of the stigma, or are wanting. 4. The *superior stem-ovary* of *Passiflora,* where the superior ovary arises from the cup-shaped axis, which bears on its borders the carpels forming the style and stigmas. 5. The *stem-pistil*; the pistil of Leguminosæ and *Lilium,* which according to Schleiden is a leaf-like expansion of the stem (!).

357. The compound ovary varies considerably in its form in different families, and even among the members of the same; the most general is the spheroidal or ovate. The outer surface is sometimes smooth and presents no signs of the internal divisions, but very often it bears indications of them in the presence of grooves or furrows along the lines of union of the carpels. The middle lines of the carpels, or dorsal sutures, may exhibit similar grooves or even form projecting ridges, rendering the ovary somewhat angular. When the dorsal portions of the carpels are inflated and separated from each other by deep furrows, the ovary assumes a *lobed* character. The epidermis of the ovary is not always smooth; it may be clothed with hairs or spines, and is not unfrequently glandular.

Compound ovaries are usually *regular,* but occasionally irregular, as in *Antirrhinum,* where the carpels are unlike, and certain Malpighiaceous plants (*Acridocarpus, Hiptage*). Simple ovaries are almost always more or less irregular.

THE STYLE.

358. The general character of the style of simple ovaries has already been described (§ 347.); in the compound ovaries they either remain distinct or become united together in various degrees. In a few orders they are divided, so as to give the appearance of a greater number, as in the bifurcate styles of *Euphorbia,* which in some genera fork again near the apex (XVI. fig. 24.). Those compound styles which remain undivided in the greater part of their extent frequently divide into a number of branches at the apex, and are called *bifid, trifid,* &c. The number of styles generally indicates the number of carpels, and the intercarpellary grooves (§ 357.) are often continued up the style, so as to indi-

cate its compound nature. The styles, being the direct prolongation of the carpel, must alternate with the dissepiments.

The style is not an essential organ (§ 344.), and where it is present it only increases the length of the passage between the stigma and the placentas, these processes being continued up into the styles. In *Primula* a little cellular process extends from the apex of the free placenta into the cavity of the style, in the earlier condition of the ovary. In the Lily the pistillary cords unite in pairs at the summit of the ovary to enter the style, and in Compositæ two similar cords pass from the walls of the ovary into the style.

The style is frequently clothed with hairs, especially near the apex. The Compositæ are furnished with these *collectors*, as they are called. The style is at first shorter than the stamens, and enclosed by the cohering anthers (§ 328.); as it developes it pushes through them, and the hairs *brush off* the pollen from the cells as the style makes its way upward. The Lobeliaceæ have a little circle of hairs just below the stigma, called the *indusium*, apparently for a similar purpose.

THE STIGMA.

359. In the account of the structure of this body (§ 348.), its usual position, whether seated immediately upon the ovary or at various points on the style, has been briefly alluded to; it was also stated that its tissue differed considerably from that of the style, consisting of papillæ, hairs, &c.; sometimes these hairs are so large and numerous as to give the stigma a feathery appearance (XVI. fig. 25.), as in the Grasses.

When the style is divided, the stigmas are divided or multiplied also; in Compositæ and the Grasses we find a double stigma with a single one-seeded cavity in the ovary. In general its divisions indicate the number of carpels contained in the ovary, whether the styles are divided or not.

The three- or five-lobed stigma of Campanulaceæ corresponds to the three or five carpels of the ovary (XVI. fig. 26.); the bilobed to the two cells of Scrophulariaceæ, &c. (XVI. fig. 27.). The shape of the lobes is various, lamellated in *Mimulus* (XVI. fig. 28.), slender and pointed in *Polemonium*. Where united into one body, they are often marked by radiating grooves or ridges corresponding to the number of constituent parts. This head, formed by the confluent stigmas, may be capitate, or larger than the style; it is then either *globular* (XVI. fig. 29.), *hemispherical, polyhedral*, &c., or *peltate* (XVI. fig. 30.), as in *Arbutus*. The peltate stigma of *Papaver* (XVII. fig. 1.) is sessile upon the ovary, and its radiating processes (*a*) appear to be formed by the free stigmatiferous borders of the upper part of the carpellary leaves. Where simple stigmas are borne on simple styles, they correspond to the carpels or cells of the ovary. Stigmas sometimes alternate with the cells, and this arises from the union of *half* of one bifid stigma with the half of that next to it. Thus in the Poppy just noticed, each ray of the stigma, like each incomplete dissepiment, is formed equally by the two adhering carpels, with the cells of which it alternates.

THE FRUIT.

360. Before describing the structure of the ovules contained in the ovary, and tracing their development up to the period when they become independent bodies, it will be more convenient to conclude the history of the parent plant, by examining the changes which the floral organs undergo during the ripening of the seeds.

The fruit is composed of those portions of the floral organs which remain attached to the stem to form a protecting coat to the seeds during the maturation. Those organs which play an important part in the process of fertilization, namely the anthers, the stigma, and conducting tissue, generally wither very soon after their functions are performed. The petals also disappear, and the calyx, except in those instances where it becomes marcescent (§ 299.) or blended with the ovary to take part in the formation of the fruit. The style is frequently persistent, forming a kind of point on the summit of the fruit, which is then said to be *apiculate*. The ovary, in the cavity of which the seed is produced, is the essential organ of the fruit, which may indeed be described as a perfectly mature ovary enclosing the ripe seeds.

Knowledge of the structure of ovaries therefore gives us a key to the composition of fruits, since the parts are the same, merely modified by certain changes taking place during the ulterior development of the ovules. Fruits then are either simple (§ 349.) or compound (§ 351.); the compound fruits again may consist of a number of carpels, more or less coherent; a fruit composed of a number of distinct carpels, like that of *Ranunculus*, is distinguished from the compound fruit as a *multiple* fruit (XIII. fig.17.). The fruit formed of one carpel is generally *unilocular* (§ 351.); the compound fruit composed of a number of carpels is also unilocular when there are no dissepiments (§ 352.), or multilocular when these exist (§ 351.); in the multiple fruit the cells are distinct. The fruit originating from the ovary and the latter generally possessing one or more styles, a fruit may usually be known from a seed or other organ assuming its characters, by the presence of some vestige of the style. Thus in the case of the fruits of many Ranunculaceæ, such as *Adonis, Ranunculus*, &c., which are vulgarly regarded as seeds, the real nature is at once determined by the apiculate summit, the vestige of the style. Where this does not exist, the fruit may be determined by examining the condition of the parts of the flower. In this way we discover that the Strawberry is not a single fruit, but the enlarged fleshy receptacle bearing the simple fruits at its surface: in *Rosa* also the hip is the fleshy calyx adherent to the receptacle.

361. The style indicates the organic *apex* (§ 350) of the ovary, whether lateral or basilar in its insertion; the same holds good with respect to the fruit; the *base* is the point where the carpels, or in some inferior ovaries, the calycine leaves, arise from the receptacle. The *axis* of the fruit is often imaginary, but sometimes exists as a prolongation of the axis, as in Umbelliferæ, Geraniaceæ, &c.

362. When the calyx is adherent (in inferior ovaries) it forms part of the fruit; even when originally free it sometimes contracts an adherence. In most of these cases the different parts cannot be distinguished in the ripe fruit.

363. The compound or multiple fruits are called *symmetrical* when composed of carpels equalling in number the organs of each other whorl, as in *Sedum* (XVI. fig. 12.); they are *asymmetrical* either by reduction or augmentation (§§ 279–282.), as in *Digitalis* (XVII. fig. 2.) and *Ranunculus* (XIII. fig. 17).

Simple fruits are generally somewhat *irregular*; the compound are *regular* when the carpels are alike, as in *Sedum* (XVI. fig. 12.), or *irregular* when they develope unequally, as in *Antirrhinum* (XVII. fig. 3.).

The fruit frequently differs very considerably from the ovary in consequence of certain parts ceasing to develope after the fertilization has taken place. Thus the ovary of the female flower of the Oak contains three cells, with two ovules in each: one ovule alone is matured, and during its development the other five ovules, with two of the cells, are obliterated. In the Horse-chestnut a similar process takes place, but the vestiges of the abortive seeds are generally visible in the ripe fruit. In the Birch the ovary is two-celled, and there is a single ovule in each; one ovule is abortive, and the other in its development forces the dissepiment out of the centre, and the cavity of the second cell no longer exists in the ripe fruit.

In the cases where spurious dissepiments (§ 351.) are formed the fruit exhibits more cells than the ovary, as in *Datura* (XVI. fig. 31.), *Cathartocarpus*, &c.

In *Nigella damascena* false cells are formed externally to the true cells in the substance of the *carpels* by unequal development of the tissue, which leaves the epithelium of the cells attached near the axis and enclosing the seed. Sometimes this epithelium is also attached to the dorsal suture of each carpel, and thus three cells are produced out of each carpel (XVI. fig. 32.).

364. The mature carpellary leaves enclosing the seeds form the *pericarp* or coat of the fruit, and the substance of this is divided into three regions, answering to the three layers of parenchyma of a true leaf; the outermost is the *epicarp* (XVI. fig. 33, *a*), corresponding with the epidermis of the under or outer side of the leaf; the inmost, the *endocarp* (XVI. fig. 33, *c*), to the epithelium lining the ovary; while the intermediate layer is called the *mesocarp* (XVI. fig. 33, *b*), and represents the *mesophyllum* or general parenchyma (§ 139.) of the carpel. This last layer is fleshy in its texture in certain plants, and has thence been called the *sarcocarp*.

In the *Colutea arborescens* we find an example of a pericarp retaining very much of the foliaceous character; in a large number of plants its general structure does not essentially alter during the ripening of the ovary, except that it gradually becomes firmer and drier. But in a multitude of fruits we find the different layers acquiring a great development, more especially the *mesocarp*. Thus the Cherry exhibits two very distinct coats,—the *stone* and the *pulp*; here the pulp consists of the mesocarp clothed by the epicarp, which forms the thin skin; the stone is the endocarp, enclosing the seed, which has its special coat, derived from the structures of the ovule. In the Almond the endocarp is the most remarkable layer, forming the woody *shell*, which is enclosed in a thin and green fleshy layer, composed of the mesocarp, with its epidermis or epicarp. In the Apple, &c. the outer skin or epicarp is the epidermis of the calyx; the flesh or mesocarp is developed out of the ovary and adherent calyx; the inner layer of the ovary forms the horny cell, the endocarp, containing the seeds. In the Medlar the endocarp is more developed than in the Apple, and forms *stones* instead of a *core*. In the Walnut the *shell* is the endocarp; the *husk*, the mesocarp and epicarp. In the Filbert and the Oak, &c. the calyx remains as a cup or husk, more or less enveloping the *nut*, the shell of which is formed of the whole pericarp. In the Cucurbitaceæ the distinction of the layers is not always clear in the ripe succulent fruit; thus in the Melon neither the epicarp nor endocarp is separable from the pulp, which itself is the mesocarp, but displays two regions; the outer greenish, and devoid of the soft saccharine character of the inner. In the Orange the *rind* contains the epicarp and mesocarp; the membranous partitions of its segments are the endocarp, and the pulp is formed by cellular tissue developed in the cavity of the ovary.

The pulp of the Tomato (*Solanum Lycopersicum*) and of the Guava is of the same nature. These cellular masses are considered to originate from the placentas.

The pulp of the Strawberry, as I have already said, is derived from the receptacle. That of the Rose is derived from the adherent calyx, and is evidently an approach to the condition met with in the Apple.

365. As the carpels present sutures (§ 352.), so also do the fruits; in the Cherry, Plum, &c. the ventral suture is very evident, even in the pulpy condition. The legume (XVII. fig. 9.) exhibits both *dorsal* and *ventral* sutures (§ 357.). Where the pla-

centation is axile (§ 343.) and the fruit consequently multilocular, the dorsal sutures alone are visible externally (XVI. fig. 18.), but with the parietal or free central placenta, the ventral and dorsal sutures alternate in the exterior wall. At each suture may often be detected a pair of fibro-vascular bundles, which, as the fruit is matured, generally become easily separable from each other; when the fruit is perfectly ripe it splits open at these sutures, sometimes at the dorsal alone, sometimes at the ventral only, or at both at once. The wall of the fruit becomes thus divided into a number of segments, which in a regular fruit equal the cavities, or are twice as numerous; the separating portions are called *valves.*

366. DEHISCENCE.—The ripe seeds commonly escape from the fruits either by the openings resulting from the separation of the valves, or by the decomposition of the pericarp; but in some cases the fruit remains unaltered until germination takes place, and the young plant then makes its way through the pericarp, which in this instance constitutes one of the permanent coverings of the seed.

Fruits are therefore divided into two classes: those which open to emit the seeds are called *dehiscent*; the remainder, *indehiscent* fruits.

The opening of the fruits takes place at various epochs: thus in *Reseda* the ovary is always open at its apex so early as the flowering stage, and in *Ornithogalum nutans*, the Balsam, and other plants, the seeds are expelled before they have become dry. The dehiscent fruits usually become dry as they ripen, and the contraction resulting from this occasions the dehiscence. The fleshy fruits are seldom dehiscent, and those which have a woody or stony pericarp seldom open spontaneously; they are usually one-seeded, and this makes its way out in germination.

Dehiscence may be either partial or complete; in *Cerastium* (XVII. fig. 4.) and many other Caryophyllaceous plants the valves only separate to a certain distance, and then resemble a crown of *teeth*, at the border of the seed-vessel; in other cases they become detached half-way to or quite down to the base.

367. VALVULAR.—Single carpels, like the *follicles* of *Pæonia, Delphinium*, &c., generally open down the ventral suture (XVII. fig. 12.), but in some of the carpels of *Magnolia grandiflora* we

have an example of dehiscence by the dorsal suture alone (XVI. fig. 34.). In the simple fruits of the Leguminosæ the carpel usually splits into two valves, the fruit dehiscing along both sutures (XVII. fig. 9.).

In the fruits with several cells produced from compound ovaries, dehiscence takes place in various ways. The most common forms are those called the *septicidal, loculicidal,* and *septifragal.*

368. The *septicidal* dehiscence (XVI. figs. 35, 36.) is the result of the separation of the component carpels, where the margins of these have been inflected toward the centre, as in the ovaries with axile placentation (§ 353.). In this case the dissepiment or septum between each cell of the fruit becomes divided into its two component lamellæ, hence the name. The position of the seeds varies in fruits of this kind; sometimes they are attached to the septa (XVI. fig. 35.); sometimes the septum also breaks away from the axile placenta and leaves the seeds attached as to a central column (XVI. fig. 36.).

369. In the *loculicidal* dehiscence it is the dorsal suture of each carpel that gives way, so that the dissepiments remain unaltered, and thus each valve is composed of two half-carpels, which are united together and have the septum which they jointly compose projecting inward at right angles from the point of union. The septa may either become so detached in the centre of the fruit as to carry with them the placentas (XVI. fig. 37.), or they may remain all attached together in the centre (XVI. fig. 38.); but the most common occurrence is for the valve to become detached from the placentas, which are left united into a kind of column in the centre (XVI. fig. 39.).

370. The *septifragal* dehiscence results from a simultaneous opening of the dorsal sutures, and a separation of the walls of the ovaries from the septa (XVI. fig. 40.); this form is confounded with the loculicidal dehiscence by a number of intermediate conditions where the septa give way at various distances from the centre of the fruit.

371. In those forms of the septicidal dehiscence where the constituent carpels become wholly disunited, leaving the centre of the fruit void, loculicidal dehiscence may also take place in each carpel, which opens at its dorsal suture to allow the escape of

the seeds from the closed cell, which resulted from the disunion of the parts of the fruit; this occurs in *Digitalis* (XVII. fig. 2.).

In the multiple fruits (§ 360.) the carpels are sometimes slightly united together by their faces, as in Umbelliferæ, Boragineæ, Geraniaceæ, Malvaceæ and other orders. Here the separation of the fruits from each other takes place by a septicidal dehiscence (XIII. fig. 19,) ; the component carpels being called *cocci*. The *cocci* open in the Geraniaceæ by a loculicidal dehiscence to allow the seed to escape (XIII. fig. 19, *c*).

372. In the compound fruits with a single cell, where the placentas are parietal (§ 353.), the dehiscence may take place at the margins of the carpels, therefore through the centres of the placentas; the valves will then bear the seeds upon their margins (XVI. fig. 41.), this is analogous to the septicidal dehiscence (§ 368.); or at the dorsal sutures, when the valves will bear the placentas up their centre (XVI. fig. 42), which condition may be compared to the loculicidal dehiscence (§ 369.). In the Orchidaceæ the placentas adhere together at the sutures and the carpel gives way along the margins just within the placental borders. The placentas bearing the ovules then appear like an open framework (XVI. fig. 43.).

373. When the placenta is central (§ 353.), the absence of seeds upon the valves prevents our distinguishing their composition by their own characters, and we have to compare their position with that of the leaves or segments of the calyx. If the valves equal these and alternate with them, they are distinct carpels analogous to those of the septicidal dehiscence (§ 368.); if equal and opposite the sepals, each valve is made up of two half-carpels, as in the loculicidal dehiscence (§ 369.). If the valves are twice as numerous as the sepals, we may generally conclude that they have separated both at the dorsal and marginal sutures, and that each valve is only half a carpel.

374. The valves usually become detached from each other at the summit, but in certain cases, as in Cruciferæ, *Chelidonium*, Geraniaceæ, &c. (XVII. fig. 5, *c*), the valves become disunited at the base. In the Geraniaceæ the styles separate with the carpels up to the summit of the central column or *carpophore* (§ 350.); the same occurs in Umbelliferæ.

All these kinds of dehiscence are included under the general name of *valvular*.

375. CIRCUMSCISSILE.—Some fruits undergo a peculiar kind of dehiscence, resembling the mode in which a portion of the calyx sometimes separates from the remainder which persists (§ 299.). The capsule of *Anagallis* (XVII. fig. 6.) and *Plantago*, with those of many Aurantiaceæ, becomes separated into two parts by a transverse fissure which extends horizontally round, and the upper half falls off like a kind of lid; this is called *transverse* or *circumscissile* dehiscence. In cases where the calyx is adherent and the upper free part of the ovary separates in this manner, the fruit is sometimes called *operculate*, as in *Lecythis*.

Transverse dehiscence takes place in some simple fruits, as in the legumes of *Coronilla*, &c., which separates into as many pieces as there are seeds. This is supposed by some authors to indicate analogy between the carpellary leaf and the pinnate compound leaves of the same plants.

376. BY PORES.—As is the case with anthers (§ 323.), some fruits open by pores instead of valves. These openings occur in different situations, being *apicular*, *lateral*, or *basilar*; in various species of *Campanula* each cell opens by a lateral and irregular aperture (XVII. fig. 7.): in *Antirrhinum* two or three orifices appear (XVII. fig. 3.), regular in their form, being results of the breaking up of little portions of the tissue, which are indicated by a circular line before the carpel is ripe; one of these is near the summit of the upper (§ 290.) carpel, the other one (or two) is in the inferior carpel. In *Papaver* a number of orifices are found all round the summit of the capsule, just beneath the overhanging peltate surface on which the radiating stigmas are placed (XVII. fig. 1, *b*).

Certain valvular forms of dehiscence are sometimes confounded with the foregoing; for instance that of *Saxifraga*, where the summits of the capsules are free (XVII. fig. 8.), and open in this free portion at the ventral sutures. The dehiscence of the Caryophyllaceæ (§ 366.), where the separation is very slight (XVII. fig. 4.), has also been included among the instances of *apicular* dehiscence.

377. KINDS OF FRUIT.—The nomenclature and classification of the different forms under which mature fruits present them-

selves have engaged the attention of botanists to such an extent, that it would require more than ten times the space which can here be allotted to the subject, even to give a slight sketch of the various systems. The want of space to enlarge upon these matters is of the less consequence, since the majority of the names which have been made use of are of little purpose save to confuse the student and render the classification artificial. I shall therefore only particularize those names most commonly in use, since the general adoption of them is the best test of their utility.

Fruits may be divided into three classes, which although artificial when considered in relation to the alliances of the families, are convenient when the definition of the fruit alone is in question; these are the *Apocarpous,* fruits in which the carpels are distinct; *Syncarpous,* where they are united; and *Aggregate,* where the fruit is made up, not merely of a number of *carpels,* but of a number of distinct *ovaries.*

378. The *Apocarpous* division will include fruits formed of simple ovaries (§ 349.), and the multiple ovaries (§ 360.) composed of a number of free carpels. Among the former may be distinguished,—

1. *The Legume* or *pod* (XVII. fig. 9.), found in the Leguminosæ. It is formed by the single carpel bearing the ovules along one suture and dehiscing both at the dorsal and ventral suture; the *lomentaceous* variety (XVII. fig. 10.) is constricted between each seed and breaks up at these constrictions when the fruit is mature.

The free carpels of multiple ovaries ripen in various ways, forming—

2. *The Achenium* (XVII. fig. 11.), where the carpel becomes dry and membranous, containing only one seed: the fruit of *Ranunculus* consists of a number of *achenia* borne on the slightly elevated receptacle; in that of the Rose they are borne in the excavated receptacle (XIII. fig. 18.); in the Strawberry on the enlarged fleshy receptacle. All these are indehiscent, and the *Caryopsis,* the fruit of the Grasses, appears to be merely an achenium where the pericarp is adherent to the seed. Closely allied to this kind of fruit are the carpels of those fruits in which they are at first united, but when perfectly ripe separate from one another, and generally dehisce. The two carpels of Umbelliferæ (sometimes called

mericarps) which separate from the carpophore (§ 350.) and are suspended from it by their apices, may be called achenia. The carpels of Labiatæ and Boragineæ, &c. may be termed *dehiscent achenia*. Those of *Tropæolum* are *achenia*, and by *Malva* we find a transition to the Geraniaceæ, where the carpels contain more than one seed.

3. *The Follicle* (XVII. fig. 12.) differs chiefly from the *achenium* in containing several seeds, and in its dehiscence, which takes place along the ventral suture. The multiple fruits of certain Ranunculaceæ, such as *Aconitum*, *Delphinium*, &c., are composed of follicles, as also that of *Asclepias* (XVII. fig. 13.). The *Samara* is only a winged follicle (XVII. fig. 14.).

4. *The Drupe* (XVII. fig. 15.) is formed when the mesocarp (§ 364.) of the fruit becomes fleshy in simple ovaries like those from which *achenia* are formed. Thus in the Rosaceæ, certain genera, as the *Cherry*, form a drupe or stone-fruit, which consists of a succulent envelope enclosing a *stony* endocarp containing the seed. The fruit of the Raspberry and Blackberry consists of a number of little *drupes* borne on the receptacle. The drupaceous fruit is closely allied to those syncarpous or fleshy fruits composed of several carpels, and containing the seeds in a number of *stones* or bony cells; of these—

5. *The Pome* (XVII. fig. 16.) has been distinguished, which has a cartilaginous endocarp enclosing several cells. A succession of forms through the Medlar to the *drupe*, and through the *Haw*, the fruit of *Cratægus*, to that of the Rose, indicate the artificiality of these divisions. The *Pepo* or fruit of Cucurbitaceæ (XVII. fig. 17.) is analogous to the Pome, and leads by *Bryonia* to—

6. *The Berry*, which is a fruit in which the seeds are contained in a mass of pulp formed by the placentas. In the Grape the ovary is free, in the Gooseberry, &c. it is clothed by the adherent calyx, &c. (§ 278.). The *Hesperidium* is the fruit of the Orange, and is only a *berry* with a coriaceous rind.

379. Simple fruits are formed from certain compound ovaries by the suppression of all the ovules but one. Among these there are three principal forms:—

7. *The Nut* (XVII. fig. 18), the fruit of the Hazel, Oak, &c., which is one-celled and one-seeded by abortion (§ 363.), and is an

indehiscent fruit, the envelope of which is hard and woody. It is allied to the *drupe* by the Walnut.

The fruits of the Compositæ have been called *achenia*, and those of *Chenopodium*, &c. *utricles*; the latter appear to differ only from the *achenia* already described (§ 378.) in being composed of several carpels, the former in receiving an additional coat from the tube of the calyx.

380. Compound fruits which become dry in the process of ripening, and dehisce by valves, fissures, or irregularly, are included under the general name of—

8. *The Capsule*, the fruit of Scrophulariaceæ (XVII. fig. 2.) Primulaceæ (XVII. fig. 6.), Papaveraceæ (XVII. fig. 1.), Caryophyllaceæ (XVII. fig. 4.), &c. &c. Certain forms are separated, as for instance—

9. *The Siliqua* and *Silicula*, the capsules of Cruciferæ, composed of two carpels, separating as valves from the placentas, which are united together by a plate of cellular tissue called the *replum*, this having previously formed a *spurious* septum (§ 351.) across the fruit. The *Siliqua* is the elongated form (XVII. fig. 5, *a*); the *Silicula* is short and broad (XVII. fig. 5, *b*).

381. Among the *Aggregate* fruits the most important is—

10. *The Cone* (XVII. fig. 19.), the fruit of the Coniferæ formed by the union of the carpellary leaves of the spike into one mass, which afterwards dehisces by opening at each carpel. This must be distinguished from the cone of *Magnolia*, which is, like the fruit of *Ranunculus*, composed of the *separate carpels* of *one* flower. A number of aggregate fruits have been called *Anthocarpous*, since the envelopes of the flower enter into their composition; the Pine-apple is a mass of cohering flowers become pulpy, as also the Mulberry. These have received the name of *Sorosis*. In the Bread-fruit, this fruit, contrary to the general rule, developes more extensively and becomes fit for food only when the seeds are mostly abortive. Those of the Fig and of *Dorstenia* are formed of the succulent receptacle, and this fruit is sometimes termed a *Syconus*.

In some species of *Lonicera* the berries coalesce so as to form a double fruit. In *Mirabilis* the fruit is enclosed in the persistent and hardened calyx (XVII. fig. 20.), as also is that of *Spinacia*.

There are a multitude of other names given in many books, but the definition of the precise form of all ripe fruits belongs more properly to the province of descriptive botany; here the object is to point out the most important changes which the ovary undergoes during the maturation of the seed, in order that the real nature of the different parts of the fruit may be recognized through a knowledge of the process of their development.

Sect. V.—The Reproductive Bodies.

* The Ovules.

382. The ovules are found under the form of small, roundish, or oval bodies, attached to the placentas (§ 353.), either immediately or by the intervention of a little stalk or peduncle; sometimes they are imbedded to some extent in the substance of the placenta, as in Primulaceæ and Myrsinaceæ. Where the peduncle is present it is a slender filament which has received the names of *umbilical cord*, *podosperm* and *funiculus* (XVII. fig. 24, *f*). The point where this is inserted on the ovule, or by which the sessile ovule adheres to the placenta, is called the *hilum* or *umbilicus*.

383. The first trace of the ovule is a little cellular papilla on the surface of the placenta; this gradually increases in size until it generally acquires a more or less obtuse conical form; this is the *nucleus* (XVII. fig. 24, *n*). The Misletoe affords an example of a nucleus remaining in this condition (XVII. fig. 21.); but in most plants the nucleus soon exhibits a circular or rather annular enlargement at the base, the upper border of this structure being clearly defined (XVII. fig. 22, *A*); this increases in size and in height, and gradually proceeds to enclose the nucleus (XVII. fig. 22, *B*), and it is in fact a cellular coat or envelope which at last quite hides it from view, leaving only a small orifice at the apex, corresponding to the apex of the nucleus, which opening is called the *micropyle* (XVII. fig. 22, *B*, *m*). This coat enclosing the nucleus, when it is the only one, is the *integumentum simplex*.

384. But there are usually two coats formed in this manner, and a second annular border is perceived upon the nucleus, indicating that there are two coats gradually proceeding to invest it, one within the other. The inner one is at first longer than the outer (XVII. fig. 23.), and so is seen externally; but the outer coat

finally overtakes and passes over it, so as to enclose the inner coat and the nucleus. The orifice in the inner coat, opposite to the apex of the nucleus, is the *endostome* or *interior micropyle*; that of the outer coat, the *exostome* or *exterior micropyle*.

The coats of the ovule are differently named by authors, especially by Mirbel and Schleiden, who take opposite views of the order of development. Thus the external coat, the *testa* of Brown and Brongniart, is the *integumentum externum* or *secundum* of Schleiden, who believes it to be produced subsequently to the inner coat; while it is the *primine* of Mirbel, who thinks it is the first formed. The inner coat is the *membrana interna* of Brown, the *tegmen* of Brongniart, the *integumentum primum internum* of Schleiden, and the *secundine* of Mirbel. The funiculus is attached to the exterior coat, and the interior is fixed at the base inside the outer coat, the point of union being called the *chalaza*. This is the point where the vessels of the funiculus pass into the nucleus.

Among the plants where these coats are not produced may be mentioned the genera *Asclepias* and *Dipsacus*. There is only one coat (*integumentum simplex*) in the Compositæ, Lobeliaceæ, Campanulaceæ, the Walnut, the Cypress, &c.

385. At first the relative position of the above parts is such that a straight line could pass through the axes of them all, viz: from the summit of the nucleus through the base of the internal and of the external coats to the hilum. Those ovules which preserve these relations in their subsequent development are called *orthotropous* or *atropous* (XVII. fig. 25.), as in those of Polygonaceæ, part of the Urticaceæ, *Juglans*, &c., but they are not very common. Usually they deviate to some extent from the straight line, and become curved, so as to bring the summit of the nucleus nearer to the hilum.

386. Thus in the Leguminosæ, Cruciferæ and Caryophyllaceæ are often found *campylotropous* ovules, where, by the curving of the nucleus, with its integuments, upon itself, the micropyle is brought into apposition with the hilum (XVII. fig. 26.); by the peculiar development of the ovule, which is greater on one side than the other, the chalaza is removed a little from the hilum, and lies on that side of it opposite to where the micropyle is applied; the convexity and concavity formed by the ovule in its curving upon

itself become organically united. The *camptotropous* ovule only differs from the preceding in the equality of the development of the two halves of the ovule (XVII. fig. 27.).

387. The nucleus is sometimes so affected by the development that the apex or the micropyle comes to be placed next the hilum and the *organic base* of the ovule, the chalaza at the opposite extremity of the ovule; the course of development of this form (XVII. fig. 28.), the *anatropous*, is shown in the figures; the vascular cord communicating with the chalaza is extended during the growth of the ovule, and the chalaza thus always communicates with the funiculus by these vessels which run in the thickness of the coats, in the exterior when there are two. This cord is called the *raphe*, because it is often distinct as a ridge upon the outside, looking like a prolongation of the funiculus adherent to the side of the ovule, and disappearing above at the point which is the organic base.

388. These forms however, in nature, are not at all clearly defined, but, like most of the peculiarities of form or structure, exhibit varieties, among which may be mentioned the *amphitropous* or *heterotropous* ovule (XVII. fig. 29.), where the micropyle is at one end and the chalaza at the other, but the hilum in the middle of one side. These have also been called *transverse* ovules.

389. Meantime certain changes are going on in the nucleus. The apex of the nucleus or *mamilla* presents various forms; it is usually roundish or hemispherical; sometimes it is cylindrical (XVII. fig. 29*), of variable length, this causing differences in the length of the canal of the micropyle (XVII. figs. 25–30, *g*). In the naked nuclei of *Scabiosa* the mamilla is at the base of a canal opening near the hilum (XVII. fig. 30.), and they are thus distinguished from the naked nuclei of *Viscum* (XVII. fig. 21.). In some plants the mamilla of the nucleus grows out from the micropyle into an elongated body, like a kind of style, as in *Loranthus* (XVII. fig. 31.) and *Santalum*. According to Dr. Dickie, tubular prolongations of the apex of the nucleus occur not unfrequently, and he describes them in *Narthecium* (XVII. fig. 32.), *Bartsia* and *Euphrasia*. They were first pointed out by Brongniart, but it still remains a question whether these really belong to the nucleus, since many authors

refer them to a different origin, which will be alluded to hereafter, when the fertilization of the ovules is examined.

390. In the interior of the nucleus is formed a cavity, the mode of production of which is variously stated by different observers. Schleiden says that one particular cell of the parenchyma of the nucleus acquires a special development, increases in size, and finally, by pressing on the surrounding tissue, causes it to be absorbed, and thus becomes a sac or cavity of variable size and form. Mirbel describes the phænomena differently; he states that the nucleus becomes hollow and forms a mere sac, lining the secundine (*membrana interna*, Brown), which he calls the *tercine*; this either adheres to the secundine or disappears. Inside the tercine another membrane is sometimes formed, the *quartine*, but this is rarely present, and is transitory in its duration. Within this is a special sac, agreeing with that above described by Schleiden, in which the embryo is developed (XVII. figs. 25–30, *c*); this is called the *embryo-sac* or *amnios*. Wydler questions whether there is any special cell or sac present, or merely a cavity surrounded by the parenchyma of the nucleus. In *Viscum* there are two or sometimes three embryo-sacs (XVII. fig. 21.).

The size and shape of the embryo-sac being subject to variation, it occupies a greater or less space in the nucleus, and is more or less affected by the changes of relation of position of the other parts (XVII. figs. 25–30, *e*).

At a certain period it becomes filled with cellular tissue, and as this grows inward from its circumference to its centre, to fill up the cavity, it is probable that Schleiden is right in supposing the earlier layers of this to be Mirbel's *quartine*. In the Coniferæ the embryo-sac becomes filled with cellular tissue, and from three to six small cavities make their appearance on the apex opposite to the micropyle. These are little sacs, closed above by a single layer of tissue, and are called *corpuscula*.

391. The cellular tissue of the embryo-sac, after fecundation, is either absorbed by the pressure of the developing embryo or remains as an envelope of that body, becoming what is called the *endosperm* or *albumen*.

POSITION OF THE OVULE IN THE OVARY.

392. An ovule which arises from the base of the cell in which it is contained, and the apex of which is directed toward the summit of the ovary, is an *erect* ovule (XVIII. fig. 1.); when it has exactly the reverse position, suspended from the upper end of the cavity, it is *inverse* (XVIII. fig. 2.). When, arising from a parietal or axial placenta, its apex is directed upwards, it is *ascending* (XVIII. fig. 3.); with the apex looking downward it is *suspended* (XVIII. fig. 4.). That position in which the ovule is attached to an axial or parietal placenta, and the hilum is in the middle of the ovule, as in the amphitropous kind (§ 388.), admits of two varieties, and the ovule may be either *ascending* or *descending peritropous* (XVIII. fig. 5.).

Occasionally we meet with ovules which are suspended at the end of a long funiculus, arising from the base of the ovary; these are called *reclinate* (XVIII. fig. 6.).

All these positions appear to be in some measure modifications of the *ascending*, arising from the peculiar situations in which the ovules are developed. Thus the *suspended* ovule arises high up in the cell, and therefore necessarily becomes curved downward, in order to have space to develope itself. The special relative directions of the hilum and the micropyle in the ovules will influence their relations in the ovary. Probably also the *erect* ovule is really *ascending*, and arises so low down in the cell that it appears to be attached to the base; the *inverse* is likewise easily referable to the *suspended* by supposing it to arise very high up, or even to be adherent to the placenta for a short distance by the funiculus.

393. Where the ovules are present in definite numbers their positions are tolerably constant, and are even to a certain extent characteristic in some families and genera. The position of the solitary ovule (*erect*) is constant in Polygonaceæ, Thymeleaceæ and Compositæ; suspended ovules are characteristic of Polygalaceæ, Euphorbiaceæ, &c.; the ascending ovules of Pomaceous genera distinguish them from the other Rosaceæ, &c.

Again, the direction of the ovules, when there are more than one present, is often constant, as in the case of *Æsculus* and other genera, where the two ovules of each cell take opposite directions (XVIII. fig. 7.); both arising about the middle of the cavity, one becomes ascending, the other suspended.

394. In the Order Ranunculaceæ however we have another example of the impossibility of making universal statements as to constancy of characters. Here we meet with ovules, erect or apparently so, ascending, peritropous and suspended.

395. When there are two ovules in a cell they may be situated as in *Æsculus*, or both have the same direction; they are then *superposed*; or they may be placed side by side, and are then called *collateral*.

If the cell contains many ovules, these may have very various directions, according to the shape of the cavity in which they develope, and the extent to which they interfere with one another (XVIII. fig. 8.), especially if the placentas are thick and fleshy; when they actually press upon each other, the form of the ovules becomes affected, and the ovoid becomes changed into various polyhedral shapes. In long ovaries, like those of some Leguminosæ and the Cruciferæ, where the superposed ovules are not crowded, they often all have the same direction and like form (XVIII. fig. 9.).

When the placentas are linear, the ovules are usually arranged in two parallel rows; in some cases where there appear to be more than two rows, this arises from the close approximation of the points of attachment, causing some of the ovules to deviate to one side, some to the other, of the line in which the funiculi are inserted on the placenta.

FERTILIZATION.

396. Having now described the structure and general characters of the unimpregnated ovule, we have next to examine into the nature of the processes which ensue upon the dehiscence of the anthers and the fall of the pollen upon the stigma.

This division of our subject, involving some of the most interesting physiological points connected with vegetable life, has of course attracted the attention of a host of observers, but in spite of the innumerable investigations which have been instituted, all is still contradictory and unsettled. The difficulty of preparing the delicate structures and the many sources of illusion may in some measure account for this, and as I have not yet been able to make any observations sufficiently decisive to warrant me in adopting any particular theory, my object will be to compare and endeavour to some extent to reconcile the leading features of the different views which are entertained by those botanists who have especially devoted their attention to this point. To mention all the authors who have published upon this subject would manifestly be impossible; I shall therefore divide the theories under separate heads, and there allude to those authors whose opinions are most worthy of attention.

397. When the pollen-grains come in contact with the fluid secreted upon the stigma, the pollen-tubes are emitted, and these slender organs insinuating themselves between the loose cellular tissue, make their way down into the conducting tissue of the style (XVIII. fig. 10.). Where the ovule is naked, as in the Coniferæ and Cycadeæ, they come at once in contact with the micropyle (§ 383.), or as in *Viscum*, where the nucleus is without teguments, immediately upon the mamilla (§ 389.) of the nucleus.

That the tubes which fall upon the stigma do make their way down to the cavity of the ovary, there can be no reasonable doubt, since not only does Schleiden enumerate more than 150 species belonging to upwards of seventy orders in which he has traced them, but they have been observed by the highest authorities—Brown in Orchidaceæ and Asclepiadaceæ, Wydler in various species of *Scrophularia*, Amici in *Yucca gloriosa* and many other plants; and Meyen states that he has traced them in many plants. Almost all authors admit that they do actually penetrate the intercellular passages of the conducting tissue, and I have myself traced them to a certain distance in *Gladiolus* and other plants (XVIII. fig. 11.). Some writers however still contend that the pollen-tubes are not necessarily formed, and that the ovule may be fertilized by the mere bursting of the pollen-grain upon the stigma, as is stated by Gasparini with regard to *Citrus* and *Cytinus*.

398. The next question is, whether the pollen-tubes do actually reach the ovule and become attached to it. Amici traced the pollen-tube from the stigma in *Yucca gloriosa*; Brongniart next observed the pollen-tubes passing down the style, and at the same time noticed filaments hanging from the mouths of the

ovules. The tubes were traced by Mr. Brown in the Asclepiadaceæ and Orchidaceæ from the stigma to the mouth of the ovule, who also observed filaments attached to the mouths of the ovules in certain species, but did not assume that these were produced from the pollen.

Schleiden asserts that he has followed the pollen-tubes from the stigma to the micropyle in all the plants above alluded to. Meyen described and figured it in several plants, and Griffith declared that in *Santalum* the pollen-tube enters the embryo-sac. It was also observed by Wydler in *Scrophularia*.

On the other hand, Mirbel and Spach are of opinion that the pollen-tubes do not enter the ovule in Coniferæ, and many other authors express great doubt on this point.

399. Among the conflicting opinions as to the origin of the embryo, it will suffice here to give the evidence supporting the three theories which appear to be the most important. These include certain modifications in their details, but may generally be stated as assuming—

1. That the pollen-tubes burst within the style, discharging a fluid containing granular matter, which reaches the embryo-sac (§ 390.), and stimulates it to a peculiar activity resulting in the formation of the embryo. (This may include the opinion that the pollen bursts upon the stigma and the granular fluid makes its way down.)
2. That the pollen-tube traverses the canal of the style, and reaches the micropyle, enters it, and coming in contact with the embryo-sac, the septum between the two is absorbed, and the embryo is produced by development of cells at the extremity opposite to that with which the pollen-tube has become blended.
3. That the pollen-tube traverses the canal of the style, and enters the micropyle and pushes the apex of the embryo-sac before it, by which the upper part of the sac is inverted, and thus it encloses the tube by a double layer of its walls. The layer which the pollen-tube first meets may sometimes be absorbed, and then the pollen-tube lies *within* the sac.

400. Among the latest supporters of the first theory are Mirbel and Spach with regard to the Coniferæ, and Giraud in *Tropæo-*

lum; Wilson also disbelieves the passage of the pollen-tube to the ovule, but figures a filament extending from the cellular mass at the base of the styles, which enters the nucleus, and, as he admits, might be assumed to be the extremity of a pollen-tube; his objections are founded upon negative observations. Gasparini states that the pollen affects the conducting tissue of the style, and that a filament is developed from the lower extremity of this, which enters the ovule. Dickie, in describing the filaments produced from the apex of the ovule (§ 389.), which have been noticed also in several orders by St. Hilaire, Brongniart and others, suggests that these may possibly become united with the pollen-tubes; but in many cases he found them terminating above in blind extremities. He is inclined to think that they have often been mistaken for pollen-tubes. Mirbel and Spach allude to these ovule-tubes in *Thuya*, and state that they enter the embryo-sac, but externally are attached to the filaments of the *suspensor* or cellular body, continuous with the conducting tissue.

Mirbel believes that the embryo originates from cells produced in the embryo-sac, and that it may begin to develope before fecundation. Treviranus states that he has seen one grain of pollen fertilize several ovules.

401. The second theory is that advanced by Meyen, and I know of no other author by whom it has been supported. He believed that the pollen-tube enters the micropyle, and comes in contact with the embryo-sac; the contiguous walls of the two bodies then become absorbed, and thus the contents of the pollen-tube are discharged into the embryo-sac. The end of the sac again becoming closed by a membrane, the upper part of the pollen-tube decays, but meanwhile a new cell has been produced in the embryo-sac, which divides by a transverse septum into two, the lower dividing again, and so on until the whole assumes the appearance of a confervoid filament. The last cell then begins to enlarge and produce new cells, acquiring a spherical form, and this cellular body is the embryo.

402. The opinion of Schleiden is as follows. The pollen-tube makes its way down the style to the ovary, where the extremity enters the micropyle (penetrating the loose cellular structure of the mamilla of the nucleus where this is present) and reaches

the embryo-sac. He states that in all the fresh examples which he examined the embryo-sac was pushed inward, so as to form a double sac (which may be familiarly illustrated by a double nightcap), but he considers it possible that in such ovules as those of Santalaceæ, some species of *Veronica* and *Martinia diandra*, where the embryo-sac is elongated upward from the apex of the nucleus, the membrane of the embryo-sac may give way, and the pollen-tube be really in the inside of the embryo-sac. The end of the pollen-tube (XVIII. fig. 14.) now appears as a cylindrical or ovate utricle of variable length, within the embryo-sac, the utricle being closed below, with a rounded extremity, and open above, in continuity with the pollen-tube. The end then becomes swelled, and forms the *germinal vesicle*, which either comprises all that portion of the pollen-tube which is within the embryo-sac, or is connected with the apex of the embryo-sac by a cylindrical process called the *suspensory filament*. Cytoblasts then originate in the contents, and the utricle becomes filled with cells. The germinal vesicle thus becomes metamorphosed into a conical or ovate cellular body (the *embryo*), and the upper part of the pollen-tube becomes detached and absorbed; where there is no suspensory filament the germinal vesicle itself becomes constricted and separated, and then lies free in the apex of the embryo-sac. This author gives the names of between thirty and forty plants in which he has traced the pollen-tube in unbroken continuity into the ovule, and in other examples followed the development of the embryo from the end of the pollen-tube after its arrival at the embryo-sac (XVIII. figs. 12–17.).

Martius does not believe that the pollen-tube pushes the embryo-sac before it, but enters a cell of the nucleus predisposed to receive it. Wydler states that the embryo-sac appeared to him to open above, and to communicate with the micropyle by a narrow canal.

Griffith has declared that the pollen-tube enters the embryo-sac in *Santalum* and *Osyris*, and that there is no organ in the nucleus, previously to the arrival of the pollen-tube, from which the embryo could be produced.

Gélésnow affirms that the process takes place as above described in *Amygdalus persica*, where he says the pollen-tube pushes the upper part of the embryo-sac before it and inverts it, but in *Iberis amara* and *umbellata* the membrane of the apex of the embryo-sac is absorbed, and the pollen-tube enters into the interior of it.

403. Such are the results of investigation so far, and in this unsettled condition I must leave it, first alluding to the hypothesis of some of those who adopt Schleiden's view of the process of fecundation and deduce from it that it is altogether analogous to the reproduction of the Flowerless plants. We have seen that the pollen is developed in a manner exactly resembling that in which the spores of the lower plants are produced, and from this fact it has been assumed by Agardh, Endlicher and others, that the production of the pollen-tube is the analogue of the germination of a spore, and that this germ in the Phanerogamous plants requires to be further developed within the parent plant, exactly as in animals some perfect the embryo of the egg, while others deposit it with merely a germinal vesicle. This hypothesis of course abolishes the sexual division of the organs, since the anther, style and ovary must respectively be regarded as ovarium, fallopian tube and uterus.

** The Seed.

404. When the fertilization, whatever may be the nature of that process, has been effected, the ovule at once begins to undergo important changes. The embryo (§ 402.) is now a somewhat globular body (XVIII. fig. 18.) at the end of the suspensory filament (§ 402.), and is contained within the embryo-sac, which is at first filled with mucilaginous fluid; this quickly becomes organized and converted into loose cellular tissue, the cells of which are produced upon the walls of the embryo-sac and extend inward; in some cases another layer forms upon the outside, increasing the thickness of the nucleus. The embryo begins to enlarge, and pressing upon this newly-formed tissue, causes it to be more or less absorbed, according to the size at which the embryo finally arrives.

405. In some cases it occupies the whole seed, being clothed merely by the envelopes produced by the integuments (§ 384.), but very frequently it does not become nearly so large, and the

tissue, generally within the embryo-sac, sometimes in the nucleus or in both, forms a solid mass, enclosing the embryo more or less, called *albumen* or *perisperm* (XVIII. fig. 19, *n*, *s*). It has been proposed to apply the name *endosperm* (XVIII. fig. 19, *s*) to the deposit formed within the embryo-sac, and restrict that of perisperm to that of the nucleus (XVIII. fig. 19, *n*). Schleiden states that the perisperm of *Canna* originates from the base of the ovule, where the union of the integuments constitutes half the bulk of the ovary; the embryo-sac is continued down to this structure, which goes on developing until it nearly envelopes the embryo and its sac. This he calls a *chalazic* (§ 384.) perisperm.

406. The albumen offers three distinct characters of structure, which are useful in the description of seeds; these are :—*

1. The *farinaceous* or mealy albumen, where its cells are filled with starch granules (§§ 17, 36.). This is peculiarly abundant in the Cereal grains.

2. The *fleshy* albumen is composed of cells which have much thicker walls, but are soft; where these cells contain oil, the albumen is called *oily*.

3. The *horny* albumen has hard thick-walled cells, in which the cavity is almost obliterated by secondary deposits, which frequently exhibit numerous layers with the dots or canals (§ 48.).

407. ARILLUS.—This term has generally been applied to various structures produced upon the ovule, giving additional coverings of various forms, in addition to the true integuments (§ 384.). Planchon however has distinguished the true *arillus* from what he calls the *arillode* or false arillus. The former term he applies to a third covering analogous to the other coats, arising from the funiculus in an annular manner, and growing up over the seed, leaving only an orifice opposite the micropyle, as in *Passiflora* (XVIII. fig. 20.). The *arillode* includes the aril of *Euonymus*, the Myristaceæ, &c. &c., and arises from the borders of the exostome (§ 384.), grows downward over the ovule, and is frequently reflected up again, covering the micropyle. A peculiar

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* These are conveniently distinguished by the action of tincture of iodine, which renders the starch blue, and all the other parts a yellowish brown. The seeds must be examined in a ripe state, as the iodine will tinge the cell-walls of the fleshy albumen blue when recently formed.

form occurs in *Opuntia*, arising by two processes from the funiculus, growing over the ovule, and almost enclosing it.

408. STROPHIOLES.—From the foregoing must be distinguished various bodies produced upon ovules, sometimes forming glandular protuberances, as in *Asarum canadense* (XVIII. fig. 22.). They originate independently both of the exostome and the funiculus, arising from various situations upon the face of the ovule, and especially along the raphé (§ 387.).

409. DEVELOPMENT OF THE EMBRYO.—The embryo we left (§ 404.) as a somewhat spherical body attached to the suspensory filament. As it developes we find, first, the end continuous with the suspensor elongating upward to form the radicle, while the globular extremity soon begins to present traces of its future cotyledonary character. The radicle therefore is directed toward the micropyle (§ 383.) and the cotyledons toward the chalaza (§ 384.); the position of the embryo is thus reversed in regard to that of the ovule, of which, as we have seen (§ 383.), the micropyle characterizes the organic apex. This is the great point of distinction between *embryos* and *buds*.

410. In certain plants, particularly in some parasitic genera, there are no cotyledons visible in the embryo, as in *Cuscuta* (XVIII. fig. 23.). In other plants, as in *Pekea butyrosa*, they are exceedingly small as compared with the body of the embryo (XVIII. fig. 24.).

Generally the *cotyledons* form the greater part of the embryo, and enclose in addition a little axillary bud, which is called the *plumule*.

In a former chapter it was mentioned that the Flowering plants are divided into two great divisions, according to the presence of one or of two cotyledons in the embryo (§§ 95, 96). This difference of structure renders it necessary to examine the conditions separately.

411. THE MONOCOTYLEDONOUS EMBRYO.—The usual form is either cylindrical, with rounded extremities, or ovoid, more or less elongated. It does not present, externally, any very evident marks of distinction into different regions. By careful examination however a little slit or a conical projection may generally be recognized at one side, and on making a section of the embryo

a little conical body is found buried in its substance, opposite the slit and just below the surface (XVIII. figs. 25–6). This is the *plumule* or *gemmule*, and by ascertaining the position of this we are enabled to determine the extent of the *radicle* (XVIII. figs. 25–6, *b*); that part below the plumule, directed toward the micropyle; and of the cotyledonary portion, all that part above the plumule, forming the chalazal end of the embryo.

412. A reference to the mode of development of the monocotyledonous stem (§ 102.) and leaf (§ 162.) enables us to recognize that the position of the plumule thus buried in the cotyledon is exactly analogous to that of all young leaves in this division; the slit is evidently the opening of the sheath or vagina (§ 162.) of the cotyledon from which the first leaf escapes. In the development of the leaves the limb appears first from the sheath of the one below it, and by folding inward at its lower part forms the sheath which encloses the leaf next following, and the development of the single cotyledon exhibits similar phænomena; it first appears as a little conical body, which becomes expanded at the base and soon presents a little paplila, the plumule, in this situation; the sides then fold inward upon the plumule and enclose it, the little slit indicating the juncture of the edges.

In *Dioscorea* the sheath never encloses the plumule perfectly (XVIII. fig. 27.), and the embryo presents a flat cotyledon with an imperfect sheath at its base, within which appears the plumule.

The plumule is sometimes distinguishable externally, when the inflected vaginal portion of the cotyledon is merely membranous, or the two sides do not meet.

Usually only one leaf can be distinguished in this sheath, but sometimes there are one or even two more, successively decreasing in size.

413. The radicle (XVIII. fig. 25, *b*) is usually much shorter than the cotyledon and of a somewhat denser structure, but in certain cases it is as long or longer than the cotyledon; embryos presenting such a condition are called *macropodous*. Occasionally it is much enlarged laterally, so as to constitute the greater part of the embryo. Its inferior extremity is usually rounded, but sometimes attenuated to a point, whence the first real radicle fibre (§ 132.) makes its way out.

414. **The Dicotyledonous Embryo.**—The embryos of this division are extremely varied in their form. One of the most common forms is that of the Almond (XVIII. figs. 28–9.), which may be taken for the description of the parts. The ovate cotyledons (XVIII. figs. 28–9, *c*) are applied face to face and form the greater proportion of the embryo; below is seen the radicle (XVIII. figs. 28–9, *r*), continuous with the plumule (XVIII. fig. 29, *p*), which is concealed between the cotyledons. The radicle here becomes itself prolonged to form the first root, and the plumule often presents two or even more little lobes at its apex; these are nascent leaves.

The cotyledons are generally nearly of equal size, but in some plants one much exceeds the other; in certain instances indeed, one of the cotyledons is so much smaller that it is not perceptible without careful examination (XVIII. fig. 30.).

Sometimes the cotyledons are so intimately connected together that they present the appearance of a monocotyledonous embryo, but here, as in *Carapa* (XVIII. fig. 31.), the plumule is in the axis of the cotyledons and directly continuous with the radicle. The line of demarcation between the cotyledons is generally pretty evident in the mature condition; in the partly developed embryo however they may be distinguished readily, as they are not at first united.

The cotyledons are generally only in contact, not really united, and they frequently become very large, as in the Almond (XVIII. fig. 28.), the Oak, &c.; they are then generally flattened at the internal face where they are in apposition, the outer faces being usually convex. In *Ricinus* they are thin and flattened on both faces, and are called foliaceous; in *Euonymus* the true foliaceous nature is more evident. Their borders are usually entire, but in the Lime, the Oak and the Walnut they are somewhat lobed (XVIII. fig. 32.). There are even indications of the nervures in some instances; most distinct on thin flattened cotyledons, seldom very evident on the fleshy kinds.

The thin cotyledons sometimes exhibit stomates (§ 66.) in their epidermis, and the foliaceous nature is so far assumed in some embryos, that the cotyledons are provided with petioles (§ 148.), or separated from the axis by a short constricted portion (XVIII. fig. 33.). In most cases however they are sessile upon the axis, and the base is then sometimes prolonged downward on each side so as to render the cotyledon cordate in its outline; when these prolongations are short and narrow, the cotyledon is sometimes termed *bi-auriculate* (XVIII. fig. 34.).

415. In abnormal cases there are sometimes more than two cotyledons in dicotyledonous embryos; in the Coniferæ however this is often the regular condition (V. fig. 17.), and these are sometimes termed polycotyledonous embryos; but the term is not applicable to all the embryos of this order, and therefore does not indicate a natural division. Whatever may be the number of cotyledons above one, they are arranged in *whorls*, and thus opposed to the single cotyledons where the first leaf *alternates* with that organ.

416. The Gymnospermous embryos, indeed, those of the Coniferæ and Cycadeæ, have many points of distinction from both the other kinds. Very frequently rudimentary embryos are formed in great numbers in the nucleus in the cavities called the *corpuscula* (§ 390.), and the single embryo fully developed always offers a peculiarity of its radicle extremity, which never presents any distinct termination, but is lost gradually in the albumen. According to Decaisne, the embryo developed in the naked nucleus (§ 383.) of *Viscum* presents a similar character.

The form of the cotyledons, which vary in number up to six, nine, or even fifteen, is then linear, and this verticillate arrangement at once reminds us of the fascicles of leaves (VIII. fig. 5) in the Larch, &c.

417. Cotyledons, as we might expect from their foliaceous nature, are not always applied face to face, as in the case above cited (§ 414.), but present arrangements analogous to those of the leaves in the bud (§ 172.). They may be *reclinate* (VIII. fig. 14, *a*); *conduplicate* (*b*); *convolute* (*d*); or *circinnate* (*g*). The cotyledons are then usually both folded in the same direction, and being parallel form as it were a single body; when they are folded in opposite directions (the cases are rare) they are either *equitant* (VIII. fig. 15, *e*), *half-equitant* (*f*), or *corrugated*, that is, crumpled up like the petals of the Poppy (§ 287.). Some of the foliaceous cotyledons (§ 414.) present special complicated

arrangements which do not admit of a precise general definition.

418. The cotyledons have various relations of position to the radicle; sometimes they are directly continuous in the line of direction of the radicle. In straight embryos therefore the radicle is perpendicular to the cotyledons, in curved embryos it follows the curve of the conjoined cotyledons, the united bodies generally describing an arc of a circle (XVIII. fig. 35.), or even a spiral line (XVIII. fig. 36.).

Very often the radicle joins the cotyledons at either an acute, obtuse, or right angle, or is even completely bent back, so as to lie parallel with them (XVIII. fig. 37.).

This folded radicle may be in contact either with the face or the border of the cotyledons; these conditions are respectively termed *incumbent*(XVIII. fig. 38.) and *accumbent* (XVIII. fig. 39.), such positions of the radicle having a relation to the folds of the cotyledons upon themselves (§ 417.).

419. RELATIONS OF THE EMBRYO TO THE OTHER PARTS OF THE SEED.—The embryo in the course of its development comes to occupy more or less space in the body of the seed; the relative length may be very small, half or even equal to that of the perisperm (XVIII. figs. 40–2.), and its thickness varies in like manner. The quantity of the perisperm will necessarily be exactly in the inverse proportion to the size of the embryo.

When the embryo lies in the axis of the seed it is termed *axial*, and may then rest upon the perisperm, merely touching it at the cotyledonary end (XVIII. fig. 43.), or may be completely buried in it with the exception of the apex of the radicle (XVIII. fig. 44.). In the Coniferæ, as I have mentioned (§ 416.), the extremity of the radicle is lost in the perisperm, or perhaps may be said to have become adherent with it by a development of the suspensor (§ 402.).

420. The embryo may lie out of the axis, being most distant from the side where the chalaza is situated; when enveloped by the perisperm, this is of course much thicker on one side than on the other; it is then *abaxial*. Sometimes it is altogether outside the perisperm and lies beneath the integuments. This condition is most frequent in seeds which have been campylotropous

(§ 386.) ovules, and then the chalaza lies in the concavity of the curve, while the embryo, which is called *peripherical,* curves round the convexity of the perisperm instead of lying within it (XVIII. fig. 35.). In a straight seed like that of the Grasses, the embryo lying upon the surface of the perisperm is very small in proportion to it.

421. The *internal* and *external* situations of the embryo in regard to the perisperm have been characterized by some writers by the terms *embryo intrarius* and *extrarius.*

422. In those cases where the development of the coats of the seed is irregular, the micropyle (§ 383.) is not opposite to the apex of the nucleus, and thus the embryo no longer lies in the organic axis of the seed, which is denoted by a line (straight or curved according to the form of the ovule) drawn from the micropyle to the chalaza. This occurs among Primulaceæ, Plantagineæ, and many Dates. The radicle is then directed to a point some distance from the extremity of the seed (XVIII. fig. 45.), and the embryo is termed *excentrical.*

423. The direction of the embryo in relation to the micropyle and chalaza is constant in the majority of cases; the radicle pointing to the former and the cotyledons directed toward the latter. But the relative position of the *hilum,* the point of attachment of the funiculus, which is visible as a sort of scar upon the ripe seed, is very variable.

In orthotropous ovules (§ 385.) the hilum coincides with the chalaza; in the anatropous (§ 387.) it is at the opposite extremity. In the former case the radicle will point directly away from the hilum (*radicula hilo contraria,* XVIII. fig. 46.); in the latter it will look toward it (*radicula hilum spectans,* XVIII. fig. 47.). In the first condition the embryo is termed *antitropous;* in the second, *homotropous.* When it is curved upon itself so that the two extremities are approximated (XVIII. fig. 35.) it is called *amphitropous,* under which circumstances the embryo is generally peripherical (§ 420.). Thus the *antitropous embryo* belongs to the *orthotropous ovule,* the *homotropous embryo* to the *anatropous ovule,* and the *amphitropous embryo* to the *campylotropous ovule.*

424. Coats of the Seed.—While the embryo is becoming

developed, the various coverings which envelope it undergo certain changes; the embryo-sac, the nucleus, the primine and secundine (§ 384.), may all persist and grow with the embryo as they are seen in the young seed of *Nymphæa* (XVIII. fig. 19.). But generally speaking, some of them disappear. The two coats, the primine and secundine, sometimes become blended together, or one of them, usually the internal, gradually disappears. The nucleus, again, pressed upon by the embryo-sac, distended by the growing embryo, becomes pushed outward and assumes the character of a thin membrane lining the outer integuments, or may disappear almost entirely, either by becoming blended with them or becoming actually absorbed. The embryo-sac, as we have seen (§ 404.), becomes at first filled with cellular tissue which may become the perisperm; sometimes this is absorbed through the pressure of the growing embryo until it then only appears as a membranous layer clothing the embryo. Thus the ripe seed generally exhibits two coats: the external, formed by the outer integuments; the interior, formed either by the nucleus, the embryo-sac, or both, blended into one membrane, or even of the internal coat of the ovule when this has not disappeared. These two coats are called the *testa* and the *internal membrane* or *endopleura*.

425. The embryo, whether enclosed in a perisperm or not, possesses two coats, the internal immediately investing the embryo, or the albumen where it is present, and following all the irregularities of its surface. Sometimes the *testa* follows the surface of the internal membrane, especially when the embryo is erect or almost erect; but where this is curved or reflected upon itself, only the internal membrane is continued into the folds, and the testa scarcely exhibits any depressions. Sometimes the membrane is exceedingly irregular and dips down into the perisperm forming numerous duplications, and thus divides it more or less deeply into lobes, giving rise to what is called the *ruminated* condition of the albumen, as in the Anonaceæ, the Sago, Areca and other Palms, &c. In other cases the testa forms various processes, such as the arillodes and strophioles (§ 407.), or even *wings*, like those formed by the carpels in the *samarous* fruit (XVII. fig. 14.).

426. The internal membrane is generally soft and delicate, and of a transparent whitish colour, but in some cases it is fleshy either in places or in its whole extent. The testa is sometimes of the same colour and texture, but usually it becomes denser and of a darker colour. It may be soft, fleshy, coriaceous or even woody; in the latter case, if thin, it is generally brittle. Very frequently it forms a thick firm layer, composed of cells perpendicular to the surface (IV. figs. 15, 16.). The external cells frequently secrete various matters. The surface may be either smooth or irregular; in the latter case it presents various characters; for instance, it is covered with various elevated markings, such as points, ridges, &c.; or depressions, such as punctations, or excavations; or as in *Papaver* and some species of *Geranium*, it is marked with a reticulation of anastomosing ridges (XVIII. fig. 48.). Some seeds are covered with hairs, and in certain orders, such as Polemoniaceæ, Acanthaceæ and the genus *Salvia*, with many others, it presents cells of a very delicate structure containing elastic spiral fibres (I. figs. 20, 21 and 23).

427. The raphé is found within the external integument in the ovule (§ 387.) and in the seed; it consequently lies within the testa, either in a channel which projects externally, or in a canal hollowed in its substance. The vascular cord traversing the raphé passes inward at the chalaza and then ramifies over the internal membrane (XVIII. fig. 49.). The two coats of the seed are generally thicker in the region contiguous to the raphé.

428. Position of the Seed in the Ovary.—In a former paragraph (§ 392.) the various positions of the ovule have been described, and although the seeds undergo great changes in this particular during development, when they have acquired their perfect condition their positions are analogous to those of ovules, although changed from those occupied by themselves in the earlier stages. Thus we have a seed *ascending, erect, inverse* or *suspended* (§ 392.), either in the same direction as the funiculus, or in the opposite; or it may be attached by its middle and thus be curved or folded upon itself (§ 388.). The same figures which have served for the ovules will illustrate these positions (XVIII. figs. 1–6.).

429. The direction of the radicle, almost constantly pointing

to the micropyle, may be in regard to the cavity of the ovary, *superior*, that is, pointing upward—*inferior*, turned downward—*ventral* or *centripetal* when looking toward the axis, and *dorsal* or *centrifugal* when directed toward the outer wall of the carpel.

The direction of the radicle therefore, together with that of the seed, informs us of the direction of the ovule, and *vice versâ*; thus, if we find an erect and straight or orthotropous (§ 385.) ovule, we may conclude that the embryo will be antitropous with the radicle superior; in the same manner a superior radicle in an erect seed informs us that the ovule was orthotropous. These characters are useful in practice where we can only obtain plants in particular conditions, as in dried foreign specimens.

430. In some plants the micropyle is visible in the ripe seed, especially in many Leguminosæ, as in the Pea, &c., where it is distinguishable as a little orifice. In other cases the seed has to be dissected, and the micropyle may be found by tracing where the radicle terminates.

The hilum is indicated by the attachment of the funiculus, and after this is detached, by a cicatrix. The chalaza is often distinguishable by a difference of colour from the rest of the integuments, being lighter or darker; when it is of the same colour, dissection is necessary, and exhibits the coats thicker and of a different tissue in this situation. It may be linear, or a circular areola, or of an intermediate form, and is always at the cotyledonary extremity of the ovule. Where the hilum is at a distance from the chalaza, the vascular bundle passing through the funiculus is continued through the external coat forming the raphé to the chalaza, whence it sometimes ramifies over the internal coat; it may almost always be distinguished by its colour, which is usually darker than the surrounding tissue. The raphé with the thickened tissue enclosing it, appears to be really a portion of the funiculus adherent to the integuments (§ 387.), as the genus *Zygophyllum* exhibits all intermediate stages between the free funiculus, the direction of which is opposite to that of the ovule (XVIII. fig. 50.), and the adherent condition where it forms a raphé. The raphé is usually on the ventral face of the ovule, that is, the face looking toward the placenta; in a few cases, as in *Fagonia cretica*, it is on the dorsal face.

431. Thus if we can determine the position of the hilum, the chalaza, the micropyle, and the raphé, upon the surface of the seed, we may thence deduce the direction of the embryo; but the knowledge of the direction of the embryo is not sufficient to determine these points upon the coat, since the position of the hilum is variable.

GERMINATION.

432. It now remains only to examine the manner in which the seeds we have been describing germinate, or exhibit the active vitality which brings them into the condition of independent, self-sustaining plants.

A certain degree of heat and moisture and the free access of air are necessary to the process of germination, and it takes place with a varying degree of rapidity in different plants. We may distinguish two stages, one in which certain changes go on in the seed itself, and the other commencing as soon as the embryo has burst through the coats.

433. Where there is a perisperm (§ 405.), chemical changes go on in this (§ 207.), which render it fit to nourish the embryo; the different parts then enlarge and absorb the matter contained in the cells of the perisperm, which sometimes wholly disappears, sometimes alters little in appearance, as in *Phytelephas*. Where there is no perisperm, this stage of the process is a mere swelling up of the parts by the absorption of water and the development of the axis of the embryo from the matters stored up in the cotyledons.

434. This increase of the size of the embryo causes it to break through the coats, and the radicle usually appears first as being nearest the surface, and moreover opposite to the micropyle, which readily yields to the pressure. The radicle of the embryo is, in fact, the first internode or merithal (§ 95–96.) of the stem, and the plumule (§ 410.) or gemmule soon disengages itself from the seed, elongating upward as the first terminal bud (§ 169.), while the lower extremity of the so-called radicle of the embryo grows in the opposite direction to form the main root. The cotyledonary portion, whether single or double, remains last in the seed-coats (XVIII. fig. 51.); sometimes it withers there, in other cases it

escapes and expands into foliaceous lobes (V. figs. 18, 19.), which become green, and indicate the junction of the first or embryonary internode of the stem with the second arising from the gemmule.

435. There are certain points of distinction between the germination of dicotyledonous and monocotyledonous embryos. The latter usually possess a perisperm of considerable size, and the cotyledon does not become disengaged from the seed-coats. Sometimes it produces an external prolongation, more or less slender and of variable length, as in *Allium, Canna,* &c. (XVIII. fig. 52.), which connects it with the axis. Sometimes it is immediately attached to the axis, which at once developes in a direction tangental to the seed. The sheathing portion of the embryo indicated by the slit (§ 411.) elongates with the axis enclosing it, and the slit gradually opens and emits the first leaves, and then the axis on which they are borne (XVIII. fig. 53.); the radicle bursts through below (§ 132.). In a few orders, such as Alismaceæ, Potameæ, &c., the cotyledon escapes from the coats and elongates upwards (V. figs. 13, 14.).

436. The cotyledons of the dicotyledons usually escape from the seed-coat and separate, mostly rising above ground; but sometimes remain within it, or are even united together, giving the embryo the appearance of that of a monocotyledon; but the plumule escapes from the interval between the bases of the cotyledons and not from the interior of a sheath.

The cotyledons persist for some time, becoming gradually exhausted by supplying nutriment to the young plant until that has acquired a sufficient development to enable it to assimilate the matters necessary for its own support and growth; they then wither, and germination is complete. The young plant therefore is thus brought to the condition described in the earlier part of this volume (Chap. V.), and begins to run through the course of development, the description of which this paragraph concludes.

CHAP. X. GENERAL PHYSIOLOGY.

Sect. I. PHÆNOMENA ATTENDING THE PRODUCTION OF FLOWERS AND FRUITS.

437. In the Chapter devoted to the examination of the physiology of vegetation (Chap. VII.), the various processes were examined, which are carried on within a plant in the performance of those functions directly necessary for its own support and growth. At a certain period, new elements enter into the question, namely, when the production of those organs takes place which are destined to reproduce the species. When the flowers are developed, and much more when the maturation of the fruit commences, a far greater demand comes to be made upon the nutrient functions, with varying consequences affecting the duration of the life of the parent plant.

438. Flowering, in a healthy condition of plants, takes place at a tolerably definite epoch in each species, and this epoch may be rendered earlier or later in the life of the plant by artificial or even accidental natural conditions, such as peculiarities of seasons, &c. The flowering period however appears to be retarded most by a too active condition of the vegetative organs; for when plants are placed in a soil more abounding in nutriment than is natural to their physiological peculiarities, they frequently go on producing leaves and branches without the least tendency to develope flowers, but by cutting the shoots or otherwise checking the activity of the developing functions the plants are caused to flower. On the other hand, plants, especially annuals, when they have acquired just sufficient development to enable them to sustain an independent existence, will frequently survive under very adverse conditions of soil, moisture, &c., and remain dwarfed, with few leaves, but still produce flowers. The flowering and fructification therefore appear to require an *accumulation* of nutrient matter, and this view is borne out by what we see occurring in our cultivated plants. After a bad season in which little fruit is produced, the next year generally presents an abun-

dant crop, and *vice versâ*. Again, by removing a ring of bark from a branch in unproductive fruit-trees, the downward progress of the assimilated nutriment is arrested, and by its accumulation causes the branch to bear an abundance of fruit. The pruning of fruit-trees is conducted on a similar principle, the buds being chosen for preservation which are seated upon the wood of the previous year instead of those on the young shoot; the seedling also, which when left to itself does not flower for several years, is, by grafting it upon an older stock having a much more considerable power of affording nourishment, rendered at once fertile. These facts render it evident that the processes of reproduction tend to *exhaust* the parent plant, and annuals possessing little means to enable them to endure this, it kills them; biennials in the flowering period exhaust the accumulated store of two years and then die. Perennial plants do not flower so early, and they are thus in a condition to withstand the exhaustive process with impunity. A proof of the truth of the above views is afforded by the process of rendering annuals, biennial or even perennial, by removing all flower-buds as soon as they are developed; the plant then produces wood and acquires a shrubby character. Converse cases are given by the examination of the roots of the Beet, Turnip, &c. before and after flowering; in the latter stage they will be found divested of all the saccharine and farinaceous matter with which they were previously densely filled; all plants indeed, the products of vegetation of which are used for economic purposes, are in the most favourable condition just before flowering. The Sugar-cane is gathered at this epoch, and all the vegetable juices possessing medicinal properties, such as that of *Hyoscyamus*, *Conium*, &c., afford the most powerful effects when obtained at this period.

Many other examples of this exhaustion by flowering, and of the lengthening of the duration of life by retarding it, might be given; some of the most striking of the former are presented by the *Agave* or American Aloe as it is called, which lives many years without flowering (formerly it was supposed for a hundred), but after the production and completion of the inflorescence, which is of enormous size and developed with amazing rapidity, the plant perishes; the Talipot Palm, which, after a life extending over many years, during which it attains a great height and bears a crown of leaves between twenty and thirty feet in diameter, flowers for the first time, produces a vast quantity of seeds, and dies.

439. The nutriment thus abstracted from the parent plant goes in great part to form the concentrated store of food which is laid up in the perisperm and cotyledons of the seed. But a large amount is consumed in the process of flowering; here there is no separation of oxygen as in the green leaves, all is development (§§ 207-8.), and the flowers absorb oxygen from the air like animals, and give off a certain amount of carbonic acid, resulting from the oxidation of a portion of the carbon of the nutriment supplied by the vegetative organs.

The same process takes place in the development of the young plant from the seed. In germination (§ 433.) there is an oxidation of carbon as in the development of flowers, and in both cases it is accompanied by the liberation or production of heat, as occurs under all circumstances when these two elements combine. Examples of the heat afforded by the decomposition of vegetable matter by oxidation, also occur in "bark-beds" heating cotton-bales, &c.

440. The liberation of heat is sometimes very extraordinary, as in the Aroideæ; it has also been observed in the *Bignonia*, the Gourd, &c. In *Arum*, at the time of the opening of the flowers in the spadix, a kind of "quotidian fever" is remarked; the heat each day rises up to a certain point and then decreases until it is little above the temperature of the surrounding atmosphere; the maximum of heat increases daily for some days, and then gradually declines. In *Arum maculatum* the maximum has been found to be from 17° to 20° above the temperature of the surrounding air; in *A. dracunculus* and *italicum* it is much higher.

441. The checking of vegetation, which has already been alluded to as favouring the production of flowers, is carried out on a grand scale in nature in the season of repose which is peculiarly characteristic of plants. This is not a hybernation like that of animals, inasmuch as the store of food is not laid up

to support the plant during the winter when it is almost perfectly at rest, but to fortify it for the increased efforts of the next season. The check appears to be first given by the diminished supply of the moisture which is especially necessary for rapid vegetation; as the summer advances the soil and air become drier and the production of leaves goes on more slowly, flowers are produced, seeds ripened, and finally, in perennials, the leaf-buds for the following year and the store of starch, &c. for their nutrition. The cold season maintains the repose, and in the spring the heat, together with the abundant moisture, stimulate the plant to fresh activity.

The periodical rains and droughts appear to bring about the same conditions in tropical climates, where there is no cold season. During the dry season, which may be regarded as analogous to our winter, all vegetation is dried up, except such plants as Euphorbias, Mesembryanthemums, &c. Roots and bulbs are dormant. When the rainy season commences the plants acquire extraordinary activity, new leaves are produced, flower-buds developed, and then again fruits ripened and bulbs, &c. produced as this season approaches its close.

442. In the maturation of fruits, very peculiar chemical changes are involved. In the first instance the carpels are analogous to leaves and liberate oxygen in the light, &c., but after some time this process ceases in those fruits which become fleshy or pulpy. The cellular tissue becomes enormously developed, and at first contains a large amount of water, which gradually diminishes its proportion to the solid matter as the fruit ripens, by evaporation (this however taking place less and less freely as the fruit advances in development) and by chemical combination with the other matters. The proportion of cellulose (§ 14.) or woody matter becomes smaller, while that of sugar increases. Besides these, albumen, dextrine (§ 18.), gelatinous matter (§ 16.), pectine, tartaric, and often malic and citric acids appear, the latter substances sometimes combined with lime, &c. The firm cellular matter, lignine (§ 14.), is deposited in large quantity in the fruits of the Pear, &c., and the cells thus hardened, scattered through the fleshy mass, give it the peculiar gritty character.

The cellulose and the dextrine undergo decomposition and are changed into sugar (§§ 20, 23.), and these chemical changes go on freely after the fruit has been detached from the plant.

443. The substance called *pectic acid* appears from Frémy's observations to play an important part in the changes taking place during maturation. The pulpy mass found in young fruits is chiefly composed of a gelatinous matter, from which, by the action of acids, he obtained the substance which he calls pectine; this, by contact with albumen, is converted into pectic acid. Pectine is soluble in water, but pectic acid is insoluble, and only absorbs water and becomes converted into a gelatinous matter. These transformations take place spontaneously in the fruit, the pulpy mass affords pectine by the action of the vegetable acids, and the pectine is changed into pectic acid by the albumen also present.

444. The presence of starch in the fruit is as rare as its occurrence is common in the seed, but in the Banana and the Bread-fruit it is abundant, and especially in those varieties where the ovules are abortive.

In certain fruits the pericarp contains a large quantity of fixed oil, as in the Olive; this is contained in special cells. Essential oils are much more common, and are generally contained in cells grouped in particular forms, such as glands, &c., *e. g.* in the Orange, Rue, Fraxinella, &c.

445. The time at which the fruit is mature varies in different plants; indeed we are accustomed to look upon them as ripe at that period when they are most agreeable as food, which in the Apple is much earlier than in the Medlar. As indehiscent fruits (§ 366.) however, they decay gradually by the oxidation of their tissues, liberating carbonic acid, and undergoing the putrefactive change, until the seeds which they contained are set free; this decaying mass which invests the seeds not only does not injure them, but probably assists in their development and germination.

446. The dissemination of the seeds is effected in a multitude of ways which it is not worth while to particularize here; in a few cases however the seed germinates while still attached to the plant, especially in pulpy fruits like those of Cucurbitaceæ. Even in

the Mangrove, a large tree, this is the case; the radicles pierce the pericarp and elongate until they reach the mud in which the trees grow.

447. Many more seeds are matured than are destined immediately or even ever to germinate; thus accidental interferences are provided against, and the wide distribution ensured, especially as the vitality of seeds under favourable circumstances appears to be almost indefinite in its duration. The Wheat from the cases of Egyptian mummies is said to have been made to germinate. Lindley mentions a case of the germination of Raspberry seeds taken from a "barrow" at a depth of thirty feet in the ground, with which were found coins of the emperor Hadrian; plants were raised from these seeds, and bore fruit.

Sect. II. Colour.

448. The phænomena of colour exhibited by plants have been investigated, but hitherto without much success as regards the determination of the principles upon which they depend. The coloured parts may conveniently be divided into two classes; those which are green, owing their tints to the presence of chlorophylle (§ 24.), and those presenting various brilliant colours of a different character, and belonging in general to the organs of the flower.

449. The green colour is displayed by the young bark, leaves and other organs having the foliaceous character, such as the calyx, carpels, &c. The intensity of this appears to depend upon the action of light (§ 208.). Certain exceptional cases are recorded, but the evidence of daily experience is too strong to be overbalanced by a few contrary instances.

These foliaceous organs are not always altogether green; they may be variegated or wholly coloured, either on one or both faces, with a different tint; in the latter case the young bark is usually of the same colour, as in the Beet, some *Atriplices*, the copper Beech, &c. In *Aucuba* the leaves are variegated with a yellowish colour, in *Caladium bicolor* with red, and in certain Saxifrages, &c. they are green above and red or brown below.

Again, many green leaves change their colour in the autumn; in Poplars, Elms, &c. they become yellow, in the *Ampelopsis* or

Virginian Creeper a bright red, in the Vine spotted with yellow or purple, and these colours often correspond with those assumed by the ripe fruit. Brownish patches often appear on leaves which are much exposed to a bright sunlight. In herbaceous plants the green colour is deepest in those leaves which have abundance of daylight, and are not much exposed to the direct rays of the sun; and in lofty and exposed situations, as on mountains, the leaves often become reddened at an earlier period than in lower districts.

Those plants called evergreen, the leaves of which do not fall in the autumn, nevertheless are of a lighter colour in the winter. The loss of the green colour most probably depends upon the gradual decrease of amount of carbon in the chlorophylle, which, as the activity of the plant diminishes at the approach of the season of repose, becomes oxidized for nutrition more rapidly than the reparative process is carried on by respiration. In the yellow withered leaves no more chlorophylle is to be found. The red colour is said to be produced from the colourless juices; it sometimes presents itself, as in *Ampelopsis*, in red granules. The white variegations are stated by Nourse to be produced by dense white cells lying over the chlorophylle. The brown spots result from a similar cause; the cells become dense and their walls imbued with a brown resinous or extractive matter, which is also frequently deposited in granules in the cells. These overlying the chlorophylle obscure it. The brown matter is apparently analogous to that found in all old ligneous tissues, such as the old wood, &c.

The chlorophylle is situated deeply in the structure of the leaf, in the *mesophyllum* (§ 139.), and this distinguishes it from all the other colouring matters of plants.

450. The bright colours of flowers are given by a matter of a very different character, always fluid and contained in cells situated immediately beneath the epidermal layer. Many of the different shades of colour are given by the superposition of cells containing different-coloured matters; thus yellow seen through red appears orange, green showing through red renders it apparently brownish. The very deep tints are produced by the close aggregation of many cells lying one above another. The layer of

epidermis or cuticle (§ 66.) of petals is colourless, and by assuming a papillose structure it gives them the peculiar velvet-like character they sometimes possess; or when less developed and filled with colourless fluid, renders the surface glaucous or crystalline in its appearance. The predominating colours are yellow, red and blue, with the various intermediate tints; sometimes these colours are converted one into another in the petal after fertilization (at which period the colours are brightest). In many Boraginaceæ the blue flowers become red; in *Myosotis versicolor* the yellow flowers become blue, and in some Onagraceæ white flowers turn red. Many flowers have their colours bedimmed or removed as they wither, especially the blue, which become most frequently white; white flowers usually turn brown; red colours are more persistent, and yellow is generally unaltered, except in certain cases, such as *Melampyrum*, and some other Scrophulariaceæ, which are blackened.

451. The chemical nature of these colours is still uncertain; it is well known that the blues are reddened by acids, the reds turned blue, green or even yellow by alkalies. Chemists have thence supposed that the red colours are more highly oxidized matters than the blue, and taking chlorophylle as the starting-point, they have deduced red colours by oxidation on one side, and blue by deoxidation on the other.

Marquart also adopted chlorophylle as the base, but from his experiments concluded that it became combined with water to form the base of the yellow, which he called *anthoxanthine*; a body which undergoes little alteration by the action of acids or alkalies in general, but acquires a deep blue from the action of concentrated sulphuric acid, according to his views, by the abstraction of its combined water. The blue matter *anthocyane*, obtained by removing the combined water from chlorophylle, is soluble in water, reddened by acids and turned green by alkalies. The green is the neutral condition between the two colours.

These theories however fail in one respect; the anatomical position of the chlorophylle is different from that of the other colouring matters, and therefore, although these may be, and probably are, closely allied to chlorophylle in a chemical point of view, as in fact are all the vegetable compounds, they must have an independent origin.

Berzelius believes that the red matter is a distinct substance, which he calls *erythrophylle*. In the leaves also he has detected a fatty substance of a yellow colour, which he calls *xanthophylle*, which appears distinct from *anthoxanthine*. It is this substance, he states, which, uniting with a matter rather blue than green, in the chlorophylle, remains after the removal of that matter, and gives them their yellow colour. There are therefore probably several distinct compounds in the colouring matters of plants.

452. The colours of wood appear to arise from chemical changes after the death of that part so far as physiological functions are concerned. The contact of air generally deepens the colour of wood.

The action of the air upon the vegetable juices is often very striking, changing their colour and even their chemical composition. Thus the root of the Madder, the cells of which are filled with a yellowish juice, when wounded becomes reddened; pure oxygen will not effect this—it requires the presence of aqueous vapour. Many of the large Fungi called *Boleti*, which are naturally white, when wounded turn blue, green or black; in the *B. cyanescens* a deep indigo. The colourless juice of *Euphorbia* is rendered opake and white when exposed to air; that of *Chelionium* yellow. The tannic acid (§ 28.) which many plants contain probably affects the colour of structures considerably at periods long after they have completed their various vital functions.

Sect. III. Development of Light.

453. On this subject little can be said with any certainty. A few cases appear to be supported by good authority. The daughter of Linnæus observed flashes of light emitted by the flower of *Tropæolum majus*. Other cases are narrated, *e. g.* in the *Helianthus annuus, Calendula officinalis, Tagetes patula, erecta, Œnothera macrocarpa, Phytolacca decandra, Arum maculatum* (in oxygen gas), *Polyanthes tuberosa*. It is said to take place in the evening, when the air is very dry, and especially in yellow or orange-

coloured flowers. The whole of these statements require further confirmation.

454. The phosphorescence of *Rhizomorpha* described by Humboldt, and of an *Oscillatoria* by Meyen, very probably depended upon a process of decay. In decaying wood, decaying Fungi, &c., the phosphorescence is often evident enough. It appears to depend upon a gelatinous matter, which invests the phosphorescent parts, and when dull the light may be revived by rubbing this. It is probably altogether dependent on chemical processes, which liberate phosphorus from its combinations.

Sect. IV. PHÆNOMENA OF MOTION.

455. Movements of three kinds take place in vegetables:—1. Those caused by hygroscopic conditions in those parts of plants which have completed their development, and may be said to have lost their active vitality. 2. Those which occur from causes yet unknown in the living and perfectly healthy cellular tissue. 3. Those motions of the whole plant which are seen in the *Oscillatoriæ*, &c.

456. The first kind is exhibited by a multitude of organs, chiefly in the execution of some function connected with reproduction, such as the bursting of spore-capsules, the dehiscence of anthers and of capsules, the separation of the carpels of the fruit in Euphorbiaceæ, Umbelliferæ and Geraniaceæ, &c.; also in the twisting of the *setæ* or peduncles of the capsules of Mosses, of the suspending processes by which the carpels of the Geraniaceæ are attached to the style, of the carpels of the ripe fruit of *Impatiens*, and the ejection of the contained fluid and seeds from the fruit of *Momordica elaterium* from the hole where it becomes detached from its peduncle. All these cases appear to be the consequences either of—1. mere contraction of the tissue by drying; 2. the reaction in consequence of elasticity when the tissues have been over-distended by fluid; or 3. of the unequal density or size of the cells in different parts, which causes them to contract unequally when the contained fluids evaporate. The contraction causes a twisting when the opposing tissue yields in a sufficient degree; when the tissue opposing the contraction is weak it gives way, and the membrane or other structure is torn.

457. Of the motions of the second kind we may distinguish two classes—1. the directions taken by organs; and 2. the motions of irritability. The influence of light upon the directions taken by organs is incontestable, but it does not appear to be the sole cause. Under all circumstances the terminal bud is directed upward and the radicle downward, except in parasitic plants, where the direction of the radicle is toward the centre of the body on which it grows. Some writers explain this by the peculiar conditions of the tissues, and Dutrochet has endeavoured to show that it results from the difference of the size of the cells, which causes peculiar conditions of endosmose. Thus, if a stem be composed of cells diminishing in size *toward* the centre, all sides will tend to curve *toward* the centre, and *vice versâ*; but in such a stem the tendencies balance one another. In the young stems which have an abundant pith, the cells diminish in size outward *from* the centre, and if the apex of the stem be split down the two sides will be recurved, from the tendency just described; for the same reason, if the stem be placed in a more or less horizontal position, the force of endosmose will be weakened in the under side, and will cease to counteract the tendency to recurve of the upper side, so that the stem will be curved upward. In the root the arrangement of the cells is exactly opposite, causing a tendency to curve *inward*; therefore a weakening of the force of the endosmose on the under side, when in the horizontal position, will cause the root to be curved downward.

The upper faces, as they are called, of leaves always endeavour to turn upward when the position of a branch is reversed (even after the branch has been removed from the stem), by twisting on their petiole, and this takes place equally in water and in darkness.

458. But that light has a considerable influence over the motions of plants is evidenced by many cases of what has been called spontaneous activity, where the motions of certain leaves are clearly dependent on this agent. A great number of leaves alter their position during the day and night, and some exhibit this peculiarity in a very striking degree. This is the phænomenon which has been called "the sleep of plants," although it evidently has no analogy to that of animals.

Some leaves make a quarter of a revolution, and then turn their points downward (*Impatiens noli-me-tangere*), others upward (*Atriplex hortensis*). Compound leaves exhibit this motion more extensively; they may either move the petiole on the stem, the partial on the common petiole, or the leaflets on the rachis, or the whole of these motions may occur together. The Leguminosæ and Oxalidaceæ are especially remarkable for the manner in which the leaves become folded up. The leaflets fold up in the inverse order of their development, the youngest first, and as the whole leaf grows old the motion gradually ceases to be produced.

Light also acts upon the flowers in a similar manner. Some flowers open at certain times in the day, others during the night, but the alternations are not often many times repeated. Very frequently the flowers open in the morning, close in the evening, and open no more; others will repeat their changes for some days. Variations in the degree of light affect the time of opening in the day, some only expanding in bright weather, as the *Anagallis arvensis*, which also appears to be affected by the humidity of the air.

459. Among the movements which are not periodical may be mentioned those of *Mimosa sensitiva* and other species, which immediately result on contact with any foreign body; of *Oxalis stricta* and *corniculata*, which fold up after a succession o. light strokes; even the leaflets of *Robinia pseudo-acacia* exhibit the same folding which takes place at night, if they are violently shaken for some time. *Dionæa Muscipula*, the Venus's Flytrap, which has long stiff hairs upon its leaves, exhibits a peculiar irritability. When an insect or any foreign body falls upon the leaf, it instantly folds up along the mid-nerve, and the hairs cross so as to enclose the object within them.

460. *Desmodium gyrans* and *gyroides* exhibit a movement which appears to be independent of external agents. The leaves of *D. gyrans* are composed of three leaflets, and the large terminal one is only subject to the changes taking place night and morning; the other two, very small, manifest continual activity in hot weather, rising and falling alternately, the point of each thus describing an arc of a circle, the mid-nerves of both always remaining in one line. This motion does not depend at all upon light, goes on day

and night, and is only rendered more active by heat and a more vigorous condition of the plant in general.

461. Certain movements occur in the essential organs of vegetation, for the purpose of bringing the pollen in contact with the stigma. The stamens frequently curve toward the stigma, usually following the order of their arrangement upon the receptacle; thus in *Ruta*, where there are two whorls, the outer curve in first. In *Parnassia* the five stamens incline inward one after another, touch the stigma, and return to their former position; in *Saxifraga tridactylites* they curve in in pairs. Sometimes the styles curve toward the immoveable stamens, as in *Passiflora*, *Nigella sativa*, some Onagraceæ and *Cacti*. In some Onagraceæ and Malvaceæ both stamens and styles move.

462. External agency will sometimes produce these motions. The filaments of *Parietaria* move when touched, and the anthers immediately burst. If in *Berberis vulgaris* the base of the filament is lightly touched, the stamen springs rapidly inward, applies its anther on the stigma, and then slowly returns to its place. *Helianthemum vulgare* and other Cistaceæ exhibit a motion of the stamens when they are touched and the anthers burst at the same time; the anthers here curve outwards. In the Lobelias, *Gratiola* and the Gentians, the stigmas move when touched; and in some of the Bignonias, the two lobes which are spread out at the opening of the flower, contract. The stigma of *Ruellia anisophylla* is usually curved; when touched it erects itself, curves in the opposite direction, and comes in contact with the hairs of the corolla upon which the pollen has been scattered. In *Stylidium* the filaments adhere to the style, forming a kind of column, bent out from the flower, which suddenly rises up when the curvature is touched.

These movements are frequently produced in nature by the action of insects or the agitation caused by wind; but in some instances, as in *Stylidium*, they occur spontaneously in the middle of very hot days, then usually taking place more slowly.

463. The third kind of motion is equally inexplicable with the second. The *Oscillatoriæ*, a genus of Algæ, are filaments composed of cells attached end to end, filled with green matter and various fluid and granular matters. During their whole life

each filament exhibits a threefold movement. The point describes a small alternating curve, the anterior half a half-elastic, pendulous bending backward and forward, and the whole gradually advances. Sometimes these movements occur singly, sometimes simultaneously.

This kind of motion is clearly analogous to that of the spores of the lower Algæ (§ 216.), which was referred to in an earlier part of this volume, and is not at all understood.

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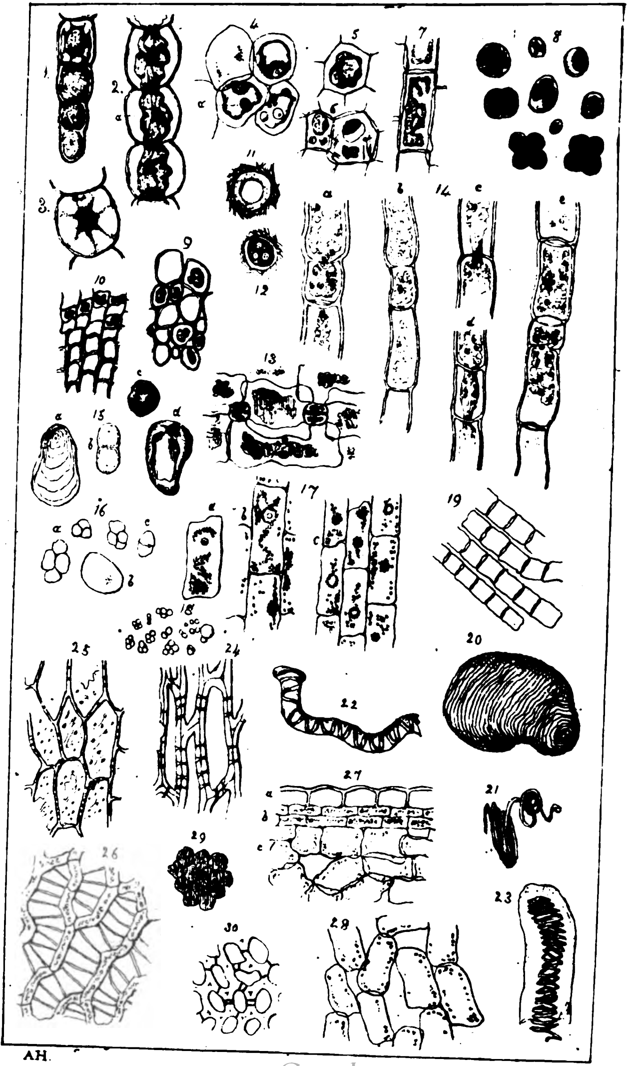
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DESCRIPTION OF THE PLATES.

⁂ Where no authority is given the figures are from original drawings.

PLATE I.

Fig. 1. Terminal portion of a hair of a stamen of *Tradescantia virginica,* showing the process of cell-multiplication by the division of the primordial utricle, and the formation of septa.

Fig. 2. An older portion of a similar hair; the cells have expanded into a spherical form. The primordial utricles enclosing the nuclei are detached from the cell-walls by tincture of iodine, and are seen to be continuous through the as yet incomplete septa.

Fig. 3. A single cell from the same hair, unaltered by re-agents; the nucleus is the centre of radiating mucilaginous threads, along the course of which at an earlier period a circulation of granules takes place.

Fig. 4. Transverse section of the stem of *Tradescantia virginica,* treated with tincture of iodine. The remains of the primordial utricles are seen with the nuclei (*a*) and also new mucilaginous utricles, probably destined to the production of starch.

Fig. 5. The same; the remains of the primordial utricle more perfect.

Fig. 6. The same; the new (starch?) utricles more developed.

Fig. 7. Longitudinal section of the same, also treated with iodine, showing the primordial utricle and permanent nucleus.

Fig. 8. *Chlorococcus vulgaris*, in various stages. This plant, consisting of a single cell, multiplies by division into four, which is effected by the formation of septa, as in fig. 1. The new cells are at first segments, but acquire a somewhat globular form before becoming detached from one another.

Fig. 9. Liber cells of *Juniperus communis*. The transverse section, which had been kept some time in spirit, shows the detached primordial utricles.

Fig. 10. Transverse section of the cambium layer of the same plant; the youngest cells, to which the power of reproduction is confined, retain their primordial utricles. (They have fallen out of some of the cells in making the section.)

Fig. 11. Very young spore-cell of a Truffle (*Tuber cibarium*) in water.

Fig. 12. Ditto; these two figures illustrate the formation of cavities in the mucilage, by means of which, according to Mohl, the latter becomes excavated until it is left as a network around and among the cavities.

Fig. 13. Epidermis of *Orchis fusca*, kept in spirit; the primordial utricles and nuclei are seen in all the cells.

Fig. 14. Articulations of *Conferva* ——? exhibiting the process of division which takes place in alternate joints. *b* exhibits a cell in a natural condition; *a*, the same, treated with iodine; *c* and *d* are joints with septa, which appeared complete until the primordial utricle was rendered visible by iodine and seen to be continuous through the septa; *e*, another portion, treated with iodine.

Fig. 15. Potato-starch. *a*, a large granule, exhibiting the nucleus or hilum and concentric striæ; long diameter $\frac{1}{370}$, short diameter $\frac{1}{780}$th of an inch; *b*, a small granule apparently undergoing division; a nucleus is seen at each end; *c*, a granule, coloured by iodine and burst by heating; *d*, a granule burst by heating in water.

Fig. 16. Starch from *Crocus aureus*. *a*, granules connected in fours; long diameter of the left-hand group $\frac{1}{1800}$th of an inch; *b*, a larger granule, exhibiting a nucleus; long diameter $\frac{1}{960}$th of an

inch ; *c*, a granule apparently undergoing division ; long diameter $\frac{1}{1300}$th of an inch.

Fig. 17. Cells from the stem of *Lilium candidum*, with nuclei and newly-formed chlorophylle granules, which were coloured blue by iodine. *a* shows the nucleus distinct from the granules ; in *b* the nucleus is surrounded by a ring of them in the upper cell and enveloped by them in the lower ; in *c* they are similarly disposed. An appearance like this probably led K. Müller to suppose that the nucleus was *converted* into starch granules.

Fig. 18. Chlorophylle granules from the same. They acquired a bright blue colour by the addition of iodine.

Fig. 19. Cellular tissue from a macerated stem of *Hyacinthus orientalis*.

Fig. 20. Spiral cell from the testa of the seed of *Cobæa scandens*.

Fig. 21. A portion from the end of the same, showing the spiral fibre unrolling (it is adherent to the membrane, which is torn).

Fig. 22. An elater from the capsule of *Jungermannia dilatata*, consisting of a cell enclosing an elastic spiral band.

Fig. 23. Spiral cell from the seed of *Salvia* ——? (purple-topped Clary). The fibre is not adherent to the membrane, and both are pressed close to the testa until the gummy matter by which they are held down is dissolved by water ; the elasticity of fibre then causes the cell to spring out. (A similar phænomenon occurs in the seeds of *Collomia* and other Polemoniaceæ and Labiatæ, &c.)

Fig. 24. Prosenchymatous cells—wood-cells of a *Cactus* in longitudinal section ; the pores of communication between the cells are distinctly visible in the walls.

Fig. 25. Parenchyma from the stem of the same *Cactus* ; the pores are seen perpendicularly, and in section in the walls.

Fig. 26. Spiral cells from *Sphagnum*. The large cells containing the spiral fibres are divided from each other by smaller ones containing chlorophylle granules.

Fig. 27. Vertical section of the stem of a *Cactus*. *a*, epidermis-cells with thickened upper walls ; *b*, tabular cells beneath ; *c*, parenchyma of the stem.

Fig. 28. Parenchyma of the leaf of *Hoya carnosa*.

Fig. 29. Horizontal section of thick-walled cells, from the epidermis of the seed of a *Lupinus*.

Fig. 30. Horizontal section of thick-walled cellular tissue of a young onion (*Allium Cepa*), boiled and treated with iodine.

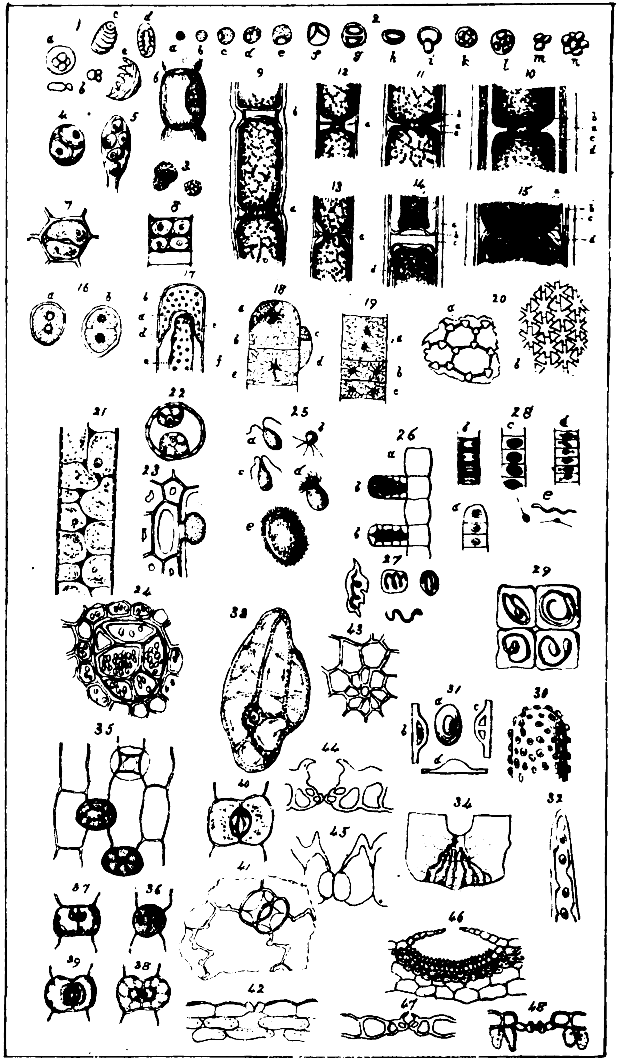
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PLATE II.

Fig. 1. Starch granules from *Vallisneria spiralis*. *a*, granules within an utricle; *b*, granule dividing; *c*, large granule exhibiting striæ; *d*, ditto burst by heat; *e*, burst by boiling in water. (*E. J. Quekett* in the Physiological Journal, No. 3, 1844.)

Fig. 2. Development of starch. *a*, cellules with homogeneous mucilage; *b*, with granular mucilage; *c, d, e*, with granular mucilage and young starch globules; *f*, with two starch globules and a clear fluid; *g, h*, with two starch granules which fill the cell, seen from different sides; *i*, a cell which has burst and allowed the granules to escape; *k, l*, with several starch granules; *m, n*, clusters of starch granules, the enclosing cellules of which have become dissolved. (*Nägeli*, Memoir on *Caulerpa prolifera*; Schleiden and Nägeli's Zeitschr. fur wiss. Botanik, Heft 1. 1844, tab. 3. p. 167.)

Fig. 3. Cytoblasts. *a*, cell forming from cytoblast, from the embryo-sac of *Chamædorea Schiedeana*.

Fig. 4. Cell from the *punctum vegetationis* of *Gasteria racemosa*, two newly-formed cells with nuclei (cytoblasts) in the original cell.

Fig. 5. A very young leaf of *Crassula portulacca*; the five cells composing it are still surrounded by the original cell.

Fig. 6. Portion of the pollen-tube become cellular in *Orchis latifolia* in the highest stage of development. The cytoblast is included in the wall of the cell. (Figs. 3–6 are from *Schleiden's* Beiträge zur Botanik, tab. 6. Leipzig, 1844.)

Figs. 7, 8. Cells with cytoblasts (from *Schleiden's* Grundzüge der wiss. Botanik, tab. 1. 2nd ed. 1845).

Fig. 9. *Conferva glomerata*. *a*, primordial utricle folding inward; *b*, septum fully formed.

Fig. 10. A septum in course of formation, treated with acid. *a*, primordial utricle folding inward; *b*, mucilaginous contents; *c*, cell-membrane of many layers; *d*, outer gelatinous investment of the fibres.

Fig. 11. The same in a natural condition; the letters refer to the same.

Fig. 12. A septum in a more advanced stage: *a*, the septum yet incomplete, as is seen by the continuity of the primordial utricle.

Fig. 13. Another example; the chlorophylle is seen arranged in a reticulated manner in the interior of the mucilaginous primordial utricle.

Fig. 14. Perfect septum treated with iodine. *a*, gelatinous layer; *b*, point where the primordial utricle turns inward; *c*, septum of cellular membrane; *d*, primordial utricle detached from the cell-membrane.

Fig. 15. Perfect septum from an old cell treated with acid. *a*, septum formed of many layers of cell-membrane; *b*, original cell-membrane (*c* in figure 10); *c*, gelatinous layer; *d*, intercellular space.

(Figs. 9–15. From *Mohl* on the multiplication of cells by division (*Ueber der Vermehrung der Pflanzenzellen durch Theilung*), Verm. Schrift. p. 362. tab. 13.)

Fig. 16. Germinating spore of *Padina Pavonia*. *a*, with granular contents and two nuclei; *b*, with a septum formed between the two nuclei, which are obscured by the granules lying upon them.

Fig. 17. Terminal joint of a filament of *Conferva glomerata* (from the sea). *a*, cell-membrane of the original cell; *b*, decaying contents, separated from the membrane and in course of solution; *c*, newly-formed membrane which has been produced on the surface of the living contents *d*. The latter are bounded by a mucilaginous layer *e*, which was at first in contact with the membrane *c*, but is now detached and retracted from it by the endosmose of the water fused in the investigation.

Fig. 18. Apex of the stem of *Sphacelaria scoparia*. *a*, compressed lenticular apical cell, pushed aside, full of dark granules; *b*, second cell, which subsequently becomes the terminal cell by overgrowing the cell *a*; it has dark granular contents, in its lower portion a transparent network of mucilage; *c* and *d*, two cells densely filled with granules which have been produced by a cell like *a*; *e*, second joint of the axis (it is the lower portion of a cell like *b*, divided into two by a horizontal wall); it has a mucilaginous network over the whole surface and in the whole cavity; in the centre is a longish heap of granules which pass first into short thick radiating threads, and further off lose themselves in the reticulated circulation.

Fig. 19. Point of the stem of the same without the terminal joint. *a*, second articulation of the filament; it is the same cell

as *e* in fig. 18; the contents are in a similar condition, except that the heap of granules has divided into two of half the size. Between these, a septum is subsequently formed; *b* and *e* represent together the third articulation, and have been formed by the division of a parent-cell like *a*. The central nucleus has already divided into two lying on the same plane; between these a perpendicular wall is afterwards produced.

(Figs. 16–19 are from *Nägeli's* Memoir on cell-formation (*Zellenkerne, Zellenbildung und Zellenwachsthum bei den Pflanzen*), Schleiden and Nägeli's Zeitschrift fur wiss. Botanik, Heft 1. 1844. tab. 1 and 2.)

Fig. 20. Stellate cellular tissue from a septum of an air-canal in *Aponogeton distachyon.* *a,* in a young condition; *b,* fully-formed cells. In *a* the septa between the cells are thicker than the remainder of their walls. (From *Schleiden's* Grundzüge der Botanik, 2nd ed.)

Fig. 21. Dotted vessel from *Cucurbita pepo* in longitudinal section; filled with young starch cells.

Fig. 22. Cross section of ditto. The cells exhibit nuclei and circulation threads.

Fig. 23. Transverse section of *Vitis vitifera,* treated with potash; showing the utricle growing through the pore into the vessel.

Fig. 24. Transverse section of the innermost wood-ring of a four-years-old stem of the Vine. The large porous vessel is filled with cells containing starch granules.

(Figs. 21–24. From Botanische Zeitung, vol. iii. tab. 2.)

Fig. 25. Zoospores of Algæ. *a* and *c, Conferva rivularis*; *b, Chætophora elegans* var. *pisiformis*; *d, Prolifera rivularis*; *e, Vaucheria clavata.* (From *Thuret's* Figures, Ann. des Sc. Nat. 2nde série, tom. 19. tab. 10, 11.)

Fig. 26. Perpendicular section through the germ-frond of *Asplenium dissectum.* *a,* cells of the frond; *b, b,* organs producing spiral fibres.

Fig. 27. Spiral fibres (spermatozoa?) bursting from the cells. (Schleiden and Nägeli's Zeitschrift, tab. 4.)

Fig. 28. *Chara hispida.* Antheridia: *a, b, c* and *d,* strings of cells showing the development of the spiral fibres; *e,* spiral fibres

(spermatozoa?); the upper perfect, the others treated with nitric acid. (Botanische Zeitung, iii. tab. 1.)

Fig. 29. *Polytrichum commune.* Cells of the antheridia containing the spiral fibres (*Unger*).

Fig. 30. Upper part of a hair from the *fornix* of the corolla of *Anchusa italica,* with wart-like thickenings on its exterior.

Fig. 31. *a,* one of these protuberances seen from above; *b* and *c,* in longitudinal section; *d,* in cross section (*Schleiden*).

Fig. 32. Upper part of an elongated cell from the pistil of *Cereus phyllanthoides,* with wart-like protuberances projecting in its interior (*Schleiden*).

Fig. 33. A cell from a berry of *Symphoricarpos racemosa* with cytoblast and branched, reticular circulation; the arrows denote the direction of the current (*Schleiden*).

Fig. 34. Wall of an old ligneous cell, with secondary layers and anastomosing canals of the pores (*Schleiden*).

Figs. 35–40. Development of stomates in *Narcissus Jonquilla.* 35. Epidermis; at the upper part is seen a four-sided intercellular space, with the outline of a cell appearing behind on a different plane; below are cells of the same kind, in focus, with nucleus and radiating filaments. 36. One of the cells divided into two. 37. The same more advanced. 38. Ditto; the septa slightly separated. 39. A later stage. 40. Perfect stomate.

Fig. 41. Portion of epidermis from the under surface of a leaf of *Helleborus fœtidus,* with stomate.

Fig. 42. Vertical section of ditto.

Fig. 43. Epidermis of *Hakea florida,* with the opening leading to a stomate.

Fig. 44. Vertical section of the epidermis of *Protea melaleuca,* showing the stomate.

Fig. 45. Ditto of *Agave lurida.*

Fig. 46. Vertical section of a frond of *Marchantia conica,* with the cavity representing a stomate.

Fig. 47. Vertical section of the epidermis of *Leucadendron decorum.*

Fig. 48. Ditto of *Hakea saligna.*

(Figs. 35–48, from *Mohl,* Verm. Schrift. tab. 4, 7, 8.)

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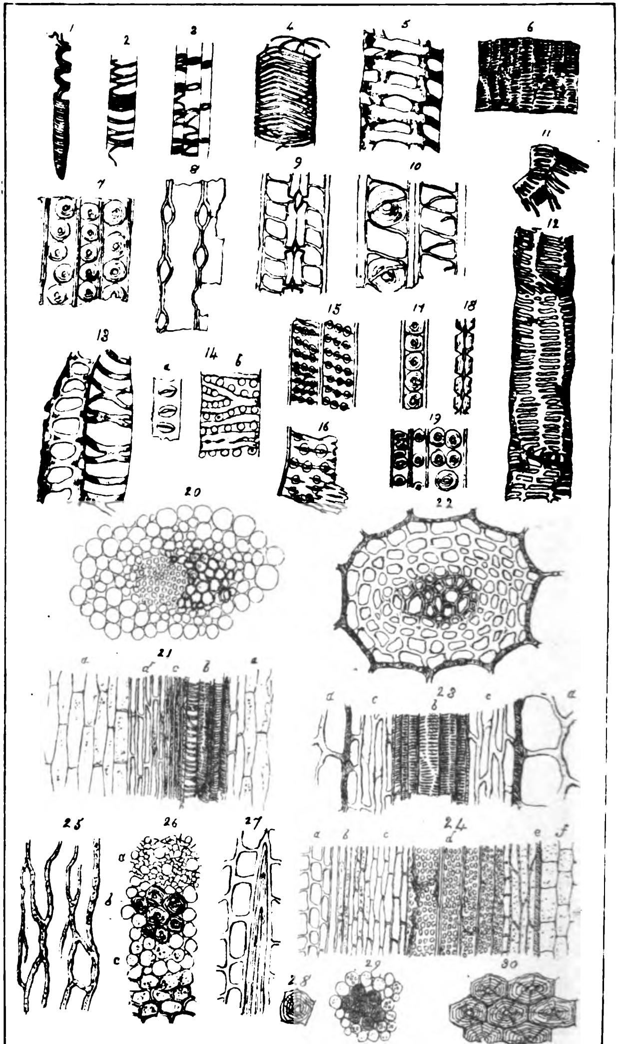
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PLATE III.

Figs. 1, 2 and 3. Spiral and annular vessels from the stem of a young Onion.

Fig. 4. Spiral vessel with several threads from the Garden Balsam.

Fig. 5. Reticulated vessel from ditto, showing that the cross fibres were not formed contemporaneously with the spiral.

Fig. 6. Portion of a scalariform vessel from *Polypodium vulgare.*

Fig. 7. Porous cells from common deal wood, showing the peculiar dots.

Fig. 8. The same, seen in section; showing the hollow spaces between the dots of contiguous cells, and the canals of the dots.

Fig. 9. Ligneous cells of Yew (*Taxus baccata*), showing the dots in section; with spiral fibres.

Fig. 10. The same, at a right angle to the last section, showing the dots in plan.

Fig. 11. Portion of a decayed scalariform vessel from the petiole of a Tree Fern; the membrane closing the pores has been absorbed.

Fig. 12. Portion of a reticulated vessel from the Garden Balsam; formed of three cells which have anastomosed.

Fig. 13. Ligneous cells of a *Cactus,* showing the conversion of spiral into porous cells.

Fig. 14. Ligneous cell of the Lime (*Tilia* —— ?). *a,* with dots alone; *b,* with dots and spiral fibre.

Fig. 15. Ligneous cell of *Clematis vitalba,* with *bordered* pores.

Fig. 16. Ditto; at the lower part on the right hand the outer layers of the cell have been removed in the section, by which the slit-like internal apertures of the pores are distinctly perceptible.

Fig. 17. Ligneous cell of *Araucaria imbricata,* with dots.

Fig. 18. Ditto, in section at right angles.

Fig. 19. Ditto, with more than one row of dots.

Fig. 20. Vascular bundle of a Monocotyledon (*Lilium candidum*), in horizontal section.

Fig. 21. The same in vertical section. *a*, parenchyma; *b* and *c*, elongated thick-walled cells (*vasa propria*), resembling the liber cells of Dicotyledons; *d*, annular, spiral and reticulated vessels.

Fig. 22. Vascular bundle of an Acotyledon (*Polypodium vulgare*, rhizoma), in horizontal section.

Fig. 23. The same in vertical section. *a*, parenchyma; *b*, scalariform vessels; *c*, *vasa propria* of Mohl.

Fig. 24. Vascular bundle of a Dicotyledon (*Rosa canina*). *a*, bark cells; *b*, liber cells; *c*, cambium layer; *d*, porous vessels or ducts; *e*, spiral vessel; *f*, pith.

Fig. 25. *Milk-vessels* from the root of *Leontodon taraxacum*.

Fig. 26. Horizontal section of the bark of Ivy. *a*, cambium layer; *b*, bundle of liber cells; *c*, cells of the bark.

Fig. 27. Vertical section of a liber cell of Ivy, with bark cells surrounding it.

Fig. 28. Horizontal section of an old liber cell, showing the secondary deposits.

Fig. 29. Horizontal section of a piece of the pith of Ivy, with cells like liber cells (*bast-zellen*).

Fig. 30. Horizontal section of old ligneous cells of Beech, showing the cavities almost obliterated by secondary deposits.

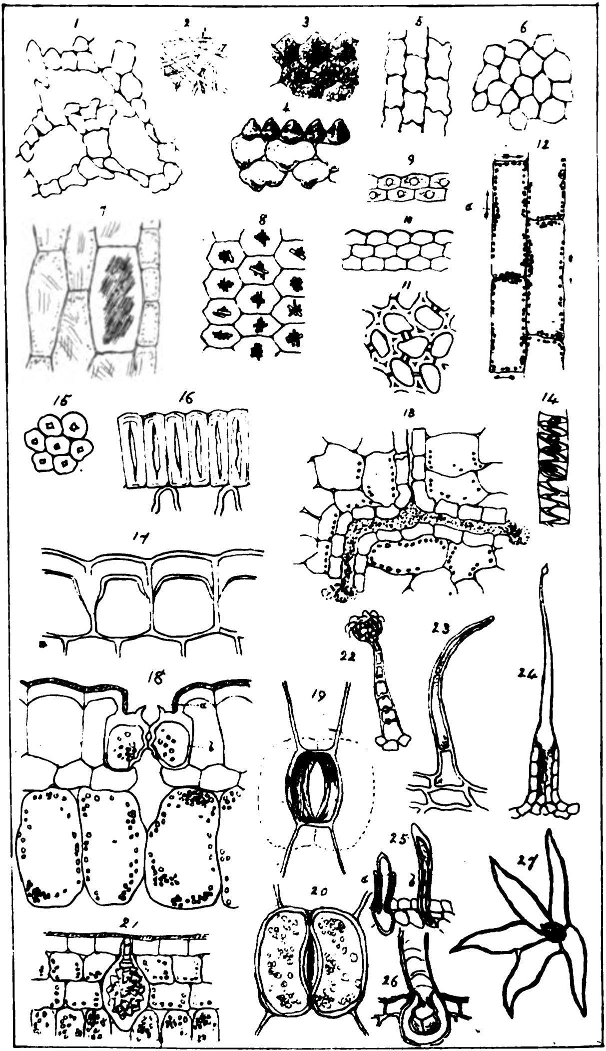
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PLATE IV.

Fig. 1. Spongy cellular tissue from the stem of *Arum maculatum.*

Fig. 2. Filamentous cells (*tela fibrosa*) from a Truffle (*Tuber cibarium*).

Fig. 3. Epidermis of petal of *Narcissus pseudo-narcissus,* seen from above.

Fig. 4. Vertical section of ditto; the lower cells are the parenchyma, containing fluid colouring matter.

Fig. 5. Vertical section of cork.

Fig. 6. Horizontal section of ditto.

Fig. 7. Cells of *Arum maculatum,* with a bundle of raphides.

Fig. 8. Cells from the base of the stem of a young Onion, containing bundles of crystals.

Fig. 9. Vertical section of the epithelium of the ovule of *Arum maculatum*; cells with nuclei.

Fig. 10. Ditto, older; cells with thickened outer walls.

Fig. 11. Thick-walled cells from the base of the stem of a young Onion boiled in water.

Fig. 12. Cells of *Vallisneria spiralis,* showing the circulation of the chlorophylle granules and nuclei; the arrows indicate the direction of the currents.

Fig. 13. *Milk-vessel* of *Limnocharis Humboldtii* (*Schleiden*).

Fig. 14. Spiral cell from the wood of *Mammillaria quadrispina*; the fibre is broad and flat, and in contact with the cell-wall by its edge (*Schleiden*).

Fig. 15. Epidermis of the seed of *Lupinus Crookshankii*; seen from above.

Fig. 16. Vertical section of the same, showing the thick-walled epidermis-cells.

Fig. 17. Section of the epidermis of the leaf of *Hoya carnosa,* showing that the thickening layers of the cuticle are *internal* to the cell-wall.

Fig. 18. Section of a stomate of the flowering stem of *Narcissus pseudo-narcissus,* with subjacent parenchyma.

Fig. 19. Horizontal section of the same at *a*.

Fig. 20. Ditto at *b*.

Fig. 21. Vertical section of part of a leaf of *Ficus elastica*, showing the stalked bundle of crystals (Meyen's *gummi keule*).

Fig. 22. Glandular hair from *Wigandia urens* (*Schleiden*).

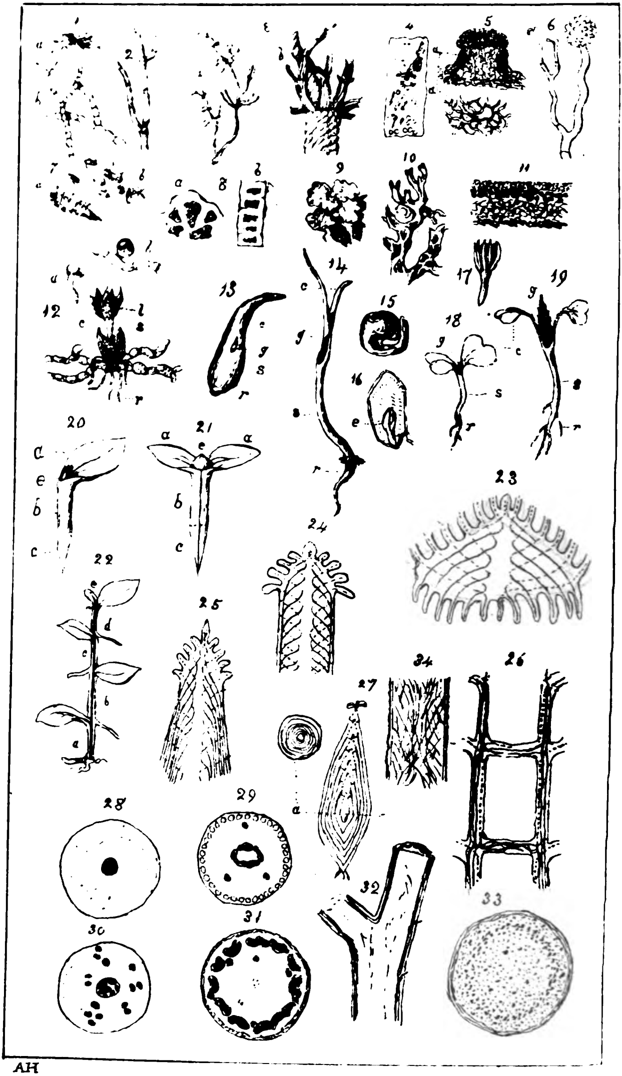
Fig. 23. Hair of the calyx of *Pelargonium* —— ?

Fig. 24. Sting of *Urtica urens*.

Fig. 25. Hairs from the stigma of *Campanula*. *a*, retracted; *b*, with circulation (*Schleiden*).

Fig. 26. Section of epidermis of *Ficus carica*, with base of a hair (*Schleiden*).

Fig. 27. Stellate hair from the leaf of Ivy.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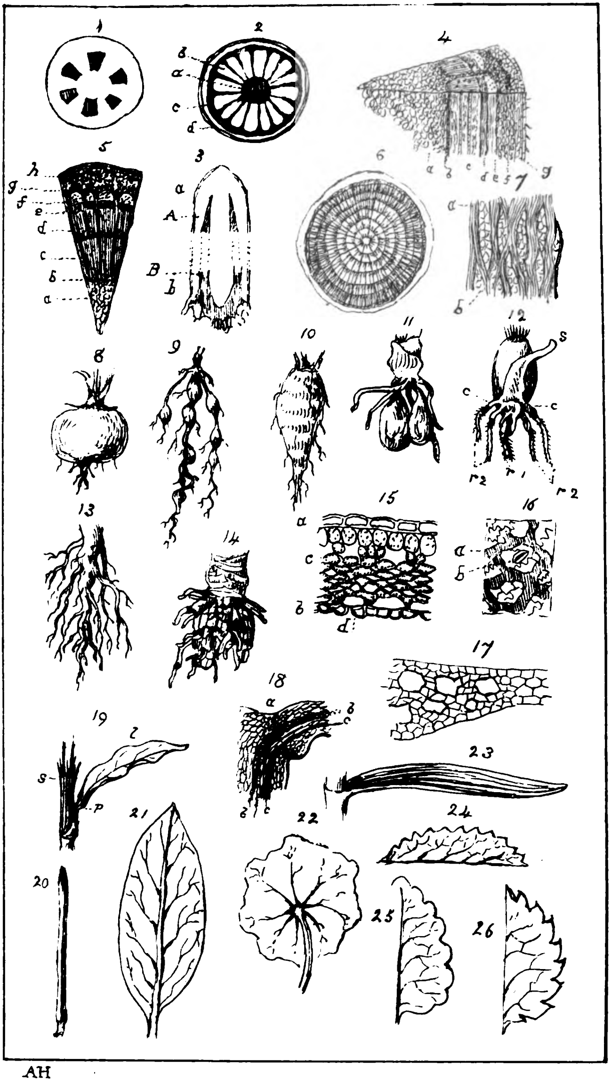
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PLATE V.

Fig. 1. Filamentous Thallus of *Hygrocrocis*. *a*, natural size; *b*, a portion magnified (*Biasoletto*).

Fig. 2. Filament of *Cladophora* (*Hassall*).

Fig. 3. *a*, Branch of *Chara*; *b*, a portion magnified.

Fig. 4. A cell of *Chara*, representing the circulation of the globules in the direction indicated by the arrows (*Varley*).

Fig. 5. Vertical section of *Tubercularia vulgaris*. *a*, the flocculent Thallus.

Fig. 6. Flocculent Thallus of *Mucor*.

Fig. 7. *a*, *Coniocybe furfuracea*; *b*, portion of the pulverulent Thallus magnified (*Schnizlein*).

Fig. 8. *a*, Portion of the membranous Thallus of *Ulva*, exhibiting the cells; *b*, a vertical section of the same.

Fig. 9. Thallus of *Parmelia*.

Fig. 10. Fruticulose Thallus of *Evernia*.

Fig. 11. Vertical section of the frondose Thallus of a Lichen, showing the three layers of tissue.

Fig. 12. Germination of *Weissia lanceolata*. *a*, *b*, confervaceous filament developed from the spore; *c*, a more advanced example, with the primordial leaves; *l*, leaves; *s*, stem; *r*, radicle fibres (*Bischoff*).

Fig. 13. Monocotyledonous embryo of *Potamogeton*. *r*, radicle; *g*, gemmule; *c*, cotyledon enclosing the stem at *s*.

Fig. 14. Germination of *Zannichellia*. *r*, radicle bursting through the sheath or *coleorhiza*; *s*, stem; *c*, cotyledon; *g*, the plumule (*Jussieu*).

Fig. 15. Dicotyledonous embryo of *Brassica*.

Fig. 16. Section of the seed of *Berberis*. *e*, embryo.

Fig. 17. Polycotyledonous embryo of *Pinus*.

Figs. 18, 19. Germination of *Sinapis*. *r*, radicle; *s*, stem; *g*, gemmule or plumule.

Fig. 20. Diagram of a monocotyledonous phyton. *a*, foliar merithal; *b*, cauline; *c*, radicular; *e*, a second phyton developing in the axil.

Fig. 21. Diagram of a pair of dicotyledonous phytons; the letters have the same signification as in the preceding figure.

Fig. 22. Diagram of the superposition of phytons in an acotyledonous plant. *a, b, c, d, e,* 1st, 2nd, 3rd, 4th and 5th phytons, whose vascular bundles, represented by the black central line, are applied directly *upon* one another.

Fig. 23. Diagram of the distribution of the fibres in the base of the bulb or stem of an herbaceous monocotyledon. The dotted lines represent the ascending portion of each fibre going to a leaf, the black lines the descending portion going to a root.

Fig. 24. The distribution in a Palm stem.

Fig. 25. Ditto in *Dracæna.*

Fig. 26. Ditto in a Grass; some of the fibres cross at the diaphragms and descend on the opposite side.

Fig. 27. Diagram of the relations of the annular layers of wood in a dicotyledon. *a, collum* or point of junction of the stem and root.

Fig. 28. Transverse section of the stem of a Moss.

Fig. 29. Ditto of a *Marsilea.*

Fig. 30. Ditto of *Lycopodium.*

Fig. 31. Ditto of a Fern; the shaded portions represent the fibro-vascular bundles.

Fig. 32. Bifurcation of a branching Fern in vertical section.

Fig. 33. Transverse section of a monocotyledonous stem having a dense cortical layer; the dots represent the ends of the fibro-vascular bundles.

Fig. 34. Vertical section of the same; the bundles forming arcs interlacing with each other and sometimes crossing to the opposite side of the stem.

PLATE VI.

Fig. 1. Diagram of a very young dicotyledonous stem, in transverse section; the shaded portions represent the woody bundles.

Fig. 2. The same at a more advanced period. *a,* the medullary parenchyma; *b,* fibro-vascular bundles; *c,* cellular envelope continuous with the pith by the medullary rays; *d,* suberous layer with epidermis.

Fig. 3. Diagram of the extremities of a dicotyledon in vertical section. *a,* the apex; *b,* the base; A, the parenchyma; B, the ligneous portion open above and closed below.

Fig. 4. Portion of the stem of a yearling shoot of the Rose, exhibiting a transverse and vertical section. *a,* pith; *b,* medullary sheath of spiral vessels; *c,* the wood composed of parenchymatous cells with dotted ducts intermixed; *d,* cambium layer; *e,* bundles of the liber; *f,* cellular envelope; *g,* suberous layer clothed with epidermis, some of the cells of which are developed into hair-like processes.

Fig. 5. Transverse section of a two-year-old shoot of the Rose. *a,* pith; *b,* medullary sheath; *c,* first year's layer of wood; *d,* second year's layer; *e,* cambium layer; *f,* liber bundles; *g,* cellular envelope; *h,* suberous layer. The primary medullary rays are seen to extend through both layers of wood; the secondary only through the outer. They are all continuous with the cellular envelope, and divide the liber into bundles corresponding to the bundles of the wood.

Fig. 6. An old dicotyledonous stem with many annual rings and medullary rays of corresponding extent.

Fig. 7. Tangental section through the bark of *Daphne Laureola* exhibiting the network formed by the liber bundles *a,* in the interstices of which appear the ends of the medullary rays *b* (*Jussieu*).

Fig. 8. Tuberous root of the Turnip.

Fig. 9. Ditto of *Pelargonium triste* (*Jussieu*).

Fig. 10. Ditto of Parsnip.

Fig. 11. Root of an Orchis with tubers.

Fig. 12. Germinating grain of Wheat. *s*, stem or plumule; *c*, *c*, *coleorhizæ* or root-sheaths; *r* 1, primary radicle; *r* 2, *r* 2, secondary radicles (*Jussieu*).

Fig. 13. Tap root with radicle fibres.

Fig. 14. *Souche* or root of *Cordyline australis* (*Mirbel*).

Fig. 15. Vertical section of the leaf of the Balsam. *a*, epidermis of the upper surface; *b*, of the lower surface; *c*, diachyma, containing chlorophylle; *d*, stomate opening into a lacuna (*Jussieu*).

Fig. 16. Strip of the epidermis of the lower surface of the same leaf. *a*, the reticulation marks the situation where the diachyma is in contact with the epidermis; *b*, an areola with stomate, corresponding to a lacuna (*Jussieu*).

Fig. 17. Vertical section of a submerged leaf of *Potamogeton perfoliatum*, with air-cavities (*Jussieu*).

Fig. 18. Vertical section through the insertion of a leaf. *a*, marks the articulation where the petiole afterwards separates from the stem; *b*, bundle containing spiral vessels continuous with the medullary sheath; *c*, cellular and ligneous bundle continuous with the liber.

Fig. 19. Leaf of a *Polygonum*. *l*, lamina; *p*, petiole; *s*, stipules taking the form of a sheath or *ochrea*.

Fig. 20. Acicular leaf of a Pine.

Fig. 21. An entire, pinninerved leaf.

Fig. 22. A peltate leaf.

Fig. 23. Leaf of a monocotyledon (*Lilium*) with parallel nerves.

Fig. 24. Dentate leaf.

Fig. 25. Crenate leaf.

Fig. 26. Serrate leaf.

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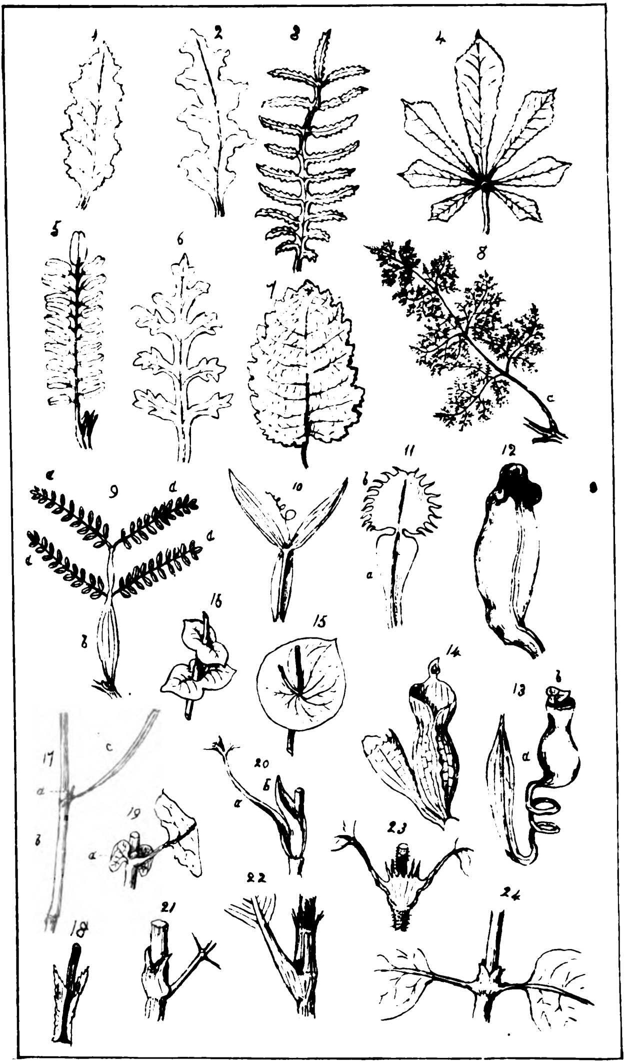
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PLATE VII.

Figs. 1—8. Forms of leaves.

Fig. 1. Pinnatifid.

Fig. 2. Pinnatipartite.

Fig. 3. Pinnatisect.

Fig. 4. Palmisect.

Fig. 5. Pinnate.

Fig. 6. Bi-pinnatifid.

Fig. 7. Bi-serrate.

Fig. 8. Tri-pinnate.

Fig. 9. Bi-pinnate leaf of an *Acacia*, abruptly pinnate in the first division. The petiole, *b*, has the form which is called a phyllode; the second rachides or petiolules have pinnules which are impari-pinnate.

Fig. 10. Compound leaf of *Lathyrus latifolius*. The petiole is winged, and terminates in a tendril, replacing a pinnule.

Fig. 11. Leaf of *Dionæa*. *a*, the expanded petiole; *b*, the lamina (*Gray*).

Fig. 12. Pitcher formed by the petiole of *Sarracenia* (*St. Hilaire*).

Fig. 13. Pitcher of *Nepenthes*. *a*, petiole; *b*, lamina (*St. Hilaire*).

Fig. 14. Pitcher of *Heliamphora* (*Gray*).

Fig. 15. Perfoliate leaf of *Bupleurum*.

Fig. 16. Connate leaves of *Crassula perfoliata* (*St. Hilaire*).

Fig. 17. Leaf of a Grass. *a*, ligule; *b*, vagina; *c*, lamina.

Fig. 18. Petiolar stipules of the Rose.

Fig. 19. Foliaceous stipules of *Salix aurita* (*Jussieu*).

Fig. 20. Axillary stipule of *Potamogeton natans* (*St. Hilaire*).

Fig. 21. Opposite stipule of *Astragalus Onobrychis* (*Jussieu*).

Fig. 22. Ochraceous stipules of a *Polygonum.*

Fig. 23. Sheathing stipules of *Spermococe rubrum,* formed by the coherence of all the stipules and the bases of the petioles (*St. Hilaire*).

Fig. 24. Interpetiolar stipules of *Cephalanthus occidentalis.*

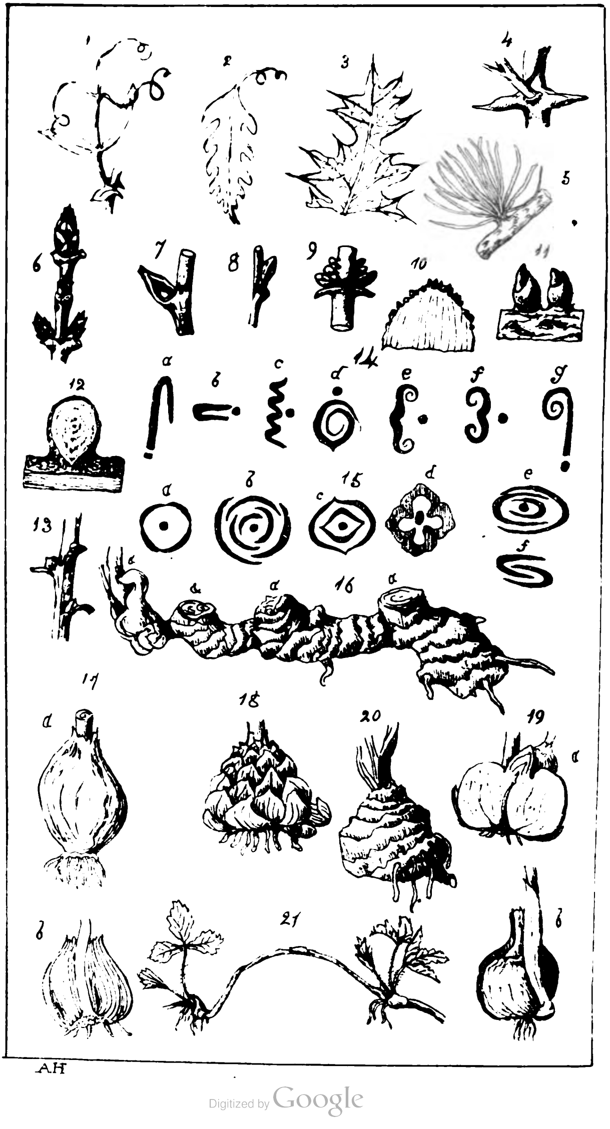
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PLATE VIII.

Fig. 1. Leaf of *Lathyrus sylvestris*; the last three pinnules appearing as tendrils.

Fig. 2. Leaf of *Mutisia runcinata*; the midrib continued beyond the lamina and forming a tendril (*Endlicher and Unger*).

Fig. 3. Part of a leaf of *Carduus lanceolatus*; the nerves produced into spines.

Fig. 4. Base of the petiole of *Robinia pseudo-acacia* with spinose stipules.

Fig. 5. Fasciculus of leaves on the Larch.

Fig. 6. Terminal and axillary buds.

Fig. 7. Section of the petiole of the Plane, showing the bud enclosed in it (*St. Hilaire*).

Fig. 8. Petiolate bud of the Alder (*St. Hilaire*).

Fig. 9. Accessory buds of *Lonicera tatarica* (*Jussieu*).

Fig. 10. End of a leaf of *Malaxis paludosa*, covered with bulbels (*Jussieu*).

Fig. 11. Adventitious buds on the lamina of the leaf of *Ornithogalum thyrsoideum* (*Jussieu*).

Fig. 12. Section of a nodule or embryo-bud in the bark of the Cedar (*Jussieu*).

Fig. 13. Stem of *Lilium bulbiferum* with bulbels in the axils of the leaves.

Fig. 14. Vernation of leaves. *a*, reclinate; *b*, conduplicate; *c*, plicate; *d*, convolute; *e*, involute; *f*, revolute; *g*, circinnate. Figs. *a* and *g* are in vertical section, the rest in transverse.

Fig. 15. Vernation of leaves in combination, as seen in transverse sections of buds. *a*, valvate; *b*, *c*, imbricate; *d*, induplicate; *e*, equitant; *f*, half-equitant. In all these figures the round spot indicates the stem, showing the relative position of the organs.

Fig. 16. A rhizoma. *a*, *a*, *a*, *a*, the points of origin of flowering-stems.

Fig. 17. *a,* A tunicated bulb; *b,* section of a tunicated bulb.

Fig. 18. An imbricated bulb.

Fig. 19. *a,* Section of the corm or solid bulb of *Crocus*; *b,* Corm of Colchicum.

Fig. 20. A tuber.

Fig. 21. Part of a Strawberry plant, showing the growth by lateral development. Roots and leaves are developed at intervals in the axils of rudimentary leaves. In the middle of the *flagellum* or runner is seen a rudimentary leaf, from which no others are developed.

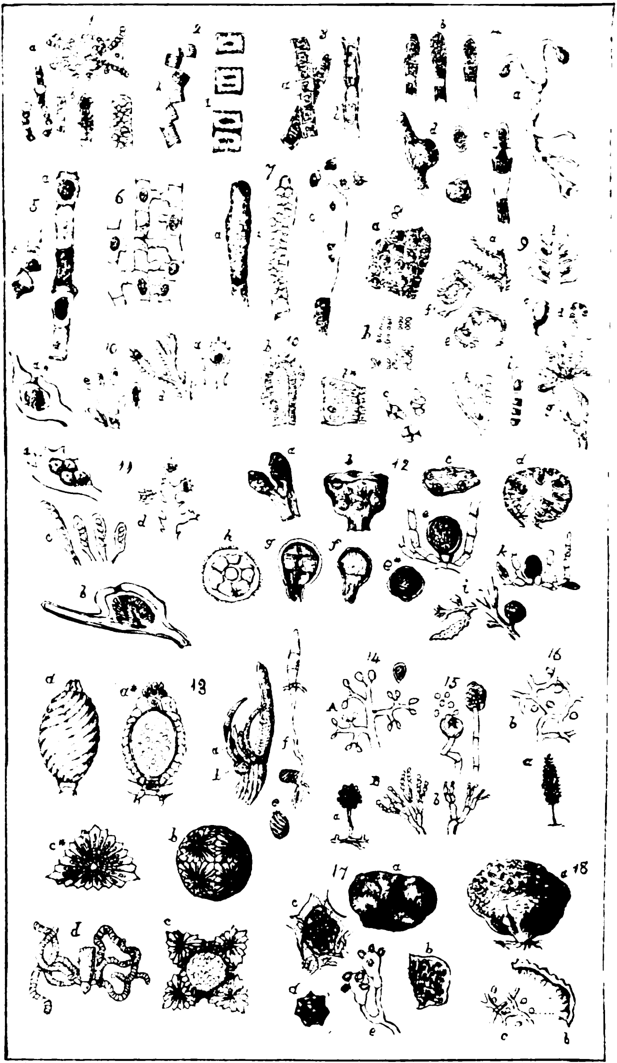
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PLATE IX.

Fig. 1. *Nostoc*; *a, N. commune* with the gelatinous investment; *b,* development of *N. verrucosum* (*Thuret*).

Fig. 2. *a,* development of *Diatoma* (*Nägeli*); *b, Diatoma flocculosa* (*Kützing*).

Fig. 3. *a, Conferva Linum* (*Schnitzlein*); *b,* cell-division in *C. bombycina* (*Nägeli*).

Fig. 4. *a, Vaucheria clavata* (*Bischoff*); *b,* formation of the spore; *c,* discharge of ditto; *d,* germination (*Thuret*).

Fig. 5. *Prolifera* (*Vesiculifera*); *a,* portion of a filament with spores; *b,* discharge of spore (*Hassall*).

Fig. 6. *Zygnema quininum* (*Schleiden*).

Fig. 7. *Achlya prolifera*; *a, b,* development of spores; *c,* discharge of ditto (*Unger*).

Fig. 8. *a,* magnified portion of *Ulva*; *b,* arrangement of the granules in *U. furfuracea,* according to *Greville.*

Fig. 9. Fructification of *Ctenodus Billiardierii*; *a,* fertile branch; *b,* a portion more enlarged, showing the receptacles alternating with the filamentous processes; *c,* one of the receptacles; *d,* section of the same, exhibiting the *conceptacles*; *e,* the summit of a receptacle, showing the filaments proceeding from the centre toward the *conceptacles*; *f,* a *conceptacle* more magnified; *g,* one of the filaments which proceed from the parenchyma of the receptacle, and become free in the conceptacle and bear the *sporangia*; *h, sporangia* or *tetraspores* with paraphyses, being the terminations of the parenchymal filaments; *i,* a tetraspore open, three of the spores having escaped.

Fig. 10. Fructification of *Delisea*; *a,* apex of a branch bearing a conceptacle; *a*,* a section of this conceptacle, showing the *antheridia* in the cavity; *b,* a *tetrasporophore,* shown in a longitudinal vertical section of the apex of a branch; *b*,* a portion more enlarged, exhibiting the spores *in situ*; *c, tetraspores*; *d.* portion

of a branch of *D. fimbriata,* slightly reduced from the natural size; *e, Antheridia* and *paraphyses* from the *conceptacle a**.

Fig. 11. Fructification of *Lenormandia*; *a,* enlarged extremity of a branch with *conceptacles*; *b,* section of a *conceptacle*; *c, thecæ* from ditto, containing spores; *d,* portion of a plant of *L. dorsifera* (9, 10, 11 after *Montagne*).

Fig. 12. Fructification of Fucaceæ. *a,* apex of a branch of *F. vesiculosus,* with two receptacles; *b,* section of a receptacle containing *conceptacles*; *c,* the same seen from above; *d,* section of a *conceptacle* containing *sporocarps* and *paraphyses*; *e, sporocarp* with *paraphyses*; *e*,* young *sporocarp*; *f, g, sporocarps* more developed; *h,* mature *sporocarp* seen from above, the *spores* closely packed within it; *i,* branch of *Sargassum vulgare,* with a capsular receptacle; *k,* from the conceptacle of *Pelvetia canaliculata,* showing a *spore* with *paraphyses* and *antheridia* (*e—h, k, Decaisne* and *Thuret*; *i, Greville*).

Fig. 13. Fructification of *Chara. a, nucule*; *a*,* vertical section of the same; *b, globule*; *c,* the same with the valves opened; *c*,* a valve detached; *d,* campanulate cell, with the filaments containing spiral fibres, from the interior of the *globule*; *e, spore*; *f,* germination of ditto (*a, b—d, Schnitzlein*; *a*, e, f, Muller*).

Fig. 14. A, *Botrytis* (*Berkeley*); B, *Aspergillus*; *a,* head of fructification; *b,* separated sporiferous filaments from the same.

Fig. 15. *Mucor mucedo.*

Fig. 16. *Stemonitis. a,* a single plant; *b,* sporiferous tissue with spores (*Berkeley*).

Fig. 17. *Tuber. a,* the entire plant; *b,* section of ditto; *c,* enlarged view of one of the cavities containing spores; *d,* a *spore. e,* young *basidia* of *Scleroderma vulgare* from *Tulasne.*

Fig. 18. *Lycoperdon. a,* the entire plant; *b,* portion of the coriaceous outer envelope; *c,* sporiferous tissue and spores from the interior.

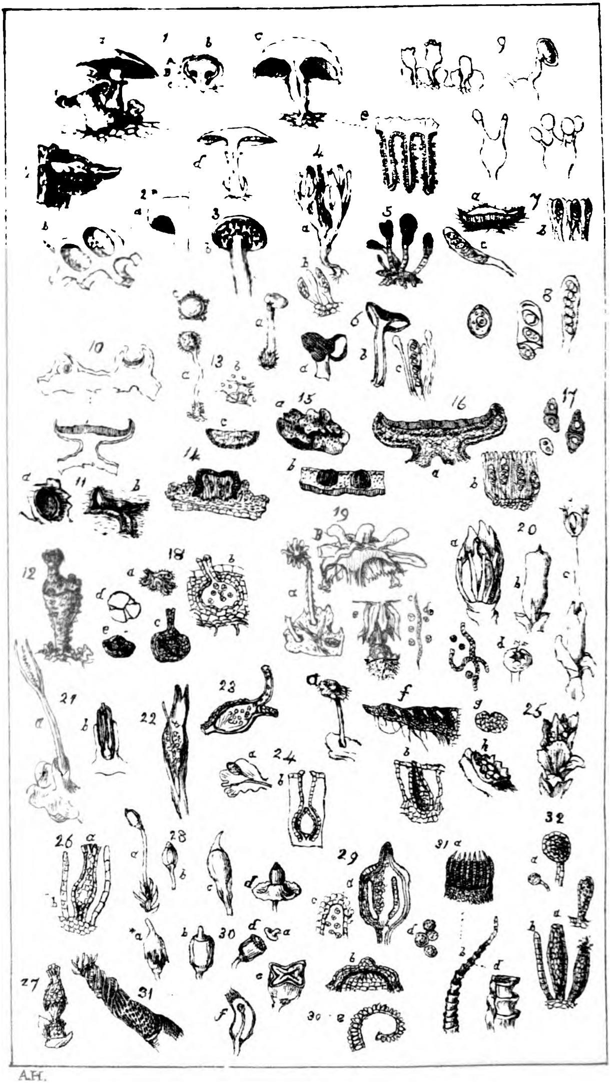
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PLATE X.

Fig. 1. Fructification of Agaric. *a,* perfect fruit growing from the mycelium; *b,* section of a young fruit within the *volva*; A, the *volva*; B, the *indusium*; C, the annular cavity, within which the reproductive bodies are developed; *c,* section of an expanded fruit; on the under side of the *pileus* are the vertical plates forming the *hymenium*; *d,* a similar section, showing the remains of the *volva* at the base, and also the *annulus* resulting from the tearing away of the *indusium* from the *stipes*; *e,* cross-section of the plates of the *hymenium,* bearing the *basidiospores.*

Fig. 2. *Polyporus fomentarius,* with tubular *hymenium.*

Fig. 2*. *a,* vertical section of *Boletus granulatus,* with tubular *hymenium*; *b,* cross-section of the *hymenium,* exhibiting the *basidiospores.*

Fig. 3. *a. Hydnum auriscalpium*; *b,* seen from below, showing the columnar *hymenium*; *c,* cross-section of one of the columns with *basidiospores.*

Fig. 4. *a, Clavaria corniculata*; *b, cystidia* and *paraphyses,* from *Clavaria pistillaris.*

Fig. 5. *Geoglossum viride.*

Fig. 6. *Helvella Klotschia. a,* the superior *hymenium*; *b,* vertical section of the *stipes* and *hymenium*; *c,* cystidia and paraphyses (after *Corda*).

Fig. 7. *a,* section of *Peziza scutellata*; *b,* cystidia and paraphyses from *P. brunnea*; *c,* a cystidium more enlarged.

Fig. 8. *Cystidia* and *spores* from *Helvella Klotschia* (after *Corda*).

(Figs. 2 to 8, from *Schnitzlein*; 6, *Icon. fam. nat.*)

Fig. 9. *Basidia* and *basidiospores* from *Agaricus campestris* (*Schleiden*).

Fig. 10. Development of an *apothecium* of a Lichen.

Fig. 11. *a,* an *apothecium* or *patella*; *b,* a *lirella.*

Fig. 12. A *podetium.*

Fig. 13. *Coniocybe furfuracea.* *a*, a single fruit; *b*, *spores* and *filaments*; *c*, half of a section of the globose fruit, showing its filamentous nature; the *spores* being borne on the surface.

Fig. 14. Vertical section of a *lirella* of *Opegrapha scripta*, containing *thecæ* and *paraphyses*.

Fig. 15. *a*, thallus of *Endocarpon miniatum*; the dots indicate the imbedded fructification; *b*, vertical section through the thallus, showing two masses of fruit with *thecæ*, &c.

Fig. 16. *a*, vertical section through an *apothecium* of *Parmelia tiliacea*; *b*, *thecæ* and *paraphyses* from the same.

(Figs. 11 to 16 from *Schnitzlein*.)

Fig. 17. Double spores of *Borrera ciliaris* (*Schleiden*).

Fig. 18. *a*, a leaf of *Riccia ciliata*; *b*, a young *sporangium* of *R. glauca*, containing spores; *c*, ripe *sporangium* of the same, burst; *d*, four spores united together, from the same; *e*, a single ripe spore (*b* to *d*, *Mohl*).

Fig. 19. *a*, fruit of *Marchantia polymorpha*, bearing *pistillidia*; A, fruit bearing *antheridia*; B, vertical section through *a*, showing the *inferior sporangia* with their *involucres* and *involucels*; c, elater; *d*, spores; *e*, a ripe *sporangium* bursting; *f*, vertical section of A, showing the superior *antheridia* with intermediate lacunæ; *b*, an *antheridium* with two *lacunæ* more magnified; *g*, a *bulbel* or *gemma*; *h*, a collection of *gemmæ* contained in an involucre borne on the thallus (*Schnitzlein* and *Le Maout*).

Fig. 20. *Jungermannia Hookeri*; *a*, *pistillidia*; *b*, *perichætium* or developed *pistillidium*; *c*, capsule dehiscing by four valves, borne on a *seta* which proceeds from the ruptured *perichætium*; *d*, capsule of *Blasia pusilla*, elaters and spores (*Hooker*).

Fig. 21. *Anthoceros*; a capsule dehiscing by two valves, showing the *columella*; *b*, vertical section through the base of the same.

Fig. 22. *Monoclea*, opening by a slit, also with a *columella*.

Fig. 23. Section through the leaf of *Blasia pusilla*, showing the imbedded *antheridium* (?), (*Hooker*).

Fig. 24. *Fegatella conica* with *antheridium*; *b*, vertical section of the *antheridium* (*Schleiden*).

Fig. 25. Antheridia of *Jungermannia Hookeri* (*Hooker*).

Fig. 26. *a*, *Pistillidium*, and *b*, *paraphyses* of a moss (*Link*).

Fig. 27. Capsule bursting from the *pistillidium* and carrying up the upper portion as *calyptra*.

Fig. 28. Capsules or *sporangia* of Mosses; *a*, a capsule of *Polytrichum* borne on its *seta*; *b*, four-valved capsule of *Andræa*; *c*, capsule of *Zygodon conoideum* with an *apophysis*; *d*, of *Splachnum luteum* with very large expanded *apophysis* (*Schnitzlein*).

Fig. 29. Development of a capsule; *a*, vertical section of a young capsule showing the different regions; *b*, the upper part at a later period; *c*, upper part of the cavity containing the *spores*; *d*, spores (*Schleiden*).

Fig. 30. *Polytrichum*; *a**, capsule covered by the *calyptra*; *b*, the *calyptra* removed, showing the *operculum*; *c*, transverse section showing the four-lobed columella; *d*, capsule with the operculum, *a* falling off; *e*, an *annulus* from *Bryum cernuum* removed from the mouth of a capsule; *f*, vertical section of the capsule of a *Dicranum*, exhibiting the *columella* and some of the teeth of the *peristome* (*From various authors*).

Fig. 31. Peristome of *Tortula ruralis*; *a*, peristome of *Bryum* with two kinds of teeth; *b*, a tooth (*processus*) from *Bryum cæspititium*; *d*, some of the cells more enlarged, showing the projections formed by the *trabeculæ* (*Schnitzlein*).

Fig. 32. *a*, *Antheridia* of Mosses in various stages, one in the lower figure bursting and emitting the spiral fibres (§ 45.); *b*, *paraphyse*.

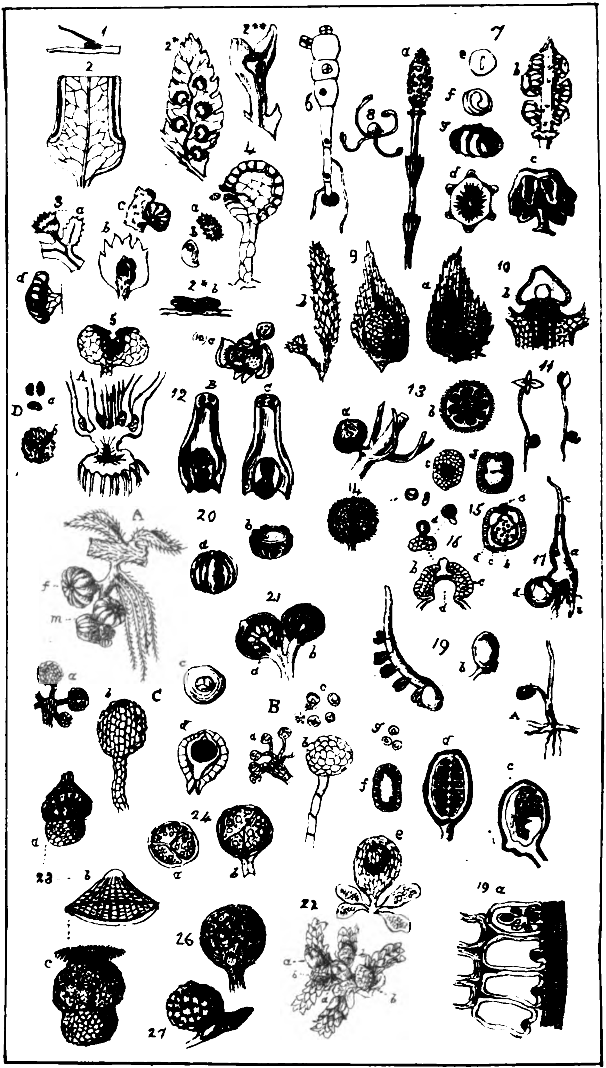
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PLATE XI.

Fig. 1. Vertical section of the fructification of *Schizoloma lanceolata,* showing the capsules lying between the leaf and the *indusium* (*Presl*).

Fig. 2. Fertile leaf of the same.

Fig. 2*. Fertile leaf of *Lastræa,* showing the *sori* with their reniform *indusia*; *b,* vertical section of a *sorus.*

Fig. 2**. *Sorus* of *Davallia canariensis* with cup-like indusium (*Schnitzlein.*)

Fig. 3. Fructification of *Hymenophyllum*; *a,* the *sorus* covered by the *indusium*; *b,* the *indusium* removed, showing the peduncle bearing the *sporangia*; *c,* a portion of the latter more highly magnified; *d,* a *sporangium* or *theca* with the *transverse annulus.*

Fig. 4. A *sporangium* or *theca* of *Scolopendrium* discharging *spores*; *a, spore,* with tuberculated external membrane; *b,* the secondary membrane removed, showing the *spore* to be a nucleated cell (*Schleiden*).

Fig. 5. Capsule, or *sporangium* of *Osmunda.*

Fig. 6. Germinating *spore* of Fern (*Asplenium dissectum*) bearing the peculiar organs containing the spiral fibres shown in Plate II. fig. 26 (*Nägeli*).

Fig. 7. Fructification of *Equisetum*; *a,* a spike of capsules; *b,* diagram of a section of a spike, showing the attachment of the capsules; *c,* a capsule seen laterally; *d,* a capsule from above; *e, f, g,* spore seen in different positions (*Bischoff* and *Mohl*).

Fig. 8. *Spore* with *elaters* after its escape from the capsule.

Fig. 9. Fructification of *Lycopodium*; leaf bearing an *antheridium*; *b,* a spike of fruit.

Fig. 10. *a,* a leaf with *oophoridium* or four-lobed capsule (*Martius* and *Endlicher*); *b,* section of a young *oophoridium,* showing the development of the mother-cell of the four large spores from the apex of the axis (*Müller*); *c, oophoridium* bursting.

Fig. 11. Germination of *Lycopodium* (*Müller*).

Fig. 12. Fructification of *Isoëtes*; A. section through the base of the stem, showing the position of the capsules imbedded in the lower part of the leaves; B, capsule containing the large

spores; C, capsule with the smaller kind; D, spores; *a,* smaller kind; *b,* larger with prominent ridges (*Mohl, Sturm*).

Fig. 13. Fructification of *Pilularia*; *a,* capsule; *b,* section of female capsule; *c,* ovule; *d,* ovule divested of the external envelope (*Bischoff*).

Fig. 14. Section of male capsule with pollen (*Bischoff*).

Fig. 15. Section of the ovule of *Pilularia*; *a,* nucleus; *b,* embryo-sac; *c,* coriaceous coat; *d,* gelatinous coat (*Schleiden*).

Fig. 16. Impregnation of the ovule of *Pilularia*; *a, pollen*; *b, nucleus* with the *pollen* imbedded in it; *c,* enlarged *nucleus*; *d, embryo-sac* (*Schleiden*).

Fig. 17. Germination of *Pilularia*; *a, cotyledon* or germ; *b, radicle*; *c, plumule*; *d,* remnant of the ovule (*Schleiden*).

Fig. 19. Fructification of *Marsilea*; A, stalked capsule borne on the petiole; *b,* the capsule enlarged (the figure on the left hand shows the manner of dehiscence); *c,* a vertical section of it, showing the divisions in its interior; *d,* a section at right angles to the last; *e, ovule-sac* with four *antheridia* from one of the cavities; *f,* an *ovule*; *g, pollen* (*Bischoff, Greville*).

Fig. 19*a*. Section of a capsule showing the position of the *ovule-sacs* and *antheridia* (*Braun*).

Fig. 20. Fructification of *Salvinia*; A, a spike of capsules; *f,* ovuliferous; *m,* polliniferous; *a,* a capsule; *b,* cross section of the same (*Schleiden*).

Fig. 21. Vertical section of two capsules; *a,* ovuliferous; *b,* polliniferous; B. *a,* a bundle of *antheridia*; *b,* one of them more magnified; *c, pollen*; C. *a,* bunch of *ovules*; *b,* an *ovule* more magnified; *c,* ditto seen from above showing the *nucleus*; *d,* a vertical section of it (*Schleiden, Bischoff*).

Fig. 22. Fructification of *Azolla*; *a,* ovate capsules; *b,* globose capsules (*Griffith*).

Fig. 23. *a,* oblong ovate capsule (ovule ?); *b, calyptra* detached from the summit (*nucleus* ?) of the lobed body *c* (*Griffith*).

Fig. 24. Polliniferous sacs from the globose capsules; *a,* transverse section; *b,* vertical ditto, showing part of the pedicle (*Griffith*).

Fig. 26. Globose capsule of *Azolla* (*Griffith*).

Fig. 27. Globose capsule of another species (*Martius*).

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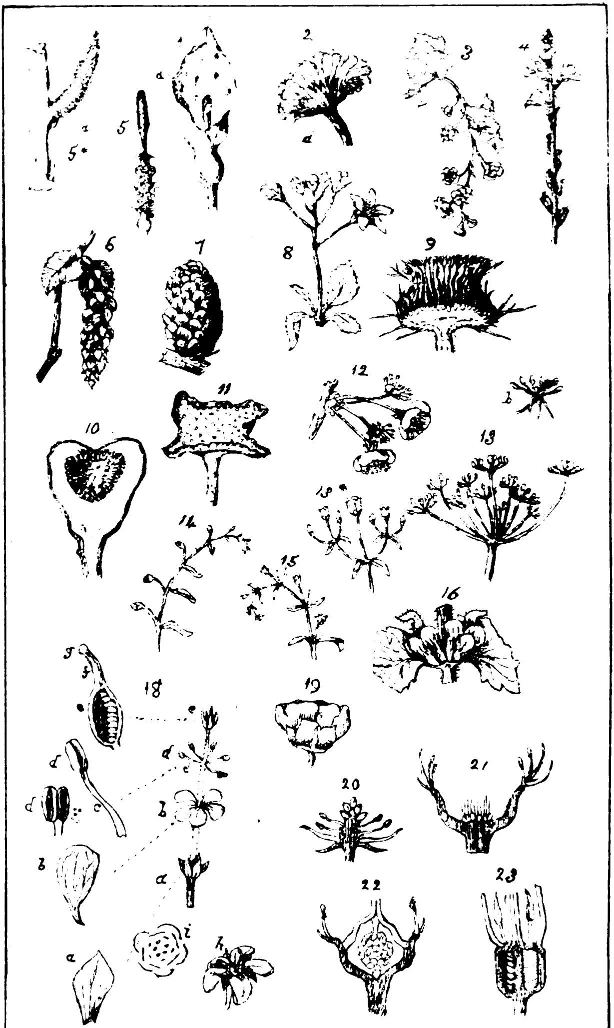

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PLATE XII.

Fig. 1. *Arum maculatum; a, spathe.*

Fig. 2. *Capitulum* of *Chrysanthemum*; *a,* involucre.

Fig. 3. *Raceme* of *Ribes.*

Fig. 4. *Spike* of *Verbena officinalis.*

Fig. 5. *Spadix* of *Arum.*

Fig. 5*. Inflorescence of *Acorus calamus*; *a, spadix.*

Fig. 6. *Catkin* or *ament* of *Carpinus* (male inflorescence).

Fig. 7. Female *cone* of *Larix.*

Fig. 8. *Corymb* of *Cerasus malaheb.*

Fig. 9. Section of a compositous *capitulum,* showing the insertion of the florets.

Fig. 10. Section of the *hypanthodium* of the Fig.

Fig. 11. *Hypanthodium* of *Dòrstenia.*

Fig. 12. *Simple umbel* of the Cherry.

Fig. 13. *Compound umbel* of *Fœniculum*; *b,* umbellule with partial involucre (*Æthusa*). (The foregoing are chiefly from *Le Maout.*)

Fig. 13*. Centrifugal *cyme* of an *Arenaria.*

Fig. 14. *Scorpioid cyme* where the leaves are alternate.

Fig. 15. *Scorpioid cyme* where the leaves are opposite; the dotted lines indicate the positions of the suppressed branches.

Fig. 16. *Verticillaster* of a Labiate plant.

Fig. 18. Diagrams of the floral organs in an imaginary flower having five organs in each whorl; *a, a,* the *calyx* composed of *sepals*; *b, b,* the corolla of five *petals*; *c, d,* the *andrœcium* of *stamens* in which *c* indicates the *filaments*; *d,* the *anther*; *e,* the *gynœcium* of five *carpels,* each carpel presenting three parts, *e,* the ovary, *f,* the style, and *g,* the stigma; *h,* the flower with the whorls *in situ*; *i,* a ground-plan of the flower showing the alternation of the organs of succeeding whorls.

Fig. 19. Flower of *Malva miniata* with *corolla, calyx* and *epicalyx* (*Schleiden*).

Fig. 20. Section of the flower of *Ranunculus,* showing the *hypogynous* position of the stamen, petals and sepals (ovaries *superior*).

Fig. 21. Section of *Dryas* with *perigynous* stamens and envelopes.

Fig. 22. Section of *Heuchera* with *perigynous calyx*; ovary *half-superior* (*Schleiden*).

Fig. 23. Section of *Leucojum vernum*; stamen and perianth *epigynous*; ovary *inferior* (*Schleiden*).

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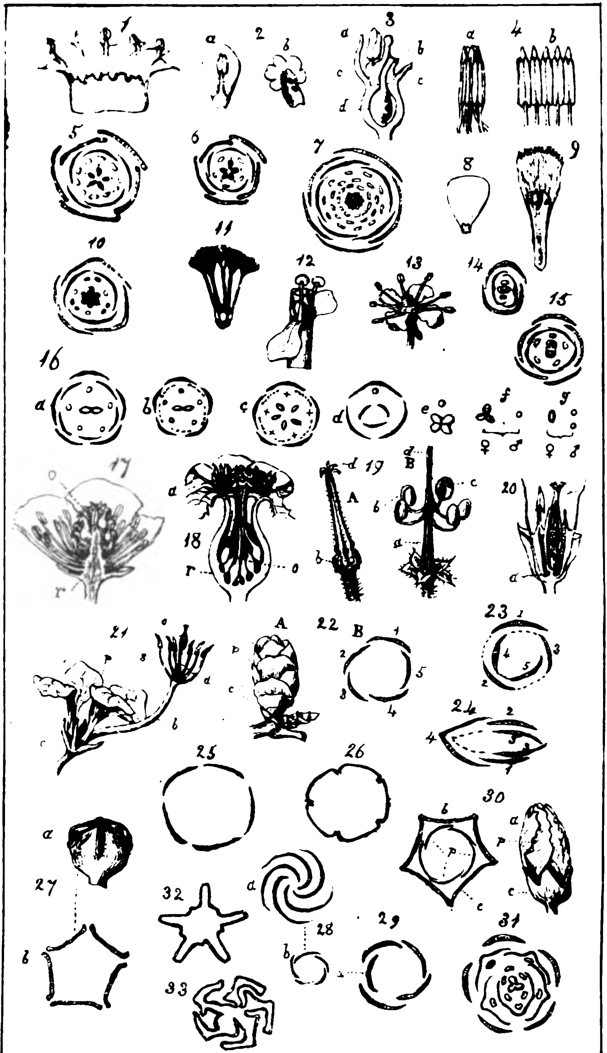
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A.H.

PLATE XIII.

Fig. 1. Corolla of *Cuscuta* with scales in the throat alternating with the lobes of the corolla (*Le Maout*).

Fig. 2. *a,* Filament of *Anagallis* adhering to the petal; *b,* corolla of *Verbena* with the filaments blended with the petals (*Le Maout*).

Fig. 3. Section of the flower of *Epipactis latifolia,* showing the gynandrous stamen; *a,* anther; *b,* the stigma; *c, c,* perianth; *d,* ovary (*Schleiden*).

Fig. 4. Syngenesious stamens of a compositous flower; *a,* in the natural condition, forming a tube; *b,* the tube slit up and spread out.

Fig. 5. Diagram of the flower of *Sedum,* exhibiting the 10 stamens.—[In these diagrams the dark central bodies are the carpels, the light oval bodies the stamens, the black lines petals, and the shaded lines the sepals (*Le Maout*).]

Fig. 6. Ground-plan of *Crassula* with five stamens (*Le Maout*).

Fig. 7. Ground-plan of *Ranunculus* with many rows of stamens (*Le Maout*).

Fig. 8. Petal of *Ranunculus* with a scale at the base.

Fig. 9. Petal of *Lychnis* with a projecting fold in the throat (*Jussieu*).

Fig. 10. Ground-plan of *Butomus* with three pairs of stamens opposite the sepals and three single stamens opposite the petals (*Le Maout*).

Fig. 11. Polyadelphous stamens of *Melaleuca hypericifolia,* five *bundles* of stamens replacing the five stamens of some other Myrtaceæ (*St. Hilaire*).

Fig. 12. Flowering branch of *Callitriche* devoid of floral envelopes (*Le Maout*).

Fig. 13. Flower of *Ruta* with four petals and two whorls of stamens each composed of four organs (*Le Maout*).

Fig. 14. Ground-plan of *Circæa* with two organs on each whorl.

Fig. 15. Ground-plan of *Solanum,* where with a pentamerous arrangement of the envelopes and stamens there are only two carpels.

Fig. 16. Ground-plans of various flowers; *a, Cuscuta* with only two carpels; *b,* the Elm, the dotted lines indicate where the suppressed petals would have been found; *c,* pistillate flower of *Xanthoxylon,* the dotted lines indicate suppression of petals, the crosses of stamens; *d, Blitum* with a perigone of three organs, one stamen and three carpels; *e, Callitriche* (fig. 12.); *f, Euphorbia,* ♀ pistillate flower, ♂ staminate flower; *g, Salix* (the same references.) (*Gray*).

Fig. 17. Vertical section through the flower of *Ranunculus* exhibiting the simple ovaries (*o*) borne upon the conical receptacle (*r*).

Fig. 18. Vertical section of the flower of *Rosa,* showing the simple ovaries (*o*) borne on the inner surface of the excavated receptacle (*r*); *a,* stamens.

Fig. 19. *Geranium*; A, carpels in the earlier stage adherent to the carpophore; B, after the dehiscence; *a,* carpophore; *b,* carpels attached by the styles; *c,* a carpel curved over so as to show its dorsal dehiscence; *d,* stigmas.

Fig. 20. Section of a flower of *Gentian* showing the gynophore (*a*) bearing the ovary (*Le Maout*).

Fig. 21. Flower of *Gynandropsis*; *c,* calyx; *p,* petals; *b,* internode developed between the corolla and stamens; *s,* stamens; *d,* gynophore; *o,* ovary (*Jussieu*).

Fig. 22. Imbricated æstivation of *Camellia*; A, lateral view; *c,* calyx; *p,* petals; B, ground-plan (*Jussieu*).

Fig. 23. Diagram of a quincuncial æstivation.

Fig. 24. Papilionaceous or vexillary æstivation.

Fig. 25. Valvate æstivation.

Fig. 26. Induplicative.

Fig. 27. Reduplicative; *a,* lateral view; *b,* ground-plan.

Fig. 28. Contorted.

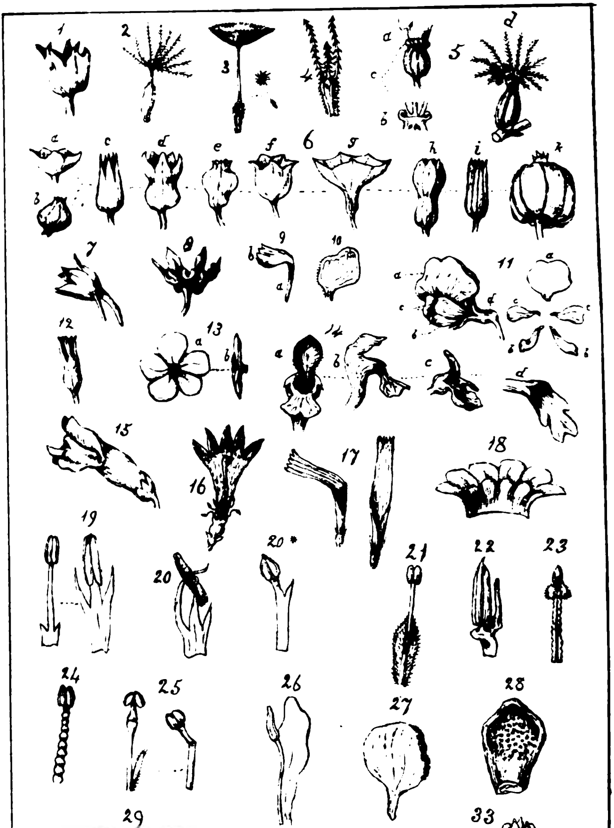
Fig. 29. Spiral contorted.

Fig. 30. Æstivation of *Althæa rosea*; *a,* lateral view; *b,* ground-plan; *c,* calyx; *p,* petals (*Jussieu*).

Fig. 31. Ground-plan of *Tryopteris ovata* (Malpighiaceæ) with stamens in the axils of the envelopes (*Jussieu*).

Fig. 32. Plicate æstivation.

Fig. 33. Supervolute.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A.H.

PLATE XIV.

Fig. 1. A bilabiate calyx.

Fig. 2. A plumose pappus.

Fig. 3. A pilose ditto.

Fig. 4. Aristate ditto of *Bidens.*

Fig. 5. Calyx of *Centranthus*; *a,* a lateral view in an early stage; *b,* vertical section of the same showing the calyx or pappus *c,* rolled inward; *d,* fruit crowned by the expanded calyx.

Fig. 6. Various forms of the monosepalous calyx; *a,* cupuliform; *b,* globose; *c,* conical; *d,* urceolate; *e,* turbinate; *f,* campanulate; *g,* infundibuliform; *h,* clavate; *i,* cylindrical; *k,* inflated.

Fig. 7. Spurred calyx of *Tropæolum* (*Le Maout*).

Fig. 8. Appendiculate calyx of Campanula (*Le Maout*).

Fig. 9. A petal; *a,* the claw; *b,* the limb.

Fig. 10. Irregular petal of *Fugosia sulphurea* (*St. Hilaire*).

Fig. 11. Papilionaceous corolla; *a,* vexillum; *b, b,* carina; *c, c,* alæ; *d,* calyx.

Fig. 12. A tubular corolla.

Fig. 13. A rotate corolla; *a,* seen from above; *b,* a lateral view exhibiting the very short tube.

Fig. 14. Labiate corollas; *a, Lamium,* front view; *b,* ditto, side view, showing the vaulted upper lip; *c, Rosmarinus* with the upper lip reflexed; *d, Echium,* the upper lip scarcely distinguishable.

Fig. 15. Personate corolla.

Fig. 16. Flower of *Scævola uvifera* (*Stocks,* M.S.).

Fig. 17. Ligulate florets.

Fig. 18. Flower of *Myosotis* laid open, exhibiting a scale beneath each lobe of the corolla.

Fig. 19. Dilated filaments of *Allium.*

Fig. 20. Stamen of *Allium sativum,* with one lobe of the petaloid filament elongated into a kind of tendril (*St. Hilaire*).

Fig. 20*. Forked filament of *Crambe* (*Le Maout*).

Fig. 21. Stamen of *Simaba*; the filament arising from the back of a scale (*St. Hilaire*).

Fig. 22. Stamen of *Borago*; filament arising from the face of a beak-like scale (*Le Maout*).

Fig. 23. Toothed filament of *Humirium crassifolium* (*Lindley*).

Fig. 24. Moniliform filament.

Fig. 25. Male flowers of *Euphorbia,* consisting of a single stamen; the articulation indicates the place where the suppressed floral envelopes would be situated.

Fig. 26. Petaloid stamen of *Canna,* one side petaloid, the other consisting of a unilocular anther (*St. Hilaire*).

Fig. 27. Petal of a monstrous Rose with pollen developed on one margin (*St. Hilaire*).

Fig. 28. Polleniferous body of *Viscum* (*St. Hilaire*).

Fig. 29. Transverse section of an unopened anther of *Neottia picta*; *a, a,* the two lobes or loculi; *b,* the connective; *c, c,* the sutures; *d, d,* the septa; *e, e,* epidermis; *f,* vascular bundle of the connective; *g,* spiral fibrous cells forming the outer walls of the chambers; *i, i, i, i,* the four pollen chambers (*Schleiden*).

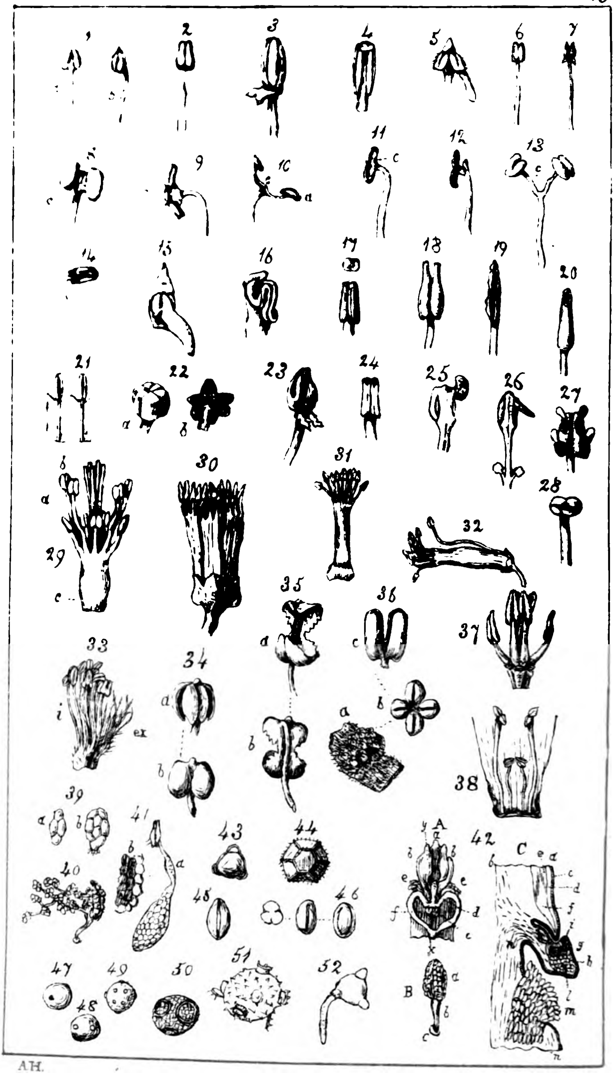
Fig. 30. Stamen of *Euphorbia Lathyris,* with a cross section (*Schleiden*).

Fig. 31. Cross section of a flower-bud of *Actinomeris alternifolia,* showing the relative position of the organs (*Schleiden*).

Fig. 32. One of the lobes of the flower of *Castrea falcata,* containing pollen in a little hole in the upper part (*St. Hilaire*).

Fig. 33. Stamens of *Bocagea viridis* (*St. Hilaire*).

Fig. 34. Androphore of *Byttneria celtoides,* the five fertile stamens cohering with the five sterile (*St. Hilaire*).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A.H.

PLATE XV.

Fig. 1. Attachment of anthers, *a*, at the base (*adnate*); *b*, at the back (*innate*).

Fig. 2. Stamen of *Tulipa*, the apex of the filament attached in a little hole at the base of the anther.

Fig. 3. Stamen of *Ticorea febrifuga*, the connective elongated below into a fleshy appendage (*St. Hilaire*).

Fig. 4. Stamen of *Xylopia grandiflora*; apex of the connective prolonged and truncated (*St. Hilaire*).

Fig. 5. Stamen of *Viola*, the connective prolonged back into a petaloid body.

Fig. 6. An emarginate anther.

Fig. 7. A bifid ditto.

Fig. 8. Stamen of *Melissa grandiflora*; connective enlarged (*St. Hilaire*).

Fig. 9. Stamen of *Thymus Patavinus*; the connective still more enlarged, separating the bases of the loculi to a considerable extent (*St. Hilaire*).

Fig. 10. Stamen of *Salvia pratensis*; the filiform articulated connective (*c*) bears one cell containing pollen (*a*), and at the other extremity an abortive cell (*St. Hilaire*).

Fig. 11. Stamen of *Stachys palustris*, the enlarged connective (*c*) bringing the two cells of the anther into one line.

Fig. 12. Stamen of *Prunella*.

Fig. 13. Stamen of *Stemodia trifoliata*, the connective (*c*) resembling a bifurcate termination of the filament (*St. Hilaire*).

Fig. 14. Stamen of *Orobanche*; the cells of the anther rendered horizontal by the curving of the upper part of the filament (*Le Maout*).

Fig. 15. Anther of *Viola odorata*; back view, showing the origin of the appendix from the connective (*Jussieu*).

Fig. 16. Convoluted anther of *Bryonia dioica* (*Jussieu*).

Fig. 17. Tetragonous anther of *Solanum*, with a cross section, showing the breadth of the sides.

Fig. 18. Anther of *Vaccinium*, with each loculus prolonged upward into a tube.

Fig. 19. Face of the anther of *Stachys* (Fig. 11.) after dehiscence.

Fig. 20. Unilocular anther of a *Polygala* (*St. Hilaire*).

Fig. 21. Ditto of *Gomphrena macrocephala* (*St. Hilaire*).

Fig. 22. Anther of *Taxus*; *a* seen from above, *b* seen from below.

Fig. 23. Anther of *Erica cinerea*, bursting by lateral pores (*Jussieu*).

Fig. 24. Anther of *Solanum*, bursting by terminal pores.

Fig. 25. Anther of *Berberis*, one of the valves opening like a lid (*Le Maout*).

Fig. 26. Anther of *Laurus nobilis*, one valve dehiscing (*Le Maout*).

Fig. 27. Anther of *Persea gratissima*, bursting by four valves (*St. Hilaire*).

Fig. 28. Anther of *Alchemilla*, bursting transversely (*Le Maout*).

Fig. 29. Monadelphous stamens of *Oxalis* (*Le Maout*).

Fig. 30. Polyadelphous stamens of the Orange (*Le Maout*).

Fig. 31. Adherence of a number of stamens in *Hypericum ægyptiacum*, forming a segment of a circle (*Jussieu*).

Fig. 32. Diadelphous stamens of *Lathyrus* (*Le Maout*).

Fig. 33. Group of stamens from *Lühea paniculata*; *i*, internal stamens, longer and fertile; *ex*, outer stamens, sterile and shorter than the rest (*Jussieu*).

Fig. 34. Anther of *Pinus*. *a*, front view; *b*, back view (*Zuccarini*).

Fig. 35. Anther of *Abies*; same references (*Zuccarini*).

Fig. 36. Anthers of *Encephalartus*. *a*, a portion of a scale, bearing anthers; *b*, anther seen from above; *c*, lateral view (*Zuccarini*).

Fig. 37. Tetradynamous stamens.

Fig. 38. Didynamous stamens.

Fig, 39. Pollen-grains united in masses. *a*, *Periploca græca*; *b*, *Inga anomala* (*Jussieu*).

Fig. 40. Pollen of an Orchidaceous plant; the viscid matter drawn out into filaments (*Lindley*).

Fig. 41. Pollen of an Asclepiadaceous plant. *a*, one of the pollen-masses; *b*, section of the outer portion of the same, showing that the outer layer is formed of empty cells, which constitute a membrane enclosing the pollen-grains.

Fig. 42. A, Front view of the anthers and stigma of *Orchis militaris*. *a*, connective of the anther; *b*, *b*, the two loculi; *c*, retinacula; *d*, lower part of the loculus of the anther, containing the caudiculus; *e*, *e*, abortive stamens; *f*, stigma. *x* and *y* represent the direction of the section C. B, Pollen-mass of *Orchis Morio*: *a*, pollen; *b*, caudiculus; *c*, retinacula. C, Vertical section of A in the direction *x* to *y*: *a*, *b*, the lower part of one loculus of the anther; *c*, epidermis; *d*, parenchyma of the wall; *e*, pollen-mass; *f*, caudiculus; *g*, the apex of the short rostellum; *h*, epidermis of the same, forming the bursicula; *i*, retinacula; *k*, portion of the bursicula which becomes absorbed afterwards, so that the caudiculus, when free, comes in contact with the naked retinacula; *l*, loose cellular tissue; *m*, outer surface of the conducting tissue (stigma); *n*, parenchyma of the discoid style (*Schleiden*).

Fig. 43. Trigonal pollen of *Œnothera* (*Jussieu*).

Fig. 44. Polyhedral pollen of *Cichorium* (*Jussieu*).

Fig. 45. Pollen of *Gladiolus*.

Fig. 46. Pollen of *Convolvulus tricolor*, seen from above, behind and before (*Jussieu*).

Fig. 47. Pollen of *Dactylis glomerata*, with a single pore (*Jussieu*).

Fig. 48. Pollen of a dicotyledon, with three pores.

Fig. 49. Pollen of *Corydalis* (*Jussieu*).

Fig. 50. Pollen of *Passiflora kermesina*, the pores covered by opercula (*Jussieu*).

Fig. 51. Pollen of *Cucurbita pepo* dehiscing, the opercula falling off the pores (*Jussieu*).

Fig. 52. Pollen of *Œnothera biennis*, emitting a pollen-tube (*Jussieu*).

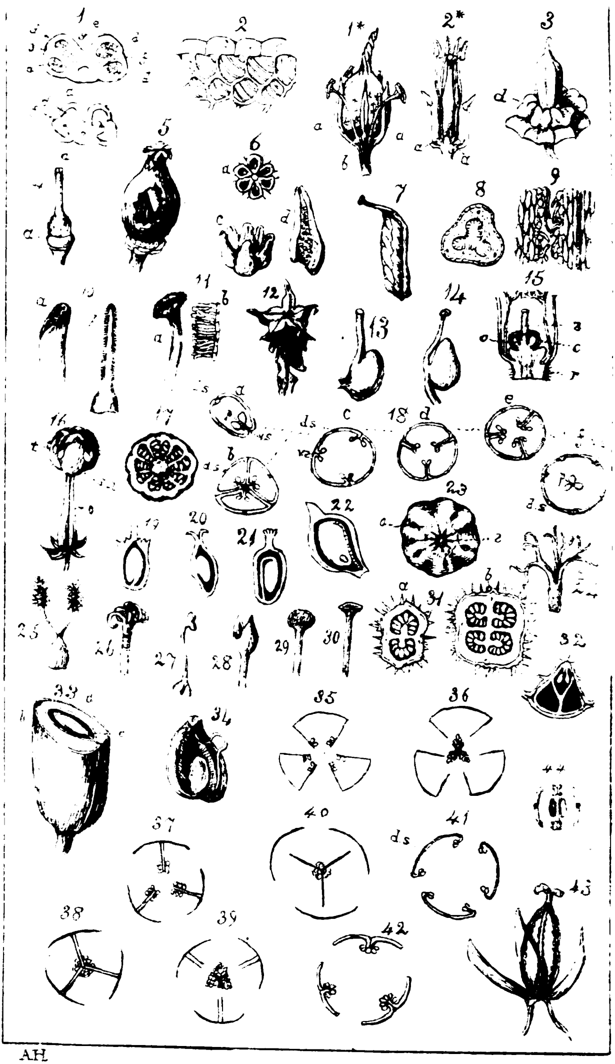
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PLATE XVI.

Fig. 1. Transverse sections of young anthers, the lower figure showing the older condition where the septa have been absorbed in the greater part of their extent. *a*, connective; *d d*, pollen-chambers; *e*, the epidermis; *f*, the septa; *g*, a dotted line through the septa, to indicate its duplicate origin.

Fig. 2. Spiral fibrous cells from the walls of an anther, situated immediately below the single layer of epidermis cells (*Jussieu*).

Fig. 1*. Stamens and pistils of *Helicteres Sacarolha*. *a*, the petaloid lobes of the disk alternating with the stamens; *b*, the elongated peduncle on which the essential organs are borne (*St. Hilaire*).

Fig. 2*. Andræcium and pistil of *Cheiranthus Cheiri*: *a a*, lobes of the disk (*St. Hilaire*).

Fig. 3. Pistil of *Cobæa scandens*, surrounded by the lobes *d* of the disk (*St. Hilaire*).

Fig. 4. Base of the pistil of *Veronica*, surrounded by the entire disk *a* (*Le Maout*).

Fig. 5. Disk of *Pæonia Moutan*, almost enclosing the multiple ovary; a portion is raised to show the carpels within (*St. Hilaire*).

Fig. 6. Young ovary of *Butomus umbellatus*. *a*, whorl of very young carpels, seen from above, their margins not yet in contact; *c*, the same, a little older, viewed laterally; *d*, section of a carpel, exhibiting the ovules all over the wall (*Jussieu*).

Fig. 7. A metamorphosed pistil of the double Cherry, partly converted into a leaf.

Fig. 8. Transverse section of a pistil, showing the passage down the centre (*Jussieu*).

Fig. 9. Vertical section of the style of *Campanula*, showing he filamentous cells lining the passage (*Jussieu*).

Fig. 10. *a*, Unilateral stigma of *Asimina triloba*; *b*, bilateral ditto of *Plantago saxatilis* (*Jussieu*).

Fig. 11. *a*, Summit of one of the branches of the style of *Hibiscus palustris*; *b*, papillæ from its surface (*Jussieu*).

Fig. 12. Multiple ovary of *Sedum*, formed of a single whorl of carpels.

Fig. 13. A lateral style.

Fig. 14. A basilar ditto.

Fig. 15. Gynobase of *Salvia*. *c*, carpels; *o*, ovules; *r*, receptacle; *s*, style (*Le Maout*).

Fig. 16. Gynæcium of an *Asclepias*, with the anthers, &c. removed. *c*, carpels; *sti*, stigmas; *t*, glandular bodies to which the pollen-masses are attached (*Le Maout*).

Fig. 17. Transverse section of the ovary of *Nymphæa*, showing the ovules growing on all parts of the dissepiments.

Fig. 18. Diagrams of transverse sections of ovaries to illustrate placentation. *d s* signifies dorsal suture; *v s* ventral ditto. *a*, A simple ovary of one carpel; *b*, a three-celled ovary with *axile* placentæ; *c*, a compound, unilocular ovary with *parietal* placentæ; *d*, *e*, compound unilocular ovaries with placentæ intermediate between parietal and axial; *f*, a compound unilocular ovary with a *free central* placenta. All but *a* are composed of three carpels, in contact either by their lateral faces or their margins.

Fig. 19. One-seeded, unilocular ovary of Compositæ.

Fig. 20. Ditto of Graminaceæ.

Fig. 21. Ditto of Plumbaginaceæ.

Fig. 22. Ditto of *Ranunculus*.

Fig. 23. Very young ovary of *Pavonia cuneifolia*. *a*, the five ovulary cavities; *b*, the ten papillæ whence originate the ten styles (*Duchartre*).

Fig. 24. Summit of the forked styles of *Emblica officinalis* (Euphorbiaceæ) (*Jussieu*).

Fig. 25. Feathery stigmas of a Grass.

Fig. 26. Summit of the lobed style of *Campanula rotundifolia* (*Jussieu*).

Fig. 27. Style and stigma of *Scrophularia* (*Le Maout*).

Fig. 28. Stigma of *Bignonia pandorea* (*Jussieu*).

Fig. 29. Ditto of *Mirabilis jalapa* (*Jussieu*).

Fig. 30. Ditto of *Arbutus Andrachne* (*Jussieu*).

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Fig. 31. Transverse section of the ovary of *Datura Stramonium*; *b* exhibits the two spurious dissepiments which are wanting in the upper part *a*.

Fig. 32. Diagram of one of the carpels of the ovary of *Nigella damascena*, with one true cell and two spurious, the latter resulting from the separation of the lining membrane from the substance of the wall of the ovary.

Fig. 33. Section of the legume of a Bean. *a*, epicarp; *b*, mesocarp; *c*, endocarp (*Jussieu*).

Fig. 34. Follicle of *Magnolia* dehiscing at the dorsal suture (*St. Hilaire*).

Figs. 35–44. Diagrams of the dehiscence of fruits.

Figs. 35, 36. Septicidal dehiscence.

Figs. 37–39. Loculicidal.

Fig. 40. Septifragal.

Fig. 41. Valves with the seeds on the margins of the valves.

Fig. 42. Valves with the seeds on the middle of the valves.

Fig. 43. Valves separating from the placentæ in Orchidaceæ.

Fig. 44. Valves separating from the placentæ and *replum* in Cruciferæ.

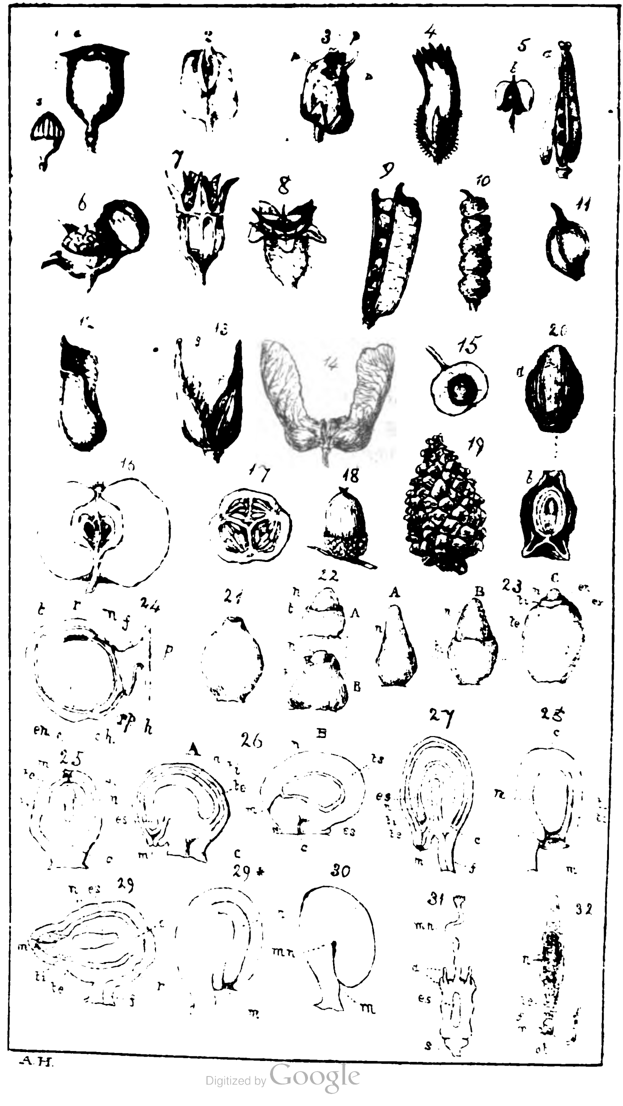
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PLATE XVII.

Fig. 1. Young ovary of *Papaver,* and ripe capsule of ditto: *a,* stigmas; *b,* pores of dehiscence.

Fig. 2. Ripe capsule of *Digitalis,* the two valves separating by septicidal dehiscence and also splitting down the upper part of their dorsal suture.

Fig. 3. Ripe capsule of *Antirrhinum*; *p p,* pores of dehiscence.

Fig. 4. Capsule of *Cerastium viscosum* after dehiscence (*Jussieu*).

Fig. 5. Fruits of Cruciferæ: *a,* Siliqua; *b,* Silicula; dehiscing by valves separating from the placentæ and replum.

Fig. 6. Capsule of *Anagallis* with circumscissile dehiscence.

Fig. 7. Fruit of *Campanula rotundifolia* dehiscing by pores inferiorly (*Jussieu*).

Fig. 8. Fruit of *Saxifraga tridactylites*; the carpels, free at their summits, opening by the ventral sutures (*Le Maout*).

Fig. 9. A Legume, opening by both sutures.

Fig. 10. A Lomentum, the upper joint half broken off (*Jussieu*).

Fig. 11. Achenium of *Ranunculus.*

Fig. 12. A Follicle, opening by the ventral suture (*Jussieu*).

Fig. 13. The two Follicles of an *Asclepias* dehiscing: *p,* placenta; *g,* hairs of the seeds (*Jussieu*).

Fig. 14. Samara of a Maple.

Fig. 15. Section of a Drupe.

Fig. 16. Vertical section of a Pome.

Fig. 17. Transverse section of a Pepo.

Fig. 18. A nut (Acorn) with a cupule or cuplike involucre.

Fig. 19. A Cone.

Fig. 20. Fruit of *Mirabilis*: *a,* lateral view; *b,* vertical section showing that it is enclosed in the hardened persistent calyx (*Jussieu*).

Fig. 21. Naked nucleus of *Viscum* (*Jussieu*).

Fig. 22. Young ovules of *Juglans* in two stages: A, very young; B, older; *n,* nucleus; *t,* the tegumentum simplex (*Jussieu*).

Fig. 23. Ovule of *Polygonum*: A, B, C, successively older specimen: *n*, nucleus; *t i*, tegumentum internum; *t e*, teg. externum; *en*, endostome or internal micropyle; *ex*, exostome or external micropyle (*Jussieu*).

Fig. 24. The seed of a Pea, the coats removed on one side, exhibiting—*m*, micropyle; *r*, radicle; *t*, testa or outer coat; *en*, endopleura or inner coat; *c*, cotyledon; *ch*, chalaza; *rp*, raphé; *h*, hilum; *f* is the funiculus, *p* the placentæ to which it is attached (*Le Maout*).

Fig. 25. Orthotropous ovule of *Polygonum divaricatum*: *m*, micropyle; *n*, nucleus; *e s*, embryo-sac; *t e*, tegument. ext.; *t i*, tegument. intern.; *c*, chalaza.

Fig. 26. Campylotropous ovules: A, *Spergula pentandra*; B, *Datura Stramonium*; the letters bear the same signification as in the preceding figure.

Fig. 27. Camptotropous ovule of *Galphimia mollis*; same references.

Fig. 28. Anatropous ovule of *Lilium*; same references.

Fig. 29. Heterotropous or amphitropous ovule of *Lemna trisulca*; same references.

Fig. 29*. Ovule of *Pedicularis palustris* showing the long, cylindrical nucleus *n*; *m*, micropyle.

Fig. 30. Ovule of *Scabiosa atropurpurea*; *m n*, the mamilla of the nucleus at the base of the long micropyle canal *m*.

Fig. 31. Flower of *Loranthus Deppeanus*: *s*, stem; *a*, remains of the stamens and envelopes which have been removed; *e s*, embryo-sac; *m n*, mamilla of the nucleus which projects out and resembles a style.

(Figs. 25 to 31 are all represented in vertical section, and are from *Schleiden*.)

Fig. 32. Ovule of *Narthecium* about the time of fertilization: *n*, nucleus; *t e*, teg. extern.; *f*, funiculus; *m*, micropyle; *o t*, ovule-tube growing out from the nucleus (*Dickie*).

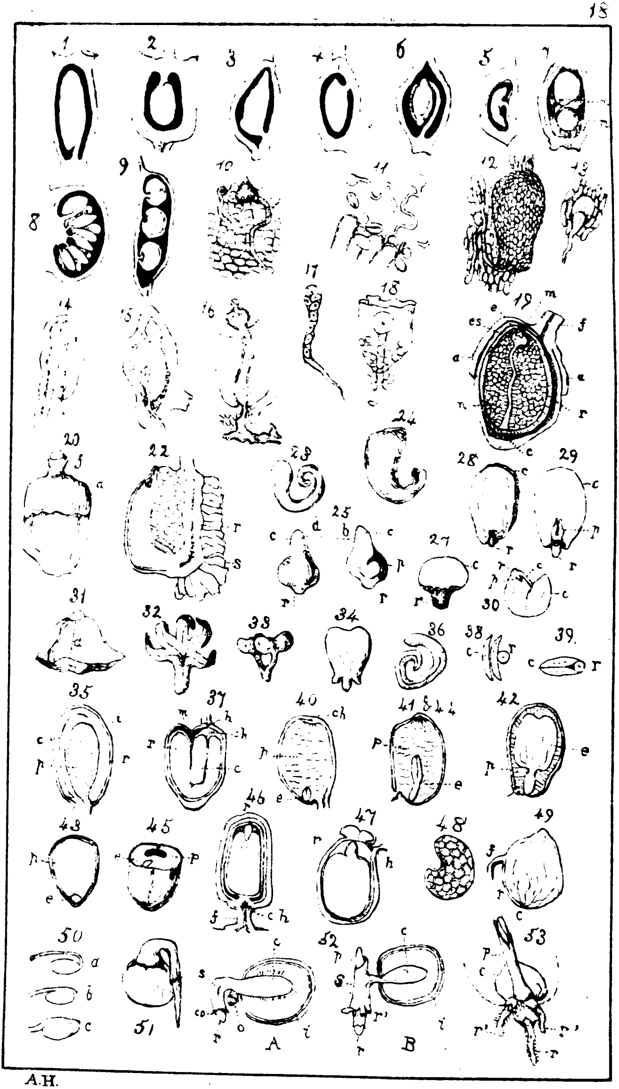
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PLATE XVIII.

Fig. 1. An erect ovule.

Fig. 2. Inverse.

Fig. 3. Ascending.

Fig. 4. Suspended.

Fig. 5. Peritropous, transverse or horizontal.

Fig. 6. Reclinate.

Fig. 7. Two ovules in one cell, turned in opposite directions: *m m*, micropyles (*Jussieu*).

Fig. 8. Ovules having various directions in the same cell.

Fig. 9. Ovules having similar directions in the same cell.

Fig. 10. Pollen-tubes passing penetrating the stigma in *Epilobium hirsutum*. The pollen is clothed with delicate filaments; the pollen-tubes issue from the pores at the angles (*Schleiden*).

Fig. 11. Pollen-tubes penetrating the stigma in *Gladiolus psittacinus*.

Figs. 12–16. Pollen-tubes entering the ovule to form the embryo (*Schleiden*).

Fig. 17. Pollen-tube drawn out from the embryo-sac of *Orchis Morio* (*Schleiden*).

Fig. 18. Embryo in embryo-sac (*Schleiden*).

Fig. 19. Section of a young seed of *Nymphæa*: *f*, funiculus; *a*, arillus; *r*, raphé; *c*, chalaza; *m*, micropyle; *n*, perisperm formed by the nucleus; *e s*, endosperm formed in the embryo-sac; *e*, embryo (*Jussieu*).

Fig. 20. Ovule of a *Passiflora*; *a*, arillus; *f*, funiculus (*Planchon*).

Fig. 22. Section of the ovule of *Asarum Canadense*, showing the strophioles, *s*, growing, the raphé, *r*; they consist of vesicles filled with oil (*Planchon*).

Fig. 23. Embryo of *Cuscuta Epithymum*.

Fig. 24. Embryo of *Pekea butyrosa* (*Jussieu*).

Fig. 26. *a*, Embryo of *Pistia obovata* : , vertical section of the same; *p*, plumule; *r*, radicle; *c*, cotyledon (*Schleiden*).

Fig. 27. Embryo of *Rajania cordata* (Dioscoreaceæ): *r*, radicle; *c*, cotyledon imperfectly enclosing the plumule (*Jussieu*).

Fig. 28. Embryo of the Almond: *c*, cotyledons; *r*, radicle.

Fig. 29. The same with one cotyledon removed: *c*, cotyledon; *r*, radicle; *p*, plumule (*Jussieu*).

Fig. 30. Embryo of *Hiræa salzmanniana*: *c c*, cotyledons; *r*, radicle; *p*, plumule (*Jussieu*).

Fig. 31. *Carapa guianensis*; vertical section of the embryo across the cotyledons; the dotted line *a* shows the line of junction (*Jussieu*).

Fig. 32. One of the lobed cotyledons of the embryo of *Tilia* (*Jussieu*).

Fig. 33. Petiolated cotyledons of *Geranium molle* (*Jussieu*).

Fig. 34. Bi-auriculate cotyledon of the Elm (*Jussieu*).

Fig. 35. Section of the seed of *Mirabilis jalapa*: *r*, radicle; *c*, cotyledons; *p*, perisperm; *i*, integuments of the seed (*Jussieu*).

Fig. 36. Spiral embryo of *Bunias orientalis* (*Jussieu*).

Fig. 37. Section of the seed of *Erysimum cheiranthoides*: *m*, micropyle; *h*, hilum; *ch*, chalaza; *c*, cotyledons; *r*, radicle (*Jussieu*).

Fig. 38. Cross section of a seed with an incumbent radicle, *r*; *c*, cotyledons.

Fig. 39. Cross section of a seed with an accumbent radicle, *r*; *c*, cotyledons.

Fig. 40. Section of the seed of *Helleborus niger*: *e*, embryo; *p*, perisperm; *ch*, chalaza (*Jussieu*).

Figs. 41 & 44. Section of the seed of *Diphylleia peltata*; *e*, embryo; *p*, perisperm (*Jussieu*).

Fig. 42. Section of the seed of *Berberis vulgaris*; *e*, embryo; *p*, perisperm (*Jussieu*).

Fig. 43. Section of the seed of *Carex depauperata*: *e*, embryo; *p*, perisperm (*Jussieu*).

Fig. 45. Seed of the Date, cross section, showing the excentrical embryo: *e*, embryo; *p*, perisperm (*Jussieu*).

Fig. 46. Section of the seed of *Sterculia balanghos*: *r*, radicle; *ch*, chalaza and hilum; *f*, funiculus (*Jussieu*).

Fig. 47. Section of the seed of *Ricinus communis*: *r*, radicle; *h*, hilum (*Jussieu*).

Fig. 48. Seed of Poppy with reticulated testa.

Fig. 49. Seed of Hazel: *c*, the chalaza ramifying on the coats; *f*, funiculus; *r*, raphé.

Fig. 50. *a*, *b*, *c*, Diagrams of the seeds of *Zygophyllum*, showing the passage from a free funiculus to the adherent condition where it forms a raphé.

Fig. 51. Germinating seed of a dicotyledon; the cotyledons still within the testa.

Fig. 52. Germination of *Canna indica* (the seeds in section). A, before the appearance of the plumule: *c*, cotyledon; *r*, radicle; *i*, coats of the seed; *o*, portion of the seed which opens like an operculum to give passage to the radicle; *s*, the slit indicating the position of the plumule; *co*, coleorhiza (§ 132.). B, the plumule *p* escaped from the sheath *s*; *c*, cotyledon; *i*, coats of the seed; *r*, radicle; *r′*, radicle fibres (*Jussieu*).

Fig. 53. Germination of *Avena*: *p*, plumule; *c*, cotyledon; *r*, radicle; *r′ r′*, radicle fibres.