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STRUCTURAL AND SYSTEMATIC BOTANY:

BEING

AN ARRANGEMENT OF PLANTS,

FORMING

A BASIS FOR THE STUDY OF BOTANY, EITHER ON THE LINNÆAN OR NATURAL SYSTEMS.

WITH NUMEROUS MICROSCOPICAL AND OTHER ILLUSTRATIONS.

BY

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THE following Treatises are devoted to the consideration of the structure of Plants and Animals; and it has been the aim of the authors to write with scientific accuracy, and with sufficient detail, without introducing discussion upon contested subjects. They trust that the work will be found intelligible to the unlearned, and instructive to those also who have obtained an elementary knowledge of the subjects.

Occasional observations will be met with, by which the reader is reminded that Plants and Animals are not only parts of the same great Creation; but that so closely are some plants associated with the so-called higher kingdom, that no definite line of demarcation can be drawn between them. It is for this reason that the reader is advised to study Botany in connexion with Zoology; and it is probable that a closer acquaintance with the structure and functions of certain parts of plants will ultimately enable us to trace more correct as well as more striking resemblances between the members of the two kingdoms than have as yet been conceived. For example, no nerves, or analogues of nerves, have as yet been found in plants; and yet it is quite clear that not only is a low degree of vital sensibility as universal in plants as in animals; but that in certain instances, as in the sensitive plant, it is developed to a far greater extent than is perceptible in animals taken from the lowest point in the scale of animal life.

This mode of investigation will give greater breadth and interest to the study of Natural History than the more simple and yet more difficult one of studying the parts of plants or of animals as detached points bound together by no universal law; and it is one, moreover, which tends to train the mind to habits of reflection as well as of observation. The authors have endeavoured to aid the mind in this search by introducing a very large number of microscopic and other illustrative engravings, which have the merit of showing the extreme beauty and elegance of design existing in the composition of plants, and offer many new points for analogical comparison with the exquisitely minute structures of animals. A microscope is now as necessary to the naturalist as a telescope to the astronomer.
In the remarks on Classification, the author of the Treatise on Botany has been drawn, by force of circumstances, to give much prominence to the Linnaean system; and this is the less to be regretted, since the analysis of the system, and the directions which follow it, may suffice to enable the reader to enter upon the study with facility, and to learn almost without trouble the positions of nearly all the most important plants of native origin. He will also find not only that there is a similarity between plants and animals from the presence of vital functions—viz., those of reproduction, respiration, circulation, digestion, growth, and decay—but that the very structures which give them bulk and form have in many instances close analogical resemblances. Thus the simple cell, which is the universal basis of animal structures, is, in like manner, and in equal degree, the universal basis of vegetable tissues. The thick-walled cells are very like to bone cells, the milk-bearing vessels to capillary blood-vessels, and their milky juice to the chyle or digested food of animals. Many other parts are analogous to those of animals in appearance; whilst others, again, are like them in function.

In accordance with the train of reasoning which this close connexion between Plants and Animals suggests, the ordinary method of arranging the animal kingdom has been reversed; the arrangement adopted having the obvious advantage of bringing together those plants and animals which so closely resemble each other as to render it sometimes doubtful to which of the kingdoms of Nature they belong.

With these few remarks we conclude the Natural History of Plants and Invertebrated Animals. The remaining portion of Organic Nature, which embraces the higher forms of animal organization, commencing with the Fishes and terminating with Man, will be concluded in another volume.

London, January, 1855.
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BOTANY.

The objects which we now proceed to contemplate have exceeding interest, not only in themselves, but in their relation to the other parts of this fair creation, and more especially to man. They were the first vital existences which appeared when the fiery mass which constitutes the earth had become covered with a stony crust of a cooler temperature, and they are the last to linger when the rigours of a Polar clime chase away all vitality. They are still the sole inhabitants of isolated spots on the burning plains of central Africa, and are the harbingers of animal life on the remotely issued lava, and the more recently emerged coral island of the southern seas.

They are found universally within limits bounded, on the one hand, by the perpetual snows of the Arctic regions, or the summits of our own Snowdon; and, on the other, by the parched sands of tropical deserts; and cover, as with a carpet, the magnificent prairies of India and America, the wild haunt of the buffalo, or jealously hide the long-lost cities of Assyria, which once teemed with wealth and myriads of human beings as busy as ourselves. Not only do they exist upon the surface of the soil, but their remains constitute a large part of the soil itself; so that seeds, which subsequently germinated, have been thrown up from considerable depths, after having lain buried more than two thousand years. The solid crust of the earth is also, in part, of vegetable origin, as in the instance of the widely-spread coal-beds, with their remains of primeval forests. Moreover, the very air which covers the earth is not free from these objects; and the waters of the rivers and the seas abound in vegetable life.

They offer the most wonderful diversities of features and proportions. There are the varied flowers which, as the daisy and buttercup, form the nosegay of infancy and the garland of youth; as the sweet violet which, on its mossy bank, sheds perfumes
on the loves of gentle maidens; as the blooming rose which adorns the bridal, and as the gloomy cypress which guards the tomb. There are the microscopic mould, which lends age to our mouldering ruins; and the gigantic forest-trees which, in the penal settlement of Norfolk Island, soar to the height of more than two hundred feet; or the celebrated chestnut-tree of Mount Etna, which sheltered one hundred horsemen.

They exist of every age, from the cell of the mushroom, which perishes in an hour, to the hoary Baobad of Senegal, which is computed to have lived since long before the days of Abraham. They quietly submit to the revolutions of centuries, with the changes of clime; and, as in the case of our own England, when the heat ceases to give life to cocoa-nut bearing palm-trees, and tree ferns, they gradually and silently appear as the modest primrose or the sturdy oak. They had traced long eras of the world’s history when no human being marked their form; and they will, doubtless, bear testimony to the progress of events until time shall be no longer. The antiquity of the blade of grass is far higher than that of the noblest families.

They have done essential service to their more highly endowed cousins of the animal kingdom, by having, directly or indirectly, fed all and clad many. They have formed the shelter of man and animals, and the chief part of the utensils and instruments of the former since his creation; and, even in our day, are presenting new treasures of infinite value for his use, as in the India-rubber and gutta-percha, so recently derived from their juices.

Thus the objects of our investigation should lose no dignity when we remember their remote antiquity, their universality, variety, beauty, and utility.

The consideration of these objects constitutes the science of Botany—a science which may be more exactly said to treat of plants, their internal and external parts, general and medical properties, geographical distribution, and classification. We purpose, in this essay, to limit our attention to the first and last portions of the subject—viz., the anatomy and classification of plants.

**History of the Science.**—The various considerations which we have already adduced, may enable us to conjecture that this science, in its rudimentary condition, must have existed from remote antiquity. If any further evidence short of direct proof were wanting, it might be gathered from the pages of sacred history, in which we find a constant reference to this division of created existences. The first authentic records on this subject are connected with the Grecian and Roman eras, and extend as far back as about the sixth century before Christ. The cultivators of the science did not then receive the wide appellation of Botanists, but the more humble and restricted one of *Rhizotome*, or root-cutters; since they chiefly directed their attention to the medicinal properties of plants.

Aristotle, of Stagira, who lived in the fourth century before Christ, is regarded as the founder of the science of botany; and from his days, through the Grecian, Roman, and Arabian eras, down to the eleventh century, considerable additions were made to their knowledge of this subject. Amongst those who cultivated this science most successfully, we may instance Mithridates, and several Grecian kings, with the younger Juba, king of Mauritania. These potentates established botanical gardens—partly, no doubt, from the love which they bore to the science, but in the instance of some of them, at least, more with a view to the cultivation of the deadly plants from which the poisonous juices were derived which killed Socrates, and which, at that period, was not an uncommon mode of execution. Tyrtamus, of Lesbos, who accompanied Alexander the Great in his victorious progress.
through some of the regions of Asia and Africa which now acknowledge the
British sway; Nicander of Colophon, Cato, Varro, Columella, Virgil, Pedacus,
Dioscorides of Silicia, who followed the Roman armies in their expeditions during the
fourth century; and, lastly, the elder Pliny. Up to this period, therefore, we owe our
knowledge of botany to the Greeks and Romans; and then, as now, war, notwithstanding
its desolation, was made to promote the interests of science.

The Arabians, in the eleventh century, were the next cultivators of botany, as they
were the most learned people then existing. After them the darkness of the middle
ages set in, during which no science was cultivated, except by a monk, here and there,
secluded in his gloomy cloister; and it was not until the rise of the illustrious Marco
Polo, of Venice, that the darkness became dispelled. He examined the treasures of
middle and southern Asia, and the eastern coasts of Africa, and described plants from
India and the Indian Ocean. From his days to the present the science has progressively
advanced; first, in the addition to our knowledge of the names of plants, and, secondly,
of their structure and physiology. The Italians, and then the Germans, in the sixteenth
century, rendered good service to the science, as did also, at the same period, the Por-
tuguese by their conquests in India, and the Spaniards by their discovery of America.

From this and the succeeding century the science of botany, as it is now under-
stood, may fairly be dated; since then, for the first time, an attempt was made to
classify the plants which had been discovered and named, and the microscope enabled
them to analyze the minute structures. Our own country now claims a distinguished
share in the honours of discovery. The Society of London for the Promotion of Science,
which was liberally supported by Charles the Second, gave much attention to the sub-
ject, and more particularly its secretary, Nehemiah Grew, who published his observa-
tions on the "Anatomy of Plants" in 1682. Another of our countrymen, Robert
Morison, Professor at Oxford, distinguished himself in the department of classification,
by the publication of various works, and especially of his "Historia Plantarum Universalis,"
with plates, in 1715. He was quickly followed by a yet more distinguished man,
John Ray, an English clergyman, who enunciated the true principles of classification,
and demonstrated the sexual characters of plants. Dr. Hans Sloane, the President of
the Royal Society, who died in 1753, and John Parkinson, the Superintendent of the
Medical Botanical Garden at Chelsea, and several successors of the latter, were honour-
ably distinguished.

We have not space to enumerate even the most distinguished names which have
adorned this science during the past two centuries. It must suffice to state that the
great Linnaeus, a native of Sweden, is by far the most eminent, and established the
sexual system which now bears his name. After him came De Saussure and Du
Hamel, Link, Rudolphi, Mirbel, Kieser, Schleiden, Darwin, and Quekett, in reference
to anatomy and physiology, and Jussieu, De Candolle, Robert Brown, Sowerby, Sir
No country has a greater claim to boast of the advantages which it has rendered to
botanical science than our own. It has established the best botanical gardens, as the
Royal Gardens of Kew and of Hampton Court, and the Medical Botanical Gardens at
Chelsea; and it has led the way in the investigation of minute structure. At the
present moment, it claims a multitude of most distinguished men labouring in one or
other of the departments of the same field.

**Definition of a Plant.**—Definitions are at all times difficult, and not the less so
that they appear easy. In this instance, as the three great kingdoms of nature pass
so insensibly the one into the other, it is impossible to show, with rigorous certainty, where the one ends and the other begins. It is a curious fact that, as science is extended and knowledge is increased, our difficulties arising from ignorance are increased in at least an equal proportion. Years ago the definition of a plant was not considered impossible; but now he would be thought a rash man who should attempt a satisfactory definition of a mineral, a plant, or an animal. This is one of the evidences that knowledge was intended to humble us by showing us our ignorance. The saying of Linnaeus,—that minerals grow, plants grow and live, animals grow, live, and feel,—is now held to be an insufficient definition. The value of this terse mode of expression is concealed in the assumption that the properties thus added in succession do not belong in any degree to the classes preceding. Thus all three classes grow, but only two live, and only one feels. This is now known to be incorrect. Thus, certain plants not only grow and live, but feel, as in the instance of the mimosa, or sensitive plant, which closes its rows of leaves on a slight shock, or the Dionaea muscipula, Venus’ fly-trap (Fig. 1), the leaf of which folds up and incloses any unhappy fly which may alight upon the three hairs (A). The disposition of most flowers to seek or shun the sunlight, and of the ears of corn in the growing corn-field to droop when the sun has set, might be adduced as instances in proof of the sensibility, apart from the mere vitality, of plants. But in addition to this, it is well known that the spores, or undeveloped young plants of Converve and of sea-weeds (Fig. 2) move about by the action of their own cilia or hairs, until they have found a resting-place to which to attach themselves. Thus we may add a degree of locomotion to the qualities of plants, and say that, in some instances, they grow, live, feel, and move. On the other hand, the sponges (Fig. 3), in their developed state, are denied the faculty of locomotion, although they undoubtedly belong to the animal kingdom.

These characters having failed to mark the distinction between plants and animals, it has been stated that an internal stomach, and the chemical principle called nitrogen or azote, are found in animals only; but this is incorrect,—since the sponge has
no internal stomach, and nitrogen is present in the seeds of almost all plants. More recently, it has been averred that the presence of a secretion, or product known as starch (Fig. 4), would clearly establish the existence of vegetables; but recent microscopic researches have shown that starch is also met with in the lower classes of animals, and in the brain and spinal cord of the higher animals, and even of man himself. Lastly, certain of the Algae, or sea-weeds, as the Desmidieæ and Diatomaceæ (Fig. 5), are still claimed equally by the botanist and the zoologist.

Thus simple as at first sight it might seem to state what a plant is as distinguished from an animal, we find it impossible to distinguish the lowest plant from the lowest animal; and have therefore no alternative than to say that we cannot give an unimpeachable definition of a plant.

**Definition of the Subject.**—We shall assume that our readers can recognise a plant, although we cannot define it, and proceed to a description of those various parts of which a plant is composed, and of the arrangement of plants into classes. These two branches of the subject—viz., structure and classification—have a necessary dependence upon each other; for the idea of classification implies that certain members have some properties or parts in common—such, for instance, as the leaf or flower; or in other words, that their structure corresponds. Therefore a knowledge of structure is essential to classification; and before we describe the latter, we must indicate the internal and external parts of which plants are composed.

**ANATOMY OR STRUCTURE OF PLANTS.**

**Elementary Tissues.**—In proceeding to a consideration of the anatomy of plants, it will be evident that, as plants in general have external organs, as leaves and flowers, so must they have more minute parts of which these organs are composed. These will correspond with the flesh and bones of the various parts of our body, and are termed "elementary tissues." We shall take them first in order, since they are formed before the organs can be developed. They will also furnish us with drawings of some of the most exquisitely-minute beauties of nature.

**Formative Fluid.**—But as the formation of a leaf, for example, implies the previous existence of elementary tissues, so does the presence of an elementary tissue imply the production of a material fluid, out of which the elementary structure was formed. This latter is called the "formative fluid," or "organic mucus," or "cambium," or "organizable matter" (all of which terms have the same original signification), and is the sole source of production of every tissue found in plants. It is, in this respect,
similar to the blood of animals; for that fluid is the source of all the solid parts of the body. It is semi-transparent and semi-fluid in the internal parts of many plants, and of young plants, and those with thick leaves, more particularly. In this condition it is also found in great abundance between the bark and the wood of all trees in the early spring months; and then separates those parts (A, Fig. 6), so as to permit the bundles of young wood to pass down from the leaves, and thus enable the tree to grow. It is under these circumstances that the woodman strips the bark from trees which are to be cut down, since then it does not adhere to the wood. The fluid is termed cambium in this situation. When this formative fluid is met with in the external parts of plants, it is still semi-transparent; but it is then solid, as may be observed by scraping the surface of a box-leaf.

**Elementary Membrane.**—The first step in the formation of any tissue from this formative fluid is the production of a solid structureless fabric, called elementary membrane, and a modification of that fabric termed elementary fibre. It will be observed that these elementary parts are structureless, and are produced, apparently, by inspissation or thickening of the formative fluid. The process may be grossly illustrated by a reference to the manufacture of paper, in which the rag-pulp (viz., rags torn into threads and soaked in water) corresponds to the formative fluid, and the paper, which is subsequently produced, to the elementary membrane. The paper thus obtained is fitted for the manufacture of books, and other articles; and, in like manner, the elementary membrane is the solid material out of which vegetable tissues are formed.

Elementary membrane, then, as in Fig. 7, is structureless; but, theoretically, it is assumed to consist of a layer of rounded particles, which lie side by side, and leave most minute spaces between them. This must be so, when we reflect that all fluids, including the formative fluid, are made up of rounded drops, with spaces between them; and that when a fluid is inspissated the drops are brought closer together. Thus, whilst evident openings are not naturally met with in membrane, except as shown by Professor Queckett, in the leaves of a moss called sphagnum (Fig. 8), it must be highly though invisibly porous, and permit certain fluids to filter through it.

It is at first thin and translucent, as may be seen in the membrane covering the seed of the gourd (Fig. 7); but in many cases it subsequently becomes thicker and more opaque. In the structures of the ferns (filices) it assumes a decidedly brown colour; and in the elaters of...
THE ELEMENTARY TISSUES.

the Jungermannia, a kind of moss (Fig. 10), it is of a beautiful red colour; these variations, and especially in thickness, result from the altered duties which it is required to perform. Thus, in the structure of bark and fruits, it is not merely thickened, but is lined by a deposit of hard sedimentary matter, of great power of resistance, in order to increase its strength and to resist decomposition. This hardened tissue is called sclerogen, or hard tissue (Fig. 9).

In less extreme cases the deposit is in much smaller quantity, and appears only as minute grains scattered over the surface. Such is the case in the pith of the elder (Sambucus niger—Fig. 11). A yet more interesting instance of this scattered mode of deposit is found in the hairs of the forix (a part of the flower) of the Anchusa italic (Fig. 12). These are covered with a series of tubercles, which are nothing more than isolated masses of a new deposit. In other instances still, the thickening of the membrane appears to have been produced by a deposit of the ordinary transparent organic mucus of which it was originally composed, and still remains transparent, and beyond this differs only from ordinary membrane in that this new matter is laid on unequally, and certain transparent spaces are found where the deposit has not taken place. These spots are oftentimes found arranged with great regularity, and sometimes in a spiral manner; so that the tissue becomes one of the most beautiful of vegetable microscopic objects. Such tissue is termed "dotted" tissue, and is found in most plants, but more particularly in the common cane (Rattan), and the vine (Vitis vinifera—Fig. 13). The use of this tissue is not well known.

Elementary Fibre (Fig. 14) is not formed from membrane, as though the latter
were cut up or drawn out into threads of almost inconceivable fineness, and therefore a production of membrane; but both it and the elementary membrane are alike formed out of the formative fluid. Moreover, it is not regarded as a substance separate from membrane, but as a deposit upon one side of a pre-existent membrane. Whenever it is found detached from membrane, we must assume that the membrane which supported it has been removed, or that it has detached itself from the membrane. This is admirably shown in Fig. 16, in which the fibre is in process of being denuded by the destruction of the membrane. It is usually, perhaps invariably, solid, and commonly has a rounded figure. It is also transparent, except in a few cases, as in those of the Jungermannia before referred to, (Fig. 10.) Its use is clearly that of supporting the more extended membrane, and of preventing any folds of it from approximating too closely to each other.

**Cellular Tissue, or Parenchyma.**

Having now considered the "raw material" we may proceed to describe the structures which are produced from it. These structures are very varied in appearance, and are ultimately applied to very varied purposes; but yet, in accordance with the simplicity which marks all the works of God, all this may be reduced to one tissue, a structure which, in addition to its being the fundamental tissue, is, in its own proper form, the most widely distributed of all tissues. This is termed Cellular tissue, to signify that it is made up of hollow cases or cells. It is, moreover, that tissue which is the first found in all plants.

* This and a large portion of the subsequent drawings have been made from original specimens. Others have been derived from various sources, and more particularly from the excellent lectures of Professor Quekett, delivered at the Royal College of Surgeons.
The cells of which it is composed may be either detached wholly or partially (Fig. 16), or be more or less conjoined in masses, (Figs. 17 and 18). Their characters are of course the best seen when they are detached from each other.

The only difficulty, if any, in reference to tissue is in obtaining a correct idea of the simplest of all structures—the cell. This may be likened to an orange (Fig. 19), when the rind, a, will correspond to the cell-wall, or boundary of the cell, and the juicy part, b, will represent the contents of the cell. Thus an orange is a cell on a large scale. Or it may be compared to a fowl’s egg, when the shell will represent the cell-wall, and the white, with the yolk, the contents of the cell. The egg, therefore, and all similar inclosed bodies, are magnified cells. But the egg has other points of resemblance to the cell. Thus, if the white of the egg be drawn from the shell through a small hole, so that the latter shall remain empty (a process very familiar to school-boys), we may form a just estimate of the cell-wall as separate from its contents. A cell in botany, therefore, consists of a cell-wall and contents, although it be so small as to be indiscernible by the unaided sight.

We have already stated that cellular tissue is formed from elementary membrane; and therefore the cell-wall is nothing more than elementary membrane folded, with the edges adherent together, so as to be able to inclose the contents.

The contents of cells are, however, of another nature, and are not produced from elementary membrane. They are of three kinds. 1st, a substance lining the inner side of the cell-wall, as illustrated by the white of egg, and called the primordial utricle of Mohl. It is well shown by the shading in Fig. 20, A. This substance is of exceeding importance in the development and growth of the cell, and in the production of its other contents.

2nd, a roundish, tolerably-large body, or nucleus, or cytoblast, represented in Fig. 21, b, met with in various parts of the cell, but usually near to some part of the cell-wall. This may be likened to the yolk of the egg, and bears the like degree of importance to the other parts of the cell that the yolk bears to the egg. 3rd, certain lesser bodies varying in size, shape, and number, termed nucleoli, formed within the nucleus.

It appears that the nucleus is a central point of all actions proceeding within the cell, but that the primordial utricle is the efficient agent. All these parts may be familiarly and readily observed in the common strawberry (Fragaria), or the mistletoe berry (Viscum album), or any other juicy fruit. We assume that our readers have a small microscope of some kind, which may be obtained for a sum varying from £2 to £4 of any respectable optician, with pieces of glass and other apparatus needful for microscopic observation. Take then, with the point of a needle, a piece from the centre of the strawberry, not larger than a pin’s head; place it in the glass slide,
and add a drop of water. Pull it to pieces by the help of two needles, and then cover it with thin glass, and place it under the microscope. It will be found to consist of a mass of large cells (Fig. 22), with transparent walls, and a slightly coloured fluid, enclosing the large rounded nucleus. It is of importance to obtain clear notions of a cell, since it is the foundation of all other tissues, and since it contains the starch and all other secretions of plants.

The figure of the cell is unimportant, and varies very greatly. It is believed to be generally accidental, as the phrase is,—the accident being that of pressure: not that by the term "accident" is meant that the figure is a matter of chance; for in certain parts of plants, as in the pith, for example, the figure, whatever it may be, is always the same. If pressure, therefore, in such cases be the efficient cause, it is exerted in determinate degrees and directions in the various parts of plants.

When the schoolboy blows bubbles of soap-and-water he makes rounded cells, because the walls are of equal weight, and the pressure of the air of an even degree all round. If, however, a drop of water be attached to the bubble it will destroy its rounded form, and elongate it in the direction of the earth, rendering the cell more or less oval. But if the same soap-and-water be well shaken in a half-filled bottle, the unequal pressure will drive the cells together, and render them distinctly six-sided.

This little experiment will convince the reader that the figure of the cell does, in a great degree, depend upon pressure, and that it may be altered as the direction or degree of pressure is changed.

So also in plants when each cell is detached from every other, as in decomposing vegetable infusions; or as in the yeast plant (Torula Cerevisia—Fig. 16), the form is spherical or ovoid; when it lies loosely in juicy fruits, as in the strawberry (Fragaria—Fig. 22), it is large and nearly round; when two or more cells are attached end to end, as in the mushroom (Fig. 23), they are ovoid or elongated; and when they are numerous and inclosed in a common skin or bark, they become more or less six-sided, as in the pulp of the orange (Citrus), from mutual and surrounding pressure (Fig. 24). It will then be readily understood that the figures of cells may be innumerable; but experience has shown that hexagonal and octagonal forms are those which most abound. These are the forms observed almost universally in pith, cuticle, leaves, flowers, and fruit; but it should be remembered that regularity of outline, although of common occurrence, is by no means essential.

But, whilst it must be admitted that the figure, in most instances, results from pressure, in other instances it proceeds from a more determinate source; viz., the direction of the growing process. This is readily understood, if we imagine a spherical cell in which the growing process is not equally carried on all over it, so that it may continue to grow spherical; but whilst the process is arrested at one point it proceeds
at an opposite one. This will terminate in an elongated cell, such as those observed in
the mushrooms \( \text{(Fungi—} \text{Fig. 23), and more parti-
}
\text{cularly in a gigantic kind
of mushroom termed the
Boletus (Fig. 25), in which
the length of the cell ex-
ceeds the breadth by many
diameters. In this mode
it is conceivable that a
tube might be formed
from a single cell, or from
a series of cells, if placed
cnd to end, and the parti-
tions broken down, al-
though no satisfactory
illustration of this mode of conversion of cells into tubes has yet been discovered
(Fig. 26).

The terms, oblong, lobed, square (Fig. 27), muriform (Fig. 28), prismatic, cylin-
drical, compressed, sinuous (Fig. 30), and stellated, have, amongst others, been devised to indicate other forms of
cells than those above indicated.

The cell varies as greatly in size as its figure;
so that, on the one hand, they may be seen by the
naked eye, as in the pulp of orange, lemon, or shad-
dock; on the other they are so minute that it is neces-
sary to examine them with a high magnifying power.
The limits of variation are \( \frac{1}{2} \text{ and } \frac{1}{1000} \text{ parts of an inch in diameter.
}

Some form of cellular tissue constitutes the whole of most of the lower classes of
plants, as the \( \text{Fungi; and in all other plants it is found in the roots, or subterranean stems
(as the potato, radish, and tur-
}
\text{nip); in bark, pith, leaves, flowers,
seeds, and fruit. The cuticle of
leaves, in general, is furnished
with cells, having a sinuous or
wavy outline, thence termed the
sinuous variety (Fig. 29).

The most interesting variety of
cell is that termed stellate, or star-
like, from the radiating form which
it assumes. This is well seen in the
rush (Fig. 30), in the sweet-burr
reed \( \text{(Sparganium ramosum—Fig.
29), in the yellow water-lily \( \text{(Nuph
}
\text{har lutea), and in many other
}
\text{water-plants of loose tissue. We have also met with a beau-
tiful illustration of it in the partitions of the cells constituting the thick central parts
of the long leaves of the Banana tree \( \text{(Musa paradisaea). The construction of this
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\text{Fig. 25.—Elongated cells of a mushroom
(Boletus) resembling tubes.

Fig. 26.—Diagram showing
a series of cells which, by
the breaking up of their
partition walls, are form-
ing a tube.

Fig. 27.—Cubical or
square cells.

Fig. 28.—Mur-
iform cells, or
cells resembling
the bricks in a
wall.

Fig. 29.—Very irregular
stellate cells from the foot-
stalk of a leaf of the sweet-
burr reed \( \text{(Sparganium ra-
mosum), showing the lac-
unae, or inter-spaces at } \text{a,
bounded by the cell walls.

Fig. 30.—Star-shaped cells
of regular character, from
the stem of a rush, having
lacunae at } \text{a, bounded by
cell-walls, and the union
of the cells indicated by the
transverse line at the mid-
dle of each arm or ray.
from of tissue is simple, and results from a puckering inwards of the cell-wall towards the centre. If an orange be cut through, and the contents partly removed, and the rind be then pressed by two or three fingers and a thumb until the projected portions approach the centre, we may form a correct idea of this form of tissue. Something more, however, is necessary.

**Inter-cellular Spaces.**—When a number of cells are pressed closely together, so closely even as to cause them to assume the form of a many (say twelve) sided figure, there will yet be spaces of triangular shape at each corner, at which the walls do not absolutely touch. These are termed inter-cellular spaces, and are the larger by so much as the cells are not closely applied to each other. When these inter-cellular spaces are placed one over the other for some distance, they constitute inter-cellular passages, and are very abundant in all aquatic plants. The relation which the inter-cellular spaces bear to the stellate cells is this, that when the cell-wall is pressed inwards, in various directions, towards the centre of the cell, the cell seems to be reduced to a series of arms (Fig. 30), whilst the spaces between the cells now appear to be a series of cells themselves (Fig. 32). These enlarged inter-cellular spaces are termed lacunae.

The uses of the inter-cellular spaces and passages are of great importance, since, in aquatic plants (in which they chiefly abound), they contain the air which imparts buoyancy, and retains it on the surface. This fact may, in some degree, account for the great size of these spaces in many aquatic plants (Fig. 33). In other plants, their use is chiefly that of a depository of secretions.

Before concluding our account of cells we must briefly refer to some modifications. The Dotted Cell differs from the ordinary cell only in having been constructed from dotted membrane in place of plain. This form is very abundant, and especially in the stem of the vine (Fig. 13) and other fast-growing plants, in the bark of most wooded trees, and in the roots of many plants, as of the common horse-radish. They are usually of large size.

**Thick-walled Cells, or Sclerogen,** are the result of the deposit of the peculiarly hard tissue termed sclerogen, on the inner side of the cell-wall. This substance is usually found deposited in concentric layers (Fig. 34), so that at length
the cavity of the cell is nearly filled. There is, however, always a central vacuity, and this is in direct connexion with the cell-wall by a series of canals, which pass through the various layers of hard tissue. This is absolutely necessary, since all actions proceeding in the cell must require the direct communication of the cell-wall.

The thick-walled cells constitute the gritty tissue of the pear (Fig. 35) —a tissue found in the form of small hard grains near to the centre of the fruit. It is also abundant in the so-called bulbs of many orchids, as the *Marchantia polymorpha*; on the covering of the seeds of many plants, as of the star-anise (*Illicium anisatum*—Fig. 34), and the apple (*malus*—Fig. 36); in the strong part of many nuts, as of the ivory nut (Figs. 37, 38), now so usefully supplying the place of ivory; in the common hawthorn (*Crataegus*), plum, and our garden fruits, and in the cocoa-nutshell (Fig. 39). It is also met with in the bark of almost all trees, as on the beech (Fig. 39). This structure is well seen by cutting a thin section, and placing it in a drop of water in the ordinary way; or, better still, by placing it in Canada balsam. If the section is too thick it must be ground down on a whetstone, in the
manner in which sections of bone are prepared for examination. It is impossible to
examine these interesting structures, and to observe how admirably they are adapted to give strength and
power of resistance to parts which pre-eminently require it, without being reminded of the great
similarity between them and bone cells in the bones of animals. There are, however, several points of
dissimilarity; and, amongst others, that the cell-wall, which is retained in thick-walled cells, is lost
in bone cells.

**Fibro Cellular Tissue.**—This form of cell is marked by having one or more fibres wound in
a spiral direction on its inner side (Figs. 41 & 43). The fibre may be loose in the cell, as in the *Opuntia
vulgaris* (Fig. 42), where it is flat, or in the elongated cell of the hairs on the seed of the *Collomia grandiflora*, or of the common sage, where it is round.

We have already referred to elementary fibre (p.7); and have only further
to remark that it obtains its spiral direction by the growing process being car-
ried on at the free end, whilst the other part of the fibre is attached to the mem-
brane. In this mode the resistance is unequal, and a circular or spiral direc-
tion is given to the new structure. This form of cell is very abundant, and
is probably more or less filled with air, since the inclosed fibre is well fitted
to prevent the collapse of the two sides of the cell.

It is usual to find the cells not isolated, but in clusters, and oftentimes
arranged in masses with

much symmetry, as may be seen in the drawing (Fig. 44) of the fibro-cellular tissue
lying *in situ* in the leaf of the *Pleurothallis*.

There is no structure in animals corresponding with the fibro-cellular tissue in
vegetables; but cellular tissue in the simple form is exceedingly abundant, and, in the
form of fat cells (Fig. 45), bears great resemblance to cells of vegetable origin. It is also an interesting fact that the cartilage of the ear of the rat and mouse (Fig. 46), and
more particularly of the rudimentary spinal column of the lamprey, is so modified
as almost exactly to simulate a vegetable cell.
This resemblance between animal and vegetable structures is equally well seen in
the tissue of the egg-shell (Fig. 31), when contrasted with the elongated
cells of the Boletus (Fig. 25).

It is an evidence of the power and wisdom of the Deity that all the
tissues, both in animals and plants, are produced from one simple
structure—the fundamental cell.

The uses of the cellular tissue are:—

1st. To contain various important secretions, as that of starch, and the organs of reproduction in all
classes of plants.

2nd. To carry on the circulation more or less in all plants, but more particularly in those which con-
sist only of this tissue. This is well exemplified in
the leaf of the Vallisneria (Fig. 47), in which the circulation may be seen proceeding under the
microscope.
3rd. By the tenacity of its structure, and the looseness of its parts, to bind the component parts of the plant together, and to increase its elasticity.

4th. It has for thousands of years been of great use to man for various economic purposes:—

First, in the form of papyrus, or the paper derived from the stem of a rush of that name, and employed as such by the ancient Egyptians, Grecians, and Romans, until long after the birth of Christ. In a similar way it is still used by the Chinese, and by them is derived from the pith of a plant (JEschynomene—Fig. 48), which they cut into very thin slices. This material lends a charm to Chinese drawings, since its cellular character enables it to absorb the colouring materials in great abundance.

Secondly, as a textile fabric. The mummy-cloths of the Peruvians, who existed long before the era of Montezuma and the Spanish invasion, are composed of this tissue only. At the present time we obtain cotton (Fig. 62 D) chiefly from America, where it is derived from the seeds of the cotton plant (Gossypium). It is far less resisting and durable than woody fibre or linen; but its comparative abundance, low price, and easy working have obtained for it great favour. The present war with Russia will probably induce a determination to use the cotton cell to the still greater exclusion of the woody fibre; and it has recently been shown in America that ropes made of cotton are far stronger and more durable than has hitherto been believed.

Paper is made from the manufactured cotton, and also from the refuse part of the raw material.

**Multiplication of Cells.**—It is not within the limits of this essay to enter upon the interesting question of the production of cells; but we may state that a common mode is that of division of the cell into two or more cells. This is effected in the following manner:—First, there is an aggregation of the contents of the cell around the nucleus, whilst the nucleus manifests a disposition to divide itself into two by a line of construction on either side. Secondly, the cell-wall is bent inwards towards the point of division of the nucleus, and by degrees insinuates itself between the two parts of the nucleus as the division of the latter proceeds, until at length the cell-walls from opposite sides meet at the centre of the nucleus, and the nucleus is divided, and two cells produced. Each of the new cells contains half the original nucleus, which now constitutes the nucleus of each cell; and after a period it is prepared to subdivide and to form another cell, and thus progressively, so long as the vital process lasts. In this way it is conceivable that an immense multitude of cells may be produced; and should the division be speedily effected, we may form a conception of the astounding fact, that in some of the fast-growing cellular plants—as the mushroom—the cells have been produced at the rate of sixty-six millions in a minute.
It is proper to state further, that certain authorities attribute the production of cells to the evolution of bubbles of gas in an azotized fluid, and they are of opinion that only by that mode can we account for the extreme rapidity with which cells are developed.

Bothrenchym, or Pitted Tissue.—We now proceed to describe the various modifications of the fundamental cellular tissue, and first, that of Bothrenchym, since it is very nearly allied to cellular tissue. It is so called from two Greek words signifying pitted tissue, to indicate that a number of translucent spots are distributed over its surface. We have already described the mode of formation of this tissue when considering dotted cells, p. 7. It differs from dotted cells chiefly in size; for it may be regarded as a series of very large cells, placed end to end, and separated from each other by obliquely-placed partitions. At a later period of life it puts on the character of a tube by the breaking-up and removal of the partitions. Its ordinary position in plants is in the stems of wooded plants, and more particularly of such as attach themselves to other trees for support, and grow rapidly. Thus it is met with on a thin longitudinal section of almost all trees, but more readily in the alder (Fig. 50), vine, clematis, cane (Rattan), and similar fast-growing plants, and wherever a rapid circulation is proceeding. In this respect it differs from mere dotted cellular tissue, since that is more commonly found in the herbaceous than wooded plants. This, in common with other vegetable tissues, retains its characters perfectly for thousands of years, as may be observed in the annexed figure of a duct (Fig. 51), taken from a piece of anthracite coal.

It is not uncommon to find a spiral fibre associated with the dotted tissue, as in Fig. 52, when the tissue may be regarded as a spiral duct with pores. It is a microscopic object of much interest, and very easily obtained. Take a piece of common cane, and having cut away a portion of the outside, take a thin section down the cane, and place it under the microscope in a drop of water. The little pits will be seen with much ease, as also the large size of the tissue as compared with the woody tissue which accompanies it. We have found the best illustration of it in a piece of deeply-coloured rose-wood, for there the dark tint of the secretion gave a peculiar distinctness to the tissue.

Its chief use in plants is to carry on the circulation with great rapidity, and is therefore particularly necessary in such plants as grow in southern and eastern climes, and yield refreshing juices, as, for example, the vegetable fountains of India. The importance of this tissue to all plants may be inferred from the large amount of vapour which they throw off by perspiration. Thus an ordinary-sized cabbage, in our climate, was found to perspire to the extent of 1 lb. 9 oz., and a sunflower to that of 1 lb. 14 oz. in a day of twelve hours; and it is evident that the great heat of southern climes must induce a far greater amount of perspiration, and, by consequence, require a more active circulation. The fluid thus exhaled is supplied chiefly by the bothrenchym, which therefore has a circulation proceeding from the roots towards the leaves of the plant. This function is not
seriously if at all impeded by the partitions which lie across the tube, as would at first sight appear; for even should such partitions be perfect, they readily permit the proper fluid to filter through them. The great size of this kind of tissue, and the large quantity of fluid which it contains, render it imperative that it should be supported by structures more resisting than its own. For this reason it is always found surrounded by bundles of strong woody tissue. Another function assigned to it in later life is that of conveying air into the interior of the plant. This occurs when the walls of the cell or tube have become imperfect, and would permit contained fluid to pass out of them; and then the fluid disappears, and its place is supplied by air. A third, and not less important duty, is that of a depository of the secretions of the plant. This only occurs when the tree is mature, and the central parts of the trunk, which are not then devoted to the rapid conveyance of fluid for the purposes of perspiration. The deep-colouring matter of rose-wood and mahogany, and all similar trees, is chiefly found in this tissue.

From the above remarks it will be evident that bothrenchym is a tissue of great interest and importance, and is seen in its integrity only in the early life of a plant. Its large size, thin walls, and active functions, seem to predispose it to injury; and therefore such tubes have the duty assigned to them of conveying air, or of storing up secretions which do not circulate.

**Gridiron Tissue.**—Under the term of gridiron tissue, Professor Quackett has described an interesting structure, oftentimes met with at the end of the ducts of pitted tissue. It consists of a series of bars which pass transversely across the tube, and occupy the position of the usual transverse septum. It is probably not a distinct structure, but only the remains of the original septum. We have met with fine examples of it in several trees, but more particularly in the alder and white birch (*Betula alba*). A similar condition has also been observed in a fossil palm found at St. Vincent’s.

**Pleurerenchym, or Woody Tissue.**—The tissue most closely allied to bothrenchym, and yet widely removed from both it and cellular tissue, is pleurerenchym, or woody tissue. This constitutes the mass of the stems of our forest trees, and is thus of the utmost social use to man. It is, also, found in all young and tender shoots, and in bundles in the stems of all, even the most delicate flowering plants. Its peculiar characteristic is that of great tenacity and power of resistance, and for this its structure is admirably adapted. As these characters are opposed to those of bothrenchym, we are prepared to find a tissue differing widely from that large and wide structure. The contrary is found in woody tissue, for it consists of bundles of very narrow fibres, with tapering extremities, and so placed end to end that the pointed ends overlap each other. Each fibre is very short, and the partitions which result from the apposition of the fibres, end to end, do not interfere with the circulation through them. Moreover, the tube is not composed of simple thin membrane only; but, in addition, has a deposit within it, which, without filling the tube, adds very greatly to the strength of the fibre. Perhaps we have here as good an illustration of the wisdom and power of the Creator as can readily be produced—viz., an arrangement whereby the greatest strength and power of resistance and elasticity shall be obtained, and at the same time the functions of circulation uninterruptedly maintained. The strength is mainly due to the shortness of each fibre, the connexion by apposite ends of many fibres almost in one direct line,
from the root upwards; and, lastly, to the deposit on the inner side of the membrane. This sentiment is irresistible, when we remember the various economic purposes to which man in all ages has applied the wood of forest trees, and also the power of resistance and elasticity which trees are required to offer while supporting large branches at a considerable angle, and to prevent their being uprooted or broken to pieces by violent storms, all of which is mainly due to the tissue now under consideration.

There are two kinds of woody tissue—viz., the plain and the glandular. The plain we have already described. The glandular is that form which more nearly resembles bothrenchym, and indeed may easily be mistaken for it. It consists of a plain fibre or tube, such as that already described; but, in addition, there is superimposed, with great regularity, a series of rounded translucent bodies called, or rather miscalled, glands (Fig. 56). These are, for the most part, arranged in single rows, and are so large as to occupy the whole face of the fibre.

There is great difference of opinion as to the nature of these so-called glands; some authors regarding them as simple concavities in the nature of a simple pit, whilst others believe that there is a pit, and in that pit is deposited the rounded, flattened body termed the gland, or bordered pore.

Professor Quekett adopts the opinion that these bordered pores lie in concavities between two adherent fibres (Fig. 57). The bordered pore is hollow; and biconvex, so as to fit into the two cavities. They are best seen in a section of wood, taken parallel to the medullary rays.

It is not a little remarkable that this form of woody fibre should be found only in one class of trees—viz., the Coniferae, or fir tribe, with their allied genera; and in such plants it is the only form of woody tissue met with. If a very thin section of a piece of fresh fir tree, or of a piece of deal or cedar, be examined with the microscope, as before directed, the glands will be seen very distinctly (Fig. 56); and if a piece of rotten fir be selected, it will not be difficult to find a spot at which the gland appears to have fallen out. Such also is the case with the coal shale, a large portion of which is composed of the stems of the fir tribe, which have been buried during thousands of years; and if care be taken to grind down a thin section, not only may the glands and their remains be seen, but in some instances the pits which once contained the gland.

This, however, is chiefly a matter of curiosity, since we do not know anything of
the especial functions of this kind of woody tissue. The botanist, however, attaches value to it, since it enables him to demonstrate, in recent and fossil woods, the existence of the Coniferae, or fir tribe of plants.

It is not uncommon to find a spiral fibre associated with this glandular structure, and sometimes, as in the yew (Taxus baccata, Fig. 60), there are two which are wound

![Fig. 57. A lateral view of two adjoining fibres to show the concavity in each, and the space formed by both for the reception of the bordered pore. B, bordered pores from the Salisburia adian-lifolia, which are naturally found in cavities similar to those in A. Fig. 58. Similar arrangement of tubercles and cavities of the Aporum anceps. A, a fibre with the tubercles or glands in situ, and projecting. D, the glands detached. C, the concavities on one fibre whence the glands have been removed. B, the spaces for the lodgment of the glands formed by two adjoining fibres. Fig. 59. Rows of bordered pores on the woody fibre of a fossil member of the fir tribe, which had been long buried in the State of Ohio. Fig. 60. Porous woody fibre in the yew (Taxus baccata), with the spiral fibres wound in opposite directions, and give the appearance of a net-work. This is presumed to assist in maintaining the patency of the tribe.

The uses of woody fibre are very varied, and most important, and may be divided into two categories,—1st, such as benefit the plants; and 2nd, such as benefit man.

1st. Such as benefit the plant.

It is the chief organ of the circulation in all woody plants, and for this purpose pervades the plant from the root to the branches, and even to the minutest leaves and flowers. The current in this tissue is slow and uninterrupted, and is directed upwards from the shoot through the stems to the leaves, and downwards from the leaves through the bark to the root. Thus its current has a twofold direction; the ascending and chief one being for the purpose of taking the raw sap from the ground, to be digested in the leaves, and the descending being devoted to the removal from the leaves of the digested sap, to be applied to the purposes of the plant, and also of the refuse matter to be carried to the roots, and thence thrown out into the soil as a noxious material. These functions are carried on more vigorously during the spring and summer seasons; but it is probable that even in the depths of winter it does not cease.

Another function of woody fibre is to be the store-house of the perfected secretions. It is well known that as trees advance in life, the wood assumes a darker colour, and more particularly that lying near to the centre of the stem. This is due to the deposit of the perfected juices in the woody fibre at that point; and when age has matured the tree, it is probable that the woody fibre so employed is no longer fitted for the circulation of the sap; and also, that the perfected sap, when once deposited, does not again
USES OF WOODY FIBRE.

join in the general circulation. The dark colour of the heart of oak, as contrasted with oak of very recent growth, is an illustration of this fact, as is also the deep colour which is met with in ebony and rosewood.

A third duty under this head is that of giving stability to the tree. It only requires a moment's reflection to enable the mind to appreciate the vast power of resistance which is placed in forest trees. The oaks of an English forest have stood a thousand years, notwithstanding the hurricanes and storms to which they have been yearly subjected; and a familiar illustration of the most violent storms, of which we hear and read, is that of the tearing up by the roots of the large forest trees. How mighty must be that power which can withstand influences so terrific as those which each person must have occasionally witnessed! This power is partly due to the mere mechanical hold which the roots have of the soil; but the tenacity of that hold is almost entirely due to the woody tissue contained in the roots and stem. Again, it is no uncommon occurrence in our old English parks to find branches of old trees which stretch from the trunk to the distance of fifty feet, and which in circumference are as large as trees of considerable growth. These do not stand perpendicularly from the ground, but pass out of the stem at an angle which is in some instances nearly a right angle, and must therefore be kept from falling directly in opposition to the effects of gravity. The strain exerted by such a branch is enormous; and yet the branch is maintained in its position for hundreds of years by the simple cohesive strength and tenacity of a series of woody fibres, each one-sixth smaller than a human hair, and too minute to be appreciated by the naked eye. It is probable that no mechanical agency at present in operation could effect that which is thus so readily effected by nature with the most simple agencies.

2ndly. Such as benefit man.

We do not refer to the almost infinite uses to which wood, in boards or masses, is applied by man, and the vast multitudes of beautiful objects which his ingenuity has enabled him to prepare out of the varieties of wood which nature has so bountifully provided.

Not less useful is the same woody fibre when reduced to very minute bundles or threads.

When the fibres are obtained in tolerably large bundles, they are used in place of bristles for street brooms, and especially when obtained from the cocoa-nut palm.

The flax and hemp which are imported so largely into this country, consist of woody fibre, obtained not from the wood of large trees, but from the stems of slender plants. From this raw material, ropes, sacks, linen, lawn, and other textile fabrics, are now made, as some of them have ever been by all nations. Uncivilized, or partially civilized nations, have been accustomed to use the bark of various trees offering this woody fibre in a very divided condition; and from this have prepared ropes and other articles of utility. It has long been known that cordage of a very strong kind was used by the ancient Egyptians, anterior, in all probability, to the building of the Pyramids; and Mr. Layard has recently exhumed sculptures which show that the yet more ancient Assyrians removed their gigantic winged bulls and other objects by cables of great size and strength.

The bark of the lace-tree (*Lagetta linearia*) yields a net-work of woody fibre of exquisite beauty, and of great utility, and is used by the natives of that clime as a ready prepared fabric.

An indisputable proof of the antiquity attaching to the use of this fibre is afforded
in the fact, that the mummy cloths of the ancient Egyptians, which are nearly five thousand years old, are found to be composed of this material.

At the present day, this tissue is abundantly used, and is derived from very various sources. Its relative value depends upon the fineness and evenness of the fibre, and upon its elasticity. It has been found that certain kinds of flax have very great powers of resistance when exerted in a straight line, but readily break when they are bent. This is the case with the New Zealand flax; and its brittleness is to be attributed only to the nature of the material deposited within the tube. The flax obtained in this country, in Ireland, and India, from the Cannabis, has less resisting characters; but as it does not break so much in the process of hackling, has a higher marketable value. The pine-apple fibre is very capable of minute subdivision, and is very resisting, and consequently very fitted for the manufacture of fine fabrics. Cocoa-nut-palm fibre is also very strong from the presence of secondary deposits.

The cost of flax has induced mercantile men to use woody fibre of less durability, but at the same time of a less costly kind—such as that derived from the Chinagrass, a species of nettle (Urtica); and from it much of the less durable linen cloth and pocket-handkerchiefs are now produced. It is well known that the tissue now under consideration occupies a medium between silk and cotton, as it regards resistance durability, and cost.

Silk is the produce of a member of the animal kingdom (Fig. 60 D), and occupies the highest position in the qualities referred to. Labillardière ascertained that bundles of fibres of equal size, of silk, flax, and cotton, gave the following unequal powers of resistance, on the application of a weight:—

Silk supported, without breaking, a weight of . . . 34 lbs.
New Zealand flax (Phormium tenax) . . . . 23½
Hemp (Cannabis) . . . . 16¼
Flax (Linum) . . . . 11½
Pita-flax (Agave Americana). 7

The resisting powers of cotton are much below the lowest now indicated.

In order the better to appreciate the characters of these textile materials, single fibres of each have been selected and placed side by side (Fig. 62), and to these have been added hairs, or fibres of wool, and silk. These have not only been used largely for centuries in the manufacture of woollen cloths, but the former is found woven with cotton in mummy cloths obtained from Othaeite.
The last use to which we shall now refer, is that of affording saccharine juices to man. This is known familiarly in this country in the wine obtained from the fermented juice of the birch tree (Betula alba). It is still better known in the Northern and Western States of America, and in Canada, from the sugar-yielding maple (Acer saccharinum). This is still a greatly valued product in the less accessible parts of the country; but the introduction of the cane sugar of the Southern States is gradually supplanting it in public estimation. The sugar obtained from it is very brown, but sweetens well, and will probably be one of the treasures of the happy housewife in the fertile paradise of the "far west" for many years to come. In both of the above instances the juice is collected in a similar way—viz., by boring one or more holes into the stem of the tree at the period of the year when the sap has most accumulated; and, as the sap exudes, collecting it in vessels placed at the foot of the tree. The sugar is thence obtained by mere evaporation and subsidence; but the wine requires the subsequent process of saccharine fermentation.

The spruce-beer in use in Norway, and the refreshing juices of India, are obtained in a similar way, and from the same vessels—viz., woody and pitted tissues.

Palm-wine is a delicious beverage, obtained from various species of palm, but especially from the cocoa-nut palm (Cocos nucifera), the gomuto palm (Saguerus saccharifer), and the magnificent Palmyra palm (Borassus flabelliformis). The latter is the most widely distributed of all the palm tribe, since it inhabits all the various regions of the Continent and Islands of India. Mr. Fergusson, in the first illustrated book which proceeded from Ceylon, has given a most valuable account of the palm trees of Ceylon. We counsel our readers to peruse it attentively, and especially that portion which describes the Palmyra palm and its products. The juice is procured by crushing the young inflorescence, and cutting off the upper part. It is then collected in a vessel attached to the cut end, and the daily discharge of the sap is facilitated by cutting a new slice every day. The fresh sap, called taree, or toddy, is very refreshing; and, if allowed to evaporate, yields a deposit of coarse sugar, or jaggery. When fer-

Fig. 62.—Fibre of flax, A; of cotton, B; of wool, C; and of silk, D; placed side by side, so that their relative size and markings may be readily contrasted. The fibre or cells of cotton are manifestly much thinner, and less resisting, than those of the other substances.
mented, it becomes a very excellent wine, and the most intoxicating of all tropical beverages.

Fig. 63.—The Palmyra Palm (Borassus flabelliformis) yielding Palm Wine.

The size of woody fibre varies from \( \frac{1}{100} \) to \( \frac{3}{100} \) part of an inch, and is the largest in hot climates, for the reasons already indicated.
The position of woody fibre is readily determined. It constitutes not only the stems of wooded trees, but is found in single bundles in the stems of delicate herbaceous plants, and may be readily seen there when the stem is torn across. In a similar manner it occupies the thin cuticle of herbs, and may be readily observed in the ridges, or veins, which run from the root upwards. It is also met with in the bark of all trees, in the veins of leaves and flowers, and even accompanying the spiral vessels into the fruit of plants.

Vascular Tissue or Trachenchym.—The tissues which we have already described are chiefly devoted to the circulation of fluids, or to the inclosure of solid substances. Those, under this head, are in great part associated with the transmission of air within the plant. They are divided into two classes—viz., spiral vessels and ducts, and are, perhaps, the most beautiful microscopic objects in plants. It is not at all times easy to distinguish between these two classes of structures, since both consist of thin membrane in a tubular form, and inclosing a fibre wound in a spiral direction. The theoretical distinction is, that the fibre of the spiral vessel may be unrolled without breaking, whilst that of the duct is inseparably connected with the membrane, and cannot be unrolled in its integrity. This general distinction is doubtless correct; but an unrolled spiral vessel, and a duct, in which the membrane connecting the spiral fibre has been destroyed, have a very close resemblance to each other.

It is highly probable that the distinction is less one of nature than one established by botanists as a matter of convenience.

The Spiral Vessel is a cylindrical tube with conical extremities, and having one or more fibres wound as a right or left-handed screw, which may unroll without breaking. It has been disputed whether the fibre is placed within or without the membrane, and whether it is solid or hollow; but we are of opinion that it is inclosed by the membrane, and that it is always solid.

These vessels are not individually of great length, but are connected together by their conical extremities; and it is not unusual to find the intervening partition ruptured. When but one fibre is inclosed the vessel is termed a simple spiral vessel (Fig. 64 A); but when two or more exist, it receives the appellation of compound (Fig. 64 B & C). In some instances, upwards of twenty fibres have been counted in a compound spiral vessel. The spiral vessels are very numerous in

Fig. 64.—Spiral Vessels, A, a simple spiral vessel, that is, having but one fibre. The lines bounding the pointed extremity represent the inclosing membrane. B, a compound spiral, or a vessel composed of many fibres, wound in a spiral manner. C, a compound spiral from the Cannna bicolor, with five spiral fibres: more highly magnified.

Fig. 65.—A bundle of spiral vessels from the veins of the hazel nut (Corylus avellana), showing their great number and very minute size. They are embedded in a mass of hexagonal cellular tissue, as represented at a. Magnified 200 diameters.
all flowering plants, but more so in certain bulbous plants, as that of a squill growing in
the neighbourhood of the Mediterranean. The inhabitants collect them, and tie them in
bundles to be used in the lighting of cigars—an office for which their smouldering flame
renders them well adapted. They are met with in all parts of plants except the roots,
but more particularly immediately surrounding the pith, and in all parts emanating
from it—viz., branches, leaves, flowers, and fruit. They may be readily obtained
by cautiously cutting through the cuticle of the footstalk of the strawberry-leaf (Fraga-
ria), and then gently separating the divided portions, when they appear as very
fine threads arranged in loose spires.
They abound in the veins of leaves,
and even in the minutest parts of the
most delicate flowers. They are also
found in the foot-stalks of all fruits,
and in the vascular bundles which
enter the minutest seeds. This may
readily be seen by tearing the seed
of the strawberry from the fruit,
and placing it in water under the
microscope. The spiral vessel is
there exceedingly minute and beau-

Perhaps, of all positions in which it
may be the best inspected, that of the
veins running over the brown coating
of the common hazel nut (Corylus
avellana, Fig. 65), after the shell has
been removed, is the most accessible.
The brown membrane should be
soaked in water for a short time,
and then the veins carefully torn open with needles, and placed under the microscope.
If the light be not passed through them, but be allowed to fall upon them, they
appear as bundles of beautifully-white glistening lines, consisting of scores of very
minute spires.

Such is also the case with other similar fruits, as those of the walnut (Juglans regia) and chestnut (Fagus castanea). They are seen to great advantage also in cer-
tain succulent stems, as those of the potato, by cutting the stem across obliquely
with a knife in bad condition, and the section placed under the microscope (Fig. 66).

They are of very delicate structure, and require other tissues to inclose and protect
them. This is chiefly performed by the woody fibre, and thus each vein of a leaf or
herbaceous stem has its central bundle of spiral vessels inclosed in a covering of
woody fibre.

The use of the spiral vessel has been the subject of much investigation, and it
appears probable that at some period it conveys air charged with an increased per-
centage of oxygen, and thus becomes a system of internal respiration, much after the
manner of the distribution of the tracheae in insects. At a later period of its existence
it is probable that it contains fluid. The spiral fibre is valuable at either of these
periods as keeping the tube open, but more particularly when the cavity is filled by
air only.
**Ducts** are tubes with conical or rounded extremities, and their sides marked by transverse lines or bars. Their size is about twice that of spiral vessels. Their appearance is very various, and depends upon the direction of the spiral fibre which assimilates ducts to spiral vessels, or the presence of other internal deposits, which renders them not unlike pitted tissue.

When the spire is so arranged as to differ from that of the spiral vessel only in that it cannot unroll, the vessel is termed a closed duct. When it is broken up at intervals, so that single coils shall be detached, the term annular is applied (Fig. 67), and properly represents the rings which are so commonly found in ducts. This form is said to be due to the rapidity of the growth, whereby the fibre is carried along more rapidly than the membrane can be produced.

The reticulated duct is perhaps the most interesting of the various kinds of ducts, and appears to be formed either by two fibres wound in opposite directions so as to cross each other, or by a single fibre which breaks and anastomoses at intervals. The characteristic feature is that of a net-work. All these various forms of duct, and also other modifications, may be found in the stem of a full grown garden balsam. The succulent stems of herbaceous plants are the more common positions in which ducts are found; but they are abundantly met with in the softer kinds of wood, as of the lime-tree (*Tilia*), willow (*Salix*), or birch (*Betula*).

We cannot omit to refer again to the analogies which exist in the structure of animals and vegetables. Thus, in the animal kingdom, we have a tube which very closely resembles a spiral vessel,—viz., the tracheo of insects. This is clearly shown in the accompanying figure of the *Dyticus* (Fig. 68), which represents a tube made simply of a fibre inclosed by membrane.

It is unnecessary to refer to all those forms of duct in which we find a secondary deposit so arranged as to give the appearance of pits, since we have already considered similar structures under the head of *Bothrichaemum* (pp. 7 and 17). But there is one not described as yet—viz., the Scalariform or ladder duct. This is so called from the resemblance which the transverse lines bear to the rounds of a ladder. The scalariform duct is of considerable size, and usually six-sided, and has a deposit so arranged, on its inner side, that either its presence or its absence causes certain transparent lines to appear at very regular intervals. In some instances so many as twelve sides have been observed; but whatever may be the number of sides, they are separated by clearly defined perpendicular lines. The transverse bars do not pass quite so far as the boundary line of the side—a circumstance which gives a greater degree of resemblance to the figure of a ladder. As there are transverse translucent spaces of about equal size and at equal distances, there will, of course, be alternate transverse and equal bars separating these spaces. These bars are continued with the boundary line of the side; and, upon the whole, it appears probable that the deposit has been placed at these points, and that the translucent
lines or pores are the parts at which no deposit has occurred. If this deposit has taken place in the spiral direction so commonly found in vegetable deposits; but it is quite certain that in a few instances the scalariform has unrolled like a spiral vessel (Fig. 70). The use of these vessels differs little, if at all, from that of other ducts,—viz., that of conveying fluids with rapidity; but there is this great peculiarity, that they are found only in one class of plants—viz., the ferns (Filices), and there supplant all other forms of vascular tissue (Fig. 71). Thus there are two great classes of plants which have distinguishing anatomical characters; viz., the Coniferae or fir tribe, distinguished by its glandular woody fibre, and the fern tribe, known readily by its scalariform tissue. The scalariform tissue is also enduring in a remarkable degree, as was stated of the glandular woody tissue; for ferns, like firs, are abundantly found in the coal measures, and Professor Quekett discovered it in a funereal urn dug up in the island of Anglesey.

This appears a favourable point at which to request the reader to look back and observe the unity of design which appears to pervade the whole structure of plants. We have just seen that there is not, in truth, any essential distinction to be made between the three classes of vascular tissue now described—spiral vessels, ducts, and scalariform vessels, all of them being composed of a membranous tube, with a secondary deposit assuming the spiral direction. It is also evident that these differ in no essential respect from Bothrenchym or pitted tissue; and from dotted cells and fibre cells, only in size and figure. Thus we have traced the essential identity of the tube with the cell, and of the highly-figured vascular tissue with the simpler cells with a secondary deposit. The woody tissue is, in like manner, an elongated cell of thickened membrane.

The arrangement or classification of these structures is not as yet in a satisfactory condition, and it is yet a desideratum to find out some general feature by which they may be grouped in a less artificial manner. That one which has already been referred to—viz., the simple membrane and the membrane with a secondary deposit—as the basis of all tissues, is a step in the right direction. It is clearly unphilosophical to regard mere markings as points of distinction, where there is not real difference in structure and functions. So far as we have now accompanied our readers there can be no difficulty in acknowledging that we have simply passed through modifications of a simple cell.

Laticiferous, or Milk-bearing Vessels.—There is yet another very interesting and somewhat less simple form of tissue to be described—viz., the milk-bearing tissue so readily inferred to exist from the white exuding juice of the cut dandelion (Leontodon), and poppy (Papaver), or the yellow juices of the Chelidonium. The essential characteristics of this tissue is its branched distribution, and the intermitting or pulsatory motion of its contents. In both these respects it differs from other vegetable tissues, and corresponds very closely with the blood-vessels of animals. It is well
known that nature never progresses by bounds, but by gentle ascents, and that, not only does one fundamental structure run through the whole of vital existences (whilst the anatomical characters of widely-separated classes are yet very distinct); yet that there are certain similarities which become, as it were, the larger links which unite them together. The structure now under consideration is the large link which binds vegetables and animals together. No other vegetable vascular tissue uniformly branches, and none has a pulsatory motion of its contents; but both these conditions are universal in the animal kingdom. There is yet another similarity:—The Lacticiferous or milk-bearing tissue (Fig. 72), is devoted to the maintenance of the vitality of the other vegetable structures, and not to any extraneous object whatever. If a stem be in great part cut through, the effect is to kill the plant—not so much by destroying its functions as by pouring out the milky juice, which should maintain the life of all the structures—in fact, by bleeding it to death. This is not the case with the woody tissue; for if that were nearly drained of its contents the plant would not necessarily perish; but if the milky juice be withdrawn too abundantly.
—as from the cow-tree (*Palo de Vacca*) of Ceylon, or the hya-hya tree, of British Guiana, which yields refreshing juices—the plant droops and dies.

The similarity between this structure and the blood-vessels of animals is well seen in diagrams, Figs. 73 and 74, which represent, side by side, the capillaries or smaller blood-vessels in the frog’s foot, with the contained blood highly magnified, and the lactiferous tissue, with its contents.

The undulatory or pulsatory motion of the contents of the tissue may be well seen in the *Limnocharis Humboldtii*, a water-plant found in hot-houses (Fig. 74), if a portion be cut off, and exposed to the sun for a short time, and subsequently placed in water. The exposure to the sun causes so much evaporation as to greatly lessen the quantity of fluid in the vessels; and the subsequent immersion in water enables the plant

Fig. 75.—The BANYAN TREE (*Ficus religiosa*), showing its original trunks, and the branches which have passed down to the ground and taken root, and have become new centres of growth and nourishment. This tree is so large that a regiment of soldiers may take refuge in its shade.

to supply its wants, and to pump, so to speak, vigorously. This diagram is also illustrative of the opinion formed by certain authors as to the relations of this tissue—viz., that it is very analogous to mere inter-cellular passages. In this view, it is not a distinct tissue, although it may have special functions.

The latex, or milky fluid, is of immense service to man, in two ways more particularly:

First—As already intimated, it constitutes refreshing beverages, readily obtained, and in large quantities, to travellers in the sunny climes of Asia. Such are the cow-tree of South America, the kiriaghuma (*Gymneuralactiferum*), and hya-hya (*Jabernantana utilis*) before-mentioned, and also the *Euphorbia balsamifera*, of the Canary
Islands, the juice of which, as a sweet milk, or evaporated to a jelly, is taken as a great delicacy, and the Banyan tree (*Ficus religiosa*—Fig. 75). Many of these juices also contain medicinal properties of great value.

Secondly—In the production of caoutchouc, or India-rubber. This invaluable substance is found in all plants, but more particularly in the Fig, Euphorbia, and Cactus trees of the East Indies, South America, and Africa within the torrid zone. Of all these, the fig, known as the *Ficus*, or *Siphonia elastica*, is the most valuable; but in the countries where the manufacture of India-rubber is a daily occupation, it is not exclusively selected. This increased quantity of caoutchouc in the *latex* of hot climates is believed to be due to the powerfully elaborating property of the sun's rays in those climates.

The following is the mode in which the India-rubber is prepared from the milky juice:

The natives having selected a fine specimen of the *Siphonia elastica*, sixty feet in height, make deep incisions into its smooth, brownish-gray bark; after which the white juice flows forth in considerable abundance. Before it dries upon the trunk, or in a hole at the foot of the tree, it is spread over bottles of unburnt clay, and dried over a smoking fire; care being taken to prevent the flame burning it. When it is dried, another coating of the juice is placed upon it, and that again is he'd over the fire; and the process is thus repeated, until the required thickness has been attained. When the process is completed the bottle of clay is broken and the pieces extracted; after which the Indian-rubber is ready for the market. It is met with in commerce of various colours, terminating in a deep black; but the juice is originally colourless, and the colour is produced by the smoke in which it is immersed in the process of drying.

This tissue is found in all parts of a plant; but, from its ramifications amongst other tissues, cannot be readily separated. It is most readily seen in the fresh stipules of the *Ficus elastica*.

**Gutta-percha** is another invaluable substance, recently obtained from the *latex* of certain plants, and especially of the class called *Sapotacea*, abounding in the Indian Archipelago. The trees whence it is obtained are large, but not otherwise valuable. The gutta-percha is obtained by incising the bark and collecting the milky juice, which speedily coagulates. Each tree yields from twenty to fifty lbs., so that the destruction of a large number of trees is required in order to meet the present enormous demand for this article of commerce. It appears that the proper term is Gutta-Pulo-Percha—gutta signifying gum in the Malay language, and Pulo-Percha the island whence it is obtained. When translated into English words, it is—"gum of the ragged island."

**The Secretions of Plants.**—We now proceed to describe the chief secretions of plants, some of which are of the utmost value to man. They are—Starch, Raphides, Silica, Oils, and Fats, and the colouring principles of plants.

**Starch.—** This alimentary substance was, until recently, believed to be peculiar to vegetables; and, although it is not strictly, it is almost exclusively confined to them. It is, moreover, the chief element in vegetables, which renders them fit to be the food of animals, and enjoys, therefore, a position of the utmost importance. Starch is not to be understood as directly represented by the article of commerce which bears its name; for, although that is starch, it has been so prepared as to lose the anatomical characteristics which starch in its natural state possesses. All plants, probably, possess this substance, but in very unequal degrees; and it is only when it exists in quantities much greater than the plant requires for its own purposes that it is sought after by
man. As a rule, a vegetable, if nutritious at all, is so in proportion to the amount of starch which it contains; but there are many plants which yield starch in tolerable abundance, but which are indelible from the presence of acid or poisonous fluids. In selecting articles of food, it is needful to bear both these facts in mind. It is most abundantly found in the seeds of plants, and especially in the cereals, or wheat tribe; and thence this article of diet is accounted to be very nutritious. It is also met with in the cellular tissue of plants, and especially in the cellular matrix of such underground stems as the potato, turnip, and radish, and the stems of such plants as the sago-palm-fig, whence it is obtained in large quantities. Green vegetables contain a considerable proportion of starch at the period of their maturity; but they are nutritive beyond the quantity of starch contained by them, since the vegetable structure itself has a very similar chemical composition to that of starch. Starch is also found in the bark of trees; and, during periods of famine, the bark of certain trees in this country has been made into bread.

This practice was more common in the northern countries, where Nature has less bountifully distributed her treasures. Mr. Laing, in his interesting "Journal of a Residence in Norway," states that he observed many trees which had been thus dilapidated; and, after referring to the country mode of grinding meal, remarks—"This mode of grinding and baking makes intelligible the use of bread of the bark of the fir-tree in years of scarcity. Its inner rind (liber), kiln-dried, may undoubtedly be ground along with the hucks and grain, and add to the quantity of meal—it may even be nutritious. I had previously been rather disposed to doubt the fact, and to laugh at the idea of a traveller dining on sawdust pudding and timber bread. In years of scarcity, however, this use of fir-bark is more extensive than is generally supposed. The present dilapidated state of the forests is ascribed to the great destruction of young trees, for this purpose, in the year 1812."

But, notwithstanding its universal distribution, it is to be found in quantities only in the storehouses provided by nature—viz., the seeds and fruit of plants; the potato (Solanum tuberosum), carrot (Daucus carota), turnip (Brassica rapa), and similar underground stems, as they are termed; and, lastly, the stems of palms, and similar endogenous plants.

Amongst plants which yield an acid juice with the starch, we may first mention the tapioca plant, or Yucca dulee, the sap of which is used to poison the arrows; but the starch is fitted for food after the roots have been beaten, dried, heated, washed, and pressed. The common arum of this country was formerly collected on account of the starch or arrowroot contained in its corm or underground stem; but the aridity of the juice was so great as to cause the hands of the operator to inflame.

The horse-chestnut is not edible for the like reason, although it contains much starch, and is excellent food for some inferior animals. It is also known that whilst the tubers of the potato are so wholesome, the berries are poisonous. The horse-chestnut was tried in this country as an article of diet in 1846, but its acidity arrested its use.

Those plants which offer the starch unmixed with deleterious matters are:

1st. All the grasses, including, wheat, oats, barley, rye, and all trinclar seed-bearing plants.

2. Many leguminous and cruciferae, or pod-bearing plants, such as the pea, bean, and lentil, cabbage, and turnips.
3. The *Maranta arundinacea*, or arrow-root plant.
4. The sage palm.
5. Several bulbs and tubers, as the onion and potato.
6. A species of plantain, which offers it so abundantly and in small masses that it was introduced and sold in this country as flour.

The most interesting illustration of the admixture of deleterious and edible substances is that of the preparation of the Cassava meal, a kind of arrow-root, from the *Mandioca farinha*, a tree possessing excellent starch, and, at the same time, the most poisonous juices. Its preparation is thus graphically described by M. Schleiden:

"In a dense forest of Guiana the Indian chief has stretched his sleeping mat, between two high stems of the magnolia; he rests indolently smoking beneath the shade of the broad-leaved banana, gazing at the doings of his family around. His wife pounds the gathered mandive roots, with a wooden club, in the hollowed trunk of a tree, and wraps the thick pulp in a compact net, made from the tough leaves of the great lily plants. The long bundle is hung upon a stick which rests on two forks, and a heavy stone is fastened to the bottom, the weight of which causes the juice to be pressed out. This runs into a shell of the calabash gourd (*Crescentia Cujete*) placed beneath. Close by squats a little boy, and dips his father's arrows in the deadly milk, while the wife lights a fire to dry the pressed roots, and by heat to drive off more completely the vitalic poisonous matter. Next, it is powdered between two stones, and the cassava meal is ready. Meanwhile, the boy has completed his evil task; the sap, after standing some considerable time, has deposited a delicate, white starch, from which the poisonous fluid is poured off. The meal is then well washed with water, and is their fine white tapioca, resembling in every respect arrow-root."—Let not our readers be alarmed when they eat their next tapioca pudding; but yet it may be well to remember how closely life and death are associated.

Starch is met with in two forms:

First, amorphous; that is in fine powder, without any distinct form or marking, as in the *Sago*, commonly sold in this country.

Secondly, and almost universally in the form of variously-figured cells.

We have nothing to add in reference to the former, except that, in common with the other form, it is found inclosed in the large cells of vegetables, as may be seen in the section of the potato (Fig. 83), and that the presence of both alike may be chemi-
cally demonstrated, if a drop of a solution of iodine be added to the smallest quantity of starch and water, and placed under the microscope. The chemical effect of the iodine is to colour the starch of a beautiful deep violet shade. We may also add, that as starch has the property of polarizing light, its presence may be readily shown by placing it in the microscope with the polarizing apparatus.

Fig. 77.—The Sago Palm (Cycas revoluta), containing a large quantity of starch in its stem.

Further attention is, however, necessary to the consideration of the second kind of starch, or that consisting of cells; and chiefly on the ground, that it is possible to distinguish the starch grains or cells of one plant from those of another, and thus to detect the adulterations which are practised in reference to flour, bread, arrow-root, and other articles of farinaceous food. Much attention has been given to this matter during the past ten years, and with the result, it is believed, of having lessened, at least, the frequency with which fraud has been perpetrated.

Starch grains are distinguished from each other by their size, figure, and markings.
In reference to their size it will suffice to glance at Fig. 78, to show that it varies very greatly, and that it is very small in the rice (Fig. 78 a), and very large in the *Tous les Mois* (Fig. 78 b); whilst wheat (Fig. 78 c) and potato (Fig. 78 d) starch occupies a medium position. The ordinary figure is rounded or oval, sometimes much flattened, as in the *Curcuma leucorrhiza*, or East Indian arrow-root; less flattened, as in the wheat and barley; oval and roundish, as in the potato and the pea (Fig. 78 i). The figure, however, although permanent in each variety in its general characteristics, varies considerably. In every specimen a multitude of smaller or imperfectly-developed granules will be observed; and they do not assume the form which is obtained by the perfect granule. The consideration of the markings and their nature is the most interesting and important part of the subject, inasmuch as they are most permanent, and imply an acquaintance with the structure of the cell. We shall therefore say a few words in reference to the composition of the starch grain before we describe the markings which distinguish the various kinds of starch.

A reference to Fig. 78 will show that in almost all instances there is a central spot (Fig. 78, 1), called the hole or hilum, and that a series of lines arrange themselves around it. This will be better seen in Fig. 78 c, which represents the cell much more highly magnified. The nature of both of these is the point in dispute. There is a cell-wall, as may be seen in Fig. 78 g, in which, on the application of heat, it has ruptured, and is a little reflected. But is there no central cavity, and do the lines observed on the granules correspond with layers within the cell-wall? There have been two leading views on these points.

1st. That the starch granule is really a vesicle or cell, having an inclosing wall, differing in consistence, and perhaps in chemical characters, from the starch-itself.
2nd. That it is a solid body, constituted by layers one upon the other, beginning either within (centripetal), or without (centrifugal).

On the first of these theories the markings upon the surface are produced by the folding of the cell-wall; and on the second, by the successive layers of the solid starch.

Leeuwenhoek, a celebrated microscopist, published certain investigations made by him nearly a century and a-half ago, in which he showed the cellular character of starch. Since his era many eminent observers have adopted his views, with certain modifications; and very recently two, whose experiments we shall describe, —viz., M. Martin, the librarian of the Imperial Polytechnic Institute at Vienna, and Mr. Busk, a distinguished naval surgeon and microscopist. Both these gentlemen agree in the theory of the constitution of the starch granule—viz., that it is a cell, having a cell-wall much larger than the contents of the cell in the dried state, and, therefore, puckered and plaited, as indicated by the lines upon the surface. M. Martin says, that "the primary form of the starch grain is a spherical or ovate cell. If this be considered as empty, and so contracted that one-half lies in the other half, a watch-glass-shaped basin is formed, which, after boiling and pressure between two glasses, appears, in consequence of the delicacy and elasticity of the membrane, as a flat, round-edged disc." Thus, in his opinion, the ovate cell is inrolled upon itself.

Mr. Busk has not satisfied himself in reference to this unfolding of the membrane, but thinks that the swelling up of the cell by the addition of strong sulphuric acid rather indicates the distinction of plaits or folds, and more particularly in such varieties of starch as have, when dried, a puckered centre, as is exhibited in Figs. 78 i, and 80. As this is a most interesting and undetermined question, and one, moreover, which our intelligent readers who have microscopes may be desirous to investigate, we subjoin the methods adopted by the observers just mentioned.

In any examination of starch it is only necessary to take a pin's point of flour of wheat, or of some other grain, or to scrape a very little morsel from the cut surface of a potato, and in both cases the starch will be found partly in free grains and partly inclosed as masses of grain within the cellular tissue of the plant.

The grains of Tous les Mois (Fig. 78 f) are the largest, and therefore, in many respects, the most convenient for examination; as also those of the horse-chestnut (Fig. 79), and pea (Fig. 78 i), when it is desired to notice the unfolding of the central puckernings.

M. Martin's method was as follows:—"Between two very thin glasses, of the same size as the stage of the microscope, a little starch, with a sufficient quantity of water, is to be put, and the former well spread out with the finger, to prevent, as much as possible, the formation of bubbles. The number of starch grains in the field of view should not exceed ten or fifteen. The glasses should lie freely on the spring-piece, which must be raised by means of two pieces of cork, introduced below it, so that while the two glasses are lying right upon the object-bearer, a current of cold air will ascend from below, and permit the little flame to continue burning in the hole of or below the stage. As the glasses are wide they protect the microscope from too great a heat or other danger. The small flame is to be obtained from a common thread, doubled and slightly waxed. This, when ignited, gives a flame quite sufficient to boil the starch."—The object of this experiment is to cause the distension of the cell-wall by the introduction within the cell of hot water, and thereby to notice what changes take place in the markings upon the surface.

Mr. Busk seeks the same end by applying the most powerful of acids—viz., concen-
treated sulphuric acid, or oil of vitriol. Our readers, whilst repeating this experiment, must exercise the greatest caution lest they burn their fingers and clothes. The following is Mr. Busk's method:—"A small quantity of the starch is placed upon a slip of glass, and covered with five or six drops of water, in which it is well stirred about; and with the point of a slender rod of glass the smallest quantity of solution of iodine is applied, which is to be quickly and well mixed with the starch and water. Any excess of water must be allowed to drain off, leaving the moistened starch between, and a portion of it is then to be covered with a piece of thin glass. It must then be placed on the microscope, and a quarter or one-fifth object glass brought to a focus close to the upper edge of the piece of thin glass. With a slender glass rod a small drop of sulphuric acid is to be carefully placed immediately upon, or rather above, the edge of the cover, care being taken that it does not run over it. The acid, of course, quickly insinuates itself between the glasses, and its course may be traced by the rapid change in the appearance of the starch grains with which it comes in contact. The course of the acid is to be followed by moving the object upwards; and when, from its diffusion, the reagent begins to act more slowly, the peculiar changes in the starch granules, now also less rapid, may be readily witnessed."

M. Martin thus describes the changes observed by him:—"First the starch grain..."
sinks in that place where the nucleus is situated. On the surface minute fissures appear, two of which almost regularly diverge towards the thicker end of the grain. The grain continues to be depressed inwards until a cavity is formed, which is surrounded by an elevated edge. In proportion as the grain swells up, this ridge increases in circumference, and decreases in breadth; that is, continues to get flatter, until fissures, mostly of a star-like form, appear in the hitherto little altered thicker part of the grain. The process is not very rapidly developed, and it is very difficult for the eye to follow it. Suddenly something is torn off, the grain is extended lengthways, and in the next moment a wrinkled skin of a rounded, generally oval shape, lies on the glass."—Further examination shows that they are collapsed bodies, consisting of an extremely fine, but strong and elastic, membrane.

Mr. Busk obtained a different impression from his experiment. He considered that the line upon the surface were simply plaits or foldings, and that the whole process consisted of unfolding these plaits, and, by distending the cell, to render the cell-wall perfectly plain and free from any markings. In Fig. 79 A, we have the starch of the horse-chestnut in its unaltered state, and at B is represented a stage of the unfolding which results from the use of the sulphuric acid. Fig. 79 C, D, and E, represent other views of this process, showing that the cell becomes gradually larger, until it reaches the great size figured at F. The fringe around the figures C, D, and E, he regards as plaits in the process of being unfolded.

Figs. 80 a b, have been copied from Schlieden's work, and represent the starch from the cormus or roots of the Arum maculatum of our hedges, and of the Colchicum autumnale, in which the star-like centre is presumed by Mr. Busk to indicate the central folding of the membrane referred to by him.

On a review of the whole evidence now offered, we may infer that the starch granule consists of a cell-wall, contracted and plaited when dry, and smooth and distended when heated with moisture, and also of contents in insufficient quantity to fill it, and thereby leaving a central cavity.

On this principle, it is difficult to conceive that the plaits can retain the same characters in the same plants under all atmospheric conditions; and it is proper that we should state that Dr. Allman of Dublin has, during the present year, published an article in the Quarterly Journal of Microscopic Science, in which, by the same processes as those above indicated, he has come to totally opposite conclusions. In his opinion the statement of Fritzche is correct—viz., that the starch cell is in fact a series of cells, placed within each other, as exhibited in Fig. 80 a. He sums up his opinions in the following words:

1st. That the starch granule consists of a series of lamellae, in the form of closed hollow cells, included one within the other, the most internal inclosing a minute cavity.

Fig. 80.—Starch cells copied from Schlieden. a, those of the Colchicum autumnale. b, those of the Arum maculatum, both showing in different degrees the central folding or cavity. c, the central cavity well developed in the starch of the Iris.
filled with amorphous (?) starch; that the concentric striae visible in the granule indicate the surfaces of contact of these lamellae; and that the so-called nucleus of Fritzsche corresponds to the central cavity.

2nd. That while the lamellae appear to be all identical in chemical constitution, yet the internal differ from the external in consistency or other conditions of integration.

3rd. That the order of deposition of the lamellae is centripetal.

4th. That while the starch granule is thus a lamellated vesicle, it cannot be included in the category of the true vegetable cell, from which it differs, not only in the absence of a proper nucleus, but in presenting no chemical differentiation between membrane and contents.

So widely do equally eminent observers disagree in their description of the same object as seen by the same means!

Rice (Fig. 78 a) is known by the small size of its grains, by their angularity, and the absence of evident markings.

Sago starch (Fig. 78 b) is very much larger than that of rice, but still less than that of wheat; it is rounded, and its surface is rather granular than plaited.

Wheat starch (Fig. 78 c) occupies a medium position in point of size, and is more regularly round than any grain of similar size. Its markings are not so distinct as those of the potato.

Potato starch (Fig. 78 d) is distinguished from wheat starch by its large size irregularity of outline, and flattened lenticular figure. The plaitings on its surface are very distinct, as is also the hilum around which they are gathered.

Pea starch (Fig. 78 i) is in size about equal to that of wheat; but it differs remarkably in its flattened figure and the star-like plaits which invariably occupy its centre.

Tous les mois (Fig. 78 g) is the largest of all known forms of starch, and from its size, void figure, and concentric rings, is not unlike a cocoon. It has occasionally two hilums or holes, and its markings are usually very regular. This article enters largely into the commerce of the day.

The starch grains, found in the Euphorbias (Fig. 82 a) are very characteristic, and are readily distinguished by their dumb-bell form from those of any other plant. The same grains are seen in Fig. 82 b, floating in the milky juice of the laticiferous tissue.

Wheaten flour, when adulterated with inferior starch, is usually mixed with potato, pea, or rice starch, each of which may be distinguished under the microscope. So also with wheaten bread, if the smallest crumb be broken up in water, and examined in the ordinary way.

It is not known if the varieties of starch possess any variation in the degree of their nutritive properties. It is therefore the quantity of pure starch which any substance can yield, conjoined with the abundance and ease with which the substance may be obtained, that gives the marketable value. It is also of importance to determine the state of perfection of any
starch-yielding plant, since, in reference to fresh vegetables, the quantity of starch differs with the season of the year. Thus in the potato the least proportion of starch is found at an early and a later period, and consequently the full-developed potato is the most valuable. Moreover, the state of health of a plant is of moment; for in disease the secretion of starch diminishes. This has been painfully investigated in connexion with the potato blight; and it has been shown that not only does the quantity of starch diminish with the advent of the disease, but cells of another and an injurious nature appear. These new cells are of the lowest order of growth, such as the mushroom, and received the name of the "potato fungus."

The diagrams, 83, 84, and 85, represent this condition; Fig. 83 showing the potato in a healthy and vigorous condition, with the cellular meshwork filled with starch granules; Fig. 84 shows the same cells nearly emptied of their contents; and Fig. 85 the diseased cells occupied by the fungus growth. The inference to be derived from these facts is, that old potatoes are not valuable, and that the diseased parts should be carefully removed.

The ordinary starch of laundresses is oftentimes prepared from potatoes which are not fit for the food of man; but the purest kinds are obtained from rice. It is prepared by simply breaking up the pulp so as to disengage the starch from the cellular meshes; then, by maceration, heat, and motion, to rupture the cell-wall of the granule, and to effect the escape of its contents. Lastly, it is filtered, in order to obtain the starch separate from the membranous cell-wall.
Raphides.—Another secretion found very abundantly in plants is certain crystal-line bodies termed Raphides, from the resemblance of some of them to a needle (raphis). The term, however, is not a happy one; since many varieties of these crystals exist which have no resemblance to a needle. They are not secreted in the form in which we see them, but are deposited from the secretions. They occupy both the cavities of the tissues and the passages which lie between the tissues, but are the most abundant in the cells of succulent plants. They may be observed with great ease in the stem of the common garden rhubarb (Rheum), or of the balsam, and in the bulbs of the onion, and all bulbous garden plants. In the former case they have a square outline, and are isolated (Fig. 87), or they are aggregated into separate star-like bodies (Fig. 88); whilst in the latter they are usually needle-form, and lie in dense bundles (Fig. 86). Their number is so great as to impart a grittiness to rhubarb-root when bitten; and the most so in the finest specimens of Turkey rhubarb. Their chemical composition is that of oxalate, phosphate, tartrate, malate, or citrate of lime, and in size they differ from one-fortieth to one-thousandth of an inch. Phosphate of lime is found abundantly in the bones of the animal body, but not in the precise form in which we observe it in Raphides. We have no instance of oxalate of lime crystals in the body; but they are not unfrequently met with in the urine of persons, both in apparent health and in disease; so that it has been inferred that they have been introduced with the food.

We do not know the uses of these substances in the vegetable economy; but although they render certain plants brittle, it is not ascertained that they are the result of any diseased action. This brittleness is the best seen in some of the large Cactus plants (Fig. 89). One which was removed, after a lapse of a thousand years, from the woods of South America to the Royal Gardens at Kew, was wrapped in cotton, and packed as though it were the most fragile of substances. They are readily seen on microscopic examination, if a thin section of an onion be placed in water in the usual way; but as they are found in all parts of a plant, from the rough bark (Fig. 90) to the delicate spiral vessels and the pollen, they will be observed in almost every investigation.

They have been produced artificially, and, so far as may be seen, in a state as perfect as those deposited from the vegetable juices. The late eminent botanist, the brother of Professor Quekett, produced the stellate and rhombohedral forms artificially
in cells, but could not produce the needle-shaped crystals. He took a portion of rice-paper, and placed it in lime-water under an air-pump, in order to fill the cells with the fluid. The paper was then removed and dried, and the process repeated until the cells were filled. After this the paper was immersed in weak solutions of oxalic and phosphoric acids, and the crystals appeared at the end of three days (Fig. 91). This, however, is a mere chemical experiment, and has no relation to vegetable tissue,

![Fig. 89](image1.png)  ![Fig. 90](image2.png)  ![Fig. 91](image3.png)

Fig. 89.—Raphides. A mass of crystals from the cuticle of a Cactus.
Fig. 90.—Raphides from the bark of the Lime Tree (*Tilia Europaea*), of considerable breadth and prismatic figure.
Fig. 91.—Crystals of oxalate of lime raphides, produced artificially in the cells of rice-paper.

except in so far that a detached morsel of vegetable structure was used as the containing vessel.

**Oils and Fats.**—The most widely distributed of all vegetable secretions, next to that of starch, is essential and fatty oil, of various degrees of consistence; and, with the exception just referred to, none has so high a value for economic purposes.

There are probably few, if any, plants from which some portion of oil cannot be obtained by distillation; but it is more particularly in the hot climates of India, China, New Holland, Africa, South of Europe, and South America, that they attain their highest degree of perfection, and are found in the greatest abundance. The mustard-seed, for example, which is grown in our climate, yields oil only in a non-remunerative degree; but in the continent of India, with its burning sun, the produce is of great value. So also with the otto or atar of roses—an exquisite volatile oil, obtained from the rose-leaf growing in Persia, but scarcely perceptible in our northern climate. This is doubtless due to the chemical influence of the sun's rays, by which all vegetable secretions become highly elaborated.

The oil is most commonly found in the seeds, as in the linseed and rape-seed, of our climate; for as the seed is the product of the plant in its most mature condition, it is the most fitted to be a depository of the most mature secretions. It is, however, found to a great extent in the leaves of plants, as the rose and the peppermint, and in the wood of a comparatively few trees—for example, the Sassafras and the Sandal-wood. The bark is not an unfrequent depository of oil secretions.

A recent discovery made by Mr. Young, of Scotland, has demonstrated the wonderful length of time during which vegetable oils retain their distinctive characters. He has obtained by distillation, at a low red heat, no less than 20 per cent. in weight of
Vegetable Oils.

Oil from cannel coal. When was that oil first formed? Thousands of years ago; and yet its quality remains so good that it is now compared with sperm oil. Its non-oxidizing property renders it peculiarly fitted for the lubrication of machinery.

As respects the varied social purposes to which it is applied, we may refer to the perfumes of Eau de Cologne and Lavender; the immense quantities of candles and soap which are manufactured in great part from vegetable fats; the oiling of machinery, which is carried to so great an extent, that the London and North Western Railway Company alone use about 50,000 gallons of oil per year; the support of artificial light by lamps; the exhibition of oil for medicinal purposes—as the castor and cocoa-nut oils; and the employment of oil as an article of diet by the inhabitants of all extreme climates. Thus but few articles of commerce can more materially influence the well-being of the community than that under consideration.

It is also worthy of remark how closely the production of oil links together the animal and vegetable kingdoms, not merely in the general chemical and economic characters of the substance, but in its minuter details. Thus we have the fluid oils, as the olive oil, and the semi-fluid, or such as require a higher temperature than that of the air in order to render them fluid, and which closely resemble the fat of animals. There is also vegetable butter, which is largely used in India to adulterate the ghee, or animal butter; and vegetable wax and tallow may, in some sense, rival the like productions from the animal kingdom. There is, however, this remarkable difference—viz., that the fat of animals and of vegetables, each abound in climates the most opposed to each other. The vegetable oils and butters are chiefly derived from the Palm trees of the hottest climates; but the animal oils and fats are met with in greatest abundance where the rigours of a polar clime call for the internal use of such articles of food in order to maintain the animal heat. Thus the fat of animals is, for the most part, employed by the Laplander as food; whilst that of vegetables is chiefly used by the Asiatic and African for external inunction, as a defence from the action of the sun's rays, and as a perfume, which is more than a luxury in the stifling atmosphere of the sunny south. Nature has thus bountifully provided for the wants of man, and in great wisdom has selected, as her depositories, that division of vital existences which is the most abundant in their respective climates. The inhabitants of temperate regions, as of England, find within their own territories only feeble representatives of the products of the two classes; and in order to enjoy them they require to collect the animal oils from the Polar Seas, northern forests, and the banks of Newfoundland, and the vegetable oils from the neighbourhood of the tropics. Commerce, therefore, is to them a necessity.

This branch of trade is as yet in its very infancy, for the Great Exhibition of 1851 has shown that a very large proportion of vegetable oils is unknown to the commerce of the world; and the great effort which has been of late put forth to increase it, has led us to infer that multitudes of vegetable sources yet remain untouched.

We cannot enter largely into this question, but shall now proceed to indicate some of the more ordinary and useful sources of this substance.

Fixed Oils.—Olive Oil is produced from the Olea Europaea, a shrubby tree, cultivated with great care in Spain and Italy, Syria, and other shores of the Mediterranean Sea. It thrives best in stony ground, and requires a southern clime, in order to perfect the oil contained in the olive berry. The virgin oil is produced by simple pressure of the olives; but that of the inferior qualities is such as is drawn off after the virgin oil has been removed, and which requires heat and water in order to obtain the full quantity remaining. It is mentioned as an article of food in the Sacred writings; and
in eastern and southern climes is almost indispensable to the inhabitants, both as food and for inunction. It is less commonly used in this country than is desirable, since it is highly conducive to health.

Its chemical composition, per cent., is, carbon, 69.38; hydrogen, 13.47; nitrogen, 0.58; oxygen, 17.092.

Palm Oil is an article but recently introduced into commerce, and has the great commendation of offering the most effectual means for the suppression of the slave trade. It is obtained from the seeds of various palms, and more particularly from those growing in barbarous states on the western shores of Africa. It is far more consistent than other oils, and approaches to the condition of ordinary fat; so that it is well fitted for the manufacture of candles, and when mixed with sulphur is the most valuable grease for railway carriage wheels. In the countries in which it grows, it constitutes an important article of food; and, from its golden colour and consistence, may be said to be a substitute for butter.

Cocoa-Nut Oil has a relationship to palm oil, inasmuch as it, too, is produced from the palm tree.

Fig. 92.—Cocoa-nut Palm (Cocos Nucifera).

It is a concrete oil, and is found in the cells of the seed of the cocoa-nut before germination. It is likewise obtained by pressure; and is of great value in the production of artificial light. Colonel Rowcroft has shown to us some very excellent candles, prepared in India, from an admixture of wax and cocoa-nut fat. It is also used not unfrequently as an article of food, in the form of butter in India, and of cocoa and chocolate in this country, and has recently been introduced as a medicinal agent in the treatment of consumption.

Its chemical constitution is—carbon, 69.62; hydrogen, 12.49; nitrogen, 0.60; oxygen, 17.850 per cent.

Linseed Oil is obtained by pressure, with and without heat, from the seeds of
the flax plant (*Linum*), grown in the British Islands, America, and the Continents of Europe, and of India. It is a common article of food to the serfs of Russia, and is regarded as the highest luxury by the Greenlanders and other inhabitants of polar climes; but it is chiefly used in the arts. It is prepared by distillation for drying, and then is fitted for the preparation of paint. A large proportion of this seed is grown in England and Ireland; but it is chiefly imported from Russia: no less than 482,813 quarters out of a total importation of 626,495 quarters of the seed having been received from that country in the year 1850. It is considered a profitable crop, and is now much cultivated in Ireland. The pressed seeds from which the oil has been partly extracted, constitute the oil-cake, much used in the fattening of cattle.

*Rape Oil* is in like manner extracted from the rape-seed, which is the product of the *Brassica Napus*, and other species of the cabbage genus of plants. It is considered to be better adapted, when purified, for the lubrication of machinery than any other oil; so much so, that 90 to 100 gallons of it are yearly expended upon each locomotive railway engine. It is also inferior to few, if any, oils in the production of artificial light in lamps. Mr. Brotherton affirms that the English grown seed is to be preferred to that imported from the Continents of Europe and India; and so profitable is the crop, that an acre of land will yield five quarters at 50s. per quarter, or £12 10s. yearly. It is, however, probable that the foreign seed is equally good with the English production, and that the inferior quality of the oil may be attributed to its careless and unskilful preparation. The importation of rape-seed in 1850 was 29,490 quarters.

*Turnip-seed Oil* (*Brassica rapa*) is very nearly allied to the rape-seed oil, and is much employed in Egypt.

*Castor Oil* is obtained from the seeds of the *Ricinus communis*, which grows chiefly in the East Indies and the United States of America. It is much used in medicine, but more particularly in the arts, and the manufacture of pomatum. When intended to be used medicinally, it is obtained by pressure without heat, and is then colourless and tasteless, and will so remain for a lengthened period; but that which is employed for other purposes is obtained by heat and pressure, after the first or virgin oil has been removed. This is slightly coloured, and has a rancid odour and taste, and consequently realises but a very inferior price. The seeds do not grow to perfection in our climate. The importation of the oil, in 1849, was 9,681 cwts., of which 9,315 cwts. were obtained from our Indian possessions alone.

*Cotton Seed* (*Gossypium*) yields a large quantity of oil on pressure; but, on account of the difficulty of removing its colouring and other impure matters it has been hitherto but little used. The seeds are very abundant, and as large as orange seeds, and are either wasted or used as manure and for the fattening of pigs. It is believed that the oil would be of great value if purified; and it could be obtained in any quantity. The seed is chiefly produced in America, Egypt, and India. We have seen immense quantities of it rotting around every cotton plantation we have visited in the Southern States of America.

The Indian corn (*Zea Mays*), or maize, in the State of New York, has been found to contain a valuable oil.

*Ground-Nut Oil*, obtained from the seed of the *Arachis hypogea*, is used largely in India, Malacca, and Java, both as food and fuel for lamps. It is a clear, pale yellow oil, and constitutes fully one-half the entire weight of the seed.

*Poppy Oil* is produced from the seeds of the Opium Poppy, or *Papaver somniferum*, whether grown in this or other countries. It is, however, chiefly produced in India,
since there the plant is scientifically and extensively cultivated by the Honourable East India Company for the opium which it yields. It has many valuable properties, and is a very good substitute for salad oil.

Mustard Oil is expressed from the seeds of the common mustard plant (Sinapis), and chiefly in the various parts of India. That our English mustard yields oil, is familiar to the eyes of every housewife who has kept it in paper, or has mixed it with warm water in its preparations for the table.

Croton Oil possesses powerful medicinal properties, and is procured by pressure from the seeds of the Narphaula, and other species of croton. It is prepared in India and other eastern countries.

Sesamum Oil, derived from the seeds of the Sesamum orientale, and the Ram-til oil, from the seed of the Guizotia oleifera, are well known, and greatly valued in India. The seed yields from thirty-four to forty-five per cent. of oil.

Vegetable Butters.—The plants which yield vegetable butters, are (besides the palm oil to which we have referred) chiefly the various species of Bassia, all indigenous to India and Western Africa. These oils consist of saccharine matter, spirit, and oil, and therefore are as well adapted for food as for fuel.

The Epie Oil is obtained from the seeds of the Bassia latifolia, and is common in the Bengal Presidency. It begins to melt at about 70°.

The Ilpa oil is expressed from the seed of the Bassia longifolia in the Madras Presidency. It is white and solid at ordinary temperatures, and until a heat of 70° or 80° has been produced. It is therefore well fitted for the preparation of both candles and soap.

The Bassia butyracea is the plant which yields the purest vegetable butter, and is common on the hill districts in the eastern part of Kamaon, and in the Province of Dotee. It is white and solid at a temperature under 120°, and is so abundant and agreeable that the butter from milk is largely adulterated with it.

Shea butter is obtained from another species of Bassia—viz., the Bassia Parkii, in Bambara (Western Africa), and at Egga, on the banks of the Niger. It melts at 97°.

Kokum butter is obtained from the seeds of a Mangosteen (Garcinia purpurea), and is not only used largely to adulterate butter, but is forwarded to this country to serve the like purpose with genuine bear's grease.

Cacao butter is solid up to 120°, and is the produce of the Theobroma Cacao, growing in Trinidad.

Crab, or Carapa oil, from British Guiana, is also another kind of butter derived from the Carapa guianensis, but of inferior quality. The natives, in its preparation, boil the kernels, leave them in a heap for a few days, then skim them, and at length beat them into a paste in a wooden mortar. This paste is then spread on an inclined board, and exposed to the heat of the sun, until the butter has trickled into a vessel placed to receive it.

Vegetable Tallow is procured from the tallow tree of Java, known as the Minyak kawon, and from trees, probably of the genus Bassia, growing in the western countries of the Archipelago.

Piny tallow is another variety produced by the Vateria indica, a fast growing plant, common in Malabar and Canara. It is white and solid, and melts at about 97°. Vegetable tallow differs from oil chiefly in the higher temperature required to render it liquid, and its solidity at the ordinary heat.

Vegetable Wax.—Wax is obtained from a variety of trees growing in similarly hot climates.

Gutta Podah is a wax of a bright-green colour, obtained from Biliton.
Myrtle or Candle-berry wax, has been made, without admixture, into candles in New Brunswick.

Wax of very good quality has been obtained from trees growing at Shanghaei, in China, in Japan, and in St. Domingo; and in connexion with this it may be mentioned that a fungoid growth, found in decayed branches of our English trees, has recently been shown by Professor Quckett to so far resemble wax, that it is not possible to distinguish it by the microscope from the waxy comb of the wasp's nest.

Volatile Oils.—The aromatic and volatile variety of oil is exceedingly extensive, and is largely employed in medicine and perfumery.

Amongst the English specimens we may mention the peppermint (Mentha piperita), and spear-mint (Mentha viridis), lavender (Lavandula), rosemary (Rosmarinus), fennel (Foeniculum), thyme (Thymus), from the leaves of all of which essential aromatic oils are procured. The seeds of the caraway (Carum carvi), aniseed (Pimpinella Anisum), dill (Anethum graveolens), coriander (Coriandrum sativum), are well known to yield medicinal aromatic oils on distillation.

It is, however, to hotter climes that we turn for the spices and perfumes which we covet, and especially to the inter-tropical regions.

The atar of roses is at the head of this series, and is produced in its highest perfection in Persia, Turkey, the Raapootana States, and other parts of the great Continent of India. The quantity of rose-leaves required to obtain a tea-spoonful of this princely perfume is almost fabulous, and more than accounts for the high price which the oil obtains. It is much adulterated, and chiefly with the oil of geranium, or Andropogon.

The atar of Keova, derived from the fragrant flowers of the screw-pine (Pandanus odoratissimus), and the jasmine atar, from the Jasminum grandiflorum, and Sambuc, are favourite perfumes in India. So also with oil of aloes wood, of saffron, and of sandal wood (Santalum album).

Orange flowers (Citrus) also yield a most exquisitely scented oil, as may be familiarly observed by walking through the orangeries of this country and of France, where the orange tree is in blossom. It is obtained chiefly from Turkey.

Oil of cloves is obtained from the Caryophyllum aromaticus, in India and the Archipelago; and oil of lemons from the rind of the fruit of Citrus Limonum; and oil of cinnamon from the Cinnamomum zeylanicum.

Oil of bitter almonds (Amygdalus amara) is obtained from the seed, and is highly poisonous. It is produced in Asia.

Cajeputi oil (Melaleuca), from India, with oil derived from the Leptospernum and the Eucalyptus piperata, of Western Australia, in addition to the medical properties of the first, have the power of dissolving India rubber and various resins, and might therefore be used in the manufacture of varnishes.

There are two other vegetable volatile oils, to which we will refer, on account of the favour with which they have long been regarded in India, and are now being viewed in this country.

The grass oil is a stimulating aromatic oil, obtained from the seed of the Andropogon schenanthus, or Calamus aromaticus; and the lemon grass oil, from other species of the same genus. Both are used to the skin medicinally, and as valued perfumes.

The peculiar odour and great durability of Russian leather is attributed to the employment, during the process of tanning, of a volatile oil obtained by the distillation of birch bark (Betula). The oil has a brown or black colour, and after it is dried up, it leaves upon paper the odour peculiar to Russian leather.
Camphor is a substance fitly associated with oils, since it is a volatile oil in a solid state. It is derived from various sources, but the best is the Barus camphor, from Borneo, the product of the Dryobalanope Camphora, growing in Sumatra. It is chiefly exported to China, where it realises a price one hundred times greater than that of ordinary camphor. Its flavour is exceedingly fine.

The Dutch camphor, or that obtained by the Dutch from Japan, is prepared by boiling chips of the root and stem with water in an iron vessel, to which an earthen head containing straw is adapted. The camphor is volatilized by the heat, and condenses on the straw. The process is varied somewhat in the preparation of China camphor. The chopped branches are steeped in water, and boiled until the camphor begins to adhere to the stick used in stirring the fluid. The liquid is then strained, and by standing the camphor concretes. It is then sublimed by placing alternate layers of finely-powdered dry earth and camphor in a copper basin, with a similar one inverted luted upon it, and heat applied, until the camphor passes off, and condenses upon the upper vessel.

Gums and Resins.—These two classes of secretions are distinguished from each other by the solubility of gums and insolubility of resins in water, and the solubility of resins and insolubility of gums in alcohol. In some instances the substance is partially soluble in both menstruums; in which case it is called a gum-resin. Each of the classes is used abundantly in the arts, and in medicine; and almost every member of them is obtained from Asia, Africa, and islands of the Southern Sea.

The cheapest gum is that obtained from roasted starch, and is used largely in calico-printing.

Gum-arabic, obtained from many species of Acacia and other genera, is carefully collected in Turkey, Egypt, Tripoli, and India. It stands at the head of this series in the quantity imported; and amounted to 33,136 cwts. in 1849, from the following sources:—India, 13,687 cwts.; Egypt, 6,232 cwts.; America, 6,064 cwts.; South Africa, 4,876 cwts.; Italy, 664 cwts.; Gibraltar, 460 cwts.; Aden, 397 cwts.; Australia, 372 cwts.; France, 212 cwts.; miscellaneous, 172 cwts. It varies very greatly in quality; and it appears that no very great care is exercised by the collectors in separating the inferior from the better specimens.

Of gum-senegal and the cherry-gum, or Tragacantha (Astragalus gumminifera), &c., from Syria, there was an importation of 6,577 cwts. and 314 cwts. respectively, in the same year.

Of the resins and olco-resins, the most abundant are turpentine and lac, both of which are of essential value in the arts.

Turpentine is obtained from the fir tribe of plants, and chiefly from the Pinus palustris, by making incisions into it, and subsequently distilling the exuded secretion. It is found in special vessels in the plant, which were discovered so early as the seventeenth century by the great vegetable anatomist Green, and also in blisters underneath the bark (Fig. 94). It is of the utmost value in its power of dissolving resins, and in mixing and drying paints. The quantity imported in 1849 was 412,042 cwts., nearly the whole of which was from the United States of America.

The distillation of impure turpentine, or turpentine as it is obtained from the tree,
is effected through the medium of water, by which the volatile oil passes over and is collected, and the resin with which it is naturally associated is left behind.

**Tur and pitch** are also produced from the fir tribe of plants at the same time that the turpentine is collected. The wood is cut into billets, and piled up in a hole made in the ground. It is then covered with turf, or some similar covering, and set on fire. During the slow combustion, the tar runs down the wood, and is collected in the dam prepared in the ground for its reception. This tar contains a portion of turpentine, but may be made from trees which have ceased to emit turpentine on incision.

Pitch is obtained when the tar is distilled; so that an inferior kind of turpentine passes over, and the pitch remains.

Resin results from the distillation of turpentine, or from the drying of the secretion as it exudes from the tree. It is brought to this country in large quantities from the United States, Asia Minor, and other parts of Turkey. It is produced from various species of Abies and Pinus. Burgundy pitch and frankincense are obtained from another pine, the *Abies excelsa* of the north of Europe, and Canada balsam from the *Abies balsamea*.

Lac is furnished to this country almost exclusively by India, and amounted to 14,786 cwts. in 1849. It is obtained from a great many sources, but chiefly from the *Coccus lacca*, and some of the firs, as the *Ficus Indica* and *Ficus religiosa*, or Banyan tree (Fig. 75). Its varieties are known by the designations of stick lac, seed lac, orange and ruby shell lac, lump and button lac, lac dye, and white or bleached lac. It is produced by the injuries inflicted upon the young shoots of various trees by an insect, the coccus lacca, which feeds upon them. It is employed in the manufacture of varnishes.

It is not possible to name even the great multitude of members of this class, and it must suffice to mention the sources of the following well-known substances:

*Assafoetida* is the product of the *Narthax assafoetida*, in India; benzoin of the *Styrax benzoin*, in Singapore; copal from the *Hyemenae* of Western Africa, *Dammara australis* of New Zealand, and *Trachycobium martiniunum* of South America; *dragon’s blood* from the *Dracena Draco* of India; (Fig. 95); gamboge, from Siam; *myrrh*, from the *Balumodendron myrrha* of Persia, and *yellow gum* from the *Zanthorrhoea hastilis* of New Holland.

![Fig. 95.—A young plant of the Dracaena Draco.](image)

A specimen in the island of Teneriffe is above 70 feet high, and 46 feet in circumference at the base, and was known to be very ancient in the year 1406.

It is highly probable that the magnificent gum trees of the continent of Australia, which have hitherto been a great inconvenience to the settler in the clearing of his land, will ere long yield gums and resins which will convert them into sources of great wealth.
Acids.—Various acids are yielded by vegetables, chiefly from their fruit, but very abundantly from the distillation of their wood. Of the former are citric acid, from the lemon Citrus, the acid juices of the apple (malic acid), pear, gooseberry, and other fruits of our own climate, and the oxalic acid from the leaves of the sorrel, or Oxalis Acetosella. All these acids appear to have distinct chemical characters, and to require distinct names.

Pyroligneous acid, or wood vinegar, is obtained from the distillation of almost all kinds of wood, and is capable of perfect purification. It is colourless, abundant, and cheap, and has therefore greatly lessened the demand for the coloured vinegar derived from the fermentation of beer or wine, and more particularly in the preparation of such pickles and other substances as would be deteriorated by immersion in coloured fluids. The process is simple—viz., the burning of billets of fast-growing wood, as poplar, in closed iron tubes or kilns, and the separation of the empyreumatic oils, and other impure substances, from the acid. This acid can be obtained in a highly-concentrated state, and is usually sold so that one part is equal in strength to eight of wine vinegar. It is thus a convenient as well as necessary article for the use of persons on ship-board, or for residents in new countries, where vinegar has not hitherto been made.

Gallie acid is obtained from gall-nuts, and tannic acid from all sources supplying tannin.

Tannin.—This is the chemical principle which is employed in the tanning of leather, and produces its effect by acting upon the gelatine contained in the skin. It is obtained from a great variety of sources, and not only from the oak bark, as is usually supposed; although it is probable that the excellence of good oak bark, and the ready supply of it afforded by our own country, will ever give it a preference in the estimation of the manufacturer. Notwithstanding the supply of oak bark from our own forests, so large a quantity as 1,200,000 cwts. of tanning materials were imported in 1849; but it must be understood that the tanning principle forms but a small portion of the barks and other materials thus imported. The following are the commercial substances which contain tannin in quantity sufficiently large to render them efficient in the tanning of leather:

Oak bark, from various species of Quercus, but particularly the Quercus pedunculata, growing in England and the north of Europe.

Cork-tree bark, from the Quercus Suber, imported from Laruche and Rabat.

Valonia, from another oak, the Quercus Ægilops, flourishing in the Morea, and the south of Europe, and Asia. No less than 333,420 cwts. of this substance was imported in 1849.

Oak-galls, from the Quercus infectoria of India and Turkey.

Terra Japonica, Kutch, and Catechu, extracts from the Acacia Catechu, growing in the East Indies. These substances contain a very large quantity of tannin.

Sumach, in powder and in leaves, from Sicily and the south of Europe. It is the product of the Rhus Coriaria.

Besides the above principal sources may be mentioned Kino, the extract of the Buchanania latifolia, of India; Divi-divi, of the Casalpinia coriaria, from South America; mimosa bark, and bark of the black wattle tree, Acacia mollisima; hemlock bark, from the fir, Abies Canadensis, of the United States of America; the bark of several trees growing in New Zealand; and the larch bark, Pinus larix, of Scotland.

Opium.—This highly important medicinal substance is procured from the Continent of India, and chiefly from the provinces of Behar, Benares, and other parts of
the Bengal and Agra Presidencies, in our East Indian possessions, and the Independent States of Malawa, and others in the south of India. It is the produce of the white poppy (Papaver somniferum), almost exclusively, in our Indian territories; but in the Independent States it is also obtained from the dark-red and other varieties of poppy.

The poppy-seed is sown in the months of October and November, in shallow beds of about seven feet square, and the plant is thence regularly irrigated throughout the season. The capsules (ovaries) are ready for bleeding, or patching, as it termed, about the end of January, when this process commences, and proceeds during the whole of the month of February. It is effected by making incisions into the poppy-head at about four o'clock P.M. daily, and allowing the milky juice to exude and thicken by evaporation upon the capsule during the night. The next day it is scraped off, placed in porous earthen vessels, and allowed to insipissate further. In this crude state, it is carried to the factory, where the drying process is carried on until the opium has attained a certain standard of spissitude, when it then retains from 25 to 30 per cent. of water. It is then made into large round balls, technically termed cakes, each ball being enveloped in a case composed of the petals of the poppy, cemented together by means of thin crude opium in lieu of paste. When the balls have become hard they are ready for the market; forty of them constitute a chest of opium, and weigh about 160 lbs. The produce of one agency, that of Patna, in 1853, was 35,000 chests, or about five and a-half millions of pounds.

The East Indian Company exercise no control whatever over the growth and production of opium in the Independent States, but impose a tax upon it on its exportation to Bombay. In the territories of the Company, however, the government not only watches over its production, but are, in fact, the sole growers of the drug. Any individual growing opium is bound to deliver it to the government agent at a fixed sum per pound; and upon his undertaking to do so, the government makes advances of money from time to time to enable him to prepare the ground, and to plant, irrigate, and gather the crop. In this mode a great many thousands of persons become the servants of the Company,—not by compulsion, but from the greater profit attending upon this, than upon other agricultural produce. The opium thus delivered to the Company is in a crude state, and still requires much attention before it is fitted for the market. No fewer than 1,200 persons are engaged in the Company's factory at Patna alone.

The opium, when packed in chests, is offered to public sale by auction for exportation, and is purchased by dealers of all nations, but chiefly with a view to the supply of the Chinese market. The profit made upon this one Indian production is the most important element in the income of the East Indian Company.

[We are indebted for the above account to Colonel Rowcroft and Dr. James Corbet, both distinguished officers of the E. I. C. Dr. Corbet for some years held an appointment at the Patna opium factory, in the province of Bekar].

Sugar.—Sugar is not exclusively a vegetable production, since it is found abundantly in honey and in milk, both of which are natural animal products, and in the blood and excretions in certain instances of disease. It is, however, chiefly obtained from vegetables, and always so when it is separated from all other substances and made marketable.

Vegetables yield it largely in their fruits, as those of the grape and apple; and many in their sap; but as an article of commerce it is obtained from three sources:
the sugar-cane (Saccharinum officinale), beet-root (Beta vulgaris), and the sugar-maple (Acer saccharinum).

Beet-root alone can be grown in our climate, but not as a remunerative crop for the production of sugar. It is, however, largely cultivated in France, Belgium, Austria, and Prussia; since those countries have no colonies whence they can derive cane sugar.

The sugar-maple is also a tree of somewhat northern latitudes, and one of great value to the new settler in Canada and the United States, since it not only yields the sugar which he so much needs, and which in his distant and solitary habitation he could scarcely otherwise obtain, but is valuable as wood also. The sugar is readily obtained by boring holes in the tree, so as to permit the juice to exude, and then causing evaporation of the latter by exposure to the air or by heat.

The quality of sugar derived from the fruits of plants, and also from the beet and the sugar-maple, is much inferior in sweetening powers to that obtained from the next source—the sugar-cane.

The sugar-cane is a member of a family which abounds in sugar, and grows readily in low alluvial lands of all southern climes, and especially in the countries bordering upon, or lying within, the tropics. Such are the states bounding the Lower Mississippi, up to about 33° of N. latitude; the West Indian Islands; the East Indies; the Mauritius, and parts of China. The cultivation requires a large capital and the employment of a great number of hands; so that, with the exception of the Indian crop, it is the product of slave labour. The plants are set at regular intervals, and grow luxuriantly with a single stalk and large waving leaves (Fig. 96), to the height of ten or twelve feet; so that a sugar plantation, with its well-cultivated fields, large red boiling-house, planter's mansion, and village of negro huts, is a picturesque scene. It is also a busy scene during the period of cultivation, but more particularly at that of boiling, when the process is not stayed night or day until it is finished. We have inspected many, and have been struck with the air of richness and wealth which usually pervades them.

When the plant is mature it is cut down near to the root, and carried in wagon loads to the boiling-house, where it is crushed between powerful rollers, impelled by steam,
until the juice has been thoroughly extracted. The juice, mixed with quicklime, is then transferred to large boilers, where it is evaporated, and afterwards set aside to crystallize. The larger portion of the sugar is thus separated from the fluids in which it was secreted; but a considerable quantity remains uncrystallized in the mother-liquor, and constitutes the molasses so abundantly used in those climates as food, and for the distillation of rum. The colour of the sugar is more or less brown, and is purified either in this country or in the country of its production, by filtration through animal charcoal. Bullock's blood was formerly used for this purpose. The coloured uncrystallized liquor which then remains is the treacle of commerce.

We may mention that, as a curiosity, some cane sugar was made from sugar-cane grown in this country, and exhibited at the Great Exhibition of 1851.

Good specimens of grape sugar were forwarded to the Great Exhibition from Tunis and the Zollverein States. Palm sugars have hitherto been mere curiosities, but they have been made from the date palm of the Deccan, the Comutus palm (Arenga saccharifera) of Java, the Nipa palm stem, and the flower of the Bassia latifolia, and might, doubtless, be procured from all palms yielding refreshing and fermenting juices.

**Colouring Principles.**—The colours presented by plants are exceedingly varied, and all alike depend upon the presence of colouring principles in the cells of colourless tissue.

There are eight principal colours recognised in vegetables—viz., white, gray, brown, yellow, green, blue, red, and black; and each of these has many distinct shades.

Of these shades of colour, nine have been associated with white: pure, snow, ivory, chalk, and milk white; with silvery, whitish, turning white, and whitened.

A similar number is also attributed to gray, and are designated ash, lead, slate, and pearl gray; smoky, hoary, and rather hoary, and mouse-coloured.

Twelve have been computed in connexion with brown; viz., brown, chestnut, deep and bright brown, rusty, red, brown, rufous and cinnamon-coloured, with lurid, sooty, and liver-coloured.

Yellow has twenty shades; thus, lemon, yellow, golden, pale, leather, waxy, and Isabella yellow; sulphur, straw, ocre, orange, apricot and saffron-coloured; testacean, tawny, and livid.

There are seven varieties of green, of the shades of olive, grass, sea, yellowish, apple, meadow, and leek.

Red has seventeen shades: carmine, rosy, purple, sanguine, scarlet, cumaba, vermillion, coppery, brick, flame-coloured, &c.; whilst its compound blue has but seven—viz., prussian, blue, indigo, lavender, violet, lilac, and sky blue; and black has four: pure, coal, raven, and pitch black.

Thus as many as eighty-six different shades of colour have been determined to exist in plants; but only two chemical colouring principles have been discovered—viz., chlorophyl and chromule.

Chlorophyl is so called from its imparting a green colour to plants; that is, that kind of green which is universally met with in all plants growing in the light. It is distributed to the tissues themselves, but more particularly to the surface of the starch cells, which are abundant in all green plants.

Chromule is the general term for the colouring principle of all other colours, although they may be so closely approximated that adjoining cells may have totally different colours.

**Dyes.**—Another highly important series of vegetable secretions are such colouring...
matters as are capable of being used as dyes of textile fabrics. These are very varied, and are also chiefly found in southern countries. This series comprehends nearly all the known dyes, since but few (as the cochineal insect) belong either to the animal or mineral kingdom. The chief substances are

*Indigo*, of which no less a quantity than 70,482 cwts. were imported in 1850. It is the product of the leaves of the *Indigofera tinctoria*, and *I. anil*, growing in the low districts of India and South America. It is a fast dye, if in the process of dyeing it be first deoxidized, but otherwise it is not permanent. It yields the Indigo colour, and also a green when mixed with yellow.

*Madder* is one of the most useful and common dyes, and is derived from the root of the *Rubia tinctoria*. Its home is Naples, France, and the North of Europe. 2,985 tons were imported for this purpose in 1850. It forms one of the most permanent dyes, and constitutes the Turkey red dye, so celebrated for its brilliancy. Garancine is the red principle of madder, obtained by the action of sulphuric acid. 2,985 tons of this substance were imported from France in 1850.

*Logwood* is the wood of the *Hematoxylon campechianum*, found in the Bays of Campeachy, and Honduras, in Central America. Its value is sufficiently great to cause the right cutting it to be the subject of a treaty between this country and the States in which it grows. Its colour is red, but black when precipitated with iron, purple with tin and alum, and brown with copper. 3,500 tons were imported in 1850.

*Brazil wood*, from the *Casalpina brasiliensis*, is one of the largest importations of dye woods. 3,120 tons were imported in 1850.

Amongst the remaining dyes are *alkanet root*, from the *Anchusa tinctoria*, grown in Asia and the North of Europe; *Nut-galls*, an excrescence on an oak, the *Quercus infectoria*, in Turkey; *Safflower*, produced in Southern Asia, Egypt, and the Levant, from the dried flowers of the *Carthamus tinctoria*; *Annatto*, a South American orange-colouring matter, from the seed of the *Bixa orellana*; *Turmeric*, from the root of a cucumber, the *Cynqua longa* of India; *Peach wood*, or *Nicaragua wood*, of the *Casalpina*, from South America; *Fustic*, the wood of the *Rhus cotinosa* of Cuba; *Camwood*, from the *Baphit nitida* of Sierra Leone; *Quercitron barks* of South America, from another oak, the *Quercus tinctoria*; the *alder barks* of this country, from the *Alnus glutinosa*; *Catechu*, an extract of the wood of the *Indian Acacia Catechu*; *red sanders*, from the *Pterocarpus santalinus* of India; the *Persian berries*, from the *Rhamnus infectoria* of the Levant; and many others of less note.

It is worthy of remark, that the lowly-organised Cryptogamic cellular plants, or lichens, afford colouring matters in great abundance, under the designations of *Orchell* and *Oudbear*. The following are the chief: *Ramulina furfuracea*, from Angola; *Roccella fusciformis*, from Mauritius, Madagascar, Lima, and Valparaiso; *Roccella tinctoria*, from the Cape de Verd Islands; *Parmelia perlata*, from the Canaries; with the *Parmelia tartareca*, *Umbilicaria pustulata*, and *Gyrophora murina*, of Sweden.

We have purposely avoided the chemical questions which naturally arise when considering the interesting and important vegetable products which have been passed in review; but we cannot omit to state here, that, although the widely-distributed substances—starch, sugar, and gum—are apparently so very diverse in their external characters and general properties, they have very close chemical relation. Indeed, so closely are they associated that they are daily and hourly converted in the living plants, the one into the other, in the order in which we have placed them—viz., starch
sugar, gum. In the early stages of development, the major product is starch; but, as maturity approaches, this is gradually changed to sugar; and to gum when the period of decay ensues, or the starch at once passes into the state of gum. So in the malting of barley: the object there is to convert the starch into sugar; but if the process of germination be carried a little too far, the sugar begins to disappear, and is supplanted by gum. The prolonged cookery of any farinaceous substance has always this tendency; so that biscuits not unfrequently contain a portion of gum, difficult of digestion, with the starch which is capable of ready conversion into the material of the blood.

Silica.—The last secretion to which we shall now refer, is one of peculiar interest—viz., silica, or flint. This is a mineral substance; and, apart from vegetable structures, is so indestructible that the strongest chemical acid is required for its solution, and yet it has structures so delicate that a stem of wheat can dissolve it with facility. It is not pretended that vegetables have the power of producing flint, but only that they are enabled to dissolve it in their juices, when water and other fluids alone cannot dissolve it. This power seems to reside at the extremities of the rootlets, for it is impossible that flint could be taken into their delicate tissues until it has been dissolved. The sources of silica or flint, are—

1. The sand which is so largely met with in almost all kinds of soil, and which has the further valuable property of permitting the rain to percolate to the roots of the plant. Its composition is chiefly that of silica, as may be familiarly inferred from its essential presence in the manufacture of glass.

2. From the flint nodules which are found in the chalk formations, and which themselves are the productions of long-buried sponges, mosses, and minute animalcules.

3. From the skeletons of animalcules which still remain in the soil. These skeletons are composed of flint, as may be proved from their non-solubility in boiling nitric acid (Fig. 97). So numerous are they that Richmond, in Virginia, United States, is built upon a stratum eighteen feet deep, and upwards of thirty miles in length; a stratum representing an innumerable number of animalcules, when it is borne in mind that each animalcule is almost too small to be seen by the naked eye. Similar deposits also exist in the old world.

These skeletons are also found in other positions. Thus guano, a substance consisting of the excrements of birds, contains vast numbers, chiefly of three genera, Actinocyclus, Galtionella (Fig. 97), and Coscinodiscus. A powdery substance is known in Germany as Berg Mehl, or mountain meal, which is chiefly composed of them. This is the produce of the strata through which the mountain torrents run, and is brought down by the waters. From its resemblance to flour, it is used in certain localities as an article of diet.

4. From the remains of plants in the form of manure or otherwise, which contain silica; as, for example, the wheat straw.

Fig. 97.—Silicious skeletons of the Diatomacea, which have been boiled in nitric acid. A, Navicula grandis. B, Campylopodia epypeus, both found in guano. C and D, Galtionella sulcata, both from the silicious soil in Virginia, U. S.
The vegetable secretion of silica.

The parts of plants in which the silica is chiefly found, are the external layers of the cuticle, as in the shining straws of our corn fields, and the canes and bamboos of hotter climates; and certain rough straws, as that of the Equisetum hyemale, which is so rough as to be used in the polishing of metals. It is also found in the interior of the joints of certain bamboos, and then is termed tabasheer, and from its rarity commands a high price. It is also found in the hard grains themselves, as of wheat and oats, and more particularly of the rice; from which cause the Caribs, the Malays, the South Australians, and other savage nations have their teeth ground down by the trituration of the uncooked grain.

The layer is exceedingly thin, but yet it is one of pure flint, as may be proved by its non-solubility in boiling nitric acid. It overlays the vegetable tissue, and assumes its form, and therefore varies greatly in appearance, according to the object examined.

In Fig. 98 we have an illustration of its appearance in the common wheat. From this silex the flinty hairs of the oat are formed; and it is well known that animals living much on oats are liable to intestinal accumulations of these indigestible hairs; and in a lesser degree men eating oatmeal are liable to a like inconvenience.

The common meadow grass (Festuca pratensis, Fig. 100), presents a silicious coating of considerable beauty.

The most beautiful examples are the Equisetum Hyemale, the Pharus Cristatus (Fig. 101), the common rice (Oryza sativa), and the stellate hairs of the Deutzia scabra (Fig. 102).

It must be clearly understood that this substance constitutes no part of vegetable structure, neither does it assume any form of organization, its sole and most important duty being to give strength to the slender stem, and to protect the delicate tissues from atmospheric influences.

That the quantity required to supply the wants of a field of corn is very considerable, may be proved from the following table; and the more
so, when it is remembered that the layer is so thin that it cannot be removed without detaching also a portion of the vegetable tissue.

Proportion of Silica, or flint, in 1000 parts of the ashes left after burning the following vegetable substances.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat straw</td>
<td>45·</td>
</tr>
<tr>
<td>Barley</td>
<td>38·5</td>
</tr>
<tr>
<td>Wheat</td>
<td>28·7</td>
</tr>
<tr>
<td>Indian corn</td>
<td>27·</td>
</tr>
<tr>
<td>Oak leaves</td>
<td>15·</td>
</tr>
<tr>
<td>Ferns</td>
<td>10·4</td>
</tr>
<tr>
<td>Pea straw</td>
<td>10·</td>
</tr>
<tr>
<td>Potato tops</td>
<td>8·</td>
</tr>
<tr>
<td>Heath</td>
<td>5·8</td>
</tr>
<tr>
<td>Beans</td>
<td>2·2</td>
</tr>
<tr>
<td>Bean straw</td>
<td>2·</td>
</tr>
<tr>
<td>Cabbage</td>
<td>2·1</td>
</tr>
<tr>
<td>Buck wheat</td>
<td>1·0</td>
</tr>
</tbody>
</table>

This subject has an important bearing upon the rotation of crops, for it is manifest that if successive crops of corn, and especially of oats, be obtained from the same land, there must be an enormous expenditure of this necessary article; but that a much less quantity suffices, if potatoes, pease, beans, or cabbage be given as intermediate crops. So, also, with regard to manures. It is clear that a manure must not only contain the carbon which forms the straw, and the salts which are always found with it, but there must be a constant and abundant supply of silica. This is effected by using corn, and especially oat straw, as manure, and also by the use of guano, which contains a large per centage of silicious skeletons.

THE ORGANS OF PLANTS.

Having now considered, in such detail as our space has permitted, the various elementary tissues which have been discovered in vegetables, and the juices and secretions which they contain, we proceed to describe the parts or organs which are formed by their combination. Such are the leaves, flowers, and fruit, and the structures which support them.

The modes in which we might proceed are numerous, and partly arbitrary, varying with the fancy of each author; for no one arrangement of the organs of plants is found in Nature which is acknowledged by all investigators to be more natural than any other.

The nearest approach to Nature will be found in proceeding either centripetally or centrifugally: that is, either first to describe the seed, and thence pass to the centre of the stem, through the fruit, flowers, leaves, and other appendages to the stem; or to commence at the stem and roots, and then clothe these organs with leaves, flowers, and fruit, in the order which nature has selected. Of these two we prefer the latter course, and shall proceed to describe the stem, with its root, and the various organs supported by them.
The Stem.—In all flowering plants the stem proceeds from the seed and that part of it termed the plumule; whilst, at the same time, the root is developed from another part of the same seed—viz., the radicle. These two newly-formed organs thence assume diverse directions, the root passing downwards to fix the plant firmly to the earth, and to abstract nutriment from the ground; whilst the stem usually emerges from the soil, and grows in a perpendicular direction, so as to bear the leaves and other organs of growth and reproduction from the ground, and expose them freely to the action of the light, air, and moisture. The point in the seed whence the stem and root diverge is known as the collum or neck (Fig. 100 b), and even in trees which attain to a considerable size this line remains more or less distinct.

When the seed has begun to germinate, and the growing points just referred to have lengthened, the other parts of the seed—viz., the cotyledons, or seed-leaves, enlarge, and take on the function of nutrition by converting the starch contained within them into sugar. At length, by their elongation, they emerge from the soil, and appear as two opposite roundish leaves, which are capable of absorbing oxygen from the air, and fixing carbon within the tissues which are then in process of formation. At this stage, then, we find a root, stem, collum, and seed-leaves, all of which are represented in Fig. 103.

The current of sap having been set in motion by the action of the cotyledons, or seed-leaves, the latter disappears, and the plumule, or young stem, continues to elongate rapidly, and until it arrives at the point whence its first leaf is to issue, is technically termed a node. At this point the stem swells, and the structures of which it is composed are bent out of their former direction, and, in part, enter within the structure of the newly-developed leaf. The stem may now fairly take on the term of ascending axis; which is usually given to it, since it has begun to develop the organs which are subsequently to be arranged around it as their centre. It has also received a variety of other names, which it may be useful to mention—viz., the caudex intermedius and ascendens, truncus or truncus ascendens, with culmus and stipes. All these have a similar signification.

The growth is not arrested by the development of a node and leaf, but proceeds for a certain period, until another leaf and node are formed; and so on progressively until the period of growth has passed away. We have then a series of nodes and spaces between them, which spaces are termed internodes. A stem may thus be said to consist of a number of nodes, with their internodes.

Nodes.—These are well seen in all grasses, as the ordinary grass of this country; with wheat, oats, and other grasses; and more particularly in the bamboos and canes of southern climes. It is there found as a distinct bulging around the stem, of a hard and rounded character, and oftentimes bending the stem from the perpendicular direction. In wooded plants, or trees, in general, it is less per-
ceptible, since the small swelling at the base of the single leaf which is there developed, bears but little proportion to the size of the trunk of the tree.

The essential difference in structure between a node and an internode is, that the bundles of wood are compressed and turned aside in the former, so as to enter the leaf, and thus a slight interruption to the course of the general circulation ensues; whilst, in the internode, the bundles of woody fibre pass perpendicularly, and lie parallel to each other. In some instances, as in the grasses with hollow stems above mentioned, this compression or contraction of parts is so great, that a septum is formed across the stem, dividing it into two or more cavities. This may readily be seen on making a perpendicular section of a stalk of wheat, or of the bamboo, and with the septum of the latter may sometimes be found the flinty deposit before mentioned, under the term of tubassher. They are then said to be closed, in opposition to the pervious or open condition, found when the pith passes through it.

When the node surrounds the stem, as in the grasses and the hemlock, it is designated as entire; and when otherwise, as in trees, it is termed divided.

As the essential element of a node is a new disposition of the woody and other tissues, to meet the requirements of a leaf, it is manifest that wherever a node exists there must be, or have been, a leaf, perfectly or incompletely developed. In many instances the growing process ends after the formation of a node and before the entire development of a leaf; and then will be formed a leaf-bud, immediately above the base of a leaf. When such leaf-bud is evident, the node is termed compound; and when otherwise it is called simple.

So far this account may suffice for both herbaceous and woody stems, but it is needful here to interrupt our description, and consider herbaceous and woody stems separately. This results from the great difference which is observed in the structure, as well as in the degree of delicacy of organization of the two kinds of stems.

**Stems of Herbaceous Plants.**—Herbaceous plants are, for the most part, annuals—that is, such as are produced and die in the same season. It is, therefore, not
necessary that they should possess the rudeness and strength of texture which appropriately belong to plants that have to combat the power of the elements through a long series of years.

The stem, for the most part, is small, seldom attaining to a greater diameter than one and a-half inch; and, with the exception of twining plants, and such grasses as the bamboo, do not exceed six feet in height. The structure is delicate, being composed of cellular tissue of a somewhat loose kind, with bundles of woody fibre running at intervals from the root upwards. They are thus but ill-fitted to resist the influence of strong winds, or the destructive propensities of animals. There are, however, some circumstances which tend to increase their strength. Such are—first, the cylindrical form of the stem; secondly, the hollowness of the stem; and, thirdly, the inclosure of the stem by a tough cuticle or bark, and, in some instances, a further layer of silica or flint. That the cylindrical form is stronger than any other is well known; but it may not be so commonly understood that a hollow cylinder, with moderately thick walls, is stronger than a solid rod of the same material. Thus that vacuity, which at first sight is indicative of weakness, is really fitted to impart increased strength. The cause of the hollowness is the more rapid development of the perpendicular than the horizontal layers of the stem.

The stem of an herbaceous plant thus consists of three parts:—a central pith, which is frequently wanting; an external envelope or skin; and an internal mass of cellular tissue and woody fibre. The pith is composed of cellular tissue, of the hexagonal or octagonal form. The woody fibre of the stem is not found in even layers, but in bundles lying detached from each other, as may be readily seen by tearing a stem across, when the bundles of tough fibres will be stretched, and project somewhat from the broken surface. It may also be seen through the cuticle of the common parsley, in ribs passing in parallel lines from the root upwards into the leaves. Each bundle is usually inclosed in a mass of cellular tissue, to which it gives firmness.

Cuticle.—The cuticle of herbs is an interesting structure, and the seat of a large part of the respiration and digestion which proceeds in those plants. It consists of two layers—an epidermis or scarf-skin, and a true skin, with certain appendages—viz., stomata, hairs, prickles, warts, and reservoirs of secretions.

The Epidermis is a layer of inspissated organic mucus, which sometimes may be readily detached from the cuticle, as in the common box-leaf, but at others requires maceration in water for some time before its existence can be demonstrated. It covers all the external surface of the plant, except the stomata and the free end of the stigma, and it even forms a covering for the hairs. Mohl considers it to be a secretion poured out from the external surface of the cells, the walls of the cells themselves being at the same time thickened by internal deposits. It is not a cellular structure, although, when removed from the surface of the cuticle, it has a cellular outline; but is a simple layer, with markings corresponding to
the cell-walls over which it is placed. Hartig has divided it into three layers—an internal, an external, and an intermediate layer; but such is not the experience of other observers. Its use is to protect the delicate structures lying beneath it, and is analogous to the scarf-skin which protects the skin of man.

The True Cuticle is composed of one or more layers of cells, the outer one being much flattened (Fig. 106 a). The cells are mostly of hexagonal figure and wavy outline. Some anatomists have denied the cellular nature of this structure, on the grounds that the cells are not demonstrable, and that the skin may readily be peeled from the subjacent tissue; but this theory is not usually admitted. Moreover, in the cactuses and orchids, and also in the Nerium Oleander, there are several layers of cuticular cells, the whole of which may be demonstrated (Figs. 106 d, and 110).

Whenever any shred of cutis is removed from the stem of a herb, some portions of woody fibre are removed with it, so that it may be questioned if woody tissue is not a component of the skin; but it is perhaps more correct to associate the wood with the structures immediately beneath the skin rather than with the cellular skin itself.

Stomata (Fig. 107) are mouths by which respiration and exhalation are carried on in vegetables. They constitute openings into and channels through the epidermis, and lead into cavities beneath (Fig. 108, A). Their structure is somewhat complicated, since, for the most part, there are a series of rounded cells bounding the opening, with two larger kidney-shaped cells in the centre, pressing closely against each other when the stoma is closed, and cemented to the surrounding cells by something in the nature of a hinge, which permits them to rise and fall with considerable force (Fig. 108, C a). In the centre of the stomate there is a raised line when it is closed, and a slit when it is open (Fig. 108, C c); and through this opening an entrance is effected to the cavity beneath (Fig. 108, A c). This cavity varies in figure and form; but it is always surrounded by cells, which communicate freely with other cells of the epidermis (Fig. 108, A). It is thus that air and moisture, having entered by the stomata, act not only in the cavity beneath that organ, but in the surrounding open cellular net-work of the leaves or cuticle.

Such is a general description of the stomata; and before entering further into detail we will request our readers to verify the above account by an examination of these structures. Take a very thin slice from the under surface of a leaf or flower of any plant, as of the lily (Fig. 109, A), the Zea Mays (Fig. 109, B), or the common geranium; or strip a thin piece of the cuticle of a herb, as of the parsley, and place it in water between two pieces of glass, and examine it with the microscope. First examine the outer surface, on which may be seen the cells and slit referred to, and then turn over
the object, and carefully notice the cavity into which the slit is directed. The minute and regular arrangement of the various parts of each stomate, and of all the stomata on

![Stomata Diagram](image)

**Fig. 109.**—View of ordinary stomata, as seen between the veins of the leaf of the Lily, *A*, or, *Zea Mays*, *B*, both endogenous plants, and of an exogenous plant at *C*.

Their regularity in figure and position, and the uniformly oval outline, will be observed.

the cuticle, will excite admiration; and the more so when, on examining a variety of plants, the little organ is found very variously figured.

The general outline of the stomate is commonly circular or oval; but in the flax plant, the *Agave Americana* (Fig. 61), and a somewhat similar one, the *Yucca gloriosa*, it is quadrangular. In *Marchantia* they resemble funnels, and are composed of several cells arranged in tiers, and forming tubes, which perforate the epidermis, and terminate in the cavity beneath. In the oleander (*Nerium Oleander*) the cells have disappeared, and the cavity is simply protected by hairs. This may readily be seen, if a portion of the leaf be placed under the microscope, as above directed. The *Myrodenron*, *punctulatum*, growing on trees in the antarctic regions, has a remarkable modification of the stomata. Dr. Hooker states that the stomate expands on both sides into a kind of cup—a condition which results from the hour-glass construction which is met with at the aperture.

But whatever may be the figure of the organ it is so uniform in the same species that certain botanists, as Brown, are of opinion that they might be made a basis of classification. This, however, would be very difficult, on account of their minute size and the necessity for the constant use of the microscope; and further, from the fact that a few plants present more than one form of stomate. Thus, in the *Nepenthes* or pitcher plant, there are two forms of stomata, one being semi-transparent and nearly colourless, of an oblong figure, and with pellucid globules within the cells whilst the other is roundish, red, and more opaque, and rests not over a cavity, but upon a gland.

It is proper to state that certain observers of eminence have denied the accuracy of the above statement, as to the construction of stomata, and have affirmed that they do not lead into a subjacent cavity, and consequently have no opening at the slit. Some German anatomists have affirmed that the supposed opening is simply a thinner translucent portion of the membrane, and that the slit is the thickened border of this space. Brown believed them to be usually imperforate, and to be formed by an opaque and sometimes coloured membrane. Such, however, is not the opinion commonly entertained; and we may confidently appeal to the investigations of our readers to refute it.

Stomata are not found upon all plants, the exceptions being such as are submersed
in water, or grow in darkness, and also the lowest classes of plants, as mushrooms, seaweeds, and lichens, except mosses. Neither are they found upon all parts of any plant, but are absent from the roots and ribs of leaves. They are most abundantly found on

the under surface of such leaves as present one surface to the soil (Fig. 106), but on both surfaces equally, if the edges only be directed vertically. They are also met with on the cuticle of stems, on flowers, and even on the seeds of a few plants, and on their cotyledons.

The number of stomata found upon a moderate-sized leaf is sometimes prodigious, amounting in some instances to 160,000 on each square inch of surface. Thomson gives the following enumeration, which shows not only the total number but the relative quantity on the two surfaces of the leaf:

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Upper Side</th>
<th>Lower Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alisma Plantago (Water plantain)</td>
<td>12,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Cobea scandens</td>
<td>none</td>
<td>20,000</td>
</tr>
<tr>
<td>Dianthus Caryophyllus (Pink)</td>
<td>38,500</td>
<td>38,500</td>
</tr>
<tr>
<td>Daphne Mezereum (Mezereum)</td>
<td>none</td>
<td>4,000</td>
</tr>
<tr>
<td>Hypericum Grandiflorum (St. John's Wort)</td>
<td>none</td>
<td>47,800</td>
</tr>
<tr>
<td>Ilex (Holly)</td>
<td>none</td>
<td>63,600</td>
</tr>
<tr>
<td>Iris Germanica (Iris)</td>
<td>11,572</td>
<td>11,572</td>
</tr>
<tr>
<td>Olea Europaea (Olive)</td>
<td>none</td>
<td>57,600</td>
</tr>
<tr>
<td>Paeonia (Peony)</td>
<td>none</td>
<td>13,790</td>
</tr>
<tr>
<td>Pyrus (Pear)</td>
<td>none</td>
<td>24,600</td>
</tr>
<tr>
<td>Rumex Acetosa (common Sorrel)</td>
<td>11,088</td>
<td>20,600</td>
</tr>
<tr>
<td>Tussilago Farfara (Coltsfoot)</td>
<td>1,200</td>
<td>12,500</td>
</tr>
<tr>
<td>Vitis vinifera (Vine)</td>
<td>none</td>
<td>13,600</td>
</tr>
<tr>
<td>Viscum album (Mistletoe)</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Syringa vulgaris</td>
<td>none</td>
<td>160,600</td>
</tr>
</tbody>
</table>

Of 28 plants in this table which had been examined, 15, or more than half, had no
stomata on the upper surface; 6 had fewer stomata on the upper than on the under surface; and 5 had an equal number on both surfaces,—leaving only two instances in which the number was greater on the upper than on the under surface of the leaf.

The number and position of the stomata must have an immediate reference to their function. It is commonly understood, as has already been intimated, that the function is that of admitting air and moisture to promote the digestion of the crude sap which had been brought to the leaves, and that for this purpose they are endowed with the faculty of opening and closing according to the momentary requirements of the plant. This will explain the necessity for their conformation. As to their position, that seems to be due to several causes. First, that by being placed on the under surface they are shaded from the direct action of the sun's rays, and are thus permitted to carry on their functions without being impeded by too great a degree of evaporation. Secondly, they are also more sheltered from the injurious deposition of dust. Thirdly, the exhalation of moisture from the ground is in the form of vapour, which, from its specific gravity, rises, and thus reaches and enters the under surface more certainly than the upper surface. It is not presumed that in any case water enters the stomates as such, but only in the state of vapour; for although plants are refreshed after a shower, it does not follow that the rain was bodily introduced within them; and it seems inconceivable that bodies of so minute a size should at the same time be fitted for the admission of gases, and of fluids of such density as water.

There are those, however, who maintain that such is not the function of the stomata, but that they are in the nature of glands. Link says that he cannot find a distinct connexion between the stomata and the subjacent cavities in the cellular tissue of the leaves. Moreover, he cannot understand how organs of so distinct a structure should only lead to mere cavities in the cellular structure; and the obstructing and covering matters which they produce have always led him to consider them as organs of secretion. Brown also affirms that they are rather of the nature of glands; but there cannot be a doubt that in the vast majority of instances this view is incorrect. It is true that in a few instances the stomata are modified both in figure and in function to perform the office of glands. Such 'is the case in the Dionæa Muscipula, or Venus' fly-trap (Fig. 1), in which the stomata are reduced each to a pair of parallel green cells, which are placed upon the surface of the leaf, and secrete a tenacious mucus; but such are exceptional cases.

It would be interesting if we could determine with certainty the precise mode in which these beautiful organs are formed; but such seems hitherto to have been a hopeless task. Mohl sought to determine it by examining the different parts of a growing hyacinth, in the expectation that the parts of the leaf, which are successively developed from above downwards, would have stomata of various degrees of perfection. He noticed that in the lower part of the leaves, or that most recently developed, small quadrangular cells, with a slit of about equal diameter either way, were placed between the layers of the epidermis. These sometimes contained a granular substance, which, higher up in the leaf, became a compact mass. At the same period a partition was formed in the middle of the cell, at first slightly, but subsequently more strongly marked, and at length unfolded, so that the simple cell became divided, and a stomate was formed. After this the surrounding cells enlarged, and the central slit increased at a still greater rate. All this and the subsequent completion of the stomate may be observed by any of our readers who may have a tolerable microscope, and will obtain by practice a certain delicacy in cutting minute structures.
Hairs are minute, semi-transparent, transparent, or opaque thread-like processes, attached to the cuticle by one extremity, and remaining free at the other (Fig. 112). They are always of a cellular character, the cells, if more than one, being larger and more numerous at the bottom, and then piled one upon the other, and laid in one or more rows, until the apex is attained, with its single elongated, rounded, or pointed cell. The figure and minute anatomical characters vary considerably, so that the above general description may require modification when applied to individual instances. Thus the hairs of certain plants are attached by their middle, and have both ends free. Such are those of Indigofera, Capsella, and Astragalus asper; but in order to bring these within the definition above-mentioned, it is customary to assert that it is not one single hair attached by its middle, but two hairs springing from the opposite sides of an elevated cell. Such, doubtless, is the correct explanation of hairs which assume a stellate or star-like form, and which are really clusters of hairs attached each by one extremity. This variety is met with readily on the leaves of the Mallows, in which, with the assistance of a small hand magnifier, the stars may be perceived. The most beautiful illustration, however, is that of the hairs of the Deutzia scabra and corymbosa (Fig. 102), and the Eleagnus, which, as has already been demonstrated, are coated with a layer of silica or flint. They are very resplendent when viewed with the light thrown upon, and not through them—that is, as opaque objects, and may aptly be compared to the jewelled star of the Most Noble Order of the Garter.

Certain hairs are bent at the points of articulation of the cells, whilst others have their points only thus distorted. This latter variety is seen familiarly in the common teasel (Dipsacus), and has been used with much sagacity by cloth-workers, for the purpose of raising the nap of the cloth. The extremity is hooked, and by that means adheres to an object with great pertinacity, as any one may prove by placing the fruit of the teasel in his hair (Fig. 113).

Another and very interesting modification is that in which the hair consists of a single cell, but having an elastic spiral fibre coiled up within it. Such hairs are almost imperceptible, so long as they remain dry; but elongate and expand, sometimes with a crackling
sound, on their immersion in water. They are found in the common mustard \((Sinapis)\), which any one may examine after immersion for three hours, and have the form of an elongated cell, terminated by a bell-shaped expansion. In the seed-covering of the Collomia grandiflora and common sage \((Salvia)\), each hair is simply an elongated cell of even diameter, terminated by a rounded obtuse end, and with a single coiled elastic fibre proceeding from the base to the apex. This is an interesting object, but requires considerable dexterity and quickness to see it with advantage. Slice the smallest portion of the outside of the common sage, and place it dry between two glasses under the microscope. No hairs will then be perceived; but if, whilst it is so placed, and the eye is upon it, a drop of water be insinuated between the glasses, until it touch the seed, there will instantly start out scores of long fibro-cellular hairs; and as the complete development occupies a perceptible interval of time, the eye may readily trace the process of elongation. When the change has been entirely effected, the object has no longer a defined smooth border, but is bounded all round by thread-like projecting points. A similar structure has been discovered in the hairs of the seed of Acanthodium, but with this difference, that two or three spiral fibres have been traced in one cell; and in some instances the fibres are broken up into numerous rings. This is doubtless a beautiful object.

All the foregoing varieties of hairs may be termed single, but there are others which may fitly be designated as compound. Such are \textit{toothed} hairs, in which there are short cellular projections on both sides of the hair; and \textit{branched} hairs when the teeth are greatly elongated \((\text{Fig. 112a})\). In a few instances this development is carried yet further, and the branches themselves are toothed, and the hair is said to be \textit{plumose}. In others, the branches are restricted to one side of the hair, when the latter is termed \textit{one-sided}.

But perhaps the most interesting circumstance in connexion with the anatomy of hairs, is, that in some plants, as the Sago-palm \((Cycas revoluta—\text{Fig. 114})\), the cuticle of the hair can be unrolled spirally. Professor Quekett has described this upon the fruit of that plant, and has delineated it in \text{Fig. 114}.

The foregoing remarks have exclusive reference to one great division of hairs—\textit{viz.}, the Lymphatic, or such as bear innocuous fluids; but there is another large division which have a different conformation, and contain juices of highly acrid and poisonous properties. The sting of the nettle \((Urtica)\) is a familiar and painful illustration, but the hairs of the leaves of certain tropical plants are yet better examples. These contain juices so poisonous, that if the hand grasp a leaf, it speedily inflames and swells, and so disturbs the whole system, that life is endangered. Such is the Jatropha when growing in our hot-houses even, and is handled only with the protection of a pair of thick leathern gloves. Moreover, if any part of the body be placed under this tree during a shower of rain, the poison which is washed from the plant by the water would, in like manner, cause very serious disease.

The anatomical difference between the lymphatic and secretive variety of hairs is, that
in the latter there is a bulging at the free end (Fig. 112, b), or immediately below the hard sharp-pointed apex (Fig. 112, e), which communicates with the other cells of the hair, or at the base of the hair, and contains a poisonous juice. Whenever such a hair is seized the sharp point enters the skin, and the end breaks off immediately below the point, and the contained fluid is emitted with a great impetus into the wound produced by the puncture. The juice in the perfect hair is maintained at a high state of tension, so that it may be emitted with violence, after the fashion of the poison in the poison-fangs of the serpent.

It will be inferred, from these remarks, that there must be a circulation of the sap in all kinds of hairs. Such is the case; and the circulation proceeds in currents from the base to the apex of the leaf and back again (Fig. 115, B). It may be seen proceeding under the microscope in the *Tradescentia virginica*, and appears to proceed between an internal and an external wall of tissue. At a certain period, a cytoblast (page 9) may be detected, and then the current appears to proceed from and return to it. When the hair has emitted its contents it shrivels, and in some instances (Fig. 116) retracts like the parts of a pocket-telecope.

Hairs are not found upon roots, nor upon any part of the plant which is buried in the ground or covered by water; and whenever they appear on one side of a leaf only, it is, with few exceptions, on the under side. When a portion only of any surface is covered by them, it is uniformly the ribs or veins. They are sometimes found within the cells of water plants, as of the white and yellow water-lilies, *Nymphaeas alba* and *Nuphor luteum*. Their functions appear to be that of promoting perspiration and of absorbing moisture, independently of that of secreting fluids.

Hairy surfaces have received various names, according to the nature of the hairs which cover them, as rough, silky, arachnoid (resembling a cobweb), stellate, bearded. The hairs themselves are also variously designated; thus, stings when they emit an acrid juice, and glandular hairs when the end is tipped with a fluid exudation (Fig. 112 b). Hooks, barbs, bristles, and velvet are terms which explain themselves. Cilia are long and sparse hairs, arranged in a row on the margin, as in the horse-leaf, *Sempervirium tectorum*. Hairiness expresses a form of hair of a rather long and soft character, as seen in the common hemp nettle (*Galeopsis tetrahit*); pilosity, when the hairs are longer and more erect, as in the carrot (*Daucus carota*); and villous, when very long, straight, erect, and soft, as in the *Epilobium*. The term tomentum expresses a mass of hairs entangled and closely pressed to the skin, as in the *Geranium rotundifolium*. The longest hairs are probably those which envelop the cotton seed (*Cossypium*, Fig. 62, B), and constitute the cotton of commerce. They are also very long on seeds of the cotton tree,
and in the willows of our own country. On ferns they are scattered, long, brown, and entangled.

Fig. 116. Fig. 117.

Fig. 116.—Two hairs from the style of a Campanula, showing in \( a \) the circulation proceeding, and in \( b \) emptied of its contents. The latter is not only collapsed, but retracted within itself.

Fig. 117.—Representing the mode of growth of hairs from a single epidermal cell; \( a \), club-shaped; \( b \), pointed. Both from the Evening Primrose (\( \text{Anothera} \)).

The development of hairs appears to be usually a very simple process, being none other than the inordinate growth of a cell of the cuticle on its free surface. Such is figured by Schleiden (Fig. 117).

Prickles are hard unyielding processes, with an acute and usually slightly curved extremity, well fitted to hold and tear any object which may be carried against them. They are very common in the rose (\( \text{Rosa} \)), and Bramble (\( \text{Rubus} \)), in which plants they are the growth of a single year. In other plants, as the Xanthoxylum juglandisfolium, they are the result of two or three years' growth. They are essentially allied to hairs, since they are cellular prolongations of the cuticle, but differ greatly from them in their far greater development, the rudeness of their texture, and the functions which they perform. They have also a less real but a greater apparent resemblance to spines, as of the sloe tree (\( \text{Prunus spinosa} \)), inasmuch as both are large and rude, and sharply pointed; but there is this essential dissimilarity—viz., that the spine is a prolongation of the wood of the tree (in other words, an abortive branch), whilst the latter is simply connected with the cuticle or the epiphloem of the bark of herbaceous shrubs. Their use is not well known; but they are not depositories or secretions, neither have they any independent circulation. They are well adapted to enable the long and slender branch to support itself by attachment to stronger plants, and also (if we may apply such an expression to a mere vegetable), to enable it to defend itself from the attacks of animals. They may be detached from the cutis by the force of the thumb and finger.

Scurf has been regarded as a production analogous to hairs, inasmuch as it is a cellular structure and is a process from the cutis. There, however, the analogy ends, and it fails in the most essential point—viz., a similarity in function. It consists of scales of various forms and sizes, adhering to the cutis by the whole or only a part of
the surface; and when by a part only, it is the central portion; and the edges become irregular in outline and crenate. This latter peculiarity has induced a belief in the mind of an acute observer, Dr. Willshire, that the crenate scale in the _Adenia_ and the _Eleagnus_ marks a transition from the simple scale to the beautiful stellate hairs of which we have just spoken, p. 65. Scurf is commonly met with in plants, and gives a spotted or leprous appearance to the cutis, as may be seen in the pine apple.

**Ramenta** are thin scales abundantly found on the backs of the leaves of ferns (_filices_), and on the young shoots of many plants. They are slightly foliaceous in their appearance, and not unlike the leaves of some mosses; but they want the structure, the position, and the leaf-buds of true leaves. Their function, as well as that of scurf, is unknown.

**Glands.**—We have now to consider a series of organs about which there has been much controversy—one party regarding them as reservoirs of secretions and true secreting organs; and another (represented by M. Schleiden), doubting if such organs can be found in vegetables. M. Schleiden writes: "I have already remarked that I can connect no precise and definite idea with the term gland, as referred to a plant. No attentive observer can avoid seeing how different is life in different cells, whether they are found in different plants or in the same plant, or near each other. It appears to me quite foolish to denominate that cell or that group of cells which contains different matter from its neighbours a gland or organ for secretions; for there are many plants and parts of plants which would then consist only of glands. It is ridiculous to call a cell containing volatile oil a gland, and to refuse the name to one that contains red or yellow colouring matter; and should we call the last glands, then almost all petals would consist only of glands. The epidermis would be sometimes an epidermis, but sometimes a glandular surface, and with many single cells we should have to admit they are partially glands and partially not so."

The force of this reasoning will be perceived when we remember that all cells have contents, and that these contents have been secreted or produced within the same cell. Each cell is therefore both a secreting and a containing organ. Again, there is no anatomical structure in vegetables which is peculiar to these organs called glands, as distinct from mere ordinary cells of cellular tissue. In animals, on the contrary, there is in most instances a special glandular structure, and beyond this there is a series of cells called epithelium, to which is confided the duty of producing the larger part of the secretions of the body. These latter offer the nearest points of analogy to the glandular structures of vegetables.

But whilst admitting that there is a difficulty in defining a gland, there cannot be a doubt as to the existence of certain small hardened masses of cells, which perform the office of glands. Thus the nectarium, on the claw of the petal of the common Ranunculus, secretes a sweet honey-like substance, and is a true gland. So, also, with the glands situate beneath the cuticle, also the base of the pitchers of the Nepenthes and other pitcher plants. These pitchers contain a considerable quantity of water, not from having collected it from the air, but from the action of the glands referred to. In the latter instance there is a broad line of distinction between such bodies or glands and that of an ordinary secreting cell; for whilst in the latter case the secreted matter is retained within the cell, and the quantity corresponds with the size of the cell, in the former the secretion is altogether emitted from the gland, and its quantity is infinitely greater than the size of the organ which produced it. The subject is, however, involved in great obscurity, and it is probable that ere long it will be necessary to exclude such
cellular organs as the lenticular glands of the willow, and to include such reservoirs as the vittae or receptacles of the volatile oils of plants.

Glands are sessile or sitting when resting immediately upon the cutis, as may be seen near the base of the ovary or seed-vessel of such pod-bearing plants as the Cruciferae. They are also found upon the calyx of some campanulas, and upon the petiole or foot-stalk of the leaves of the peach, the cassias, and the passion flower. Their forms, colour, and appearance are very various, and of many it may be doubted if they are true glands.

Stalked glands (Fig. 118), are such as are elevated from the cuticle by something in the nature of a hair, and are simple if they consist of one or perhaps more cells and have a stalk of but one conduit, and compound where there are several cells and several conduits. This division of glands has been termed indifferently stalked glands or glandular hairs. They are common in the rose and brambles, the Hypericums, the Rue, the Tatropha, the Snapdragon (Antirrhinum), the Lysimachis, the Drosera or sun-dew, and many other plants. In the sun-dew the hair of the leaf has an internal fibre, and is therefore a fibre cell; and the gland head consists of several layers of cells, the outer ones being small and cuticular, whilst the inner ones are long and columnar, and sometimes contain a spinal fibre.

Before proceeding to a consideration of the stems of wooded plants we will direct attention to two modifications which are met with, not exclusively, but chiefly, in herbaceous plants—viz., first an enlargement of that part which is under ground, and which lies between the roots or rootlets below, and the true stem above; and secondly, such stems as take a horizontal rather than a perpendicular course above ground. These are termed respectively subterranean and aerial stems.

Subterranean stems, as the potato, onion, and turnip, include almost all the receptacles of starch, except seeds, provided for the use of man. There can be no doubt as to their analogies, seeing that they do not possess the anatomical and physiological properties of roots, and do, notwithstanding their deformity, resemble stems. They are commonly arranged under four heads—the bulb, corm, tuber, and creeping stem.

The creeping stem (sboles), unlike the others is unimportant as an article of food, but yet is of great value from the property which it has of insinuating itself rapidly amongst the sandy particles of loose soils, and binding them together. It may thus lay the foundation of hills of sand which shall suffice to resist the encroachments of the sea. It is represented by the couch grass (Triticum repens), the bane of farmers, not only from the property above mentioned, but from the rapidity with which it multiplies itself whenever the stem is broken by the farmers' efforts to clear the land.

The tuber or potato is an irregularly ovoid enlargement of the stem, having upon its surface a number of growing points, familiarly termed eyes. The tubers of the same plant are all connected together and to the parent stem by single bands of small diameter, consisting chiefly of woody fibre for the purposes of the
circulation of the plant. The precise mode in which the tuber enlarges is unknown but it is quite clear that it must be freely supplied with circulating juices from the stem. This is effected by the woody fibre, and bundles of it ramify within the tuber, and pass to each growing point.

The structure of the tuber is very simple, being only a large mass of cells containing starch, inclosed in a layer of condensed cells or cuticle. The woody fibre and other structures bear no proportion whatever to the cellular tissue, and are not readily detached. The cellular character is at once evident by placing a very thin slice of it under the microscope, when a number of straight lines will be observed forming cells of much regularity, and inclosing a large number of starch cells (Fig. 83). The starch may be demonstrated by the addition of a watery solution of iodine whilst the section is under examination, when a beautiful violet colour will be instantaneously produced.

This form of stem is also found in arrow-root, and has a more regular figure in the asparagus potato.

The Corm, as in the crocus, colchicum, and arum (Fig. 119), is a rounded, flattened, solid organ, bearing a bud upon its point or at its side, and leaves from its upper part. It is a compressed stem, and is restricted to monocotyledonous plants, and intervenes between the true roots and the reproductive buds. It usually contains much starch, accompanied by an acrid poisonous secretion, which militates against its employment as an article of food.

The bulb, as of the onion and lily, is also an underground stem, or a stem in the rudimentary state of a leaf-bud. It is a fleshy, conical body, with scales surrounding
Aerial Stems.

A growing point, and emitting roots from its base, and thus theoretically resembles the leaf-bud of an aerial stem. It reproduces itself by developing buds, or cloves, at the base of its leaves or scales, which buds grow at the expense of the parent plant, and at length destroy it. There are two kinds, according to the arrangement of the leaves: First, the tunicated (Fig. 120), when they more or less surround the whole organ, and cohere in a membranous sheet of tissue. Such is the case in the onion (Allium). Secondly, the naked, when the scales are smaller and more fleshy, and are imbricated in rows one above another, as in the tulip. Both of these forms contain much starch (Fig. 121).

Aerial Stems are of five kinds, the Sucker, the Vine, the Rootstock, the Runner, the Offset, and the Pseudo-bulbs of orchidaceous plants.

The Sucker is common in monocotyledonous plants, as the pine-apple, and consists of a branch proceeding from the col- lum of a plant underground, which becomes erect and bears leaves, and subsequently emits roots from its base. In other instances it proceeds from the stem downwards to the earth, and there takes root.

The Vine, as in the Vine (Vitis vinifera) and Cucumber (Cucumis), is a slender twining stem, which situates itself amongst and adheres to other plants for support. It does not give off roots along its course.

The Runner, on the other hand, is also a creeping stem; but it emits a bundle of...
roots and leaves at intervals, and, in fact, forms new plants (Fig. 122). Such is the Strawberry (*Fragaria*).

The Offset, as in the House-leek (*Sempervivum tectorum*), is a short branch terminated by a cluster of leaves, and capable of independent existence after separation from the parent plant.

The Rootstock, or rhizome, is a thickened rooting stem, as in the Ginger (Fig. 123), and Iris, which produce young branches or plants yearly.

The Pseudo-bulbs of orchadaceous plants (Fig. 124) very closely resemble tubers, except that they retain the marks of leaves which they once bore. They exist above ground, and contain amorphous starch.

**Woode Stems.**—Having now offered such remarks on herbaceous stems (distinguished from woody stems) as seemed to be required by their greater delicacy, we proceed to describe woody stems and their appendages. When treating of the modifications of herbaceous stems (page 59), we intimated that such changes also affected woody stems, but in a lesser degree, and shall therefore not again refer to them under this head.

There are, however, a few preliminary remarks which are necessary as to the general conformation of the tree before we enter upon an examination of the internal structure.

The general divisions of a stem are called branches (*rami*), and the arrangement of them as a whole is termed corona, a head, as that of a forest tree. (Figs. 125, 126.) When they proceed from either side of the stem, and then pass from the base to the apex of the tree, it is called a *caulis excurrens*, but when the stems break up into a mass of branches, it is known as a *caulis deliquescent*. Incompletely grown shoots are termed innovations, and ramuli, or twigs, when very young. If the shoot is long and flexible, it is called a vimen; and when it proceeds from the stem at nearly a
right angle, it is called brachiate. This arrangement of the branches is further used to distinguish trees, shrubs, and herbs. A tree (arbor) is composed of a trunk supporting perennial branches; and, when small, it is called arbusculus. A shrub differs from a tree in there being no central stem or trunk, but the branches proceed directly from the earth. This is called frutex, fruticulus when small, and dumosus when low. The undershrub (suffrutex) has the same arrangement of branches; but it approaches nearer to the herb, since it wholly or partially dies annually. It has, however, wooded branches, and not merely, or chiefly, cellular ones. The stem of a forest tree, and of any other which has not its growth terminated by a flower-bud, or any other organic cause, is said to be indeterminate, and determinate when otherwise.

Fig. 126.—Representing a variety of trees, all of exogenous growth.

The science of Botany is rich in descriptive terms; and although they may be disagreeable to a student, are very welcome to the botanist who would intelligibly describe a plant. We must therefore counsel our readers not to pass them hastily by, but to read them attentively, and, if possible, commit them to memory.

Woody Stems are divided into two great and well-defined classes, according to their internal conformation—viz., such as grow from without (exogenous), and such as enlarge from within (endogenous). The former are more common in cold, and the latter in hot climates. There are, however, the following points of resemblance:—Each has a
cellular basis through which the bundles of wood pass, and each is inclosed by a cuticle or bark (endogens are said to have no bark). The cellular system is horizontal, and constitutes the woof of the structure; whilst the vascular and woody system is longitudinal, and corresponds to the warp.

**Exogenous Stems.**—On examining a section of the stem of an oak, or any other of our forest trees (Fig. 127), we observe the following parts—first, the pith, *a*, or its remains, in the centre; secondly, the bark, *c*, on the outside; thirdly, a mass of wood, *b*, between the two, broken up into portions by the concentric deposition of its layers, and by a series of lines or rays, *e*, which pass from the centre to the circumference. Thus there are always pith, bark, wood, and medullary rays (Fig. 127). It has already been mentioned that each stem has two systems, the cellular and the vascular; and the parts just mentioned must belong to one or other of those systems. Thus the pith, medullary rays, and bark belong to the horizontal or cellular system, and the wood, with its associated ducts, constitutes the longitudinal or vascular system.

This division of stems comprehends nearly every wooded plant of our climate.

*The Pith* occupies the centre of the stem (Fig. 128, *a*), and remains throughout the period of growth of some trees, as of the elder (*Sambucus nigra*), or is absorbed after a few years, as in the oak and almost all large trees. In the latter class of plants there are some remains of the pith for many years after the process of absorption has commenced; but at length no vestige can be detected, and its position is known only by the central spot around which the wood is placed in circles. It is, however, at this period found in young shoots just as it was at the earliest moment of the formation of the plant (Fig. 129).

When it exists, it passes uninterruptedly from the root to the end of each branch and leaf-bud; but is sometimes thickened, and rendered more dense, as in the ash, at the nodes—the place, indeed, where all the structures are somewhat compressed.

Its structure is at all times cellular; and, for the most part, the cells are hexagonal in form, as shown in Fig. 11. The cells are commonly

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**Fig. 127.** A, transverse, and B perpendicular section of an exogenous stem, showing parts of which it is composed. *a*, the central pith; *b*, four layers of woody fibre; *c*, the cambium in the spring; *d*, the bark; *e*, the medullary rays.

**Fig. 128.** A scheme of the parts of an exogenous stem. *a*, the pith; *b*, the bark; *c*, medullary rays unifying the pith and the bark (greatly exaggerated); *d*, woody fibre.

**Fig. 129.** Section of young shoot of the Maple tree (*Acer campestre*), showing the large size of the pith, *a*; the bundles of wood of one year's growth, and the bark with its hairs.
of large size, and may be well examined in the pith of the elder. Their colour is green whilst they freely perform their function; but subsequently the tissue is nearly colourless. In the old age of the plant the pith often assumes a colour which it has obtained from the juices which have been deposited within it. In a majority of instances the pith forms a solid cylindrical mass; but in certain fast-growing plants, as in the hallow stems of the Umbelliferae, it is torn, and vacuities are left.

In a few plants the ruptured pith assumes a very regular form, and is thence termed chambered pith, since it is divided into a series of compartments which pass across the column in small stems. Such is the case in the walnut (Fig. 130), as may be readily seen by selecting a very young shoot and slicing away a portion of one or both sides. According to the researches of Professor Morrison this change depends upon the lateral elongation of the cells, and the consequent disappearance of the contents of the cells, and is induced immediately by the absorbing action of the leaf-bud.

The connexions of the pith are highly important, and demand special enumeration. It has already been intimated that it does not exist in the root, at least, of tolerably grown plants, and therefore its functions are confined to the stem. First. It is in direct and unbroken connexion with every branch, leaf, bud, and flower, and is the structure which first conveys fluids to, and receives fluids from, the newly-developed leaf. It thence becomes the main organ of nutriment; and, at the same time, the chief depository of the secretions. Secondly. It is in equally direct and unbroken connexion with the bark, through the medium of the medullary rays; and thus becomes the centre of all the movements of sap which proceed in the horizontal system;—it is that system which more especially presides over the life of the plant.

The mode in which its ultimate disappearance occurs has been a matter of doubt and speculation. It seems quite clear that it is not converted into wood, as was asserted by Mirbel, and there are certain facts which militate against the opinion that it is gradually compressed by the wood; but since it is known that in the growth of the plant much compression of the previously formed wood must occur, and since this compression is a reasonable theory by which to account for the disappearance of the less resisting pith, it is now pretty generally admitted to be at least one of the causes of this occurrence.

As a general rule, the pith, so long as it exists, is not mingled with other than cellular structures; but, in a few instances, woody fibre has been found with it; and in others, as Nepenthes, spiral vessels have been detected.

The economic uses of pith have not been numerous, but amongst them must be mentioned the rice-paper used in China, and prepared by cutting the pith of the Ἀσχynomene (Fig. 48), and the Aralia papyrifera, in a circular manner, so as to obtain large, thin, and evenly cut sheets. It is used for drawing and for writing. The cellular pith-like stems of the Ἀσχynomene aspera, called "shola," have been forwarded to this country from India, and have been made into various ornaments, models of buildings, hats, boxes, and life-buoys. Its lightness, and non-conducting property of heat, render it very fitted for the manufacture of hats.

**Medullary Sheath.**—Immediately surrounding the pith of all exogenous plants there is a layer of vascular tissue, which has received the name of medullary sheath.
(Fig. 128). This sheath has no special walls, but is simply bounded by the pith on the inner, and by the wood (when it exists) on the outer side. It is in this situation that we may find ducts of various kinds, and spiral vessels; and in all cases it conveys the vascular structure from the root direct to each leaf and flower. The integrity of this structure is therefore highly necessary to the life of the plant. It is said to retain its green colour to the latest period of the existence of the plant; thus showing the importance of the functions assigned to it.

**Medullary Rays.**—These structures come next in order; and, as has been already intimated, belong to the horizontal cellular system of the stem. They constitute the channels of communication between the bark and pith, and are composed of a series of walls, of single muriform cells resting upon the root, and proceeding to the apex of the tree, and radiating from the centre. They lie between the wedge-like blocks of wood, and, as they have a lighter colour than the wood, they are evident on a section of any stem, and are called the silver grain (Fig. 131). Their colour and number suffice to enable us to distinguish various kinds of wood, and greatly increases their beauty. They cannot, of course, exist before the wood is formed, and are therefore not met with in the earliest condition of the plant. They begin to exist with the first deposited layer of wood, and continue to grow outwardly, or nearest to the bark, so long as the wood continues to be deposited.

**The Bark.**—As the medullary rays terminate in the bark on their outer side, we are naturally next led to a consideration of that structure. It forms the outer covering—a sheath of the tree, and, in some form or other is present in all plants. When discussing the constitution of the cuticle of herbaceous plants we explained the points of difference between the two varieties of the same structure, and showed that the rudeness of the bark of wooded trees had destroyed many of the characters of the cutis, such as stomata and hairs. We have now to regard it as a dense cellular organ, well fitted to endure the influences of seasons through a long series of years.

It may anatomically be divided into two structures—viz., an outer one, which is cellular, and an inner one, which is vascular or woody. The former is sub-divisible into three parts, whilst the latter is composed of several layers of the same material, and forms a link between the wood and the bark.

The three divisions of the cellular part are the Epidermis, the Epiphloem, and the Mesophloem.

The Epidermis is the most external layer, and is continuous with that upon the leaves. Its cells are flattened and lengthened, and but very rarely possess stomata.

The Epiphloem has acquired much importance from the fact of its being the part of the bark in which the cork is deposited. It cracks and peels off at intervals in almost all trees. In the birch and cherry it may at times be seen hanging from the stem in silvery shreds, and in other trees as rough broken patches. In the cork tree (Quercus suber) it remains firm until the tree has attained a certain age, after which it exfoliates in the large masses in which it is brought to this country. It is probable that the deposition of cork proceeds in all trees; but in the cork tree it attains so great a thickness as to become a highly important article of commerce.

The removal of the cork from the cork tree is not left to natural exfoliation; but, when
the tree is sufficiently mature, incisions are made from the top to the bottom of the stem, so that the cork may be more quickly removed. The sheets are then placed upon the ground to flatten, and are at length cut up into convenient lengths for packing. The tree will permit this process to be renewed during seven or eight successive years.

The cause of the exfoliation has not well been determined. It certainly does not depend upon the growth of the tree, as though the increased size of the stem caused the bark to rupture and thence to fall off; but it is said that a layer of tabular cells are formed within it which cuts off its communication with the internal structure of the stem, and thence it dies. No doubt can exist as to the fact of the constant destruction of the old bark and the formation of new structures, and it appears to arise either from the death of the external layers only, or from the formation of cork on the innermost layer of the bark, which causes an arrest of the circulation, and at length the death of the more external parts.

It is said that the bark of exogens is much more extensible than that of endogens; and that, as a consequence, the stems of the former exceed in diameter those of the latter. But the fact just mentioned seems to prove that in fact the cellular part of the bark of exogens possesses but little extensibility; for, when the enlargement of the trunk has proceeded but even to a moderate extent, the bark cracks off from a lack of this power of extension. It is far more probable that the increasing size of the zone of bark is less due to the extensibility of the old bark than to the formation of new cells year by year as the stem enlarges, and in a layer at all times proportioned to the increasing size of the stem—in fact, that the old coat becomes too small, and rends, and a new one is supplied of larger dimensions. It is quite clear that the external layers, after rupture, either peel off, or the width of the rents increases as the tree grows larger.

The *Epiphleum* consists of several layers of thin flattened cells, usually without colour.

Thirdly, the *Mesophleum* is a thin layer of green cells lining the epiphleum, and, in the cork tree, exfoliating with it. Its cells lie in a direction different from that of the cells of the epiphleum, and sometimes contain cellular secretions.

The vascular part of the bark is called the *liber*, from its offering a smooth enduring structure, which was formerly used as paper (*liber* a book). It consists of several layers of small interlaced bundles of woody fibre, connected together by loose cellular tissue. In some trees, as the lace bark tree (*Lactecta lintearia*, Fig. 132), it resembles a textile fabric, and may be obtained from the tree in sheets of large size. The woody fibre of the liber has always the peculiarity of being very strong, and of lying in small bundles, and has been used as cordage by most nations. It is still employed in Russia in the manufacture of mats, and in many parts of the world for whip-lashes. It is not equally smooth on both aspects; since, on its outer side, it has cellular connexion with the mesophleum, but on its inner surface it is opposed to the smooth wood, or is covered by the semi-fluid cambium. Its mesh-work character permits the medullary rays to pass through it, and to keep up a circulation with the cellular part of the bark. It is not subsequently converted into the wood of the tree,
as some have supposed, but is formed in the Spring season from the leaves with the wood, and lies in successive layers within the mesophlænum.

The more immediate use of the bark is that of giving protection to the wood. If bark did not exist there would be no cambium, and without cambium there could not be any deposition of woody fibre; and thus the presence of bark is necessary to the growth of the tree. It is also essential to the life of the tree, from its connexion with the cellular system, and with the undeveloped leaf-buds.

The bark contains a large number of air vessels and vasa propria, and not only conveys refuse matter from the leaves to the soil, but is in almost all cases a depository of elaborated secretions. This is well seen in the oak bark, yielding tanin; the cinchona bark, producing quinine; and the fir-tree, emitting turpentine. There are also many milk vessels; but, with the exception of the Nepenthes, there are no spiral vessels. We have oftentimes found thick wall-cells, as in Fig. 40, arranged in columns with great regularity.

Wood.—We now proceed to the most important division of the parts formed in exogenous stems—viz., the Wood—a substance not merely giving stability and beauty to the tree, but offering the greatest service to man. We find it occupying nearly the whole body of the trunk, and arranged, as a rule, in a very regular manner in this class of trees. On taking up any piece of wood, but more particularly the entire section of a stem, we first notice a series of circles, which increase in diameter, and are separated by wider intervals as we approach the bark. In this manner the trunk is composed of numerous zones inclosed within each other. Again, in almost all trees, we observe the medullary rays before-mentioned passing in straight lines from the centre to the circumference; and as the circle of the stem at the bark is much larger than any circle near to the centre, it follows that the medullary rays will be wider apart at the bark than at the pith. On this view of the subject we may state that the stem is composed of a series of wedge-shaped blocks, which have their edges meeting at the centre. The combination of these two views gives the correct idea of the arrangement of the wood—viz., a series of wedges, each divided into segments of unequal width by circular lines passing across them. From this description it must not be supposed that these various portions are detached, or may be readily detached, from each other; for, although the medullary rays and the circular mode of deposition both tend to a less difficult cleavage of the wood, they yet bind the parts very closely and firmly to each other.

The explanation of the occurrence of distinct zones of wood is that each zone is the produce of one year, and that in our climate, more so than in tropical countries, the period of growth of wood ceases for many months between the seasons, and thus induces a distinction in appearance between the last wood of a former and the first wood of the succeeding year. This distinction is maintained throughout each year, and throughout a long series of years.

The inclosure of zone within zone is owing to the mode in which the wood is produced, and the position in which it is deposited. Wood is formed by the leaves during the growing season, and passes down towards the root between the bark and the wood of the previous year (if any), or in the position in which cambium is effused; and, as the
leaves more or less surround the whole stem, the new layer at length completes a zone, and perfectly encloses the wood of all former years. This is the explanation of the term exogenous, which is derived from two words signifying to grow outwardly, for the stem increases in thickness by successive layers on the outer side of the previously-formed wood. That this is the mode of growth has been abundantly proved by experiment, and demonstrated by accidental discoveries. Thus, if a plate of metal be inserted between the bark and wood, it will in progress of time become inclosed by the new wood which has overlaid them. So in like manner, if letters be cut deeply through the bark and into the wood, the spaces will not be filled up from the bottom, but may be seen in subsequent years overlaid by new wood. A statement appeared in a daily paper, during the past year, to the effect that in cutting down a tree a cat had been discovered inclosed in the wood of the trunk. These facts prove that the wood is applied from without. Again, if a branch be stripped of its leaves down to a certain point, it will not grow above that point; and so, in like manner, if branches be stripped from one side of a tree, the tree will not grow on that side. If a circle of bark be removed from a branch above and also below a leaf, it will be found that increase of size will occur below, but not above that bud; and so, likewise, whenever a ring of bark is removed from a tree, the new woody fibre will not proceed from the lower but from the upper free edge. Further, if a scion be engrafted upon a stock having wood of a different colour from that of the scion, it will be found that the wood produced from the scion overlays that of the stock. This may actually be seen in operation in the spring season, if a leaf be exposed immediately below its base; for then bundles will be seen to shoot below the ring of bark or cuticle, and to divide into two sets, one of which proceeds to the liber, and the other to the wood of the trunk.

These facts are undoubted, and the inferences seem to be indisputable; but yet various men of eminence have held contrary opinions. Thus, Linnaeus believed it to be the produce of the pith, and Malpighi, that of the last year's wood; whilst Du Hamel affirmed that it was produced by neither, but solely from the cambium, which, according to him, was secreted by the bark. It cannot be denied that the bark exercises an influence in the formation of wood; for if a zone of red bark be made to grow upon a tree having white bark, all the wood appearing below this new bark will be red. But this is not the result of any power in the bark to form wood, but simply that the wood, as a part of the horizontal cellular system of a plant, has a controlling influence over its secretions. These experiments, and others of a similar character, may be most readily performed by any one of ordinary ingenuity. And what amusement could be more instructive to our young friends of both sexes, and possibly through them to the world at large?

If our readers will cursorily glance at the cut surface of any stem, they will at once perceive another fact in relation to the zones of wood, viz., that whatever may be the thickness of the zone for the year, it is rarely equal around the whole circumference of the stem. This is no matter for wonder; but, on the contrary, it is surprising that there is any approach to regularity, seeing that the position of leaves upon the branches seems to be an accidental rather than a circular or spiral one. The occurrence is readily accounted for on the theory above propounded, and is due to the lesser abundance of leaves on the branches of one side than on the other, or to the prevalence of winds, or some other physical cause, acting in that direction in opposition to the growing process.
SECTIONS OF EXOGENOUS STEMS.

Figs. 134, 135, 136, 137, 138 exhibit horizontal and perpendicular sections of an exogenous stem, from the end of the first to the end of the fifth year. In each figure

the pith occupies the centre, and is the largest at the end of the second year; after which it progressively diminishes. Immediately around it is the medullary sheath. The bark is on the outer boundary; and the woody and pitted tissues occupy the intervening spaces, and increase at the rate of

one layer or zone per year. The medullary rays pass from the pith to the bark.

From the preceding remarks it will at once be inferred that a plant of one year's growth has but one layer of wood; and that that, therefore, does not inclose wood, but pith only. When the tree has reached the end of the second season it will have two layers; and so on, successively, through any number of years. The above Figures represent each a horizontal and vertical section of a stem at various periods; and in Fig. 138 it will be seen that the stem of a plant five years old exhibits a central pith, five zones of wood, and the bark, besides the cambium in the spring season and the medullary rays.

The age of trees has been inferred, when a section of the whole stem could be examined, by counting the number of rings of wood which have been deposited around the pith. When only a part of the stem remained, and yet its original diameter was known, the same end has been sought by multiplying the width of one zone by one half the diameter, or by counting the number of zones from the pith to the bark, should so
much of the stem be found. In a large proportion of cases these modes will evoke tolerably accurate results; but there are several sources of fallacy to which we must refer.

First, it is highly probable that in tropical climates the wood of more than one year may produce but one zone; for as there is but a short if any period of cessation of growth, but very slight evidences of any line of demarcation can be detected. The real age of trees may thus be underrated.

Secondly. It is highly probable that in some plants more than one zone of wood is formed in the year; for such is evidently the case in the root of the Beta Vulgaris. This would unduly increase the age of the tree.

Thirdly. When examining a fragment of a tree the observer should remember that the zones are not of equal thickness throughout, and that it is quite possible that in some years no wood whatever was formed in the fragment under examination. The varying width of zones results from the age of the tree; so that it is less as the tree advances in life, as also from the interruption to growth, which not unfrequently continues on one side of a plant throughout a greater part of the growing season. This may be readily observed by noticing a section of almost any stem; for then it will be evident that the pith does not occupy the geometric centre of the plant. Dr. Lindley gives the measurements of two sides of four stems, which he selected from East Indian trees, which exemplify this fact clearly:

<table>
<thead>
<tr>
<th></th>
<th>Real age or No. of zones.</th>
<th>Total diameter.</th>
<th>Diameter of Smaller side.</th>
<th>Larger side.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st stem</td>
<td>40</td>
<td>45 lines.</td>
<td>9 lines.</td>
<td>36 lines.</td>
</tr>
<tr>
<td>2d</td>
<td>36</td>
<td>30 &quot;</td>
<td>8 &quot;</td>
<td>22 &quot;</td>
</tr>
<tr>
<td>3d</td>
<td>17</td>
<td>31 &quot;</td>
<td>11 &quot;</td>
<td>20 &quot;</td>
</tr>
<tr>
<td>4th</td>
<td>8</td>
<td>34 &quot;</td>
<td>11 &quot;</td>
<td>23 &quot;</td>
</tr>
</tbody>
</table>

"Suppose that a portion of the smaller side in the first example were examined, the observer would find that each zone is 0.225 of a line deep, and as the whole diameter of the stem is 45 lines, he would estimate the side he examined to be 22.5 lines deep, consequently he would arrive by calculation at the conclusion that as his plant was one year growing 0.225 of a line, it would be a hundred years in growing 22.5 lines, while in fact it has been only forty years."

Thus, whilst it is difficult to ascertain with great certainty the age of any tree when a whole section can be obtained, the difficulty is vastly greater when only a fragment can be examined.

The great size of the trunk of a tree is prima facie evidence of its antiquity; and judging from that fact alone we should be disposed to admit that the following remarkable trees must be very aged:

The Chesnut of Mount Etna (Castanea de Centi Cavalli) is 180 feet in circumference.

A Plane tree in Turkey, 150 feet in circumference.

Some of the Brazilian Hymenæas, 84 feet in circumference.

In respect of height, it is known that the Araucarias sometimes attain to the height of more than 200 feet.

The Pinus Dargliciana of Oregon is 193 feet high; and the Pinus Lambertiana is 226 feet in height.
The real value of these enormous dimensions will be best felt if our readers would make a circle in a field of 180 feet in circumference, and then measure a distance of 70 yards to indicate the width and height of a tree.

There are several ancient oaks in England, through the remains of whose hollow trunks coaches have been driven; and in New Zealand it is said to be a common occurrence to use decayed trees as stables.

The following list of ancient trees may be found in a French work, the "Tératologie Végétale," and their ages have been computed upon the principles now laid down.

List of old trees, according to Maguire and Tandon. There are known:—

<table>
<thead>
<tr>
<th>Tree</th>
<th>Age in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palms of</td>
<td>200, 300 years</td>
</tr>
<tr>
<td>Cereus</td>
<td>300</td>
</tr>
<tr>
<td>Chirodendron</td>
<td>327</td>
</tr>
<tr>
<td>Ulmus (Elm)</td>
<td>355</td>
</tr>
<tr>
<td>Cupressus (Cypress)</td>
<td>388</td>
</tr>
<tr>
<td>Hedera (Ivy)</td>
<td>448</td>
</tr>
<tr>
<td>Acer (Maple)</td>
<td>516</td>
</tr>
<tr>
<td>Larix (Larch)</td>
<td>576</td>
</tr>
<tr>
<td>Castanea ( Chesnut )</td>
<td>626</td>
</tr>
<tr>
<td>Citrus (Orange)</td>
<td>640</td>
</tr>
<tr>
<td>Plantanus (Plane)</td>
<td>720</td>
</tr>
<tr>
<td>Cedrus (Cedar)</td>
<td>800</td>
</tr>
<tr>
<td>Juglans (Walnut)</td>
<td>900</td>
</tr>
<tr>
<td>Tilia (Lime)</td>
<td>1076</td>
</tr>
<tr>
<td>Abies (Spruce)</td>
<td>1200</td>
</tr>
<tr>
<td>Quercus (Oak)</td>
<td>1600</td>
</tr>
<tr>
<td>Olea (Olive)</td>
<td>2000</td>
</tr>
<tr>
<td>Taxus (Yew)</td>
<td>2888</td>
</tr>
<tr>
<td>Schubertia</td>
<td>3000</td>
</tr>
<tr>
<td>Leguminosae</td>
<td>4104</td>
</tr>
<tr>
<td>Ádansonia (Baobab) of Senegal</td>
<td>6000</td>
</tr>
<tr>
<td>Dracaena (Dragon's Blood Tree) of Teneriffe</td>
<td>6000</td>
</tr>
</tbody>
</table>

When we remember that the two latter periods carry us back to the days of Adam, and contrast them with the ordinary destructibility of vegetable growths, they appear to be incredible, and we cannot but suspect that some elementary error has crept into the computation.

Since the quantity of woody fibre produced depends mainly upon the number of leaves upon the tree, and the number of leaves must bear some proportion to the size of the tree, it might be inferred that the quantity of wood deposited would increase with much regularity as the age of the tree advanced. This increase might be manifested in two, or one of two ways—viz., the increasing length of the zone and its increasing width. It is very probable that an increase does take place in the annual deposit, until the tree has attained its maximum of growth; and it is quite clear that so long as the tree enlarges, the circumference of each zone must increase likewise; but there is no evidence that the zone at the same time increases in thickness. This militates against the oft-repeated attempt to determine the age of a tree from its diameter; and if there were no other source of fallacy, it would suffice to remind our readers that the growth of trees must depend upon the varying nature of the soil, the
CELLULAR STRUCTURE OF TREES.

changing seasons, and the prevalence of winds; and that all these act with tenfold greater effect upon a full grown than upon a very immature tree. It may therefore be affirmed, that the zones of wood increase in length, and decrease in thickness, as the age of the tree advances, and that both proceed from determinate causes, but that the increase and decrease alike do not follow any rule of universal application.

Moreover the width of the zones of wood, in the same species of tree growing in different positions, is not the same. Thus the Scotch Fir (Pinus sylvestris), growing at various altitudes, produces rings of wood varying from 0·39 lines, to 10 times that amount. That such must be the case we may readily infer from the fact, that in any plantation trees of the same species, and planted at the same time, attain, within a few years, to very different dimensions. This dissimilarity is far greater when we compare trees of various species; but yet, in reference to all wooded plants, it may be stated that there is a general resemblance in the size, both in height and thickness, which plants of the same species attain in the course of years.

Numerous efforts have been made to discover a relation between the height and the thickness of trees; but whilst there may be an approach to similarity in trees of the same species, there is not a shadow of resemblance in wooded plants as a whole. Thus it has been found, that of two species of Pine the difference was so great, that whilst the relation was as 1 to 5 in one instance, it was as 1 to 120 in another.

Such speculations may tend to increase a spirit of inquiry, but hitherto they have had no other good effect.

The foregoing description may suffice for exogenous stems which follow this usual course of development, and therefore for the great majority of trees; but it is readily conceivable that a difference in figure may exist to a great extent, as in the cells of cellular structure, considered at page 11.

Fig. 139.
Fig. 140.
Fig. 141.

Fig. 139, representing the section of a tree in which, from the irregular development of the stem, there are no concentric zones of wood.
Figs. 140 and 140*, showing, in the section of a stem of a Bignonia, four internal deposits of bark, a, by which the wood is divided into four wedges. The lines crossing the centre are well developed medullary rays.
Fig. 141.—The stem of a Clematis, in which the medullary rays are greatly thickened. a, the pith; b, the smaller; and d, the larger wood bundles; c, the large medullary rays; e, the bark.

Thus, whenever the process of growth is so disturbed that it proceeds on one side, whilst it is nearly arrested on the other, it is evident that the figure of the stem will
not be cylindrical, and that the layers of wood will not be in perfect zones. So also when this disturbance is restricted to a portion only of one side, there will be no growth at that part, and in process of time a depression in the stem will result, giving it a furrowed appearance. At a still later period, assuming that the like causes exist, this furrow will become deeper, but at the same time it will be narrower; for the woody fibre, as it passes down on either side, will find little resistance in that direction, and will push into the furrow and lessen its size. At the same time the bark will also increase in thickness, and in process of time the original furrow will have disappeared.

A section of such a stem would show a triangular interval in the circumference of the trunk, which would either be vacant or filled up with layers of bark. If, whilst these changes are proceeding, others of a similar character were met with in other parts of the circumference, the section, instead of exhibiting a circular outline, would greatly resemble the figure of the stellate cell (page 11). These are the explanations of a great variety of twining stems growing in hot climates, and which are angular, or present a cruciate appearance on section.

An interesting modification, and one very nearly allied to the above, is that in which the medullary rays increase in thickness so greatly as not only to be mere lines, giving a grain to the wood, but large wedge-shaped blocks between alternate masses of wood. This is not remarkable, when we remember that at every moment of growth there are two processes going on, one the cellular or horizontal, and the other the woody or vertical; and it is no more a matter of surprise that nature should occasionally increase the one at the expense of the other, than that she should rigidly adhere to the rule which she has laid down; for both the rule and the exception are alike wonderful and inexplicable. Such exceptions, greatly varied, but yet for the most part originating in the "Wood," or cellular structure of the stem, are by no means uncommon.

The general configuration of exogenous stems is conical, the circumference being, for the most part, circular, and the base much larger than the apex, or the free terminal part of the stem. This necessarily results from the remarks which we have made on the production of wood; for it is manifest, that if the wood be a product of the leaves, and the number of leaves on the tree increases from above downwards, the quantity of wood deposited will be greater below than above. The apparent exceptions to this rule are in such fast-growing trees as grow in the midst of a dense wood, where the light reaches them only at the top. Such trees run up of nearly even diameter, and without a branch, until more than two-thirds of their entire height has been attained; but from the point where branches arise, the conical figure may readily be traced. The common asparagus

![Fig. 142, showing the component parts of a stem in the fourth year of growth. A, a part of a transverse section. B, a perpendicular section, the parts of each arranged accurately over the other. a, the pith; b, the surrounding medullary sheath; c and d layers of wood and bothrenchym intermingled. The open-work in A shows the position and the extent of bothrenchym more clearly; e, the bark.](image)
plant is also said to be an exception to this rule. The circular figure of the stem is due to the somewhat even distribution of the leaves around the trunk; and this will be the most perfect when the tree has grown apart from others, and where it is freely exposed on all sides to the influence of light.

The wood of plants is not composed exclusively of woody tissue, but with that structure is both parenchyma, or dotted tissue and ducts, in greater or less abundance. This, as before mentioned at page 17, is more particularly the case in fast-growing plants. The diagram on page 85, of an exogenous stem, shows how largely pitted tissue is intermingled with the wood.

Fig. 143, representing a Palm forest, and some of the leading characters of endogenous growth.

**Endogenous Stems.**—We now proceed to a description of stems which will be less familiar to our readers, and which can usually be examined in museums, or as dried plants only. These are almost peculiar to tropical regions, and are exclusively so if we refer to wooded plants of considerable size. The giant representative of this class is the Palm tree, with its wonderful utility and beauty.

The class is represented in this country, and in almost all cold climates, by plants of lesser growth, and more particularly by the grasses; yet, with the exception of the direction of the veins of leaves, they afford but unsatisfactory indications of the peculiar structure of the plant. The most ready illustration will be found in the common Cane and Bamboo; and these will suffice for a sufficient inquiry into this subject.

The term "endogenous" signifies to grow inwardly, and is explained by stating that the bundles of wood sent down from the leaves do not range themselves in layers
on the outer side of the previously-formed wood, but pass down in irregular masses near to the centre of the stem. Such stems, like exogenous stems, are composed of a woof and warp, each of which holds the same relation to the other in both great divisions of trees, and they differ only in their relative proportions and mode of arrangement. Thus the cellular or horizontal warp is proportionally increased in endogenous rather than in exogenous stems; and this, together with the arrangement of the woody fibre into bundles, gives a more open character to the section of the stem.

A section of an endogenous stem (Fig. 144) exhibits the following structures: — First, an external inclosing layer or bark, \( x \); secondly, a series of circular lines, which represent the cut surfaces of vascular tissue, \( y \); and thirdly, the mesh-work intervening between the bundles, which is the cellular tissue or pith, \( z \). We shall consider each of these separately.

**Cuticle.** — The epidermis, cuticle, or bark, of endogenous stems, differs materially from the analogous structure in exogenous plants. It cannot, in any normal instances, be separated from the stem, as may be readily seen by attempting to peel a cane. It does not naturally crack and separate as does the bark of our forest trees; but is hard, dense, smooth (usually), non-corrugated, inelastic, but slightly extensible, and is a permanent unchanging structure. Thus, the diameter of such stems is necessarily greatly restricted; and it is in length only that endogenous plants can be greatly developed. It does not consist of a series of layers, which may be detached from each other, and distinguished by various names, but is simply formed of one or two layers—a mass of flattened cells, with bundles of woody fibre intermixed, and connecting it with the internal parts of the stem. The non-extensibility of these layers is not evident until the tree has attained to somewhat of its natural diameter; for the bamboo may appear at first as large as the finger only, and subsequently exceed in circumference a man's thigh. Moreover, a few plants, as the Dracaena or dragon's blood tree, referred to at page 1, has attained to a circumference of forty feet. Thus, whilst it is true that the width of endogenous stems, as compared with their height, is much less than in exogenous trees, we must admit that the cuticle is extensible, and must infer that its further development is prevented by a degree of expansibility which does not proceed beyond a certain point; or that its further non-development is simply a part of the general law which governs the growth of these plants. It is difficult to agree with the common opinion, that the limited power of expansion, which the cuticle is said to possess, is the cause of the limited diameter of the stem; and it seems more philosophical to assume, that it is only a part of these occurrences which accompany the normal development of these structures.

That the size of the stem remains the same at all periods after its full development...
is quite evident from the fact that twining plants may encircle it for many years without compressing it; but this is begging the question; for if the stem be fully developed, as at first referred to, no further increase of the tree is expected. The truth seems to be, that endogens cease to grow at their lower part, whilst growth proceeds above; and thereby the cuticle may have attained to a maximum of extension near to the base, whilst it may be comparatively undeveloped above.

Schleiden explains the peculiarities of the cuticle of endogenous stems, as distinguished from that of exogenous ones, by employing the term "limited growth" to the former, and "unlimited growth" to the latter; and explains them by stating, that in the former, after a certain period, the production of the fast-growing thin walled-cells of the cuticle ceases, and the partitions become thicker; whilst in the latter, the cells are continually reproduced throughout the whole period of growth of the plant. This seems to be rather a statement of the facts than an explanation of them.

It is the fashion to state that endogens have no bark, since none is separable from the wood, and that the cuticle is simply the hardened exposed cells of the stem, with the ends of bundles of woody fibre intermixed. If analogies are truly founded upon function, and not upon structure, we must admit that there is a cuticle or external protective covering to endogenous stems.

**Vascular Structure.**—This is a mixture of woody fibre and bothrenchym, with the addition of spiral ducts or spiral vessels.

If we examine a transverse section of a cane, we do not find a central pith, with wood arranged in layers around it, but a surface marked by fourteen cut ends of round bundles of vascular tissue, set in a cellular matrix. So also on making a perpendicular section, we notice that the surface of the section presents a number of perpendicular defined lines, which may be torn out, and a series of intervening connecting substances. The distinguishing peculiarity of endogens is the arrangement of the woody fibre.

The general direction of the woody fibre is clearly from above downwards; but it is highly probable that it does not descend in straight lines, and that when the tree has attained a tolerable height the wood does not descend directly to the root. As the structure is not indigenous to climes where scientific men abound, the observers have been few; and as the subject is an intricate one, it has not, as yet, been fully elucidated. Mohl is the best authority, and he affirms that the bundles of fibres descend from the leaves in arcs, which direct their convexities towards the centre of the stem. Thus the fibre, in its descent, first passes towards the centre, and thence towards the circumference, until it reaches the bark, or nearly so, when it passes down in a more direct manner towards the root. Each fibre will therefore somewhat represent a hedge-hook with a long handle—that is, have the form of an arc above, and a straight line below. The centre of each arc will not correspond with the central point in the height of the stem, but will be distant.
from either end of the arc about one foot and a-half. It is not presumed that all the fibres enter the bark, but that some curl and attach themselves to it, whilst others pass to the roots. Thus the perpendicular section of a Palm would exhibit a series of arcs, intersecting each other, and originating in points gradually ascending as the tree grew in height. These arcs would proceed from every point of the circumference of the stem, and present their convexities towards the centre.

Thus far, the best observers are agreed; but the precise point of origin is still a matter in dispute. That they proceed from foliaceous organs, as in exogens, is certain; but whether from the fully-developed leaf, or from undeveloped interfoliar organs, is undetermined. The former is the opinion of Mohl, and the latter of Schleiden; whilst Mirbel occupies a midway position, and asserts that they proceed from an independent part of the growing point, or Phyllophore. The successively ascending points of origin of the arcs are explained on either of these theories; for in endogens the foliaceous organs, whether developed or undeveloped, are placed only on the top or head of the stem, and are yearly supplanted by others rising from above them as the stem elongates.

There is, however, a material difference of opinion as to the immediate direction taken by the growing wood, according to the views above expressed. Thus, on Mohl's theory, the woody bundles are formed at the highest point—viz. within the leaf itself, and have but one direction, that from above downwards; but on Mirbel's theory, the point of origin is below the leaf, and the bundles pass in two directions—one upwards into the leaf, and the other downwards into the stem. If we adopt the latter theory we must admit that the oldest part of the wood is neither at the top nor at the bottom of each bundle, but at an intermediate spot—a point near to the upper extremity.

It is agreed by all observers, that there is no evident dissimilarity between an exogenous and endogenous stem up to the end of the first year of growth; for in both cases there is a central pith and an external layer of wood, which has been divided into two portions, one of which has applied itself to the bark, and become the liber; whilst the other is the true wood, which surrounds the centre. The distinction begins in the following year, when the divisions of the bundles of woody fibre into liber and wood does not again take place in endogens; and, as in those plants, the whole wood passes down into the bark, and near to it, the lower part of the stem, as in palms, is much more solid and resisting than the upper part.

The uses of vascular tissue in endogens are the same as those of exogens, but the proportion of saccharine juices which it contains is greater in the former than in the latter. This is a beautiful arrangement for the convenience of those inhabiting hot and often arid countries, where animal milk and water are but sparingly afforded. (See page 24.)

**Pith.**—The pith in endogens may be said to occupy the whole of the stem, and to form the bed into which the woody fibres pass. If we deny the existence of bark in endogens, we must affirm that the pith also forms the cuticle, having first had its cells thickened to render it more resisting. On the section of a stem it will therefore be found to intervene between the bundle of vascular tissue, as exhibited in Fig. 146, and to form the very boundary to the stem itself. In the endogenous plants of our climate, as the grasses, and in many similar fast-growing specimens of hot countries, as the bamboo, the central pith is ruptured, and ultimately absorbed; so that there is a central vacuity, except at the nodes, where a partition of pith still continues.

The uses of pith are chiefly two: first, to supply a soft, elastic, and yielding struc-
ture, through which the vascular tissue may pass from the leaves towards the roots and secondly, to contain starch, oftentimes of great purity and abundance, as in the stem of the sago palm (*Sagus Rumphii*).

The points in the external characters of endogenous stems, which are peculiar to these structures, are the following:—

First. As a rule the stem does not give off branches, but proceeds either singly or dihotomously (divided into two) from the base to the apex.

Secondly. The leaves are therefore found only at the head of the stem, and surround it by numerous insertions, arranged above each other in a spiral manner. They are usually of large size, and thus compensate for their paucity in numbers. When their duty has been performed, they wither and decay upon the stem, or ultimately fall from it, leaving a mark called a cicatrix to indicate the points to which they were formerly attached. The succession of leaves takes place from below upwards, and thereby a palm of some years growth presents a series of cicatrices. As the age of the tree cannot be determined by the number of the concentric circles of the wood, it is inferred from the number of rows of cicatrices, which indicate the successive seasonal formation of leaves.

Thirdly. From the above reasons, the stem is not conical, but cylindrical, and is tall in proportion to its diameter. Not that it is cylindrical, as opposed to conical, to the very apex of the plant, (for the very apex has not so large a diameter as the inferior part,) but since the reduction in diameter is somewhat sudden, and is found only very near to the terminal part of the stem, it is more truthful to state that the figure of the stem is a truncated cylinder than a cone.

In all these respects the stems of endogens are very unlike the stems of exogens.

**The Descending Axis or Root.**—Having now completed our account of stems, it will be more convenient to state the little which may be necessary respecting roots, before we proceed to a description of the numerous and complex structures which are attached to stems.

We have already stated that the stem and root proceed in the seed from a central spot termed the collum, and that they hence take opposed directions,—the stem ascending, the root or radicle descending. This direction of the root is almost universal; and wherever it is once attained, no power short of the death of the plant can prevent its progress.

As the root naturally seeks to bury itself in a medium much more dense than itself, it is so formed that its extremity has but a very minute diameter, and at that extremity it is composed of the most delicate structure. The vital process of growth enables it to insinuate itself, without injury, between stones and other resisting substances. Thus the root has naturally a conical figure, with its base opposed to the base of the stem,
and the whole plant may be said to consist of two cones, attached by their bases. The thicker part of the root is termed the caudex, the minute apex, the fitrilla, and its terminal point, the spongiola. Both of these parts, as has been proved by experiments, have the power of elongating themselves, but more especially the part near to the free extremity. Our readers may satisfy themselves of this fact by taking any fast-growing root, as of a hyacinth growing in water, and tying a thread around the roots at known intervals, and, after the lapse of a few weeks, ascertain, by admeasurement, the total and relative elongation of the root and its parts. If a plant be selected, the root of which grows in the ground, it will be found that the relative proportions of growth of the upper, as contrasted with the lower portion, is infinitely less than in plants growing in water. This is to enable the root to penetrate with less difficulty the resisting medium. In this mode the roots of forest trees are enabled to penetrate the soil for many yards from the base of the stem, so as to enable them to get the water and other articles of food which may not be readily afforded at the base of the stem.

The tissues of which the roots are composed are nearly the same with those of the stem, viz., woody fibre, ducts, and cellular tissue. The woody fibre does not penetrate into the spongioles, but is restricted to the parts immediately above it, whilst ducts and cellular tissue are met with exclusively in those organs. The reason of this arrangement is that the spongiole is an organ of absorption as well as of growth, and by it all the fluids which enter the plant are introduced; it is, therefore, not restricted to one point, as the apex of the root, but is found on various parts of it (as may be seen on the side of the radish), wherever absorption can be effected; and it is of the greatest importance, in transplanting trees, to avoid the destruction of too many of these delicate thread-like organs. Some writers restrict the term spongiole to the very extremity of the delicate fibrilla, which is somewhat tumefied; and there it is said to consist of a mass of small cells. This is probably the true statement of the case, as may be seen by placing a thin section of the end of a root of the radish under the microscope; and then we must regard the ducts to which it leads as organs destined to convey fluids from the spongiole to the caudex of the root. The spongioles have also the power to emit from the root effete and deleterious substances. Thus it is said that trees (as a pear

Fig. 148.—The Pandanus, or Screw Pine, emitting aerial roots at a, b, c, d, and e, which ultimately reach the ground, and give increased stability to the stem.
The leaves of plants will not grow upon the spot where a tree of the same species recently grew; and that, not because the soil was exhausted, but that a poisonous excrementitious matter had been deposited there by the roots of the former plant.

There are certain plants which emit their roots above the surface of the soil, as the Pandanus or Screw Pine (Fig. 148), and the Mangrove tree. Such roots are termed aerial roots; since, until they have sufficiently elongated to reach the earth, they remain above the ground. Their natural tendency, however, is to bury themselves in the ground, and they become eventually roots.

Roots vary greatly in figure, and therefore demand special names; the most common is the fibrous, as in the oak and forest trees, where the body of the root is divided into many smaller, elongated, conical portions. If there is but one conical elongation, the root is termed fusiform. When the root seems to terminate suddenly at the body, it is termed premorse, or bitten off; if it be fleshy, and divided into several globose parts, it is known as many-headed, or as tuberolae in some of the orchids.

It is often of importance to distinguish accurately between an underground stem and a root; this is chiefly effected by negative evidences. Thus a root has none of the appendages of the stem, such as leaf buds, leaves, scales, scars, and stomata; and in exogens it has no pith. Some roots have the power of forming adventitious buds, but the buds never proceed in a regular manner from fixed points. So also with branches, when they occur; they proceed not from leaf buds, but in an irregular way from any point of the surface. By these various signs we infer that such enlarged parts of plants, as the potato, turnip, and radish, are true stems, although they are situate underground, and that they give off the true fibrillae or roots from their apices or sides.

Appendages of the Stem.—Under the head of appendages of the stem or axis we shall have to consider the respiratory and reproductive parts of plants, such as the leaves, flowers, and fruit, with their subordinate structures, and shall take them in the order in which they appear upon the stem.

Leaves.—The leaf is the type of construction of all the appendages of the axis, no matter how developed soever may be their external configuration. It is therefore not only imperative to a right understanding of other organs that these should be well studied, but a knowledge of the composition of the leaf is the readiest mode of becoming acquainted with the structure of its prototypes. We will, therefore, invite our readers to bear in mind that the immense variety in the figure of the leaf, and in the leaves and other parts of the flower and fruit, does not imply any difference in structure, but that a knowledge of one is a knowledge of all.

The leaf is technically said to be "an expansion of the bark at the base of a leaf-bud;" but such a definition gives no idea of its structure. A more tangible definition is, that it is a flattened and expanded stem; for every structure, which enters into the composition of the stem and none other, is present in the leaf. Thus there is cellular and vascular tissue inclosed on each side by a cuticle.

The leaf is, for the most part, a flattened organ, having two surfaces, or pagina, a border, a bore, and an apex, the whole of which constitutes the lamina or blade; and frequently it is connected with the stem by a foot-stalk or petiole. The surface is
commonly marked by a number of ridges which are called veins, and which consist of woody tissue, spiral vessels, and cellular tissue; and they are retained in their position, and the intervening spaces filled up, by cellular tissue. The tissues of the veins are brought in closer proximity in the petiole, which is a small stem, and having passed through it into the stem, one part enters the bark, whilst the other traverses the wood and penetrates to the medullary sheath at the centre of the stem. Thus every leaf is in direct communication with the stem, and not only so but it is a prolongation of the very pith, spinal vessels, and wood of the stem. The similarity between the leaf and the stem may be carried yet further, for not only do the same structures enter into the composition of both, but in both there is a double set of vessels, one of which conveys the fluid from the root, and the other back again towards the root. The only difference between a leaf and a stem is, that the parts of the stem are more widely distributed in the leaf, and there is an increased quantity of cellular tissue to fit them for their peculiar functions.

We have already, in a previous page, described the cuticle of leaves, with its appendages, and may, therefore, at once proceed to consider the internal structure of these organs.

The veins of leaves are distributed on an uniform plan, and not as a matter of accident, and may be arranged under two heads—viz., the venation of exogens and the venation of endogens. The leaf of an exogen is said to be reticulated, and that of an endogen straight or parallel veined.

The venation of an exogen, as an oak or the holly, consists of a central midrib and a series of festoons, arranged on either side of it (Fig. 150). The large branches proceeding from either side of the midrib are termed primary veins (2); and after they have proceeded for some distance towards the edge of the leaf they form a series of curves by which they communicate with each other, and which are termed curved veins (3). The curved veins in their turn become trunks, from which other and lesser veins are given off (4), which from their relative positions are known as the external veins; while others, of a still smaller size, distributed to the margin of the leaf, are termed marginal veinlets (5). Thus far all the veins have proceeded from one source, and clearly belong to one system, being a series of arches placed upon each other, and all resting upon the midrib. But besides these veins there are others, which may be said to belong to an inner system. Thus the costal veins (6) are small branches which proceed from the midrib, at points intermediate to the primary veins; whilst the branches of the primary veins themselves are termed proper veinlets (7), and their anastomoses common veinlets (8). Such is Dr. Lindley’s arrangement, and it is one which merits approbation.

It must not be supposed that these systems of veins can be traced in all leaves; for in the leaves of mosses, and other plants of the lowest class, there are no veins; and in
certain thick fleshy leaves, as those of the aloe, the veins are altogether concealed. The first are called *veinless*, and the last *hidden veined*.

The venation of endogenous plants offers a wide contrast to the foregoing, since there are no reticulations, and the veins run in nearly parallel lines (Fig. 151). Such leaves are found in grasses, in palms, and in many exotics grown in hot-houses. They are termed *straight-veined*, and their venation consists simply of a series of primary veins running parallel with, and proceeding from, the base of the midrib, and by a transverse arrangement of proper veinlets. An endogenous plant may therefore be distinguished from an exogenous one by the absence of all reticulation in the venation of its leaf.

There is a kind of exogenous leaf, which closely resembles the straight-veined or endogenous leaf—viz., the *ribbed*, in which three or more midribs spring from, or near to, the base of the leaf; but it differs in having a reticulation of small veins between the ribs. When the midribs proceed from the base, the leaf is said to be *three* (or more) *ribbed*; but when they originate a little above the base the distinguishing term *triple-ribbed* is given.

There are other arrangements of veins, as the *equal-veined* of ferns, the *netted*, the *curve-veined*, the *radiating*, and *feather-veined*; but they are not of sufficient importance to merit further notice.

Whatever may be the precise distribution of the veins, they all tend towards the edge or border of the leaf, and do not there terminate, but are reflected back upon themselves, so as to be accurately applied to the under surface of the one now described. So perfectly is this effected that an observer could not detect the double distribution of veining in any leaf attached to the tree, and it is only when the leaf is greatly decayed that the two layers become separate. If such a leaf be handled, so that the veins on the two surface be drawn asunder, a distinct division of the structure will be perceived. This division may be accounted for in two ways: first, that there is such a process as that just described; secondly, that both sets are formed at the same time, and, from the earliest moment, are connected together by their extremities; and that as the leaf increases in size both sets of vessels elongate equally at the same moment. It must not be supposed that there is any substance intervening between the two sets of vessels, for it is highly probable that the two sets form but one bundle.

The importance of clearly establishing the existence of a double set of vessels is, that there is clearly a double current; one by which the sap is carried to the leaf, and the other removing it from that organ. The former occupies the upper, and the latter the under surface of the leaf.

We have already intimated that the veins consist of bundles of woody fibre and spiral vessels, with a prolongation of the cellular pith of the stem.

The cellular structure of the leaf is somewhat peculiar, and is admirably adapted to the lung-like functions of that organ. It is divisible into two portions, a *cuticular* and a *parenchymatous* (Fig. 152). We have already fully explained the structure of the cuticle in leaves, and shall only further add, that the cuticular cells vary greatly in size, figure, number of layers, thickness, and hardness; but that as a rule there are two layers of cuticular cells on each surface of a leaf. The parenchyma of the leaf consists
of several layers of somewhat large and thickened cells, which have the power of remaining distended, even when examined under the microscope—a quality which, in some instances, is assisted by the presence of a spiral fibre within each cell (Fig. 44). These cells also very freely communicate with each other (Fig. 152). It may be fairly questioned if this is not a peculiar structure, since it is admitted that the cell-walls are not perfect, and it is certain that they do not collapse when cut open so readily as other cells.

The connexions of the parenchyma are the cuticular cells above and below, and the veins of the leaves which pass through it. It is also, unlike all other cells, exposed to the direct action of the atmosphere, since it receives air through the stomata, which have their chambers within its structure.

The functions of the parenchyma is to receive the juices from the upper layer of veins, and, by the exposure of them to the atmosphere and other influences, to elaborate them, and thus to yield them up to the under or recumbent set of vessels, to be returned to the stem of the plant. It is therefore somewhat the analogue of both the lungs and the stomach in animals, for it performs the functions of both these organs. All the functions of respiration, which are attributed to the stomata, are fairly due to the parenchyma of leaves; for the former bear to the latter only the relation which the mouth and wind-pipe do to the lungs. The parenchyma, in common with the cuticular cells, is usually of a green colour, from the presence of starch and chlorophyle within the cells.

Forms of Leaves.—The form of leaves is very varied, but is permanent in the same species, and is consequently the result of design. Except in a few instances the leaf is never so far modified in form as that the functions of respiration and digestion are interfered with, and therefore the precise necessity for the infinite variations is not clear, except as evidence of that Creator's goodness which cares for the beauty as well as the utility of his works.

The shape or outline of the leaf depends on, or is modified by, the length and relative position of the veins. When the midrib divides into branches, and when all the branches diverge in the same plane, the leaf is flat, and this may be called the normal state of leaves (Fig. 153); when
the veins diverge in different planes, the leaf is orbicular (round), as the leaf of the common sheep-rot (Hydrocotyle vulgaris, Fig. 154). In succulent or fleshy leaves, such as the leaf of the house-leck, sedum, several pinks, &c., the veins spread in different planes, and the parenchyma is so much developed as to conceal the veins, which consequently are neither prominent nor visible, as they are in the greater number of leaves.

The leaf, when complete, consists of two parts (Fig. 155), a, the petiole, or leaf-stalk; b, the lamina or blade. The petiole connects the leaf with the branch or stem, and is composed of the unexpanded bundle of fibres, covered by the epidermis; the ramification of the nerves constitutes the skeleton, and the veins and veinlets, with the cellular tissue and epidermis, constitute the entire leaf. When the petiole is not present, the leaf is termed sessile. Sessile leaves often partially or entirely surround the stem, and in this case they are termed semi-amplexical or amplexical (half embracing, or quite surrounding the stem).

The most obvious division of leaves is into simple and compound. In simple leaves the limb consists of one piece, either quite entire, or variously indented, cleft or divided at the margin. (See Fig. 155, an entire leaf; 154, a crenate; and 153, a toothed or incised leaf.) Compound leaves are composed of one or more pieces, called leaflets, each of which is jointed to the common petiole or rach, as it is termed when the leaf is winged. (See Fig. 156, which represents a pinnate, or winged leaf.)

Simple Leaves.—The shape or contour of the leaf is regulated or modified by the angle of divergence of the lateral or secondary veins, and by their length. When the divergent veins are but slightly distant, and extend from the base to the apex, including only a narrow slip of parenchyma, the leaf is called linear. The leaves of grasses are familiar examples of this form. When the veins extend from end to end, and are rather more distant in the middle of the leaf, the lanceolate form is produced. In these two forms the veins usually diverge at the base; but in the second, viz. the lanceolate form, the relative length of the secondary veins and their wideness of angle produce a lanceolate leaf (Fig. 157). When the secondary or branching veins are nearly of equal length, both at the base and apex, the leaf is elliptico-lanceolate (Fig. 158). The oblong leaf differs from the latter merely in being rather broader at the base and tip (Fig. 159). When the branching veins are nearly equal, the leaf, being obtuse at both ends, is called a rounded leaf.
All these, and many other forms of simple leaves, depend upon the relative proportions of development in the longitudinal and lateral directions; for in every case the apex, or free end of the leaf, is first formed, and then the blade enlarges in both directions. As a rule, the growth proceeds more longitudinally than transversely; and thence, for the most part, leaves are longer than broad. But when it is equal in all directions, the orbicular or rounded form of leaf results. Again, the lateral development never proceeds equally from the base to the apex of the midrib, but is usually greater at the former than the latter, thus constituting the ovate forms of leaves. In a few instances, however, the contrary is observed, as in Figs. 160, 161; and it obtains the prefix ob—as obovate or obcordate. When development proceeds regularly in these two directions the surface of the leaf is flat, and may be familiarly represented by the palm, or aspect of the hand with the fingers outstretched; but when between any two veins or fingers the transverse development is uneven, a degree of puckering will ensue, as in the leaf of the holly (Ilex). In a few instances of tolerably even growth, the resulting leaf is not flat, but somewhat tubular, as may be imperfectly shown by contracting the hand so that the whole thumb and little finger shall approach each other.

The most frequent variation is the arrest of development at the margin of the leaf. If the lateral development were complete, it is clear that the edge of the leaf would be even or entire; but in many instances it is incomplete, and thence a deficiency ensues which gives a tooth-like or crenate appearance to the edges (Fig. 162). Such a leaf is termed serrated, toothed, or crenate. The extent of this deficiency varies much, and

Fig. 160.—Obovate leaf.
Fig. 161.—Obovate leaf.

Fig. 162.—Serrate leaf.
Fig. 163.—Doubly-serrate leaf.
Fig. 164.—A pinnatifid leaf.
Fig. 165.—A doubly-pinnatifid leaf.
Fig. 166, 167.—Hastate and lyrate-shaped leaves.
Thence the figure necessarily changes. Thus, when it is much greater than that of a serrate leaf, the leaf exhibits a series of lateral prolongations or lesser leaves, the attached end of which is yet distant from the midrib, and the whole is termed pinnatifid (Fig. 164). In other instances the arrest of development is equally great at certain points with the pinnatifid leaf, but is not so universal; and thence a lyre-shaped or halberd-head shape results, as in Figs. 166 and 167.

In all these examples the longitudinal system of development is perfect, and the lateral deficiency is so arranged that the edge of the dentation is entire; but in many cases the latter is so modified that the dentations are themselves dentated or serrated. Such leaves are known as doubly-serrated (Fig. 163), and doubly-pinnatifid (Fig. 165). When the longitudinal system is modified, at the same time that the transverse development is restricted, the leaf puts on a lobed character. Such is represented in Figures 168 and 169, in both of which the modification is but slightly evident; but in others the division of the lobes is so great that the line of separation passes nearly to the petiole, as in the palmate leaf shown in Fig. 170, and quite to the petiole and primary veins in the Water Crowfoot (*Ranunculus aquatilis*).

It is not necessary that we should enter minutely into the mode of development of every variety of leaf; and it is probable that we have already given such examples as will enable the reader to apply the principles now enunciated to any other form which may present itself. We shall therefore only name a few other forms which are not unusually met with. The reniform or kidney-shaped leaf is represented in Fig. 172; cordate or heart-shaped, and sagittate or arrow-shaped (Fig. 173).

Leaves are, for the most part, developed symmetrically—that is, each half closely resembles the other; but in some instances this rule is not observed. Thus in the Begonia the leaf is manifestly unsymmetrical, having one side far less developed than the other; and in some
of our ordinary trees the transverse development commences on one side whilst it is absent on the other. Such is shown in the elm leaf, Fig. 153.

*Compound Leaves* have already been defined to consist of several pieces connected together at one extremity by the petiole, the whole of which taken together constitutes the leaf. There is also another explanation of the term, to which we shall refer presently. Compound leaves, then, are lobed or pinnatifid leaves, with the divisions carried down to the midrib or petiole. In their first development they appear as simple leaves only; and in their subsequent progress may still be regarded as simple leaves with extreme subdivision. This may be at once appreciated if Fig. 164 be contrasted with Fig. 174; or Fig. 170 with 175; or Fig. 168 with the Strawberry leaf, Fig. 176;—in all of which the reader cannot fail to observe that this mode of division of leaves into simple and compound is purely artificial. The divisions of a compound leaf are termed *leaflets*; and, for the most part, each leaflet is of smaller
size, both longitudinally and transversely, than simple leaves. They are subject to
great variety of forms; and in their development are guided by similar laws to those
already explained in respect of simple leaves.

The most common form of compound leaf is the _pinnate_ (Fig. 180), in which there
are a series of small leaves arranged on each side of the midrib. When they are in
pairs on opposite sides of the midrib, they are said to be _opposite_; and when single
they are termed _alternate_. In many instances the leaf is terminated by an odd leaflet
(Fig. 177), and the branch is said to be _determinate_; when otherwise, the development
of the leaflet has been arrested; and if no flower exist at the end of the branch, it is
called _indeterminate_. An intermediate condition is found in such leaves as have small
foliaceous organs attached to the midrib between the leaflets; and then the leaf is
 termed _interruptedly pinnate_ (Fig. 178). It is understood that the normal arrangement
of the leaflets is alternate, as may be inferred from a consideration of Fig. 160; for it
is there seen that, although each side is symmetrical, the primary veins (which would
form the midribs of the leaflets of a compound leaf) do not leave the midrib at points
directly opposite to each other. This is also deduced from the observation, that at the
formation of the first leaf at the first node (see page 58), there is no opposite leaf, but
that one is subsequently formed at the next node; and hence it is inferred that when-
ever leaves are placed opposite to each other, as seems to be the rule in the development
of the leaflets of a compound pinnate leaf, there has been the suppression of an inter-
vener leaf and node. This suppression is carried to a yet greater extent in the arrange-
ment of leaves in _whorls_ (Fig. 179); for then not only are there two opposite leaves,
In other instances the leaflets are not arranged in a pinnate manner, but form a kind of tuft, as in Figs. 175 and 176; but even in such cases there is no difficulty in tracing an analogy between them and the whorled form of leaves shown in Fig. 179.

We intimated at the head of this section that there is another form of compound leaf besides that now described, and it is one which is based upon distinct anatomical characters. It is such leaves as are connected with the petiole by means of an articulation or an immoveable joint. If the leaf of an apple or an oak tree be examined, it will be seen that the midrib passes uninterruptedly down into the petiole; but the leaf of an orange presents a transverse line with a slight swelling on either side of it (Fig. 181  a), and at this point the blade of the leaf may be somewhat readily broken from the petiole. There is no arrest of circulation at this place, although the separation is easily effected, for the vessels pass uninterruptedly from the petiole to the midrib. It is thus not easy to show how or why such an anatomical peculiarity should exist; for the common opinion, that it is the terminal leaflet of a compound leaf with the lateral leaflets undeveloped, does not much help us. It is also found in the common berberry (Berberis vulgaris), and in a few other plants.

We have already stated that a leaf without a petiole is termed sessile, or sitting, but when it entirely surrounds the stem it is known as perfoliate (Fig. 182), and when it runs down the stem, as in certain thistles, it is called decurrent (Fig. 183).

The petiole, or foot-stalk of the leaf, is the assemblage of the veins of the leaf which conducts the juices to and from the stem. As it contains all the vessels of the leaf it must possess two sets of vessels, one devoted to the conveyance of fluids to, and the other from, the leaf. There are also spiral vessels and so much cellular tissue and cuticle as may connect and inclose the vessels in the most compact forms. The figure of the petiole is rounded; but in many instances the upper surface has a channel, and thence is called gutter-shaped. In other cases it is perfectly flat, or has processes on its sides which give it the appearance of winged; or it is rigid, twisted, or hooked. The grasses and the Ranunculaceae have a sheathing petiole, or one which passes down the stem, and is so large as nearly to embrace it. It has at its point of connexion with the blade a little organ found universally in grasses, called the ligula (Fig. 184  a). The petioles of the leaflets of a compound leaf are termed petiolules.

The distal extremity of the petiole is the part first formed in the bud; and when at
length the whole is perfected it may be so closely connected with the stem that it does not break off when the leaf has decayed, but hangs with the remains of the leaf until the following season. A stem thus covered is said to be *induplicate*; but in a majority of cases the petiole falls from the stem, and leaves a mark which is known as the *cicatricle*. The angle between the point of insertion of the petiole and the stem is termed the axile or *axilla*, and is the normal position of the leaf-bud and the flower.

Petioles have several important modifications. Thus in certain so-called leafless plants, as the acacias, they assume the function of leaves, and are termed *phyllodes*; but that they are veritable petioles is proved by the fact that they bear leaflets at the earliest stage of their development, and have parallel veins, although occurring in exogenous plants. Such are the petioles in the *Dionaea muscipula* or Venus's fly-trap (Fig. 1), in which plant they are expanded laterally, and resemble the true leaves. This modification is due to an unusual development laterally; but there is another in which it proceeds solely in the longitudinal direction. Such are *tendrils*, or spiral-spring-looki
Stipules are leaf-like organs occurring in pairs at the point of connexion of the petiole with the stem (Fig. 184*). They are formed at the very earliest appearance of the leaf, and then are seen as two small tumours, continuous with the leaf-like expansion; and since they grow more rapidly than the leaf itself, they at length become one of its protective coverings. They usually assume all the external characters and internal anatomy of leaves (except in size and position), and, no doubt, perform the functions of those organs. In certain pod-bearing plants, as the sweet pea (lathyrus), they cannot be distinguished from leaves; and, although they appear as distinct organs in certain roses, they sometimes subsequently become true leaves. In the polygonums and rhubarbs they do not assume this leaf-like character, but appear simply as a membranous, almost colourless, sheath, which surrounds the base of the petiole and the stem, and is known as an ochrea (Fig. 186). When they are found at the base of the petiole of a pinnate leaflet, they are distinguished from the stipules of the whole leaf by the term stipel. The stipel differs from the stipule in being developed after its leaf, and in proceeding in its growth very slowly. It is occasionally difficult to distinguish the stipule from certain membranous parts formed at the base of the petiole of the common crowfoot and umbellifers; and in most monocotyledonous or endogenous plants, they are not met with.

We have now completed our account of the fully developed leaf, with its lamina, petiole, and stipules, without having as yet discussed the constitution of the embryo leaf or leaf-bud, because, although the leaf is developed from the bud, and the bud is the first to be formed, yet in the earliest development of a plant the first leaf is produced without a bud, and passes through its course of development before a leaf-bud appears. The leaf-bud is an imbricated or scaly coniform organ, placed in the axis of a leaf, and is a rudimentary leaf or branch formed as the growing season is about to close.
In it, therefore, we rather find the place and the nidus in which the leaf will be formed in the coming Spring than the parts of a leaf in a rudimentary condition. There are only two parts which need attention—the central growing point and the imbricated scales (Fig. 187).

The growing point is composed of cellular tissue, possessing special powers of vitality and growth, and connected with the horizontal system, or pith of the stem. There are no vascular structures within the point itself, but spiral vessels and woody fibre approach near to its base (Fig. 105 a). It has a highly important function to perform, for not only is it the point from which all the future leaves must be developed, but it is probably the means whereby the circulation of the sap of plants is again effected after the quietude of the previous winter. To what anatomical part of the growing plant this “pumping” power is to be attributed is unknown, and the vital principle which excites it to action has not been discovered; so that we must at present regard this property simply as being a part of its constitution, and of that of the plant as a whole. This growing point has a certain analogy with the embryo in the seed; inasmuch as both tend to growth and reproduction; but they differ inasmuch that the leaf-bud needs no fertilization for its development, and propagates the individual as well as the species, whilst the embryo imperatively needs fertilization, and continues the species, not the individual. There is also a resemblance between leaf-buds and bulbs, page 71.

The imbricated scales (Fig. 187 b), are called tegmenta or coverings, since their duty is to protect the delicate growing point. They are foliaceous organs, and are considered to be identical with stipels. The outer ones are usually harder and of ruder texture than the inner ones or those more immediately surrounding the growing point; and in cold climates a further protection is afforded by a thick downy covering, as in willows, whilst the scales are thinner and smoother in plants growing in tropical regions. All the scales, at least in many plants, are ultimately developed into leaves.

The normal position of a leaf-bud is in the axil of a developed leaf; but, according to the opinion of certain physiologists, the sap has the power of producing buds in any position. It is well known that they have been produced upon the stems of plants and upon the leaves of the Bryophyllum (Fig. 188); and the fleshy parts of most plants, as of the bulb of the Hyacinth, may, by care, be compelled to produce buds, and to repro-
duce the plant. Still such instances must be regarded as exceptional and irregular; and hence the buds so formed are termed adventitious.

**ORGANS OF REPRODUCTION.**

The foregoing descriptions have referred to those parts of a plant which are concerned in maintaining its own vitality and increasing its development, and may therefore be termed personal; but there are other parts which have for their functions the production of new individuals, and may hence be called relative. Such are the organs of fructification, and they are known generally as flowers, seeds, and fruit. We shall consider these in their order.

The flower is in part a reproductive organ, with certain protective coverings. It consists of various parts, as the bract, calyx, corolla, stamens, and pistils, in their order, proceeding from without inwards.

**The Inflorescence.**—A number of terms have been devised to enable us readily to designate the arrangement which the whole arrangement of flowers presents upon the flower stalk, and it will be convenient to place them here before we enter upon the consideration of the parts of each flower. Such an arrangement of flowers is commonly termed the inflorescence.

The flowers are immediately supported upon the stem in one of two ways; either by a more or less elongated branch, or foot stalk, termed the peduncle, or by a flattened more or less fleshy organ, as in the Strawberry, known as the receptacle. The peduncle differs in no essential respect from the foot stalk of a leaf, its variation being merely that of size and form to enable it to support the flowers. When it supplies the place of a stem, as in the Cowslip (Primula), it is called a scape; and when it is elongated, and passes in a straight line throughout the inflorescence, it is called an axis, or rachis, as in Grasses, Fig. 184. In many instances, as in the Umbelliferae (the Parsley), it is divided into a number of lesser peduncles, each one still supporting many little flowers, and the divisions are termed pedicels.

The receptacle is very commonly met with, and more particularly in the most numerous class of plants, the Compositae; but it is there not fleshy, and is sometimes distinguished from the fleshy receptacle of such plants as the Strawberry by the term thalamus. The juicy part of the Strawberry is the receptacle, as may be observed by noticing the position of the little seeds which are placed upon its outer surface. The receptacle is the terminal growing point of the stem, and is closely analogous to the flower head of the Arum, Fig. 192.

The arrangement of the flowers upon the foot stalk or receptacle is primarily divisible into two classes—vis., such as have no other intervening foot stalk, and then are called sessile or setting, and such as are stalked. The examples of sessile inflorescence are the Spike, Locusta, Spadix, Catkin, Capitulum, and Glomerulus.
The spike (Fig. 190) is represented by the Plantago, and the locusta by the common Grass; and they differ from each other, chiefly in that the former has the envelopes of the flower distinct from each other, whilst in the latter the bracts form the sole covering.

Fig. 192.—The inflorescence of the Arum. a, the spadix inclosed by the spathe; b, the fleshy rachis, or spadix denuded of flowers; c, the spadix covered with sessile flowers.

Fig. 193.—A Capitulum in the Composite. a, florets of the ray; b, florets of the disk; c, floret of the ray detached; d, floret of the disk detached.

The catkin, as in the Willow, so far resembles the locusta, that the coverings are not distinct from each other; but it differs inasmuch that the rachis with the flowers falls in a single piece after fructification, whilst the rachis of the locusta is permanent. The Spadix, as in the common Arum, is an inflorescence with a fleshy rachis, to which the flowers are closely attached, and inclosed in the modified bract called a spathe, Fig. 192. The Capitulum is a head of flowers sessile upon a receptacle, page 105; and in the Compositae the flowers are divided into two classes, the florets of the ray (Fig. 193 a), which are usually ligulate or strap-shaped, and the florets of the disk, or centre, which are commonly smaller, Fig. 193 b and d. The Glomerulus consists of a series of heads in a common involucre.

The second division, or those modes of inflorescence in which the flowers are each supported by a pedicle or stalk, is an extensive field, and comprehends the most beautiful flowering plants. It is divided into the Raceme, Fascicle, Corymb, Cyme, Panicle, and Umbel.

The Raceme is the simplest form, and consists of a series of stalked flowers arranged on a common peduncle (Fig. 194), the pedicels being of nearly equal length. When the lower pedicels are so much larger than the upper that the flowers are supported at nearly an equal height, so as to form a kind of head, the terms Fascicle and Corymb are applied, the former, as in the Sweet William (Dianthus), when the expansion of the flower is from within outwards; and the latter when from without inwards. The remaining varieties of inflorescence are somewhat more complicated, since the stalks or pedicels are divided, and bear many flowers instead of one only. Thus the Panicle is a
r raceme, each pedicel of which bears many flowers; but where the rachis itself divides, and no longer exists as an axis, the panicle is termed deliquescent. This latter form gives rise to another variety—the Cyme (Fig. 198), as in the Elder (Sambucus nigra) which consists of a series of deliquescent panicles that have become short and corymbose, with their central foot-stalks meeting at a common centre.—The last form is the Umbel, and is divided into two classes, the Simple and the Compound (Fig. 199). The Simple Umbel consists of a number of corymbose branches, meeting at a common point, as in the Cyme, and differs from the Cyme only in that the branches are corymbs and not panicles. The Compound Umbel is distinguished from the Simple Umbel by the division of the pedicels, so that they divide and bear other Umbels. The whole head of Umbels is then called an universal umbel.

Such is a written description of this somewhat complex and difficult subject; but in order to a ready familiarity with the various kinds of inflorescence, it will be necessary to select the illustrations, and carefully study them with the descriptions,
and after a little attention it will be found that the eye will intuitively, as it were, recognise the leading forms. We now proceed to consider the several parts of which a flower is composed.

**Fig. 198.—The Cyme.**

**Fig. 199.—The Umbel.**

The Bract is the outermost envelope, and closely resembles a foliaceous organ, and bears the like relation to the flower that stipules do to the leaf. Its colour is more or less green, and as it oftentimes bears much resemblance to a leaf, it is not always readily distinguished from those organs. The rule adopted in making the diagnosis is, that all organs, of whatever size, form, and colour, which intervene between the true leaves below, and the flower above, must be bracts. This definition is too expansive to render the determination of this question easy in every case, and therefore much attention must be given by the botanist to each particular instance of difficulty. Whenever the last leaf on the one hand, and the Calyx (to be mentioned presently) on the other, can be clearly determined, then whatever intervenes must be of the nature of bracts; but whilst it is to be distinguished from leaves only by its lesser size and higher position, and from the Calyx by its foliaceous character and lower position, there must be great difficulty in determining its nature in many instances. In some plants it is necessary to know the number of the divisions of the Calyx, and then to regard all parts external to these, even if almost identical in colour and structure, as bracts.

So long as they resemble leaves it is not needful to attach to them any more particular name than that of bracts; but when they are sensibly modified, it is convenient to give them other designations. Thus in grasses they supplant all other coverings of the flower, and are known as Glumes (Fig. 200).

The arrangement of the parts in the flower of the grass is so peculiar as to present much difficulty to the botanist, and consequently various designations have been given to the parts or organs. The three parts which constitute the coverings of flowers are bracts, calyx, and corolla; but, in this great class of plants, either they do not exist, or they are incapable of separate definition. On reference to Fig. 200, it will be observed that there are a series of scales or valves connected by their bases to the common stalk on which they are supported, and having their apices free and oftentimes prolonged into beards or bristles. The outer ones, b 1, are large and empty, and are suitably termed Glumes or Gluma exterior. Within these are a series of similar but smaller scales, attached
in like manner on either side, and opposite to each other, 62, and which differ from
the outer ones in that they bear the organs of fructification, and
each one, in fact, is a separate
flower. These have been known
as the Gluma interior, or more
recently as the pales or chaff. Within
each of these is a third structure
consisting of two minute and some-
what fleshy scales, d, to which
the term glumella or squamul has
been given. Of these three struc-
tures it is probable that the first
n the external glumes have the
greatest analogy to bracts.
The Cupule or cup, as in the
hazel-nut (Corylus), and acorn
(Quercus), is another instance in
which the bracts constitute the
covering of the flower.
The Spathe is a large bract
coloured on its inner side, as in
the common Arum, and in palms,
and in the numerous plants ar-
ranged with them. In this in-
stance there is much evidence
that the inner coverings of the
flower exist, but are indissolubly
connected with the bract.
In the Compositae, or compound
flowers, as the rosemary, there are
many rows of bracts around each head of flowers on its external surface. This
is called the common involucre; but besides these there are other bracts placed upon
the head between the little florets, and from their resemblance to chaff they are called pales.
In the sedge tribe (Carex) each floret has two bracts adherent at the edges named
uroculus, or perigynium.
The term involucre is employed whenever a series of bracts surrounds a number of
flowers. The word universal is also added in the umbelliferous plants, as the caraway
seed (Carum Carvi), to distinguish the common involucre of the whole head of flowers,
whilst the term partial designates the involucre of each little division of the flowers
(umbellules).
Perianth (Fig. 201) is a term employed to designate such flowers as have the two
next coverings, the calyx and corolla, combined. Such is the flower of the tulip and
the orchis. In many instances the inner divisions of the perianth are more gaudily
coloured than the outer ones, thus indicating the separation into corolla and calyx
which naturally occurs, and it is customary to describe the three outer leaves of the
perianth as a calyx, and the three inner as a corolla.
The Calyx is that covering of the flower which externally is enclosed by the bracts,
and internally lies in apposition to the corolla. As the bract is usually situate at a distance from the flower, the calyx is in fact the external envelope (Fig. 202). In colour and general texture it resembles a foliaceous organ, and thus may usually be distinguished from the corolla. When any difficulty occurs in determining the nature of the coverings of flowers, it is customary to regard the external series as a calyx, whatever may be its appearance, and thus no flower can be without a calyx (except such as are composed of bracts only); whilst many are met with without a corolla. The calyx is evidently subservient to the corolla; for, although it exceeds the latter in size up to the period of the unfolding of the flower, it usually becomes relatively smaller by reason of the growth of the corolla, and, in many instances, in the mature state of the flower, bears no proportion to the corolla in size. The calyx is commonly continuous with the peduncle, and is permanent; but in many instances it is deciduous, and falls away on the opening of the flower, or immediately afterwards, as in the poppy and the Crucifera, or pod-bearing plants. When the enlargement of the inner parts of the flower causes the calyx to fall, it usually separates from the peduncle in one piece, and is called operculate, except in falling it be ruptured, when it is termed calyptrate.

The calyx is originally formed of several distinct pieces, which are termed sepals; and when, in its after development, these adhere to each other by their sides, and become but one tube, it is termed mono-sepalous; but when they still remain distinct, each part is known as a sepal, and the whole calyx is termed poly-sepalous. The sepals have all the properties and analogies of common leaves, but have the superadded function of protecting the essential parts of the flower. There is, however, one class of plants in which the calyx has exceptional characters, viz., the Composite, or compound flowers.
The flowers in this class are arranged on a capitulum, and are very numerous upon one common receptacle. Each floret is perfect, and therefore has a separate calyx, either rudimentary or developed; which, on account of its membranous character, is termed pappus. When its divisions are broad, it is called paleaceous, or chaffy. The terms pilose (velvety), plumose (feathery), and setae (bristles), express various conditions under which it appears in its connexion with the ovary.

The position of the calyx is described in reference to that of the central organ of reproduction, the ovary, and is called superior or inferior, as it appears to arise above or below that organ. But in truth it is simply a question of appearance, for since the ovary is the central and final point in the development of the plant, all other organs must be arranged around and therefore below it (Fig. 203). The calyx is consequently always inferior; but whenever it adheres to the ovary, or the parts surrounding the ovary, so that it appears as a separate organ only at a point above that organ, it is, in indefinite language, said to be superior. Pappus is a superior calyx, since it is closely attached to the ovary. The form of the calyx is a material incident in the description of a plant (Fig. 205), and many terms have been invented to express it beyond those which indicate the number of its sepals, and its permanency or otherwise upon the peduncle. Moreover the form and size of each sepal, and the character of its margin, are always referred to; and the calyx is said to be regular or irregular, according to the uniformity or otherwise of its divisions.

As a rule, the number of sepals has a relation to the number of the divisions of the corolla; so that if there be five of one there will probably be five of the other.
The Corolla.—The arrangement of the various parts of the plant upon the stem is
agreeable to a definite course in obedience to a known law, as already intimated,
commencing with that of leaves and ending with the ovary. It has also been stated
that each foliaceous organ is normally formed separately and not in pairs, or in greater
numbers, and as the parts are not produced on the same plane or in right lines, but at
different heights and in a spiral manner, each one appears to be alternate to the other.
When the parts are widely separated this is readily apparent, but when they are brought
close together, the observer is disposed to doubt the fact. Yet in such instances they
are never so closely arranged that they occupy, or appear to occupy, the same spot, but
are placed more or less side by side, and by multiplication ultimately encircle the stem,
and are said to be in whorls. Such whorls of leaves oftentimes seem to be on
the same horizontal plane; but if such be really the case, it is an exception to the
established rule. Thus it will be evident that the whorls of leaves taken collectively,
cannot be on the same plane, but must be relatively above and below it; and also that
each member of the whorl will be alternate with a corresponding member of the whorl
above and below it. Such is the rule, liable to many exceptions; and when, as exceptional cases, leaves are found opposite or in whorls and not alternate, it is assumed
that an intermediate leaf, or set of leaves, has been suppressed, or that the opposite or
whorled leaves have each really split into two, and thus doubled the original number.
This is a difficult subject for investigation, but it is highly probable that the former
theory is correct. From this statement the reader will infer, that if the development of
the tree begins with the formation of leaves, and ends with the production of fruit, the
leaves and all parts between them and the fruit must be situated below the fruit. Thus
the bracts are placed above the leaves, the calyx above the bracts, the corolla above
the calyx, the stamens above the corolla; and finally, we arrive at the pistil or centre organ
of the whorle. The relatively external and alternate position of the various parts of
the flower are well exhibited in the outline sketches in Fig. 206.

A knowledge of this fact is a fundamental one in botany, and enables us, at this
point of our subject, to include all the parts within the term corolla which lie between
the stamen internally and calyx externally (Fig 203.); and, moreover, whenever the
calyx and corolla are not very distinct from each other, the inner whorls of leaves are
thus appropriated to the corolla.
The corolla, then, is distinguished from the calyx by its normally superior and
alternate position; but it has a further characteristic in being unusually gaily coloured.
It is that part to which the term flower is commonly restricted in ordinary
language, and is longer and larger than any other part. It is almost invariably
caducous, and falls very soon after the impregnation of the inclosed organs. When it
consists of one piece, it is termed mono-petalous; and when divided into several pieces,
its divisions are known as petals; and the corolla is tri-petalous or poly-petalous, according
to the number of its petals. The number of petals is very variable; and whilst it
remains tolerably fixed in the same species, so long as it retains its wild condition, it is apt to vary greatly when the same plant is cultivated. Thus, if we take the rose as an illustration, we find that its normal number of petals is five, as in the hedge rose; but, when cultivated, the number vastly increases, until a "perfect" rose, in horticultural language, should present to view nothing but petals (Fig. 207). Whence, then, has the rose obtained its additional petals? Not from new formations, since that would be in opposition to the established law of development, but from a modification of other organs which were originally formed for another purpose. This applies not only to the corolla, but to every part of the flower; and, as a further rule, it may be remarked, that the parts so modified are usually, if not invariably, those which are naturally placed higher on the stem than those into which they become transformed. Therefore the petals are not produced from sepals, and sepals from bracts; but, on the contrary, the bract may assume the place of calyx, and the calyx that of corolla. The newly-formed petals are therefore the product of transformed stamens, or the parts of fructifica-

Fig. 207. A perfect Rose, having nearly the whole of its stamens converted into petals.
tion which lie immediately within the corolla. In this mode the number of stamens diminishes in proportion as that of the petals increases; and this transformation may readily be traced in any garden rose. The gradual conversion of the one into the other is well exhibited in Fig. 208.

It thus becomes evident that the number of the petals can seldom be employed with certainty as a distinctive mark in the classification of plants. But yet it is not without its value in such plants as retain their natural habits; and the more so when it is known that any increase is usually that of a multiple of the original number, as that five petals become ten or fifteen.

In respect of position, the corolla naturally places itself below the ovary (Fig. 208); but whenever it is so attached to the side of the ovary, so that it separating itself only when above that organ, the relative terms of superior and inferior are still employed. Thus all corollas are said to be either superior or inferior.

As a petal is the analogue of the leaf, it is probable that it will have similar parts; and thus we describe the expanded part as the lamina, and the contracted part by which it is inserted as the unguis, or claw. In many instances, as in the rose, there is no unguis, just as many leaves are destitute of petioles; whilst in many others the claw is several times the length of the lamina, as in the pink, and the petal is termed unguiculate. The short claw of the petal of the Crowfoot (Ranunculus) has on its inner surface a small gland which secretes honey, and is a true nectarium (page 69), but which may probably be a modified stamen.

The forms of the corolla are extremely numerous, as is familiar to every one, and require special designations. If we first examine a monopetalous corolla we find three parts, which, by their variations, give variety of form. First, there is the expanded portion, which consists of a series of laminae, connected at their margins, and which has its free border more or less indented or divided in such a manner that the divisions are regular or irregular (Fig. 210); secondly, the tube, constituted of the united edges of the claws; and, thirdly, the point at which the tube is inserted, or expands into the expanded laminae, which is termed the /aux or throat. In a few instances, other parts enter into the formation of a corolla, as the corona or cup observed around the throat of the Narcissus (Fig. 209), and the true Nectaria, or honey spots, so well known to the honey-bee. A campanulate, or bell-shaped corolla (Fig. 210a), as in the Campanula, has little or no tube; and so in like manner with the flattened rotate or
wheel-shaped corolla. The tube is greatly elongated at the upper part in the hypocrate form or salver-shaped corolla (Fig. 212); whilst the infundibuliform, or funnel-shaped corolla, differs from the latter chiefly in having the tube expanded at its upper part. There is yet another form of monopetalous corolla, called the labiate, and which offers the greatest resemblance to the infundibuliform variety. Its distinctive mark is the division of the expanded part into two portions, which in some degree resemble lips (Fig. 210 b), and are so placed that one is called the lower and the other the upper lip. When they are widely separated, as in the dead nettle, the corolla is said to be ringent (Fig. 211), or grinning; and when the upper lip is hollowed and expanded, as in the Monkshood, it is called galeate, or helmet-shaped. When, on the other hand, the lips are pressed closely together, as in the Snapdragon, the corolla is said to be pternate. These are fanciful terms, but yet in many instances give a familiar idea of the forms to be represented.

The forms of a polypetalous corolla are perhaps less varied than those now described, and, for the most part, will readily suggest the names by which they are designated. Such, for example, is the cruciate corolla, which is divided into four parts like a Maltese cross, and having six stamens, four of which are long and two short. There is, however, one very marked variety, which offers some complexity, viz., that of the Pea, and many other plants, called the papilionaceous or butterfly-winged corolla (Fig. 213). Such a corolla has also five divisions or petals, four of which are arranged in pairs, and one separately. The pairs form the carina, or keel, a, and immediately inclose the sexual organs; the alee, or wings, b, which lie on either side of the carina; and, lastly, the large vexillum, or standard, c. The two former names are not inappropriate; but the latter one might have been well exchanged for some term designating a sail.

The anatomical structure of the corolla differs in no essential respect from that of leaves. There is, however, a greater delicacy of organization, and variation in the relative proportion of parts. Thus, whilst there are stomata as in leaves, they are fewer, and are accompanied by a smaller quantity of the parenchyma. The veins of the corolla contain a larger proportion of spiral vessels, and less of woody fibre, than is found in leaves. The colours, even the pearl white met with in the corolla, are due to a colouring matter termed chromule (page 53), placed within each individual cell; and so carefully is this distributed, that adjoining cells may vary considerably in colour. The function of the corolla is that of leaves, with the superadded one of protecting the organs of fructification.
The Stamens.—We now enter upon the description of the essential parts of the flower—viz., the sexual organs, or those parts concerned in the process of reproduction. All the organs which have hitherto been described are accidental, and not essential, since many plants are met with without them, and since their sole duty is to minister to the wants of these central and ultimate objects of vegetable organization. No plant exists which has not organs of reproduction of a higher or a lower grade of organization; whilst many are wanting in every other accessory structure.

The stamens are placed within the corolla, and immediately surround the central point or pistil, and are regarded as the male organs of reproduction. When longer than the corolla, they are said to be exserted (Fig. 215); and when shorter, they are included (Fig. 214). Their number is very variable, from one to fifty, and even more; and from the causes already mentioned (page 112), it is not permanent in the same plant, or the same class of plants. It is, however, commonly the same as the petals and sepals; or, if it vary, it is a multiple of that number (Fig. 215). They may constitute one whorl only, which will consist of an equal or double number of the petals, and if of the same number, they will be alternate with them; or there may be several whorls, all of which lie nearer and nearer to the pistil, and follow the same law as the outer whorl. It is not an unusual occurrence to find the stamens placed opposite to, and not alternate with, the petals, or with an inner whorl of themselves; but this is an abnormal condition, and arises from the suppression of alternate individuals or whorls. This may be readily understood by reference to Fig. 206, in which the stamens are double the number of the petals; so that each alternate stamen in the whorl will be alternate with, and each other stamen opposite to, the petal. If, therefore, these stamens be removed, or placed in an inner whorl, which are opposite to the petals, the stamens will then be alternate with the petals; and thus the normal number and position of the parts of the flower be produced. But if, on the other hand, the suppressed stamens are the alternate and not the opposite ones, the flower will become more abnormal by the alteration.

The stamens are also necessarily placed on a plane lower than that of the pistil or ovary, and, therefore, must be inferior, as represented in Fig. 203. But not unfrequently they are said to be superior, from the attachment which they contract with the sides of the ovary (Fig. 204). Three Greek terms have been devised to express this apparent relation in position between the stamens and the pistil—viz., Hypogynous, as in the Poppy, when normally placed below the ovary (Fig. 225); Epigynous, when growing
upon the ovary (Fig. 218); and Perigynous when placed around it (Fig. 217), and attached to the calyx or corolla, as in the Rose—all of which terms, although inaccurate, are in constant use.

The point of insertion of the stamens is into the peduncle, at its terminal point; but sometimes they contract adhesions with themselves, which give such plants a distinctive peculiarity. Thus of ten stamens in the Pea tribe of plants, nine are united together, and constitute a bundle, to the exclusion of the tenth (Fig. 221 a). In the Geranium and the Mallows the whole are united into one body (Figure 219); whilst in the Hypericum (Fig. 220) there are three, four, or more bundles. These conditions are expressed by Greek words, which signify the number of bundles or brotherhoods.

Thus the Geranium is Monodelphous (one brotherhood), the Pea Diadelphous (two brotherhoods), and the Hypericum Triadelphous or Polyadelphous (three or many brotherhoods). This union of the anthers refers to their lower parts, and is sometimes so close as to have received the name of columna, or gymnostemium, as in Orchids; but there is another which has exclusive reference to the upper—viz., such as is met with in the Composite. Like that great class, the number of stamens in each floret is usually five; and they are so connected together at the top as to form a tube, through which the pistil passes (Fig. 222). Such a condition is termed Syngenesia (to grow together). Again, there are differences in size as well as position, both accidental and essential. The accidental are such as have shorter ones, from an uneven development within the period of growth, either from original tardiness of appearance, or from some subsequent hindrance to growth. This may be well seen in the Poppy, in which the great number of stamens offers a facility for this kind of investigation. In the oxalis, also,
it is not unusual to find one-half of the stamens shorter than the other. The essential differences in size are such as are permanent in the same species; and of these there are two examples. Many flowers with a bilabi ate corolla, as the Foxglove and Mint, have two long and two short stamens; whence they are called Didynamous (Fig. 223). The cruciate corolla, as in the Turnip and Radish, has usually four long and two short stamens; and to them the term Tetradynamous (Fig. 224) is aptly applied.

The number and arrangement of the stamens was a chief element in the classification of Plants by Linnaeus; and of the twenty-four classes arranged by him we have now referred to five. Eleven others vary simply according to the number of stamens, from one upwards, and are named from Greek words having that signification. Thus Monandria signifies one stamen; Diandria, two stamens; and so on to Dodecandria, which represents twelve or more stamens up to twenty.

Two others—viz. Icosandria and Polyandria—have an indefinite number of stamens, which in the former are perigynous, and in the latter hypogynous (Fig. 225). Thus no fewer than eighteen out of twenty-four classes are arranged according to the number, length, and place of insertion of the stamens.

We have hitherto regarded the stamen as a whole, but it is naturally divisible into three parts, each of which has special functions and analogies. These are the filament, anther, and its contained pollen, the first of which may be entirely absent.

The filament is, as its name implies, a thread-like organ, attached by its base to the peduncle, and by its apex to the anther, and is simply a pillar on which to rest the latter, and a conduit through which vessels and fluids pass for the nourishment and growth of the pollen and its case—the anther. It is the analogue of the petiole of the leaf, and like it consists of a bundle of vascular tissue, enveloped in cells, and a delicate cuticle. Its figure is seldom quite cylindrical, but more commonly tapers towards the top, when it is said to be awl-shaped. In a few instances, as in the Meadow Rue, it is the thickest at the top; in others it is spiral, or is bent like an elbow or knee (geniculate), or bifurcates into two branches. In some instances it assumes a foliaceous form, and likewise in most sterile stamens. The
outer whorl is the most subject to this modification, and also to the transformation into petals. Its colour is usually white; but in the Evening Primrose and the Fuschia it is gaily coloured.

The anther is essential only so far as it protects the pollen, which is the male essence in the plant. It consists of a series of cells, which are attached to the top of the filament in three recognizable modes. First, when the base of the anther-case is connected with the apex of the filament (*innate*, Fig. 229); secondly, when the union is at the back of the anther (*adnate*, Fig. 231); and, thirdly, when it is so slightly attached, as in grasses, that it can swing freely in almost any direction (*versatile*), Fig. 237 b. This and other facts will be better understood by a reference to the analogies of the anther; for as that organ is the modified lamina or blade of the leaf with its edges so folded that it can inclose contents, it would evidently be expected that in its normal state it should be attached to the filament or petiole by its base.

This view of its construction will also lead us to infer that there are two cells (one on each side of the midrib), with two points of union—*viz.*, one behind, called the midrib, or *dorsal suture*, and one in front, known as the newly-formed *ventral suture*. There will also be one line of separation or division—*viz.*, that lying between the dorsal and the ventral sutures, called the *connective*. Such, it is probable, is the normal type of construction of the anther; but in the extremely modified form in which the leaf thus appears, it is no matter for wonder if the relations of parts should be found much altered. Thus the connective is sometimes absent, and then the anther is one-celled; and, on the other hand, a new septum arises across each cell, and the organ becomes four-celled; and this latter, according to the investigations of Schleiden, is the more common form of anther (Fig. 227).

Its actual construction is best seen at the period of its opening or *dehiscence* for the expulsion of the pollen, and the precise mode of its rupture has been carefully investi-

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**Fig. 227.**

Fig. 227, representing a cross section of an Anther. A, the *connective* with the bundle of vessels at a; B, the halves of the Anther corresponding with the halves of the leaf; d, processes subdividing each lateral half, so as to form four loculi or cells.

**Fig. 228.**

Fig. 228.—Exhibiting the ordinary mode of dehiscence at a, by longitudinal fissure, leaving the cell open, and some grains of pollen attached, and at b, the opening by the rupture of the valve or face of the Anther c, which then curves back, as in the Berberry.

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gated. It is certain that the line of rupture runs longitudinally along the ventral suture, and not transversely, except in a few instances, as in the Duck-weed (*Lemna*), Fig. 226 b, and that the cells open by a separation of two portions or valves, which
diverge more or less widely from each other, and thus give the appearance of a one-celled organ. In many plants the cells are either unequal, or one only is developed, as in the Sage (Fig. 226 f), Canna, and the Arrowroot plant; or after the commencement of the process of development the two cells become confluent, and produce a single cell. As each cell will have a separate line of dehiscence or fissure, a two-celled anther will have two fissures, and a four-celled four fissures, and the latter is probably of common occurrence. But besides the number of fissures, there are other points of disagreement with the general law. Thus in a few instances the pollen is emitted not by a fissure, but by small holes, or perforations; or the fissure does not occupy the whole length of the cell; or the cells burst first into each other, and then have a common dehiscence; or a large portion of the whole face of the anther comes away in a piece (Fig. 228 b). But however much so minute a matter may vary, it is of importance to bear in mind that it proceeds on a fixed plan, and that its whole organization has a known correspondence with it.

When the line of dehiscence is towards the petals, the anther is said to be extrorsae, and when inwards towards the pistil, it is called introrsae. The lining membrane of the cells is called Endothecium, and usually consists of fibro-cellular tissue, whilst the pollen occupies the position of the normal parenchyma.

The Pollen.—The parts of the stamen already described seem to include in their analogies the whole leaf; for the filament represented the petiole, and the anther the lamina, with the parenchym in which the pollen is deposited. But yet there is another and the most essential part of the stamen as yet undescribed, and one which has also its analogies in the leaf itself. This substance is known as the pollen, and is the immediate source of fructification. It is a powdery substance of various colours, but more commonly colourless, as may be noticed upon any fully-developed flower. It is that material which is shaken like dust from the flower, and which is not infrequently adherent to the nose when that organ is searching out the sweet odours of flowers.

Its normal position is the anther case, where it remains until it has arrived at a stage of maturity fitted for the performance of its functions, when it is emitted by the dehiscence or sudden rupture of the anther, or pollen case, and is ultimately deposited upon the free end of the pistil. The quantity of small grains of pollen upon a single stamen is immense—infinitely greater than is needful for the fertilization of the pistil; but that is a wise arrangement to insure fructification, despite the influence of winds, the sterility of some of the stamens, and the irregularly-placed pistil. If our readers will examine any half-dozen plants, which may be near to them, in full bloom, and notice the relative height of the pistils and stamens, they will wonder not why so great a waste of pollen has been provided by nature, but that the fertilization should be effected with so much certainty. The improbability of this occurrence is of course greater where the male and female parts do not exist in the same flower; yet not only does it proceed regularly where there are separate flowers for males and others for females, but in our large forest trees, in which one tree has male flowers only, and another only female flowers. In such cases the pollen is carried by the wind—that very influence which at first sight seemed more likely to cause an entire waste of the
fertilizing material; but in other instances, as in the Bee Orchis (Fig. 230), it is probable that insects and birds are the means of conveying the pollen to the pistil.

Before we describe the influence of the pollen, it is needful to refer to the anatomical characters of that substance. The pollen appears to the naked eye, or with a lens of low power, to consist of a number of particles or granules, of various sizes and figures, which are technically termed cells. The more common figure (as is the case in all cells which lie loose) is spherical, or ovoid; but the most diverse forms have been noticed. Thus they are square in the Bladder (Senna), and triangular in the evening primrose (Fig. 233). In various compound flowers they are many-sided; in other plants they are twisted; and in Dill they are cylindrical. Such, however, are exceptional cases; and whether they may be attributed to pressure as in the cells of cellular tissue, is not known.

When examined with high magnifying powers, as with the eighth of an inch object glass, they are found not to be simple cells, but cells having a cell-wall divisible into two or three layers, and inclosing a turbid-looking fluid, termed fovilla. The external layer of the cell-wall is usually itself composed of cells, and is called the extine; whilst the inner one is of greater delicacy and extensibility, and known as the intine. In some instances, as in the Yew, there is a third membrane between these two, and named the extintine, whilst in the Evening Primrose a fourth has been described as the intexine. It is probable that all pollen cells have the two former; but it is not indubitable at present that the two latter are at all commonly found.

The fovilla usually consists of two portions, which are in constant motion, as may be seen in the garden plant, Clarkia pulchella, one of which is larger and more oblong than the other; and as it differs from all other vegetable structures, it is presumed to be the fructifying substance.

Such is the structure of the pollen before it is applied to the stigma; but after it has commenced its fructifying function it exhibits characters unseen before. Thus, immediately it has fallen upon the soft viscid tissue of the pistil, it begins to emit one or more minute processes, which traverse the length of the pistil, and are called pollen tubes (Figs. 232, 233). These tubes terminate in the placenta, and thus constitute a medium
of communication between the pollen upon the surface of the pistil and the young embryo. It is presumed that some undetected material is conveyed through the tube, which is the immediate source of fertilization; and it has been observed that the flower has begun to fade immediately after this occurrence, as though the function of that organ had then ceased.

How minute and wonderful are the structures and their functions found in vegetables! equally so with anything known in the animal creation. Thus all the parts of a plant, external to the stamen, are created in perfect subserviency to the functions of that organ; and of the stamen itself, how small a portion seems to be essential. The filament supports the anther, the anther incloses the pollen, the cell-walls of the pollen inclose a little matter, and it is only a part of that ultimate production which is essential to the function for which the plant was chiefly created!

Before leaving this part of our subject we must refer to a substance lying between the true stamen and the pistil, and which appears under various forms, according to the so-called superior and inferior positions of the ovary. In the Composite and Umbellifers, with their inferior ovary, the disk is a fleshy body, placed upon it, and oftentimes assumes a scaly appearance. In others, as the Dead-nettle and other labiate plants, it is found beneath the ovary, and has some resemblance to glands. As it is a mass of undeveloped stamens, its position will always be below the ovary, although it may adhere to that organ, and seem to be perigynous or epigynous.

![Fig. 232. Pollen tubes, passing from the pollen, through the conducting tissue in the pistil of an Antirrhinum.](image)

Fig. 232.—Pollen tubes, passing from the pollen, through the conducting tissue in the pistil of an Antirrhinum.

![Fig. 233. Pollen tubes in the Enothera biennis.](image)

Fig. 233.—Pollen tubes in the Enothera biennis.

![Fig. 234. Grains of Pollen; a, Fuschia; b, Scirpus romanus; c, Salvia; d, Armeria fasiculata; e, Acacia.](image)

Fig. 234.—Grains of Pollen; a, Fuschia; b, Scirpus romanus; c, Salvia; d, Armeria fasiculata; e, Acacia.

The Pistil.—The pistil is the female part of the flower, and the central point around which all the organs placed upon a branch are arranged. It is usually a complex organ, and oftentimes compounded of many leaves. It is readily distinguished by its central position, and the dissimilarity between it and the stamens in height and form, and more particularly by the absence of an anther at its apex. Occasionally it puts on a foliaceous appearance, as in Fig. 235.
In a majority of instances it is alone; but not unfrequently there are several pistils so as to constitute one or more whorls. When only one exists, it is termed Monogynia, from two Greek words signifying one female. Digynia will signify two pistils, and so on (as was explained with regard to the stamens), until we arrive at Dodecagnia, which represent about twelve pistils. In this mode eleven orders are added to the classes referred to at page 118; and to these one other is appended—viz. Polygynia, which signifies an indefinite number of pistils. The number of pistils, as well as of stamens, forms an essential element in the Linnaean classification, and is so employed that a plant with one stamen and one pistil would be arranged in the class Monandria, and order Monogynia.

The pistil, like the stamen, is divisible into three parts, each of which, as well as the whole, being a modification of the parts of a leaf. They are, first, the free end or apex, called the stigma (Fig. 236 d); second, the dilated base, or ovary (b); and, third, the intermediate structure, or style (c).

The stigma is one of the few external parts met with in vegetables, which are not covered with cuticle,—at least in the vast majority of instances. Its surface is usually
turgid, and covered with a viscid tenacious fluid. It is either simple or divided into two or more parts, and when divided the divisions for the most part arrange themselves in a whorl. The simple form has also usually a notch in the side (Fig. 237, A), indicating the normal division of even a simple stigma into two parts (see page 126). The anatomical character of the stigma exhibits a series of cells of various sizes, bounded on the sides by another series, which are the cuticular cells. It is in direct connexion with, and in fact is formed by the conducting tissue, to be described with the style, and through which the pollen tubes pass (Fig. 232). The function of the stigma is that of collecting the granules of pollen upon its surface, and conveying the emitted pollen tubes to the style. It is oftentimes assisted in the collection of the pollen by hairs which surround the style, and which, by the movement of the air, are enabled to sweep the pollen out of the ruptured anther (Fig. 238). Whether it exercises any influence upon the pollen, so as to cause it to emit its pollen tube, or whether the property of omission is exclusively that of the pollen is not known. The part of a leaf with which it corresponds is the very apex of the midrib; and as the leaf is folded inwards on each side of the midrib in order to form the pistil, it is manifest that the stigma will be formed by the two surfaces folded together, and thus be double and lateral (not absolutely terminal). It is present in all fertile plants, except in such trees as the Fir tribe, in which the seeds are naked (Fig. 249), and is stalked when situate at the end of the style, and sessile when the style is absent, as in the Poppy.

*Style.*—This resembles the filament of the anther; and as its function is that of sustaining the stigma at a convenient distance from the ovary for the reception of the pollen, it may be entirely absent. It varies in form, being flattened and leaf-like in the iris, very thick and sometimes angular in other instances, whilst its most usual character is that of a thread-like or tapering process. It is almost always colourless.

The anatomy of the style is somewhat peculiar, since it not only has bundles of vascular tissue inclosed by a cuticle, as in the filament and the petiole, but there is a superadded structure called the conducting tissue (Fig. 232). This tissue is of cellular character, with the cells loosely arranged, and probably is a prolongation of the placenta (page 126). It is connected above with the stigma, and below with the ovary, either at its highest point, as is usual, or at its side, and varies much in quantity. It is analogous to the elongated midrib of the leaf.

*The Ovary.*—This is the expanded base of the pistil, and is destined to contain the seed, and to become the fruit. It is therefore a most essential part of the organs of reproduction, and is the seat of the latest developments of the plant. It is a hollow organ, consisting of a single cell, or divided into two or more compartments, in each of which one or more ovules or seeds are normally found. The ovules are attached to the ovary by the intervention of a small mass of cellular tissue, called (from its analogue in animals) the *placenta*, and not unusually have an intervening thread of tissue named the *funis*.

The form of the ovary is usually spherical or conical, but sometimes it is flattened and angular. The size varies very much. It is usually sessile, or sitting upon the end of the peduncle; but in a few instances, as in the Passion flower, it is supported on a long stalk.

The analogue of the ovary is the lower expanded portion of the leaf, or, more properly speaking, the whole of the lamina except the terminal extremity of the elongated midrib. This is the type of the construction of the ovary; and one which enables us to determine the conformation of the ovary with considerable accuracy. We shall now
direct attention to this interesting but difficult subject; and in doing so shall consider the pistil as a whole.

If we take up any oval sharp-pointed leaf, such as that of the Poplar, and fold its edges together, so as to inclose the upper surface, we shall have the mode of construction of the ovary. It will then present an internal cavity without any partitions, bounded on each side by a plate or valve, which is the half of the lamina on each side of the midrib. There will also be two lines of union, or sutures, one on the back formed by the midrib, which in the leaf naturally unites the two sides of the lamina, and the other in front, formed by the union of the edges of the leaf. The former line of union is called the dorsal, and the latter the ventral suture. Each ovary will thus have an expanded base and a narrower apex, with a single cavity, two lateral pieces or valves, and a dorsal and a ventral suture lying between them. Such an ovary is termed simple; and as it develops the placenta, upon the inner edge of the ventral suture, the placenta will be partly attached to one side and partly to the other, and thus be double. So, in like manner, with the stigma above mentioned; it is situate at the extremity of the midrib, on the ventral suture, and will be formed by both sides, and consequently be double. The style, when it exists, will have, on its dorsal aspect, the vascular structures belonging to the midrib; and on its anterior or ventral part, the new tissue described as the conducting tissue (Fig. 228), which will either be a mass of placenta or a prolonged placenta. Thus the stigma, conducting tissue and placenta, occupy the ventral suture; whilst the vascular tissues are formed at the dorsal suture.

This description will apply equally to an ovary, which consists of many such leaves, so far as each separate leaf or carpel, as it is then termed, is concerned, provided the development of each part proceeds normally. But something further must be said in reference to the arrangement of the leaves or carpels.

If the various carpels are so situated that they are not connected with each other, the ovary is called Apocarpus (Fig. 240); but if, as is usually the case, they are closely and indissolubly associated, the ovary is said to be Syncarpous (Fig. 241). When only two carpels are formed they may be placed side by side, that is, with their ventral sutures having the same direction; or facing each other, when the same sutures will regard each other (Fig. 239). If three or more carpels are formed, they will, in obedience to a general law, be placed in a whorl, and consequently have all their dorsal sutures directed outwards, and their ventral sutures directed inwards, or towards a common centre. As the carpels will thus be placed side by side, there will be spaces, however small, between them; and thus there will be alternately a carpel and a space (Fig. 243). The space will be bounded by a carpel on either hand, and may therefore be said to have double walls. The space and the boundary walls are together called the dissepiments, or septa; and when the carpels are united into one mass, the whole may be
regarded as one cavity, divided into several compartments by these septa, as in the Orange, which exhibits an ovarium of ten carpels. These compartments are called cells; and an ovary made up of many carpels is said to have so many cells, as, for example, a four-celled ovarium (Fig. 242). But it often-times happens that the septum becomes imperfect, and thus reduces the number of cells or compartments; and should this be the case with all the septa, a many-celled might be reduced to a one-celled ovarium, as in the Poppy. So far, then, a compound ovary consists of a whorl of carpels and a number of cells and septa. Its style will also be compounded of the midribs of so many leaves, and have an equal number of bundles of vascular tissue and lines of conducting tissue. The stigma will be compound, and

![Fig. 240. Apocarpus ovary, in which each pistil is separate. A, situate within the rows of stamens on the flower; B, detached.](image)

![Fig. 241. Syncarpous ovary, or an ovary in which the carpels are indissolubly united. a, ovary; b, limb of the calyx, united to the side of the ovary; c, the disk surmounting the ovary; d, placentae; e, ovules; f, style; g, stigma; h, peduncle.](image)

represent the same number of leaves, or double the number should each half of the stigma of each be separate; or it may be that the styles and stigma of each carpel remain distinct, and then there will be as many pistils as there are carpels. This is an arrangement of the ovary found very frequently; but in the Ranunculus or Crowfoot, the Strawberry, and many others (Fig. 240), the ovarium is still more complicated. The further complication is due to the presence of two or more whorls of carpels instead of a single whorl. We will consider an ovarium of two whorls only, since, if that be understood, the reader will readily comprehend the arrangement of any number of whorls. When two whorls exist, one will be within the other; and thus the dorsal sutures of the inner will be opposed to the ventral sutures of the outer whorl; and in obedience to the law mentioned at page 116, the members of the inner whorl will be alternate with, and not opposite to, the members of the outer whorl. Thus a member of the inner whorl will be immediately in front of the septum, or line of dehiscence, of two members of the outer whorl. This will also apply to the styles and stigmas of the inner as opposed to those of the outer whorl.

Reference is frequently made to two circumstances connected with the arrangement of the carpels—viz., the position of the placentae and dissepiments relatively to the stigma and other parts. As the placentae and stigmas are both formed on the inner side of the ventral suture (Fig. 244, e), the position of one may be determined by that of
the other; and should the edges of the ventral suture be open at the point of development of the placenta (Fig. 239), and closed at that of the stigma, there will be two

placentae to each carpel, and the latter will have a placenta on either hand. So, also, should the stigma be double whilst the placenta is single, the two stigmas will be on either hand of the placenta.

As the dissepiments consist of the interval between the carpels, as well as of the walls which bound it, and, in fact, lie between the carpels, they will be alternate with the stigma, placenta, and carpels (Fig. 243). They will also be perpendicular or longitudinal from the base to the apex of the leaf, and will be equal in number to the carpels, at least when more than two carpels are present, and one carpel cannot have a dissepiment.

Various irregularities occur in the development, or subsequent growth, of the parts of an ovary, and especially in reference to the placentae and septa. Thus, when the placentae are not developed on the inner surface of the ventral suture, but upon the outer surface—that is to say, on the part looking into the space between the carpels—the septa and placentae will be opposite to and not alternate with each other; and then the placentae will be alternate with the stigma. Again, in many cases, as in the Poppy, the Lychnis, and the Violet, the septa are imperfect, and do not extend from the dorsal to the ventral suture. In the Lychnis the portion to which the placentae are attached at the ventral suture remains, whilst the remainder is altogether removed; and thus the placentae, with a small portion of the septa, remain isolated at the centre of the ovary, and are termed “free central placentae” (Fig. 245). In other instances the central part, or the ventral suture alone, is removed; and then the placentae are situated on the

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**Fig. 243.** Showing two rows of carpels, one within the other.

- \( e \) indicates the dorsal and \( e \) the ventral suture; whilst \( d \) is and the bracket mark the position and composition of the dissepiment or septum. The dorsal suture, \( e \), of the inner whorl is opposed to the dissepiment of the outer whorl.

**Fig. 244.** Representing the alternate position of the dissepiments, or septa, with the placenta and carpels in an ovary with three carpels, \( a \); \( b \), is the dissepiment, or the interval between the carpel and its boundary walls; \( c \), represents the ovules and placentae at the angle of the carpels, and separated from each other by the dissepiments.
sides of the septa, and are called lateral placentæ (Fig. 246). In others still, the whole dissepiment is removed, and the placentæ are placed near to the dorsal suture (Fig. 247).

Fig. 245.—Representing an ovary with free central placentæ.
Fig. 246.—Lateral placentæ in the Poppy; the centre being vacant.
Fig. 247.—Lateral placentæ placed very near to the dorsal suture, as in the Violer.

The source of the placenta is still a matter of doubt; but it is either the termination of the growing point, as Schleiden affirms, or it is a modification of the cells of the leaf at the ventral suture. As the position of the placenta is the centre of the very extreme end of the branch, and as it is the point of attachment and growth of the ultimate organ of reproduction in plants, it is probable that Schleiden's theory is both more correct and more philosophical than that which has been more universally received.

Before leaving this part of our subject we should state that the pistil is rarely, if ever, transformed; but occasionally it is itself a transformed stamen, as in the Horse-radish (Cochlearia armoracia), and the House-leek (Sempervivum tectorum).

The Ovule.—Having now described the house provided by nature for the seed, or embryo plant, we proceed to consider the organs for the protection and growth of which it was designed.

The ovule is the unripe seed, and consequently is the product of the organs of reproduction in the plant. It resembles a leaf-bud in its function, and also in its structure, in so far that it has a central growing point and protective coverings; and in many instances, as the Mignonette and other plants, it has directly produced leaves, without the intervention of a leaf-bud.

The nucleus is the central growing point (Fig. 250, a), and consists of a mass of cells, having the chemical constitution of albumen; within it is a cavity containing fluid called the amniotic sac and fluid (Fig. 250, b). It is formed at the earliest mo-


Fig. 248.—Representing the relation which the base and apex of the nucleus bear to the hilum and foramen in the normal and abnormal conditions.
The dot represents the foramen, the * the chalaza; the outline is the primine, and the opening into it is the hilum at which the vessels enter.

ment of the development of the ovule, and subsequently is inclosed in two coverings or sacs, open at the top, the outer one of which is called primine (Fig. 250, c), and the
inner one secundine (Fig. 250 e*). The secundine is very delicate, and is larger than the primine, and usually protrudes through the opening, or foramen (Fig 250 b), and can be examined only at the earliest period.

It has already been stated that the ovule is connected with the ovary by means of a placenta, and a delicate cord, termed the umbilical cord (Fig. 250 a); and this is universal, except in such plants as have naked seeds, or seeds and ovules developed without ovaries (Fig. 249). Such are the Conifere and Cyeads, whilst the Mignonette has the seeds partially naked. When it grows from the base, or near to the base, of the ovary, it is called erect and ascending, respectively; and when suspended from the top, or near to the top, is termed pendulous and suspended, respectively. The relative position of the nucleus, covering, foramen, and funis, is variable, and is important, since it enters into the classification of plants. In the normal position the base of the nucleus is next to the placenta, and is marked by a hilum on the coverings at which the vessels enter, whilst its apex is directed to the foramen. Such an ovule is termed orthotropal (Fig. 248 a). When this arrangement is changed only so far that the foramen is curved down so as to approach the hilum, the expression campylotropal is employed (Fig. 248 b). In other cases the nucleus changes its position; so that its poles are reversed, and its base is removed from the hilum to the point most distant from it, whilst the foramen with the apex of the nucleus is brought near to the hilum. This change is called anatropal (Fig. 248 c), as in the Apple, Almond, and Cucumber. The terms amphitropal and semianatropal (Fig. 248 d and e), indicate that the two ends of the nucleus are transverse with respect to the hilum.

Whenever the nucleus has its base removed from its normal position at the hilum, it is in danger of dying from want of nourishment, since thus it is separated from the placenta and umbilical cord (Fig. 248 e), the source of its nutriment; but this is averted by the formation of a bundle of vessels called a raphé (Fig. 248 e), occupying the ventral suture of the ovary, and passing from the hilum to the base of the nucleus, where it distributes itself in a star-like form, termed chalaza. The chalaza, therefore, cannot exist apart from the hilum without a raphé, and both are absent so long as the base of the nucleus is in apposition to the hilum in the membranes.

FRUIT.

When the ovary and its contents, of which we have now treated, have arrived at maturity, they are named fruit, and that quite independent of any edible quality which
they may or may not possess. At this stage the ovule has matured into a seed, and the ovarium either remains still as a mere containing vessel, or certain parts of it have become fitted to sustain the life of the seed during the earlier periods of its germination. It is to the latter form, as the Apple, that the term fruit is popularly applied; but, in botanical language, the term still comprehends the ovarium with its contents, whatever may be the nature of either.

Fruit, then, consists of various parts—viz., the ovary and its contents; but in many instances there are additions to it, in the form of the remains of some or all of the other parts of the flower. Thus, in the Strawberry and Apple, the calyx remains, and is converted into a succulent substance, or the part of these fruits which is eaten; and in the latter the corolla also remains. The Pine Apple is composed of all the parts entering into the composition of the ovary—viz., bracts, calyx, corolla, and ovary. The Orange (Figs. 181 and 19) is an ovary containing the seeds, and a succulent mass, in which the refreshing juice is placed. On the upper part of this ovary, and at the centre, will be found a circular spot, at which the pistil was formerly attached to the ovarium, and traces of the like attachment may be found upon most fruits; but in certain large classes, as the Labiata and Rosaceæ the style passes from the side, and not from the centre of the superior aspect of the ovary. In a few instances only is the ovarium absent; viz., in the case of the naked seeds of the Coniferae and Cycads (Fig. 249), and in one or two others, in which the ovarium is ruptured, and the seeds escape long before the maturity of the fruit; but when the fruit has been formed, the term ovarium is no longer applied.

The structure of the fruit is precisely that of the ovarium, except in the instances in which the maturation of the organ has caused certain malformations; and although the former is undoubtedly the rule, the latter occurs so frequently that an examination of the parts is at all times necessary. Thus, on the one hand, the number of carpels seems to be lessened, as in the three-celled ovarium of the Cocoa-nut (Cocos nucifera), in which but one cell and one seed remain in the fruit. Such is also the case in the common Hazel-nut, except that the absorption has progressed a step further, and has left but one cell and one seed out of three carpels and six ovules. In a few other cases the number of cells is at least apparently increased, since new partitions are placed across the ovarium, in order to separate the seeds from each other.

The fruit, like the ovary, is also said to be superior or inferior, and for the same reasons—viz., the adherence of the envelopes of the flowers in the latter and not in the former. It is divisible into two distinct parts—the seed and the pericarp.

The Pericarp is composed of three parts or layers, one within the other—viz., the Epicarp (a) or external layer; the Endocarp (b) or internal layer; and the Sarcocarp (c) or fleshy substance lying between them (Fig. 259). Thus, in the Apple the outer skin is the epicarp, the juicy part of the fruit the sarcocarp, and the tough thick wall-celled covering to the seeds (Fig. 36) is the endocarp. The same relation is found in stone fruit; and the stony covering of the seed is the endocarp. The epicarp is less subject to
variation than the other structures; but the sarcocarp and endocarp assume every possible variety of form and consistence.

We have not hitherto referred to the mode of opening of the ovarium, since it is not until that organ has attained its maturity that it becomes necessary to make provision for the emission of the seed. This occurs in the fruit, and is a matter of much interest. From the construction of the ovary it may be assumed that the normal mode of rupture of the fruit would be between the carpels; and such a mode of dehiscence, as it is termed, is said to be septicidal (Fig. 252 a). When the whole back of the carpel comes away from the septa and the ventral sutures, the dehiscence is called septifragal (Fig. 252 b); and when the septa remain perfect, whilst the ventral sutures become detached from each, and the dehiscence proceeds through the dorsal sutures of each carpel, it is termed loculicidal (Fig. 252 c). The pieces into which the fruit is thus broken, are termed valves; and in the first mode (dehiscence), each valve consists of an entire carpel, whilst in the second it is formed by parts of two adjoining carpels. When the fruit is simple, that is, composed of but one carpel, as in the Pea (Pisum, Fig. 260), the dehiscence is through sutures, and is called sutural, and there are no dissepiments.

In the Scarlet Pimpernel (Anagallis) there is another mode of dehiscence, one in which the upper part of the capsule or ovary is detached; and, as the line of separation is horizontal and not perpendicular, the term circumcisile has been employed.

**Classification of Fruits.**—The great variety which exists in the external appearance and anatomical characters of fruit, renders it necessary to devise terms which may serve easily to distinguish one kind from another; and as the number of such terms is very considerable, it has, at all times, been customary to classify them according to their relationships. This has been effected by various writers, with different degrees of success; and, as we cannot devote much space to a consideration of this question, we think it will be most useful to transcribe the newest, and perhaps the most comprehensive, system,—that of Professor Lindley.

**Class I. Fruit simple. APOCARPI.**

One or two-seeded:—

| Membranous | UTRICULUS. |
| Dry and bony | ACHÆNIUM. |
| Fleshy externally, bony internally | DRUPA. |

Many-seeded:—

| Dehiscent: | |
| One-valved | FOLLICULUS. |
| Two-valved | LEGUMEN |
| Indehiscent | LEMENTUM. |
CLASS II. Fruit aggregate. AGGREGATI.
Ovaria elevated above the calyx:—
Pericarpia distinct: ... ETÆRIO.
Pericarpia cohering into a solid mass: ... SYNCARPIUM.
Ovaria inclosed within the fleshy tube of the calyx: ... CYNARRHODUM.

CLASS III. Fruit compound. SYNCARPI.
Sect. I. Superior:
A. Pericarpium dry externally:
   Indehiscent:
      One-celled: ... CARYOPSIS.
      Many-celled:
         Dry internally:
            Apterous: ... CARCERULUS.
            Winged: ... SAMARA.
         Pulpy internally: ... AMPHISARCA.
   Dehiscent:
      By a transverse suture: ... PYXIDIUM.
      By elastic cocci: ... REGMA.
      By a longitudinal suture: ... CONCEPTACULUM.
      By valves:
         Placentæ opposite the lobes of the stigma:
            Linear: ... SILIQUA.
            Roundish: ... SILIricula.
         Placentæ alternate with the lobes of the stigma:
            Valves separating from the replum:
               Replum none: ... CAPSULA.
B. Pericarpium fleshy:
   Indehiscent:
      Sarcocarpium separable: ... HESPERIDIIUM.
      Sarcocarpium inseparable: ... NUCTJLANIUM.
   Dehiscent:
Sect. 2. Inferior:
A. Pericarpium dry:
   Indehiscent:
      Cells two or more: ... CREMOCARPIUM.
      Cell one:
         Surrounded by cupulate involucrum: ... GLANS.
         Destitute of a cupula: ... CYPSELA.
   Dehiscent or rupturing:
B. Pericarpium fleshy:
   Epicarpium hard:
      Seeds parietal: ... PEPØ.
      Seeds not parietal: ... BALAUSTA.
   Epicarpium soft:
      Cells obliterated, or unilocular: ... BACCA.
      Cells distinct: ... POMUM.

CLASS IV. Collective fruits. ANTHÔCARPI.
Single:
Perianthum indurated, dry: ... DICLESIUM.
Perianthium fleshy: ... Sphalerocarpium.
Aggregate:
Hollow: ... SYCONUS.
Convex:
An indurated amentum: ... STROBLUS.
A succulent spike: ... SOROSIS.
VARIOUS KINDS OF FRUIT.

The most common kinds of fruit are the Pomum (Fig. 256), or Apple; Drupa, or Drupe, as the Plum (Fig. 258); Strobilus, as the Pine Apple (Fig. 257); Glans, as the
Acorn (Fig. 261); Legumen or Legume, as in the Pea (Fig. 260); Siliqua, or pod, as in the Mustard (Fig. 255), and which differs from the Legumen chiefly in the longitudinal false dispériment at a being present in the former, and dividing the cavity into parts; Capsule, as in the Larkspur (Delphinium) or Poppy (Fig. 254); and Bacea, or two berry, as Currant.

The Seed.—The seed is the mature ovule, and in its internal anatomy maintains a great resemblance to that body. The process of growth and development has, however, induced certain modifications which it needful to understand, and the more so that the characters of the seed have of late years become of great importance in the description and classification of plants. Like the ovule it consists, in general terms, of a growing point, and contains membranes. The term embryo is expressive of the former (Fig. 262 b), and testa, in a general sense, of the latter.

The testa, or coverings of the seed, are divisible into three or more layers—viz. the outer one, or primine; the inner one, or secundine; and the third coat, or tercine. The detection of these three coats is oftentimes a matter of difficulty; but our readers who have tolerably good microscopes, and who have attained to a certain degree of delicacy of manipulation, need not fear to enter upon it. It will be needful to examine a seed in its fresh state, and to seek the separation of its coats by immersion in water for some hours, and subsequently by the aid of the needles.

The outer integument is commonly smooth, somewhat dense, and resisting; but it may assume every variety of character. The most interesting departure from the established rule is in the instance of the Cotton seed (Gossypium), Sage (Salvia, Fig. 263), and the Collomia grandiflora, in which a large number of shrivelled hairs are attached to this membrane. There is no difficulty in seeing them in the Cotton plant under every condition; but in the latter examples they are inappreciable to the naked eye, until they have been immersed for an instant in water, when they start out, and give a fringed character to the seed. The hair in this case contains a spiral fibre (Fig. 263), which is the cause of its elasticity (pages 14 and 66). In other instances it is largely developed and fleshy. The inner membrane is placed immediately within the outer integument, and itself incloses the most external or third coat. This latter envelope is in immediate proximity to the nucleus or embryo, and is diagnosed from its inclosing covering simply by the non-perforation of its apex.

These various membranes are seldom distinct in the seed, and consequently it is customary to speak of the testa of the seed rather than of the primine, or any other specific part of the covering.

The Nucleus.—This is the growing point already referred to at page 129, as the nucleus of the ovule, and now consists of two distinct parts,—the true growing point, or embryo, which, in the future germination, elongates upwards and downwards to
form the new plant; and, in most instances, one or more masses of albumen destined to supply food to the newly forming plant.

The direction of the embryo in the seed varies as greatly as that of the nucleus in the ovule, and is always determined by similar means—viz., the position of the chalaza, micropyle, and raphé. The terms employed to designate this relation are similar to, but not identical with, those given at page 128 in reference to the ovule. Thus antitropal in the seed corresponds with orthotropal in the ovule, the sacs of the ovule not being inverted, but the embryo inverted with respect to the seed, as in the Stinging Nettles. Orthotropal in the seed, as in the Apple, is the antitropal of the ovule; amphitropal in the seed, that of camphylotropal in the ovules, as in the Mignonette, and have both apex and radicle next to the hilum; and last, heterotropal in the seed, is the amphitropal or semi-anatropal of the ovule, and they lie across the seed. In the antitropal and amphitropal forms there will be neither raphé nor chalaza; whilst in the orthotropal and heterotropal varieties both these parts will be present.

The above is indicative of the relation which the embryo bears to other parts of the seed; but there is also a relation which the whole seed has to the fruit of which it forms a part. The seed is termed ascending, when the direction of its apex is that of the apex of the fruit; descending, when the contrary, or towards the base of the fruit; centrifugal, if towards the sides; and centripetal, when towards the axis of the fruit.

The albumen varies greatly in quantity, as may be seen by contrasting the split Pea with the white of the Cocoa-nut. It also offers great diversity in solidity, from a mass of jelly-like consistence, to the hardest ivory, as in the Ivory Nut (Fig. 38) in its dried state. It is not present in all seeds, and in many is so minute in quantity that the microscope alone can detect it. Wherever it exists, it immediately surrounds the growing point. Its structure is cellular, as shown in Figs. 37, 38, 39, and others, as may be readily proved, by placing a very thin portion of a green pea under the microscope. When it is met with in the embryo sac (page 129) it is called Endosperm (within the seed); and when it constitutes the nucleus it is known as the Perisperm (around the seed). Sometimes it is placed near to the chalaza; but it never occupies the position of the membranes. In Dicotyledonous plants, as the Pea, the seed readily separates into two halves, which proves that the mass is divisible into two lateral and symmetrical portions, termed Cotyledons, or seed-leaves (Fig. 262). In Monocotyledonous plants, as the Palms, the albumen cannot be divided into parts, and hence the terms Monocotyledon, or one seed-leaf (Fig. 264); and in certain plants it is so reduced in quantity that the seed is termed Acotyledonous, or a seed without cotyledons. These terms are of great moment, and of constant employment, since the two former correspond to the exogenous and endogenous divisions of plants referred to at page 81, et seq. All flowering exogens, or nearly so, are Dicotyledons; all endogens, or nearly so, Monocotyledons; and all flowerless plants, Acotyledons. The arrangement of the parts in the embryo varies in the classes just mentioned, as might be expected, when in germination one puts forth no seed leaves, another only one, and a third two. The direction of the Cotyledons is usually straight; when two or more exist, they are placed face to face. They are said to be incumbent when they are folded with their back upon the radicle, but accumbent when their edges occupy that position.
The seed of a Dicotyledon, as the Pea or Apple, presents the following parts (Fig. 265): two Cotyledons, or seed-leaves, $a$, at the upper part, within the base of which is a minute point, destined to become the stem, named the plumule, $b$; and at the bottom of the seed is the radicle, $c$, having dimensions larger than those of the plumule, and separated from the Cotyledons by an unseen line, the caulicle. Sometimes the Cotyledons are absent, or cohere into one mass, or divide into a greater number, as four in the Cruciferae, and double that number in some of the Coniferae.

An approach to the condition of a Monocotyledenous seed, is seen in such Dicotyledons as have great inequality in the size of the Cotyledons; so that one of them is scarcely perceptible. In this class (Monocotyledons, represented in this country by the Grasses), there is no such distinction of parts as that now referred to; but the lower part of the seed emits a number of radicles (Fig. 264 $r$), whilst from the upper part the thread-like green plumule, $p$, is emitted. Thus the growing points are sheathed by the embryo, which remains within the testa throughout the process of germination. There are many exceptions to this description; but they do not materially invalidate the rule now given. Monocotyledenous plants are as exclusively endogenous (p. 86) as dicotyledenous are exogenous in their general structure.

There are certain plants in which distinct Cotyledons have not been discovered, and hence have been termed Acotyledons; but this would not be a correct mark of distinction for the members of the two classes now described, since it is probable that there are parts analogous to Cotyledons. The true diagnostic is, that in these plants the germination does not proceed from fixed points, as the plumule and radicle, but indifferently from any part of the surface of the seed. This is the condition of the embryo in the great class of plants to which we shall presently refer—viz., the flowerless plants.

There are yet one or two points to which reference must be made, before we conclude this account of the seed. The Amnions (Fig. 250) is a fleshy bag surrounding the embryo in many seeds, and consequently lying within the innermost integument. It has also been termed the Vitellus, or Yolk-bag, and it probably performs an analogous office in the sustentation of the embryo.

We have already referred to the hilum and other vascular parts of the ovule and seed, and need here only to state that the hilum is the umbilicus, or the spot at which the vessels from the placenta enter the seed. In many plants it can scarcely be seen, whilst in others it is of a dark colour, or is very large, as the Pea, Bean, and Horse-chestnut. The micropyle, or foramen, is the opening in the seed to which the radicle is always directed, and may be at the end of the seed opposite to the hilum, or the two may be close together, as in the Pea; or it may occupy other positions, as shown at page 128, in reference to the ovule. Its position determines that of the radicle, and consequently is of importance. The chalaza and raphé have precisely the same indications in the seed as in the ovule; but the latter is always distinctive of the face of the seed when the figure of that organ does not render the determination of that question easy.

The placenta is the cellular expansion by which the seed is attached to the ovary, and brought into direct connexion with the sexual organs of the plant through its prolongation—the conducting tissue of the style.
The \textit{funis}, or umbilical cord, when it exists, connects the hilum of the seed with the placenta, and conveys the vessels to the ovule and seed.

The \textit{aril} is known familiarly to our readers by the spice called mace, which is the aril of the nutmeg, as may be determined by an examination of the preserved fruit. It presents a great variety of forms and characters in various plants, and oftentimes it is difficult to distinguish it from other structures; but here, as in the case of bracts, negative evidence is of value, and supplies us with the expression, "that everything proceeding from the placenta, except the seed, must be an aril." It is not of large size, except in fully developed seeds. It is closely applied to the outer integument both of the seed and ovule, and in its analogies has been regarded as an ovulary leaf. Arils are divided into two classes—\textit{viz.}, true and false arils, the distinguishing mark being, that in the former the micropyle or exostome either is covered, or would be covered, by the aril, if it were sufficiently extended; whilst in the latter the micropyle is at all times free. It is probable that the aril of the nutmeg belongs to the latter class.
FLOWERLESS PLANTS.

There yet remains, before we conclude this first division of our subject—viz., the structure of plants—to mention a few special modifications of those organs now described as they are found in the flowerless plants; and in doing so we beg our readers to bear in mind, that they are not new structures but modifications of those belonging to flowering plants. There is, however, the most marked line of demarcation between flowering and flowerless plants, both in their minute composition and their external configuration; and we might almost venture to affirm, that we have here an exception to the rule, that nature ascends and descends by imperceptible degrees. There is, however, no new element in structure, in this lower division, than has already been described in reference to the flowering plants; so that the existing diversity is due to the number and arrangement of these elements in the general fabric.

It is customary to consider flowerless plants as more lowly organized than those which bear flowers, although it is through them that the vegetable kingdom approaches the animal. This seems paradoxical, seeing that the animal kingdom is manifestly of a higher grade than that of vegetables; and proves that, from the highest members of the animal kingdom, we do not pass through the lowest to the highest vegetables (as would be the case were the views commonly received properly carried out), and thence to the lowest plant, but that the well-defined members of both kingdoms are wide as the poles asunder, whilst the lowest members are so intimately associated, that it is yet undecided whether they belong to the animal or the vegetable kingdoms.

There is reason, however, in considering the flowerless plants as the lowest members of the class, since their organization is more simple. Precisely so, also, in respect of animals;—and thus the two kingdoms may be likened, not to one cone with an artificial line drawn across it at some undefined point, but to two cones with their apices connected, and their expanded part, or base, at either extremity.

The great point of dissimilarity is that connected with the organs of reproduction; and the question of sexes, and their product, has ever been, as it now is, the bone of contention. That every member of the whole is endowed with the faculty of reproduction is perfectly evident; but the precise mode in which it operates, and even the immediate seat of its operation, is shrouded in mystery. This, however, is only the counterpart of the condition of the lowest animals; and therefore the one is no more matter for wonder than the other. In both kingdoms the lowest examples have abundant power of reproduction; but the distinction of sexes is not evident. When, therefore, we affirm that there is nothing new in the class of flowerless plants, we mean that every part of the structure has its analogue in the higher division of the vegetable kingdom.

The flowerless plants are numerous and very varied, and comprehend chiefly the Ferns, Club-mosses, and other kinds of Mosses, Lichens, Mushrooms, and Sea-weeds.

Ferns.—This extensive class of plants is known in this country only by herbaceous varieties, or such as have their stem or root in the ground, and present to view a series of leaves only (Fig. 266). But in hotter climes the stem is above ground, and often attains the height of fifty or sixty feet, and a diameter larger than a man's thigh (Fig. 270). The following are their chief anatomical peculiarities:

The leaves are termed fronds, and they bear the organs of fructification in little cups or receptacles on their edges, or on their under surface (Fig. 267). These exhibit
little masses of granules, of defined forms, termed sori, and consist of a containing organ
called sporangia, theca, or capsules, surrounded by a ring (gyrus, or annulus), and a
number of contained cells, termed spores or sporules, from which new plants are directly
produced. Thus the organs of fructification may be likened to the ovary with its con-
tained seeds, and doubtless this is their true analogy; but to the naked eye they have
a greater resemblance to the anther with their contained cellular specks of pollen; and this latter idea is further
strengthened by the fact that the spores, as well as the pollen, are produced on and from the cells of leaves. The
sporangia burst with elasticity; but this property is possessed alike by both anther and ovary. There can be
no reasonable doubt but that they are the female organs or ovaries, with the spores or seeds.

There is much difficulty in determining what are the male organs, if any, existing in Ferns. Some have
referred them to the articulated hairs which are found surrounding the sporangia; and others again have imagined
that the layer of epidermis which covers the sporangia in many Ferns, called indusium, may be connected with that
function. Nothing certain, however, is known.
There are no sporangia in that division of Ferns known as the adders' tongues; but the whole leaf is rolled up on either side of the midrib, and becomes a containing organ. At maturity the leaf opens by transverse valves, and emits the spores (Fig. 268).

The foot-stalk of the frond is called the *stipes*, and consists of bundles or plates of hard woody fibre and scalariform vessels, connected together by cellular tissue, which pass down into the stem within the bark, and appear to form a part of the zones of wood.

The arrangement of the parts in the stem of the Tree Fern is very peculiar; and although it has no close resemblance to either the exogenous or the endogenous arrangement, it seems to be more closely allied to the latter. Thus the rind or bark consists of one or two layers only of cellular tissue, and is marked by the cicatrices of leaves or fronds, arranged somewhat irregularly, and at considerable distances below, but regularly and closely near the apex of the tree, showing that its leaves are produced at the head only, and in successive clusters. Again, a large portion of the transverse section of the trunk is seen to consist of cellular tissue; and through this the wood passes. The points of resemblance to exogens are, that its centre is occupied by a mass of scalariform (Fig. 71) and large spiral vessels, which in some degree may represent the medullary sheath; and the wood is arranged in circles, but only near to the bark, and the circles have a wavy outline. These pass up into the fronds, or rather are sent down from the fronds; and as the fronds surround the stem, the bundles sent down from them lie side by side, until they form a circle. There are, moreover, lines of communication between the medullary cellular tissue and the bark, which are the analogues of the medullary rays.

There is a peculiarity in the growth of the Tree Fern —*viz.*, that the interval between the cicatrices enlarges as the size of the tree increases, showing that the stem of the tree increases in height, not only at the apex for the time being, but afterwards in the body of the trunk (Fig. 270).

As there is no definite growing point in the sporule, its germination must differ widely from the exogenous and endogenous forms of plants. The sporule, after extrusion from the sporangia, bursts its envelope, and emits a leafy expansion from its centre, which subsequently forms a bud, and from thence a plant.

![Fig. 270.—Tree Fern, forty feet high, growing in the moist climates of small tropical islands.](image-url)
This subject has been discussed with much judgment by an eminent English botanist, Mr. Henfrey, who has given the following account in the *Gardener's Magazine* for 1851, p. 23:

"The germinal frond must be taken very young, while yet not more than one-eighth of an inch in diameter, and before any sign of the first leaf appears.

Figs. 271, 272, 273, 274, 275.—Successive stages of development from the spore (Fig. 271). In Fig. 275 are seen two of the antheridia.

rising from its upper surface. The little frond will then be found in the shape of a rounded

Fig. 276.—A germinal frond (it is a simple cellular plate like the leaf of a Moss): a are two ovules; b a number of antheridia; c root fibrils.

Fig. 277.—A more highly magnified view of a piece of the frond with two antheridia, one containing the vesicles (b), the other burst (d).

Fig. 278.—Side view of b in the last figure.

Fig. 279.—The same bursting to discharge the vesicles, which again discharge the spiral filaments e.

or heart-shaped disk, formed of delicate green cells (Fig. 276); a single layer, except in
the middle, having been gradually developed into this form through the stages represented in the annexed figures (Figs. 271—275). To see the peculiar organs, the disk-like cellular plate must be carefully laid face downwards upon a slip of glass, and washed clean, gently removing the grains of soil, with a camel-hair pencil, from among the rootlets. When placed under the microscope, a number of projecting cells (Fig. 276 δ) are generally found scattered about the frond. These are seen to be again filled with minute vesicles (Figs. 277 and 278), which escape by the bursting of the protruding cell, either spontaneously or by slight pressure on the glass covering the object (Fig. 279). As the vesicles emerge they burst also, and from them springs out a spiral thread-like body, thickened at one end, and furnished with cilia, as represented in the woodcut (Fig. 280). These, the so-called animalcules, swim about with great rapidity,

Fig. 280.

Fig. 280.—One of the spiral filaments, or animalcules, more magnified.
Fig. 281.—Side view of an ovule.
Fig. 282.—The summit of the same, seen from above.
Fig. 283.—Side view of an ovule from Suminski, representing the embryo-cell at the bottom of the cavity.

shooting forward, and continually whirling round on their own axes. To see them clearly, their motion must be stopped by adding a little solution of iodine.

On the thickened part of the frond, near the notch, are to be found, in most cases, not always, cellular structures of larger size, and more complicated (Fig. 281). They consist of conical papillae, with cellular walls, containing a cavity in the centre, as represented in the Figures 282 and 283.

In Club Mosses (Lycopodium), the containing reproductive organs are also called thecae,

Fig. 284.

Fig. 284.—The Lycopodium Aphodium, or Club Moss.
Fig. 285.—A, full-grown plant of Marsilea pubescens; B, spore (opened), natural size; and C, section of spore magnified, with the contained spores. Both of the Olnaria globulifera.
capsules, or sporocarpia, and, as a rule, are filled with sporules (or pollen) in the form powder like granules, when they are called antheridia; or they contain several rounded fleshy bodies analogous to buds, much larger than sporules, and named Oophoridia. In Marsilea the organ of fructification is a modified leaf, and consists of two valves. The fructification is immediately placed upon a number of spikes, covered by ovules and anthers, attached at first to the modified leaf by a mucilaginous ring. The Split Mosses and the Urn Mosses have organs of fructification placed at the summit of their branches. These are called Antheridia, and have an elongated flattened form; and, on being ruptured, emit a multitude of spiral threads, with an enlarged extremity, sometimes curled, and at others straight in their figure.

These are said to be abortive Antheridia by certain writers; but there is no doubt, from their configuration and rapid motion, that they are true Phytozoa, or organs of reproduction.

This organ in the Urn Mosses, as the Funaria hygrometrica (Fig. 288), is somewhat more complicated, and possesses parts which are most sensitive to the presence of moisture; so much so, that the observer breathing upon them causes them at once to contract. It is
known as the sporangium or theca, and its contents are called sporules; but besides these, there are several bodies called prosphyses, enveloped in a membrane which subsequently bursts, and is curved to form the calyptra. The calyptra is termed dimidiate when the sporangium bursts on its side, and mitriform when the membrane is detached at its base. The sporangium is covered by a lid or operculum, and incloses a multitude of sporules surrounding the central axis, or columnella, and oftentimes inclosed in several cells, with their septa attached to the columnella. The whole rests upon an elevated stalk, or seta. It is lined and also inclosed by two membranes—the inner and outer peristomia—which have a toothed edge; and by closing the orifice, especially when moistened, as by the breath, constitute the tympanum. It is bounded above by an elastic external ring, or annulus.

Whether any, and what part of the above organs can be appropriated to the sexes, is a subject of much dispute; but it is highly probable that the sporules are the analogues of the pollen in flowering plants, and it has been ascertained that they emit tubes very similar to pollen tubes.

There is an arrangement of the internal parts of the organs of fructification in the Horse-tails which greatly resembles that described in the Lycopodium—viz., a spiral fibre moving with great rapidity, and influenced, as in the Funaria, by moisture. There are usually two or more such fibres having an enlargement at their free ends, and connected to a central organ, around which they wrap themselves spirally (Fig. 289). On the application of moisture they instantly wrap themselves around the spore, \( b \), but on it its withdrawal they relax their hold, \( a \). These structures are contained with cases or sporangia, which are arranged around the apex of the stem in the form of a cone (Fig. 290). It is probable that the elaters represent the male, and the spores the female parts of the sexual organs.

In Liverworts, as Marchantia polymorpha, the foliaceous organ is termed thallus or frond indifferently, and is a flat lobed organ, lying flat upon the ground. Its reproductive organs are three in number.—1st., little green bodies, or buds, placed in cups (Cystula) on the upper surface of the frond, believed to be a viviparous apparatus; 2nd., sporangia, or female parts, placed beneath calyptra, or a stalked receptacle; and 3rd., oblong bodies, or anthers, found in other sporangia on the upper surface of the frond. These last resemble the spiral fibres of the Chara vulgaris (Fig. 291).

The Scale Mosses (Jungermannia) have a pericladium arising amongst the leaves, from which a seta proceeds, and bears a valvular brown case, or sporangium, containing a number of spiral fibres (Fig. 296), which are highly hygometric, and are intermixed with sporules, or female organs. There is also a calyptra or the ruptured membranous bag (Epigonium).
None of the members of the various kinds of Mosses now described have any vascular tissue, but are wholly composed of cellular tissue of various forms.

**Lichens.**—This important class of plants are more particularly found in regions so far north that more highly and more delicately formed plants cannot exist; as in the instance of the Iceland Moss (*Cetraria Islandica*), so useful to the reindeer in its native regions, and employed as a medicinal agent in this country. It consists of a lobed leaf, called *frond, thallus, or blatemas*, of various forms and degrees of consistence, and which

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**Fig. 291.**
- a, Phytotoma, or male parts, *in situ* within the cells; b, the same, detached from the cell-wall in the chara.

**Fig. 292.**
- Marchantia Polymorpha, or Liverwort, with its broad frond, A, and organs of fructification, B.

**Fig. 293.**
- Lichen growing upon a piece of rotten wood.

**Fig. 294.**
- The fructification of the Jungermannia. A, very young spore-case still covered by the calyptra; B, the same, quite developed, with the hyulina pe and bursting, and presenting to view the inclosed spores.

**Fig. 295.**
- Spiral fibres or elaters of the Jungermannia (Scale Moss.)

**Fig. 296.**
- Acrostalagmus Cinnabarinus, very highly magnified, with the fructification at the end of the filaments.

differs from the like organ in all higher members of the vegetable kingdom, in the fact that not merely a part but the whole of its intra-cuticular substance is devoted to

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the functions of reproduction. The upper cuticle is pierced by two forms of fructifying organs—viz., soredia, or masses of powdery bodies, scattered over the surface; and

Fig. 296.*

Fig. 297.

Fig. 298.

Fig. 299.

Fig. 296.*—Section of the shield in a Parmelia, showing the position of the spores.
Fig. 297.—Magnified representation of the cellular structures of Sea-weeds. (Algae.)
Fig. 298.—P. Vesiculosus, or Bladder-wrack.
Fig. 299.—Promelia Perforata:—Lichen, with projecting shields.

shields (Scutella, Fig. 299, A), surrounded by a rim, and containing asci, or tubes filled with sporules.

Fungi, or Mushrooms.—This is a most extensive family of plants, and assumes forms infinitely more diverse than is represented by the members to which the name is
popularly applied. The most common, and at the same time the least noticeable, forms are the minute substances which appear in and upon decomposing fluids, and as vegetable parasites upon many living plants and animals (Fig. 300). All alike, however, consist exclusively of cellular tissue, but differ greatly in its arrangement, and especially in the nature of their reproductive organs. In the minute bodies just mentioned, the organ of fructification is simply one enlarged cell, containing the sporules or spores; but in the common Mushroom there are true sporidia contained in asci or sporule cases, and in a few there are moveable spiral fibres or elaters. The former division of fungi is the most interesting and accessible; so that we would urge our readers, possessed of some microscopic knowledge, to examine the various forms of mould so universally distributed. No preparation or subdivision of the substance is necessary, except that of placing a very small portion of it in a little water.

Algae, or Seaweeds.—This is the last one of the Fungi, the lowest forms of vegetable life and growth, and is the boundary line of, or rather the neutral territory between, the animal and vegetable kingdoms. The members of this class are universally distributed, and are all different, from the string of cells found in a drop of stagnant water to the beautifully varied and large sea-weeds familiar to many of our readers (Fig. 297). It is a class, however, which is best represented in the southern or tropical seas; for there, not only is there greater variety of appearance, but the masses in which they abound almost exceed belief. Moreover, in such, as also in many representations on our own shore, it seems almost impossible to deny the animal characters with which many observers have invested them. Nothing can so much relieve the monotony of a sea-side residence as to fix a microscope on the sands, and examine these beautiful objects, fresh from the salt water.

As in other families, the reproductive parts, for the most part, are called spores, and are found in the ordinary cells of the plant, as in Fig. 297, or are gathered together into sporangia, or spore-cases, of various kinds. We cannot enter into the dispute as to the sexuality of these as of other members of the class of flowerless plants, but
would remark that a kind of conjugation has been noticed in the Confervae, or lowest members of the class (Fig. 302), from which the spores are believed to result. These spores are endowed with the faculty of motion within the cell, and more particularly soon after their extrusion, as mentioned at page 4, Fig. 2.

In closing this account of the structure in flowerless plants, we would remark that a great multitude of terms have been invented to describe certain minute peculiarities in reference to the seeds or sporules, and the cases or ovaries in which they were developed; but as they would occupy much space, and be tedious to readers of all classes, we omit further mention of them. In reference to the sexual organs of the whole class, it must still be admitted that the whole question is sub judice, and that we can only affirm that, whilst such plants reproduce themselves with the most astonishing rapidity (a rapidity which seems to be in the inverse ratio of their organization), distinct sexes either do not exist, or are possessed of forms as yet unrecognised. Lastly, cellular tissue, and that alone, is the form of organization of all except the highest divisions; but the cells are very varied in figure, size, and arrangement, and are commonly coloured green or red, as in the Confervae and Sea-weeds; or are resplendently coloured, as in many Fungi. They are not the less beautiful and interesting because their structure has a simple basis; but, on the contrary, evidence, in a remarkable degree, the power and wisdom of the Creator in the infinitely varied and beautiful arrangements of so simple an object.

Fig. 302.—Confervae, with spores lying within cells, which have undergone the process of conjugation, at 1.
SYSTEMATIC BOTANY, OR THE CLASSIFICATION OF PLANTS.

Having, in the preceding pages, described all the parts and organs which enter into the composition of individual plants, we are prepared to take a wider view, and determine the mode by which masses of plants may be grouped together. This is termed Classification.

This department of botanical science is vastly more extensive than that which treats of the structure of plants; so that it is not possible, in a treatise like the present, to consider the subject in any lengthened detail. We therefore purpose, after offering some introductory remarks, to consider the Linnean and the natural systems of classification, and to name the most common or important plants which have been arranged under each head.

The necessity for a classification of plants must have been felt at all periods, even in the Grecian and Roman eras, when the total number of known species did not exceed 1,000; but since, at the present day, upwards of 100,000 species have been named and described, the necessity has become absolute. The only question on which botanists have been at issue refers to the principles on which that classification should be founded. In the first place it is imperative that each plant should have a distinctive appellation, or any description of it would be in vain. Then, again, since 100,000 distinct names, assuming for a moment that so many could have been invented, could not have been borne in mind by any person, the next step in the process would be to ascertain if any of this number could be grouped together under one name, but yet having a special term to indicate its individuality.

The success of this inquiry would, of course, depend upon the existence or otherwise of any anatomical characters which would at a glance be found common to both. Such resemblances were soon discovered; and the term Rose, for instance, was found to suffice for very many species, with the addition of white, red, &c., to mark their individuality. Thus the term Rose denoted a genus, and white the species; and in this mode the number was reduced within reasonable proportions.

But this first was not the last step, for it was ascertained that on some one point, or on many points, the genera resembled each other; and thus the term Icosandria, for example, was devised, which should comprehend the Rose, and the Apple, and the Strawberry, and others having these characters in common. This then gave rise to a system of classes and orders, the term Icosandria representing one of the classes. The orders were subdivisions of the classes, and referred to certain minutiae in which all the members of the orders did not agree. Thus the nameless plant became at length the Rosa Alba, of the class Icosandria, and order Polygamia.

This is precisely the plan adopted in the classification of animals. Thus the Cow is the Bos taurus of the class Mammalia and order Ruminantia. It is not, however, a perfect plan; and as the number of objects to be included have continually increased, it has been found necessary to invent a more general term—as that of family—which shall comprehend a number of classes. Reversing, then, the order of classification which has already been given, we may first refer a plant to a family; next to a class and order; and then find its generic and specific names.

The term variety has also been introduced to indicate the existence of some trifling change in a species; and although the boundary between a species and a variety is not capable of nice definition, yet it may be stated that a variety does not so reproduce
itself by seed as that its own form shall result, but so that a return to its original species shall inevitably follow. There are also Hybrids in plants as in animals, and resulting from the operation of the same law—viz., the admixture of the sexes, not of the same, but of different species of one genus.

The first point will probably depend upon one or two features only; but the last will require a knowledge of every part of the plant. Thus, whilst the multitude of names which have no necessary significance tends to confuse and weary the mind, the various steps of that classification render the task the lighter, and indeed infuse a deep interest into the study. It is a mark of unbounded knowledge, on the part of the Creator, to have made so great a multitude of varied objects; but it is not the less so that He has made many of them on a common plan, and has given to us the capability of unfolding His designs. It is no mark of our mental capability to have found or seen a plant; but it is not a little flattering to us to have discovered or perceived the principle on which the plant was constructed; and this is the central point of interest to the philosopher.

But the school-boy is not without his gratification. To point out the flower, the name of which we know, and to gather that to-day which long ago we first discovered, and discovered in the company of some one whose society we cherished, may yield pleasure to any one. Thus we would offer encouragement to the young botanist, by the assurance that the road is not so hilly as it appears to be, and that it is rendered shorter by the snatches of pleasure which fall to the lot of the anxious traveller.

There have been, and still are, various modes of classification; and since all depend upon the selection of certain parts of plants as their basis, it cannot surprise us that they should be held in various degrees of estimation.

A prime consideration, in the selection of distinguishing characters, is, that those characters shall be constant, and not greatly influenced by accidental circumstances. Such a condition, if it exist at all, can only belong to those parts which are essential to plants. These essential parts are connected with the function of reproduction, and have been referred to in every system of classification; but as nature does not slavishly follow the path which she herself has marked out, we meet with occasional variety even here. The flower would naturally attract attention; and in the earlier attempts at classification, its permanent parts, the stamen and pistils, were exclusively selected. This was called the sexual system; and was first pointed out by our renowned countryman, Grew, in the seventeenth century, and a century later was perfected by Linnaeus.

This one prime principle of constancy, then, was that upon which the Linnaean system was founded, and to which it still owes its continued existence. The system is, moreover, very simple in its arrangement, and therefore has been at all times in favour with beginners, and with all those who have not cared to drink deeply of the Pierian spring; and, in spite of its insufficiency, it will doubtless be handed down to succeeding generations.

A perfect classification, however, demands more than mere constancy; and it is in these further requirements that the Linnaean system has been found wanting. It is necessary that no violence be offered to that uniformity of organization which is well known to exist in the vegetable kingdom, so that plants evidently widely dissimilar shall not be grouped together. Again, since all plants have qualities which are beneficial or prejudicial to the health of man or animals, and since these qualities are known to be associated with certain similarities of organization, it is demanded that plants of greatly dissimilar properties shall not be classified together. These two last require-
ments clearly call for a more extensive knowledge of the anatomy of plants than that upon which the sexual system was founded, and should more nearly approach to a natural association of these products of creation. Systems have been founded which are intended to answer to all the three above-mentioned requirements, and have been termed natural system, in opposition to that of Linnaeus, which, from its narrow basis, was known as the artificial system. It is evident, however, that the natural systems are the more desirable, and they are rapidly superseding the Linnaean arrangement; but as we are addressing ourselves to an extended circle of readers, we deem it a duty, first, to make them acquainted with the latter, and then to give them an insight into the former.

Linnaean System.

The Linnaean system is based upon the existence of sexual organs, and is varied according to the number and position of each division of these organs. It consists of classes and orders; the former associated chiefly with the stamens, and the latter with the pistils.

There are 24 classes, of which 23 belong to flowering and one to flowerless plants. A reference to the annexed plan will show that the first eleven classes are named according to the number of the stamens—viz., from 1 to 12 stamens; the last, however, admitting also of more than 12 stamens. The 12th and 13th classes have an indefinite number of stamens; but in the former (Icosandria) they are all attached to the calyx, whilst in the latter they remain free from their origin in the receptacle. This difference appears to be a trifling one, but it is constant, and in practice, moreover, is well defined. The 14th and 15th classes depend upon the number and relative length of the stamens, there being two long and two short stamens in the former, Didynamia, and four long and two short ones in the latter, Tetradynamia. In the 16th, 17th, and 18th classes, the stamens are associated into bundles; one bundle in Monodelphia, two in Diadelphia, and three or more in Polyadelphia. In the 19th class the stamens are also united into one bundle, Syngenesia; but they thus form a tube through which the pistil passes. The class termed Gynandria, indicates that the stamen and pistils are united together. The 21st, 22d, and 23d classes, comprehend plants in which the male and female parts are not met with together in the same flower. Thus in Monencia separate male and female flowers are found on the same plant, whilst in Diacea one plant is entirely male and another exclusively female; and in Polygamy both bi-sexual and uni-sexual flowers grow on the same tree. The 24th and last class embraces an heterogeneous assemblage of low organized plants, having this one property in common, that their sexual organs are concealed, whence the term Cryptogamia.

The foregoing 24 classes are divided into numerous orders. The orders of the first 13 classes are based upon the number of the pistils, which vary from one, Monogynia, to twelve, Dodecagynia, and more than twelve, Polygynia; whilst the 16th, 17th, 18th, 20th, 21st, and 22d classes are subdivided into orders according to the number of their stamens. The nature of the ovary determines the orders in the 14th and 15th classes. The 23d class, or that termed Polygamia, has but one order, and that depends upon the fact that certain of the flowers on the same plant are bi-sexual, whilst others are uni-sexual. The 19th class, or Syngenesia, has orders depending upon the forms and fertility of the florets; and the last one, Cryptogamia, is subdivided according to the families of which it is composed.

The following tables contain a complete summary of the Linnaean plan of classification. The reader will understand that the table reads across the two pages.
COMPLETE SCHEME OF THE LINNÆAN CLASSIFICATION.

1. Mon-andria (μονος, one; ανδρος, male)  1. Stamen.
2. Di-andria (δυς, two)  2. Stamens.
3. Tri-andria  3. do.
4. Tetra-andria  4. do.
5. Pent-andria  5. do.
11. Dode-caandria  12 or more Stamens.
12. Icos-andria  20 do. 
13. Poly-andria (πωλες, many) 20 do. attached to Calyx. 
15. Tetra-dynamia  4 do. 2 long, 2 short.
16. Mono-delphia (μωνος, one; δελφος, brotherhood)  6 do. 4 do. 2 do.
17. Dia-delphia (δις, two)  Filaments united into 1 set.
18. Poly-delphia  do. do. 2 sets.
19. Syn-genesis (συν, together; γενεσις, birth)  do. do. 3 or more sets.
21. Mon-cecia (ακος, house) Stamens attached to the Pistil.
22. Di-cecia Flowers with Males only; others with females.
23. Poly-gamia (γαμος, marriage) only on the same tree.
24. Cryptogamia (κρυπτω, to conceal) Flowers with Males only; others with females.

The simplicity of the system will be better observed on reference to the following plan, adopted from the "Encyclopédie des Connaissances utiles."

TABULAR VIEW OF THE CLASSES OF THE LINNÆAN SEXUAL SYSTEM.

Plants with Sexual organs apparent.

<table>
<thead>
<tr>
<th>Classes</th>
<th>Number of stamens.</th>
<th>Number and insertion.</th>
<th>Proportionate size.</th>
<th>By their filaments.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free.</td>
<td>do.</td>
<td>do.</td>
<td>do.</td>
<td>do.</td>
</tr>
<tr>
<td>United.</td>
<td>do.</td>
<td>do.</td>
<td>do.</td>
<td>do.</td>
</tr>
<tr>
<td>Flowers of one sex only.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sexual organs hidden.

As we propose to give, in very brief detail, both the Linnæan and the Natural systems, and shall therefore have to travel twice over the same ground, it will be more
THE LINNÆAN CLASSIFICATION.

COMPLETE SCHEME OF THE LINNÆAN CLASSIFICATION.

ORDERS.

Monogynia Digynia (γυνα, a woman)  
Do. do. Trigynia  
Do. do. do.  
Do. do. Tetracygni

Monac, Di, Tri, Tetra, Fenta, and Polygynia  
Do. do. do.  
Do. do. do. do. Heptacygni

Do. do. do. do.  
Do. do.  
Do. do. do. do. Decacygni

Do. do. do. do. do. Dodecacygni

Do. do. Polygynia  
Do. do. do. Polygynia  
Do. do. do. do. do. do. Polygynia

Gynoecpermia (γυναικ, naked; σεπμα, seed)  
Angiospermia (αγγος, a vessel)  
Siliculosa, small pod; Siliquosa, large pod.


Do. do. do. do.  
Polygamy equalis, Superfina, Necessaria, Segregata.

Monandria, Dianandria, Hexandria.


Monoeiea, Dioecia.

Filielles, Lycopods, Muscals, Lichenals, Fungals, Algals.

convenient to our readers, if we illustrate the Linnaean system from the English flora exclusively, and the Natural system from the foreign plants.

CLASS I.—MONANDRIA.

This is distinguished by having but one stamen, and is subdivided into two orders, Monogynia (one pistil), and Digynia (two pistils). It contains but few English plants—viz., five genera and fourteen species—and these remarkable neither for beauty nor utility. Four genera—viz., Salicornia, Hippuris or Mare's-tail (growing in ditches), Zostera, and Chara, commonly known as Stonewort or Water Horse-tail—have but one pistil; whilst the Callitrichae, or Starwort, is the only genus having two pistils. The Chara offers the most numerous species (six), and is, perhaps, the least uninteresting of all the genera. It is found in ditches both of fresh and salt water. The organization of members of this class is of a low grade.

CLASS II.—DIANDRIA.

This class has two stamens and two orders—viz., Monogynia and Digynia. It contains several plants of interest in the eleven genera, and thirty-nine species of which it is composed. Under the order Monogynia we find the well-known Privet (Ligustrum); the Fraxinus, or common Ash tree; the prolific, and almost ubiquitous weed Veronica, with its nineteen species; the Pinguicula, found in bogs; Utricularia;
Lycopus, or Cat-mint; Salvia, or Sage; Circea, or the Enchanter’s Night-shade, found in country parks and under field-hedges; the Lemna or Duckweed, covering every stagnant pool; and the Cladium. The first eight genera have inferior monopetalous flowers, whilst the Circea has a superior flower, and the two last are destitute of flowers.

The most agreeable member of this class is the Anthoranthum odoratum, a sweet scented meadow-grass, which possesses two pistils; and, as it has but two stamens, is cut off from the great family of grasses, to which it clearly belongs.

**Class III.—Triandria.**

This is a most extensive and invaluable class of plants, comprising all our British grasses except one, including the various cereals, as wheat and oats, so necessary to man. The members of this class are the means of sustaining the life of man, and of almost all animals, and are the most widely distributed, and the most abundant of all plants.

There are forty-eight genera, and one hundred and sixty-five species, arranged in three orders, Monogynia, Digynia, and Trigynia.

The order Monogynia contains twelve genera, of which five have superior flowers, and contain medicinal or poisonous plants, as the Valeriana, Crocus, and Iris. Six others have superior flowers, and comprehend many of the common rushes; and one is a true grass, the Nardus stricta. The order Digynia is remarkable for its natural assemblage of grasses; twenty-eight of which have chaffy flowers in panicles, arranged in bracts containing one, two, or three flowers. Five others—amongst which are the Wheat, (Triticum), and Barley (Hordeum)—have a spiked inflorescence. Of all these genera, only one is known to possess poisonous properties—viz., the Lolium temulentum, or Bearded Darnel. The Festuca ovina and Duriuscula are the most common grasses.

This is a class of plants offering great difficulty to the young botanist, on account of the apparent resemblance of many genera, and the absence of the calyx and corolla of other plants. But this difficulty is not unconquerable; and when it has been surmounted the pleasure attending the acquired knowledge is very great. The characters of this inflorescence have been discussed at pages 108 and 109.

The third order, Trigynia, has nothing in common with the last order unless we except the number of stamens, and this tends to show the great defect in the Linnaean system. It contains but three genera—Montia, Polycarpon, and Holostenum.
Class IV.—Tetrandra.

The flowers in this class have four stamens, and one, two, or four pistils—Monogynia, Digynia, and Tetragynia. It is not an extensive class, having only twenty-two genera and sixty-five species; and of these the large majority are valueless weeds.

The order Monogynia is the largest, and contains fifteen genera, four of which have no petals—viz., Alchemilla, or Lady's-mantle; Sanguisorba, Isnarda, and Parietaria; whilst nine are monopetalous, and two are polypetalous, with four petals. There are seven genera, possessing four pistils, and amongst them the Holly, Ilex, Lime-tree, Tilia, and Pond weed Potamogeton. A few plants are supposed to possess medicinal properties, as the Rubia, or Madder; Galium, or Bed-straw; and Sanguisorba officinalis, or Great Burnet. The Dipsacus Fullonum, or Fuller's teazel, the hairs of which (Fig. 113) are so useful to clothworkers, belongs to this class. Several other members possess a certain degree of beauty—as the Scabiosa and the Ilex, which is the cheering emblem in our Christmas festivities. The most numerous plants, under this head, are the Plantago, or Plantain, with its spike of sessile flowers, the Alchemilla, and the Potamogeton.

Class V.—Pentandria.

This is a most important, numerous, and varied class of plants, and has ninety-four genera and two hundred and ten species. The plants have five stamens, and one, two, three, four, five, six, or an indefinite number of pistils (Polygynia). It is not possible to give any one expression which shall represent this class as a whole; but there are many of its members which may be arranged together both in structure and properties; so that the class is a compound of several bodies or classes of plants.

The order Monogynia is very extensive, comprehending no fewer than forty genera. Thirty-one of these have monopetalous corollas; six are polypetalous of five petals, and three are apetalous. Ten genera are closely associated together, as shown by having inferior monopetalous flowers with two or four naked (so-called) seeds, and a covering of rough hairs over the plant. Such are Symphytum or Comfrey, Echium, Borago, Anchusa, or Alkanet-root, Cynoglossum, and the sentimental Myosotis or Forget-me-not. This is a compact and well-defined body of plants. Fifteen other genera are distinguished from the above, by having the seeds more manifestly inclosed in a seed vessel; and amongst these are the beautiful Primula or Primrose, and Cowslip, Menyanthes or Bog-bean, Anagallis, Convolvulus, Polemonium or Jacob's-ladder, Vinca or Periwinkle, and Verbascum; as also the poisonous Atropa, Belladonna or Deadly Night-shade, the Hyoscyamus and the Solanum Tuberosum, with its poisonous berries and edible subterranean stem, known as the Potato.

The six genera, with superior monopetalous flowers, are of mixed characters, and
three of them are well known—viz., the Lonicera or Honeysuckle, Campanula or Bell flower, and Lobelia.

Of the six genera with polypetalous flowers, four have them inferior, as the Viola or Violet, and Rhamnus or Buckthorn; whilst two are superior—viz., the delicious Ribes or Currants and Gooseberries, and the Hedera Helix or common Ivy.

The order Digynia is also very extensive and important, since there are thirty-six genera belonging to it, many of which possess valuable medicinal properties. Two of these are monopetalous—viz., the Gentiana and the Cuscuta; and four apetalous, the Beta maritima, Chenopodium, Salsola, Ulmus or Elm-tree, and Herniaria. The greater number are, however, distinguished by the umbelliferous mode of inflorescence, and constitute a naturally associated division. All have five superior petals and two seeds, but differ amongst themselves as to the presence and arrangement of bracts. Amongst this numerous and highly-important class of plants we may mention the Carum carvi or Caraway seed, Meum Foeniculum or Fennel—with its aromatic oil contained in the vitta of the seeds, the Daucus Carota or Carrot, Heracleum or Cow-parsnep, Pastinaca Sativa or common Parsnep, Bunium Flexiosum or Earth-nut, sought after by boys and animals, and the Apium graveolens or Wild-celery; the stately Angelica, the poisonous Conium Maculatum or Hemlock, Cieuta Virosa or Water Hemlock, Sium or Water Parsnep, the bitter Gentiana, and the Hydrocotyle with
its peltate leaf. The various genera of Parsley and Parsnep exceed any other in number; and nearly the whole of this large subdivision may be naturally arranged together.

In the order Trigynia are two genera with superior flowers, which are well known: the Sambucus Niger, or Elder, with the inflorescence called a cyme, and the elegant Viburnum or Lilac; and also three others of less notoriety, which have inferior flowers.

The orders Tetragynia and Hexagynia have each one genus known well to botanists, and growing on boggy ground—viz., Parnassia in the former, and Drosera or Sundew in the latter. The Drosera is remarkable as being the only English plant which exhibits sensibility to touch in a marked degree. It possesses a number of remarkable glands upon the surface of its leaves (page 70), which emit a tenaceous fluid by which flies are caught, and which are subsequently approprist as food for the plant.

The order Pentagynia possesses three genera, two of which are of interest—viz., the Statice or Thrift, with its cheerful head of flowers, and the Linum or Flax plant.

The last order, Polygynia, includes but one genus, and that of but little value—the Myosurus or Mouse-tail.

Our readers will now perceive how remarkable is the combination of plants brought together by this class of the Linnean arrangement, and how unfitting it is that so many varied alliances should be enrolled under one head. It is also well to remember that three well defined natural classes may be formed out of many of its members,—the one with the umbelliferous inflorescence (Umbelliferae), another with a rough hairy cuticle (Boraginaceae), and a third with highly poisonous properties and sombre aspect (Solanaceae). It is a class remarkable both for the beauty and utility of its members—a utility embracing both medicinal and dietetic qualities.

**CLASS VI.—HEXANDRIA.**

This class is characterized by having six stamens, and is divided into four orders—viz., Monogynia, Digynia, Trigynia, and Polygynia; and contains twenty-six genera and eighty-five species.

It is remarkable as a class of flowering plants for the endogenous structure of its members, as evinced by the straight veins of its leaves, and possesses many plants of great beauty and a few of considerable utility.

The order Monogynia comprehends nineteen genera, or two thirds of the whole class; and, with the exception of the Berberis or Berbery, with its compound leaves (page 101), sensitive stamens and fruit capable of being used as an excellent pickle; the Peplis and the Frankenia, and a few others, have a perianth (Fig. 201), as a covering of the flower, and a bulb for their underground stem. As examples of the class, we may mention the Galanthus nivalis or Snowdrop, or Narcissus Ornithogalum or Star of Bethlehem, Hyacinthus, Scilla or Squill, and Tulipa, all of which contain starch in their bulbs, and have beautiful flowers. The Convallaria or Solomon’s Seal is an elegant member of this class. The Asparagus officinalis, and Allium or Garlick, are edible. The Acorus Calamus or Sweet Flag, emits an aromatic odour from its leaves and root, and is a grass not only used medicinally, but is much
employed in India as an artificial shade, when it is drawn into a frame, and water thrown upon and air driven through it so as to produce a low temperature and an aromatic odour.

The genera having the greatest number of species are the Juncus or Rush, and the Luzula or Wood-rush, under which terms are comprehended most of the Rushes growing in fresh and salt water in this country. They comprehend thirty-seven genera.

The orders Digynia and Polygynia have but one genus—Oxyria in the former, and Alisma Plantago or the Water Plaintan in the latter. In the order Trigynia we find five genera, two of which are worthy of mention: the Colchicum Autumnale, with

![Fig. 316. Hexandria Polygynia.](image)

![Fig. 317. Hexandria Trygynia. Hexandria Digynia.](image)

its beautiful flower and medicinal cormus, and the common Rumex or Dock, and Rumex Acetosa and Acetosella, the common and the Sheep's Sorrel. The latter class of plants have no corolla.

Thus, whilst a few of the members of this class are worthless weeds, many others form the choicest parts of the collections of the horticulturists, and have obtained more attention in their cultivation and improvement than almost any other native plants. They comprehend nearly all our native flowering endogenous plants.

**Class VII.—Heptandria.**

This class possesses but one genus, the elegant European Chickweed Winter-green
Trientalis Europea, which has seven stamens, and one pistil. Its calyx, corolla, and seed-vessel are each divided into seven parts, and well illustrate the law mentioned at page 111.

Class VIII.—Octandria.

The plants of this class have eight stamens, and are divided into four orders—viz., Monogynia, Digynia, Trigynia, and Tetragynia. These are, however, few in number; forming only thirteen genera and forty species. The general characteristic of the class is rather that of beauty than of utility; and yet it is far from being wanting in either.

As instances of beauty, we may mention that in the first order there are the Œnothera biennis, or Evening Primrose; the Epilobium, or Willow-herb; and the gentle Erica, or Heath,—than which nothing can be more lovely in their separate characters.

Amongst the genera which may be termed useful, we instance the Acer, or Sycamore
and Maple; Vaccinium Vitis-idaea, or Cowberry; Vaccinium oxyccoccus, or Cranberry, Vaccinium myrtillus, or Bilberry, with Daphne Mezereum, or Mezereum, and Polygonium, both of which possess valuable medicinal properties. The last-named plant belongs to the order Trigynia; and three others, Adoxa, Paris, and Elatine are ranged under the order Tetracygnia. The Epilobium is the most abundant and fruitful in species, having nine, which inhabit either dry or moist localities. It is probable that the whole class must be regarded as possessed of irritating properties.

**CLASS IX.—ENNEANDRIA.**

This class, like Heptandria, contains but one genus and one species, the beautiful Butomus Umbellata, or flowering Rush, growing in ditches and the borders of stagnant waters. It has six pistils; and, consequently, the sole order in the class Enneandria is Hexagynia.

**CLASS X.—DECANDRIA.**

This is a well-defined class of plants, the members of which are, for the most part, fitly associated together. They have ten stamens, and two, three, or five pistils, and consist of twenty-one genera and one hundred and seven species. A few are beautiful; but the majority are weeds, though not without a certain degree of interest, since they enliven by their small and modest flowers our mossy banks and waste places.

The order Monogynia has five genera, two with polypetalous flowers—Monotropa and Pyrola, or Winter-green—and three with only one petal, as the Arbutus or Bearberry. There are five genera in the order Digynia—viz., Scleranthus, Chrysosplenium, Saxifraga or Saxifrage, Saponaria, and Dianthus or Pink; whilst the order Trigynia has the Arenaria or Sandwort, Stellaria or Stitchwort, Silene or Catch-fly, and Cherleria—all weeds. The fourth order, or that called Pentagynia, has seven genera—the Lychnis; Cerastium, or Mouse-ear Chickweed; Sedum, or Stone-crop; Cotyledon; Oxalis Acetosella, or Wood-sorrel; Agrostemma; and Spergula. The Dianthus, Saxifraga, Lychnis, and Oxalis are doubtless the most beautiful; whilst the Pyrola and Arbutus exhibit certain feeble medicinal qualities. The class is somewhat remarkable for the number of species in proportion to that of the genera.
THE CLASSES DODECANDRIA AND ICOSANDRIA.

CLASS XI.—DODECANDRIA.

Hitherto the classes have succeeded each other by the addition of one stamen; but this addition is of two, there being no English plant with eleven stamens. The order contains but five genera and eight species (each plant having twelve stamens), subdivided into five classes—viz., Monogynia, Digynia, Trigynia, Tetragynia, and Dodecagynia (twelve pistils). The genus and species Sempervivum tectorum, or House-leek, is the best known, and belongs to the order Dodecagynia; after which may be placed the Agrimonia Eupatoria or Agrimony (Digynia), and then Reseda (Trigynia), and Asarum and Lythrum (Monogynia). The Agrimonia is presumed to possess slight medicinal properties; but the whole class is deficient, not only in number, but in beauty and utility.

CLASS XII.—ICOSANDRIA.

This is a most interesting class of plants, second, if at all, only to Triandria; and is one of those which chances to be well comprised in the Linnaean system. It contains twelve genera and sixty-seven species; and, with the exception of the Pyrus Aucuparia, or Mountain Ash, is either edible or harmless. It is distinguished less by the number than the position of the stamens—for there are an indefinite number of stamens but they are attached to the calyx (Epigynous, Fig. 218 and so distinctive is that arrangement, that a member of the class is instantly recognized.

It is divided into three orders—Monogynia, Pentagynia, and Polygynia. Prunus, or the Cherry and Blackthorn, is the only occupant of the first order; whilst three delicious plants—Mespilus or Hawthorn and Medlar, Pyrus (Pear, Apple, and Crab), and Spiraea or Meadow-sweet—have from two to five
stamens, and are arranged in the order Pentagynia. The third order has more than five pistils, and is termed indefinitely Polygynia; and in it are found the Rosa or Rose, Rubus or Bramble and Blackberry, Fragaria or Strawberry, Geum, Dryas, Tormentilla, Potentilla, and Comarum.

It is thus evident that this class comprehends nearly all our edible juicy fruits, besides the beautiful flowers which precede them, and such others as the Rose. It is a class of plants most readily diagnosed, in whatever part of the world they may be found, and, moreover, are, with few exceptions, healthful as food. A slight medicinal astringent influence is attributable to the Tannin, which is present in small quantities in such plants as the Potentilla, Tormentilla, and the Rose; and it is not improbable that, in a slight degree, it pervades the whole. This class of plants is, however, of greater use to the horticulturist than to the physician; for none are more susceptible of improvement from culture and admixture of species than the beautiful Rose (Fig. 207), the Strawberry, Apple, and other juicy fruits.

Class XIII.—Polyandria.

This class differs, in a remarkable degree, from the preceding, especially in the powerful medicinal qualities with which its members are endowed. In this respect it resembles only a part of the heterogeneous class Pentandria, and with that division of plants furnishes many poisonous narcotic and narcotic-acrid substances. It has nearly double the number of genera, and yet fewer species than those possessed by Icosandria viz., twenty-two genera, and fifty-five species. It is determined by the presence of numerous but an indefinite number of stamens, similar to the class Icosandria; but the two classes present some difference, the former having the stamens inserted beneath the ovary, and therefore hypogynous (Fig. 225), as in the Poppy. It is divided into three orders, named Monogynia, Pentagynia, and Polygynia.

The order Monogynia contains eight plants, of which four (viz., the Papaver or Poppy, Chelidonium, Glaucium or Horned Poppy, and Actaea) have only four petals; whilst two (the Helianthemum) or Rock Rose, and Tilia Europea (or the Lime Tree), have five; and two others, which are water plants (the Nymphaea Alba or the White Water Lily, and the Nuphar Lutea and Pannila or the Yellow Water Lily), have an indefinite number of petals. The above distinctions are, however, somewhat illusory; since no plants more than these now mentioned have the power of multiplying their petals by cultivation at the expense of the
stamens (page 114); but they are of value, inasmuch as the number is either the original one, or some multiple of it.

The order Pentagyenia contains five genera of beautiful plants, which have from two
to six pistils, and includes the splendid Paeonia or Pæony, Delphinum or Larkspur, Aconitum or Monkshood, Aquilegia or Columbine, and the Stratiotes.

There are nine genera in the order Polygynia, each of which have an indefinite number of pistils; and many of these are remarkable for their sombre beauty. Thus there are the Clematis, Anemone, Helleborus or Hellebore, Adonis, Ranunculus or Crowfoot, Thalictrum or Meadow-rue, Caltha Palustris or Marsh Marigold, Trollius, and Ficaria.

This class is therefore remarkable for its powerful medicinal or poisonous properties —properties which pervade the class as a whole—and for its flowers, of a deep colour and sombre beauty. Amongst the former we may mention the Papaver, which supplies so vast a quantity of Opium (page 51), Helleborus Niger or Black Hellebore, and Aconitum, all of which still supply medicinal preparations; whilst the Chelidonium, Delphinum, Ficaria, Ranunculus, and several others, are known to be poisonous. The Tilia affords a delicious scent when in bloom; whilst the flower of the Nymphaea Alba, Paeonia, Helianthemum, Delphinum, Aquilegia, Anemone, and Adonis, may well take rank amongst the most favourite productions of our gardens and ponds. The Nymphaea is also remarkable as yielding beautiful stellate cells (page 11); whilst the Papaver and Chelidonium possess a large quantity of laticiferous tissue (page 29) and milky juices. The Ranunculus is the only plant bearing a true nectarium on the claw of its petal (page 69).

CLASS XIV.—Didynamia.

We have now passed in review all the classes which are founded simply upon the number of stamens and their position, and proceed to those which are based on more complex phenomena. The one now under consideration has only one other element added to that of number—viz., the relative length of the stamens, not as an accidental but an essential fact. The class Didynamia is characterized by having two long and two short stamens (Fig. 223), and is divided into two orders—viz., Gymnospermia, in which the seeds do not exceed four in number, and appear to be, but really are not, naked at the base of the flower; and Angiospermia, having the seeds in
a manifest capsule. It is requisite to remark, that when Linnaeus founded his classification, the seeds in the order Gymnospernia were believed to be naked; but more recent investigation has shown that they were inclosed in a flattened two or four-celled ovary. This, therefore, is an incorrect division of the class; but it has its value, since the seeds, as they lie at the bottom of the ovary, seem to be naked.

There is a further general characteristic of this class—viz., the labiate or bilabiate corolla (page 115), which is found in the major part of its members.

There are thirty-four genera, and eighty-five species, in the class Didynamia, and of these twenty genera are arranged in the order Gymnospermia. The calyx is two-lipped in six genera—viz., the Origanum or Marjoram, Thymus or Thyme, Prunella, Scutellaria, Melittis, and Clinopodium; but it is nearly regular, and divided into five segments in the major part of the order, as the Mentha (Peppermint, Spearmint, Bergamot-mint, Pennyroyal, &c.), Nepeta or Catmint, Marrubium or Horehound, Betonica or Wood Betany, Leonurus, Glecoma or Ground Ivy, Lamium or Dead Nettle, Galeopsis, Teucrium or Wood Sage, and others. Nearly the whole of the members of this order are common way-side and water-side plants; but they possess valuable medicinal properties, as in the essential oils found in little reservoirs of the leaves of the Mentha, Origanum, and Thymus; and a bitter principle, which is well known to herbalist housewives, residing in the Marrubium, Betonica, and others. It is probable that no member is decidedly poisonous.

The order Angiospernia differs not only in having an evident capsule, but in the possession of poisonous qualities, at least in several of its members; and is an instance in which plants of diverse affinities have been improperly arranged together under the same head, simply because one point in their organization seemed to indicate a resemblance.

The number of sepals is again a mark of distinction. Thus the genus Orobanche has but two sepals, whilst the Euphrasia or Eye-bright, Rhinanthus or Yellow Rattle, Lathrea, Bartsia, and Melampyrum, have four segments of the Calyx, and eight have the Calyx five-cleft. The last division contains the most important members of the order, and of these the Digitalis, or Foxglove, takes precedence. That plant yields a product from its leaves which is of great value in medicine, and which on many occasions has inadvertently produced death. There are also the Scrophularia or Figwort, common in ditches and on banks, Antirrhinum or Snapdragon, Linaria or Toad Flax, Pedicularis or Lousework, and the modest Linnea Borealis, named after the great founder of this system.

None of the members of this order possess the aromatic properties mentioned in the preceding order; but there are several which add much to the gaiety of our fields and shady lanes. In neither order are there any plants which afford nutriment to man.

**Class XV.---Tetradynamia.**

This class resembles the last, inasmuch as it has stamens of different lengths; but it differs in having four of them long and two short (Fig. 344). The two short ones are
placed at the sides of the others, and the whole are inclosed in a flower, which has invariably four petals, arranged in the form of a Maltese cross, and hence termed Cruciate (Fig. 344). Upon the whole it is a well-defined and arranged class, and may be readily distinguished by the construction of the flower and the pod-like seed vessel which its members possess. It is divided into two orders by somewhat indefinite boundaries—viz., Siliculosa, signifying a short pod (Fig. 345); and Siliquosa, indicating a long pod (Fig. 346). There are twenty-eight genera and sixty-eight species in the whole class.

The order Siliculosa is again subdivided into such members as have the pod entire at the top, and others in which the pod is there notched. The former comprehends ten genera, amongst which are the Cochlearia Armoracia or Horse-radish, Crambe Maritima or Seakale, Cakile or Sea Rocket, and Subularia or Awl-wort; whilst in the latter there are Thlaspi or Shepherd's-purse, or Candy-tuft, and Lepidum or Pepper-wort.

The second order, Siliquosa, contains fourteen genera, and amongst them are plants of greater interest. Thus there is the Brassica (Cabbage, Rape, Turnip, Navew, and Seakale), Sinapis or Mustard, Raphanus or Radish, Nasturtium Officinale or Water-cress, Barbarea or Winter Cress, Arabis or Wall and Rock Cress, all of which are useful edible plants; Cardamine or Ladies' Smock, and other species, Matthiola or Stock, and Cheiranthus or Wall-flower, which are favourite indigenous flowers.

The class Tetradynamia is therefore ranked amongst the most useful of our vegetable productions, since it supplies much of the green vegetable food used by man, as well as condiments and aromatic perfumes. The nutritive properties of the Brassica or Cabbage are computed as 1 to 16 of Horse Beans, Lentils, Peas, and Haricots; 1 to 8 of Wheat and Oats; 2 to 1 of Turnips, and of equal proportions to Carrots and old Potatoes; and is chiefly due to the relative quantities of starch contained within their cells (page 32).

**Class XVI.—Monodelphia.**

This and the succeeding classes are founded upon another feature in connection with the stamens—viz., the adherence of their filaments, so as to produce one, two, or
more sets. In the small class, now under consideration, the filaments are united together into one bundle, which may consist of five stamens, as in Erodium or Stork's bill; of two stamens, as in the allied genus Geranium; or of an indefinite number of stamens, as the Malva or Mallow (Fig. 219), Althea or Marsh Mallow, and Lavatera or Tree Mallow. These four genera constitute the whole class, and are subdivided into the following orders as above intimated—Pentandria, Decandria, and Polyandria. None of them are either edible or poisonous; but the Malva and Althea have been employed in domestic medicine on account of the mucilaginous juices which they yield. The indigenous Geranium, or Crane's bill, offers thirteen species; but, whilst they are interesting wayside herbs, they are infinitely inferior in beauty to the cultivated flowers which more commonly bear that name. The whole class consists of five genera and twenty-two species.

**Class XVII.—Diadelphia.**

This is a class of very great importance, and is fitly associated with the Icosandria, Triandria, and Tetradynamia, in supplying nutritive and pleasant food for man and animals. It contains eighteen genera and seventy-four species, and, as a whole, is a tolerably well-associated class of plants. It is characterised by having the filaments of the anthers arranged in two sets (the second set usually consisting of but one filament, Fig. 221); and, as a rule, they are inclosed in the carina or keel of the Papilionaceous corolla (Fig. 213). It is divided into three orders, according to the number of the stamens—viz., Hexandria, in which there is but one genus, the Fumaria, or Funitory growing in corn-fields; Octandria, also consisting of one genus, the Polygala or Milkwort; and, lastly, Decandria, which comprises the remaining genera. The orders Hexandria and Octandria offer nothing of importance; so that it is to the Decandria that we direct our attention. In this order the ten stamens are invariably arranged in

![Fig. 350. Diadelphia Hexandria.](image)

![Fig. 351. Diadelphia Decandria.](image)

![Fig. 352. Diadelphia Octandria.](image)

a set of nine and an odd one, which is not readily separable from the nine by any one ignorant of its separate existence. It usually lies attached to the thin edge or face of the mass of filaments. The following are the chief members of this class:—the Pisum or Pea, Vicia or Vetch, Anthyllis or Kidney Vetch, Orobus or Bitter Vetch, Lathyrus or Vetehling, Hippocrepis or Horseshoe Vetch, Astragalus or Milk Vetch, Ervum or Tare, Trifolium or Clover, Lotus or Bird's Foot, Ulex or Furze, and Genista or Broom; the latter, with the Ulex, Anthyllis, and Ononis being the only instances in which all the stamens are united at their base. The Pea is the only member supplying human food under ordinary circumstances; but in seasons of dearth others have been used, and again may be used with great advantage. Nearly all the remaining genera are commonly used as food for animals, and a very few have medicinal properties, as the Genista and the Fumaria Officinalis. None are poisonous.

They are, for the most part, climbing plants with pinnate leaves, and the midrib
THE CLASSES POLYDELPHIA AND SYNGENESIA.

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elongated into a tendril or cirrhus (Fig. 185). The prevailing colours of the corolla are yellow or red.

CLASS XVIII.—POLYDELPHIA.

This class consists of one genus, Hypericum or St. John’s Wort, and eleven genera, and has the stamens divided into three, four, or more sets (Fig. 220). It is not otherwise of interest. It belongs to the order Polyandria.

CLASS XIX.—SYNGENESIA.

This is the largest class of plants in every Flora, and is one of exceedingly well-defined characters. It is also one of some difficulty to the young botanist in determining the species, and even some of the genera; but the mere class-characters are, even to him, of most ready discernment. Its distinguishing feature is the union of the anthers (not necessarily of the filaments also) into a tube through which the pistil passes (Fig. 222). The flowers are also arranged on a capitulum or head, and, in many instances, those of the margin or ray differ in size, or other particulars, from those of the centre or disk; and hence the flowers of the head are frequently divided into florets of the ray and florets of the disk. The whole florets are surrounded by an involucre of bracts, and each separate floret has a small calyx, which is commonly chaffy. The part upon which the flowers are placed is called the receptacle (Fig. 193). There are forty-one genera, and one hundred and thirty-three species.

This class is divided into three orders. The first is Polygama Equalis, in which all the flowers are perfect, having five stamens and one pistil, and producing one seed. It contains 22 genera and 71 species, and is subdivided into three parts, according to the form of the corolla. Twelve genera have all the corollas strap-shaped. Such are the Cichorium or Chicory, the root of which is ground to powder, and used as a substitute for Coffee; Lactuca or Lettuce, which in its wild state is poisonous, but...
when cultivated may be eaten with impunity; Prenanthes, or Wall-lettuce; Leontodon taraxacum or Dandelion, with milky medicinal juices; Sonchus or Sow Thistle; Hieracium or Hawk Weed; Apargia or Hawkbit; and Tragopogon or Goat's Beard. The ten remaining genera have all the corollas tubular; six with the florets spreading so as to form a hemispherical head and face, with the florets lying parallel and crowded together, and forming nearly a level surface at the top. Amongst the former are the Carduus and Cnicus, two forms of prickly thistle, and Arctium or Burdock; and of the latter are the Bidens or Bur Marigold, Diotis, Eupatorium, and Chrysocoma.

The second order is Polygemia Superflua, in which all the florets are fertile; but yet in many cases those of the ray have pistils only. The marginal florets appear wanting in the Artemesia or Wormwood, Tanacetum or Tansy, Gnaphalium or Cudweed, and Conyza or Spikenard; whilst they are developed, and have a strap-shaped figure, in all the remaining orders. Amongst the latter are found the modest "wee crimson tipped flower," the Bellis Perrennis, Tussilago farfara or Colt's-foot, Anthemis or Camomile, Achillea or Millefoil, Senecio or Groundsel, Aster or Starwort, Chrysanthemum or Ox-eye, and Corn Marigold, Pyrethrum or Fever-few, Solidago or Golden Rod, Inula or Fleabane, and Cineraria or Fleawort.

The third order is called Polygemia Frustranea, and has perfect and fertile florets of the disk; but the florets of the ray have neither stamens nor pistils, and hence the term "Frustranea." The Centaurea, or Centaury, is the only genus, with its seven species.

On taking a review of this extensive class we find that the Lettuce, in its cultivated state, and the dried root of the Chichorium, are the only members which afford nutriment to man. Certain others, as the Sonchus, Leontodon, Carduus, Cnicus, and Senecio are eaten by various animals. Many members have been more or less employed medicinally, and it is probable that medicinal properties are possessed by the whole class. Those which have been most commonly used are the Anthemis, Tussilago, Artemesia, Leontodon, Hieracium, and Inula. Some of these, with the Lactuca and many other members of the class, abound in Laticiferous tissue and milky juices; and to these may chiefly be attributed the medicinal effects of the plants. They grow exclusively, or nearly so, on dry land, and many of them in waste places. But few have been thought worthy of horticultural cultivation.

Class XX.—Gynandria.

This is a very curious class of plants, and at the present day are very fashionable. In this country they grow chiefly in meadow lands and moist soils; but in tropical
regions they are beautiful parasites upon decaying trees. No more splendid conception of a flower can be obtained than that which is offered by some members of this class now collected in the Royal Gardens at Kew. The class is distinguished by having the stamens situate upon, or connected with, the style or other part of the pistil. There are three orders—Monandria, Diandria, and Hexandria; but all the British genera belong to the first, except Cypripedium, which has two stamens, and Aristolochia, which has six stamens.

The order Monandria has ten genera, while the whole class consists of twelve genera and thirty-seven species. The anther is fixed, terminal, and permanent in the Epipactis; and moveable and deciduous in the Malaxis and Corallorhiza. It is parallel to the stigma, and of two cells close together in the Neottia, Goodyera, and Listera; and either of two vertical cells; permanent, fixed to the summit of the style in Orchis, Aeras or Green Man Orchis, Ophrys or Fly Orchis, and Herminium or Green Musk Orchis.

Our native specimens of this class are not especially interesting, except the common Orchis, with its variegated corolla and green leaves spotted with black, as it is growing on a rich moist meadow. They are not used as food, except the so-called tubers of a few members which have yielded an amorphous form of starch. The general characteristic of the class is acridity; but they are not employed in medicine. The whole class is peculiar, inasmuch as from the conformation of their sexual organs they need the intervention of an insect, as the Bee, to carry the pollen from the anther to the stigma, and ensure fructification.

**Class XXI.—Monœcia.**

In each of the preceding twenty classes every flower has been bisexual, and consequently every tree bearing flowers must have them in this hermaphrodite condition. The three following classes are exceptions to the general rule, and have flowers of one sex or of two sexes, and on the same or on different trees. In the class Monœcia the flowers are unisexual, some having stamens only and others only pistils on the same plant. It is a highly important class, since it contains a considerable number of our forest trees. It is divided into seven orders—viz., Monandria, Diandria, Triandria, Tetrandria, Pentandria, Polyandria (more than five stamens), and Monodelphia (filaments united into one brotherhood), and together contains twenty-five genera and one hundred and eight species.

The order Monandria (one stamen) possesses but two genera—the Euphorbia or
Spurge, which is a common weed on waste land, and the Zannichella. Triandria is chiefly occupied by the Sedges, under the names of Carex, which alone claims sixty of the whole hundred and eight species found in the classes Typha or Reed Mace, and Sparganium or Bur-reed; all of which, with the Elyna, grow in marshy and muddy places.

The order Tetrandria (four stamens) has five genera—viz., Aluno Glutinosa or Common Alder-tree, Buxus Sempervirens or Box-tree, Urtica or Stinging Nettle, Littorella, and Eriocaulon. The stinging secreting hairs of the Nettle, with their circulation, have been described at page 67. There are only three genera in the order—Pentandria (five stamens); Bryonia or Bryony; Xantheum, and Amaranthus; whilst the order Polyandria (more than five stamens) has ten genera, several of which are our most important wooded trees. Thus we find the Quercus or Oak, Betula or Birch, Fagus or Beech (Fig. 125), and Chestnut and Corylus or Hazel, amongst trees; with Carpinus, Sagittaria (Fig. 173), Ceratophyllum and Myriophyllum; and, last, the Arum Maculatum or Wake Robin (Fig. 76), with its starch-containing cormus. The valuable Pinus, or Pine-tree, is the sole occupant of the last order, or Monodelphia.

It is scarcely possible, in so heterogeneous an assemblage of plants, to fix upon any leading common characteristic; but although no member, except the corm of the Arum, and the nuts of the Fagus, Quercus, and Corylus, offers anything for the food of man or beast, neither is any, except the Oak-bark, employed in medicine, it is highly probable that valuable astringent and perhaps acid properties are common to them all. The
Betula yields a fermenting juice, from which a good wine is produced (page 23); and the Pinus affords turpentine and resins; but it is the wood which this class yields that contributes to its value.

**Class XXII. Diöcia.**

This agrees with the former in all the flowers being unisexual, and having either stamens or pistils alone; but it differs in this respect, that the two sexes occupy different trees. Thus one plant has wholly male flowers, and another has exclusively female ones. It contains fourteen genera and eighty-two species, divided into twelve orders, —viz., Monandria, Diandria, Triandria, Tetrandria, Pentandria, Hexandria, Octandria, Enneandria, Decandria, Icosandria, Polyandria, and Monodelphia. This extreme division of its contents clearly proves that it possesses very heterogeneous materials.

The order Diandria is occupied by the genus Salix—a genus which affords sixty-four of the eighty-two species of the class. It is known by the catkin inflorescence described at page 166. Triandria and Tetrandria have three genera each; and of these only one of the latter, Viscum Album, or Mistletoe, deserves mention. The valuable and scarce Humulus, or Hop, occupies the outer Pentandria; and Tamus, or Black Bryony, the order Hexandria. Populus, or the Poplar-tree, is found in Octandria; and Mercurialis and
Hydrocharis in Enneandria. Coniferous trees monopolize the last order, Monadelphia—viz., Juniperus or Juniper, and Taxus, or Yew.

Fig. 378.—Diœcia Decandria. Fig. 379.—Diœcia Polyandria. Fig. 380.—Diœcia Monadelphia.

The Salix and the Populus are capable of yielding a medicinal substance, which is said to be a good substitute for Quinine; the Juniperus an oil which is employed both medicinally and in the preparation of Hollands; and the Humulus a bitter principle, which should be used in the manufacture of ale, and a narcotic principle which is employed in medicine. The Taxus is one of our most enduring trees, and has been known to live upwards of two thousand years. The latter plant offers glandular woody tissue, with a spiral fibre (Fig. 60). The Mistletoe Berry, Viscum Album, is an essential element in our Christmas arrangements, and has been so for many ages. The plant is one of those which took part in the ancient Druidical rites. The whole class possesses acrid or narcotic acid poisonous properties.

Class XXIII.—Polygama.

This represents a condition of the sexual organs which is intermediate between the two last classes; and has hermaphrodite or unisexual flowers indifferently on the same or on different plants of the same species. It has but one member—the Atriplex, a common and valueless weed on dunghills and waste places. It has seven species.

Class XXIV.—Cryptogamia.

The characteristic peculiarity of the members of this class is, that they do not possess sexual organs, or that they so conceal them that they have not as yet been discovered. But very few, comparatively, were known to Linnaeus; and of those known in our day, the most beautiful, as well as the greatest numbers, are foreign to our shores. Some of them inhabit the most desolate regions, as the Lichens of Lapland; whilst others abound in tropical regions, as the Tree-ferns, to which reference has already been made. They are commonly known as Sea-weeds, Mushrooms, Lichens, Mosses, and Ferns, all of which are flowerless Sea-weeds.

The term Algae is a comprehensive term, capable of wider signification than the corresponding one of Sea-weeds, by which it is commonly represented in our language. It comprehends a very large proportion of the lowest division of the vegetable kingdom, or that which seems to be almost common ground between the lowest forms of both vegetable and animal organization. It is now commonly divided into several groups, as the Brittle-worts, Confervas, true Sea-weeds, Rosetangles, and Charas.

Brittle-worts (Diatomaceae and Desmidia) constitute the slime which is found upon the surface of stems, and are commonly so minute as to be microscopic objects. They are fragmentary, brittle bodies, generally bounded by right lines, and of a green colour; and with the slime in which they nestle afford protection and food to microscopic animalcules. Many of them inhabit salt, and others the fresh waters, and most of them develop starch within their cells. Amongst the chief genera we may mention Diatonia,
Desmidium, Achananthes, Gomphonema, Exilaria, Fragillaria, Micromega, Beckleys, Cymbella, Navicula, and Euastrum.

Conifers also inhabit both salt and fresh waters, but are commonly of an olive, violet, and red, rather than a green colour. They consist of a series of cells of various forms, as cylindrical tubular globes, or elliptical, and grow by the subdivision of their cells, and the propagation of spores within the cells. Their forms are extremely varied, and their distribution almost universal. The Protococcus, Hæmatococcus, Porphyra (stewed and eaten, as Lava), Ulva, Common Nostoc, or Star-jelly, Palmella, Con- 

Fucus, or Sea-weeds, are closely connected with Conifers both in structure and situation. They differ in their mode of reproduction, for the reproductive organs are situate without the plant, appearing as little green worts invested by a thin membrane; and the male organs, or antheridia, have the spiral filament, before described under the head of Mosses. Some of them are eatable, and are eaten by various people in the Pacific, as well as in the instances of the Alaria Æsculenta, and Fucus Vesiculosus, by the inhabitants of Ireland, Scotland, and the northern islands. They are, however, of still greater use to man by affording soda in the impure form of kelp, which is used largely by soap makers and glass manufacturers, and also iodine, which is yielded by many genera, but more particularly by the Ecklonia Buceinalis of the Cape of Good Hope, and by many on our own shores.

Rosettes (Ceramicées) or the Corallines, are also Sea-weeds, but usually have a rose or purplish colour. They consist of cells of various forms, arranged in one or more rows, so as to produce an articulated frond, and are propagated by spores formed in threes or fours within a mother cell. They are entirely marine; and yield a greater number of genera, which are edible by man or animals, than any other form of Sea- 

The Charas are submerged plants of a green colour, with regularly-branched brittle stems and whorls of small branches or leaves. In some of these, as the Nitella, the circulation may be seen in its progress up and down the stem by the aid of the microscope.

Mushrooms.

The general term Fungi represents the varied members of this extensive class of plants, but very inadequately, since the class comprehends, besides the true Mushrooms or Fungi, Moulds, Morels, Mildews, Blights, and Puff-balls. The members, therefore, vary from a size so minute as to be almost or quite invisible to the naked eye, to a mass much larger than the human head. They grow, for the most part, upon decaying substances, and usually increase in size from within. A few, as the Agaricus fiétens, are said to possess lactiferous vessels and spiral filaments. The major part of them are, moreover, very ephemeral in their character. Some of them are edible, as the common Mushroom (Agaricus campestris), Helvella or Morel, and Tuber or Truffle, all of which, with some others, are commonly eaten both in this country and on the Conti-
ment of Europe. Others, however, are very poisonous; and it is believed that species which are sometimes wholesome become poisonous when grown under other conditions, or eaten by persons of peculiar sensibilities. Upon the whole, it is a class of plants which should be sedulously avoided, although a very considerable number are known to be edible in various parts of the world. The dry rot is due to the Polyporus destructor, and other species; the blight of corn to the Puccinia graminis; the rust to the Uredos and Puccinieae; and the mildew to the Mucedos (Fig. 301). They also attack cheese, bread, preserves, fruit, and almost every article of food, and are then known as mould; and it is a curious fact that the presence of any perfume prevents their formation. A few of them are phosphorescent. The number of genera is so vast that it is useless to attempt any very limited selection.

**Lichens.**

These are directly opposed to Fungi, inasmuch as they are perennial, and consist of a lobe and leaf-like thallus. They constitute the gray, yellow, and brown stains which give an air of antiquity to the walls of our churches; or they are found on broad patches of a leprous appearance on the trunks and branches of trees. They are useful to man in two modes—first, by affording dyes as described on page 54, and, secondly, as food. The latter quality is found in the Cetraria Islandica or Iceland Moss, Genomyce rangiferina or Reindeer Moss, Sticta pulmonacea, Alectoria usnoides, and various species of Gyrophora, which furnishes food to the Canadian hunters. Many others possess medicinal properties of value. It is an extensive family of plants, but hitherto it has not been studied with the care which has been bestowed upon other, but not less valuable and interesting, vegetable productions.

**Mosses.**

This great class is subdivided into several portions, and exhibits a degree of organization considerably beyond those to which we have hitherto referred. Amongst the subdivision we may instance the Scale Mosses (Jungermanniace), Split Mosses (Andraeacea), Urn Mosses (Bryaceae), Club Mosses (Lycopodiaceae), Crystal Worts (Ricciaceae), Liver Worts (Marchantiaceae), and Horse-tails (Equisetaceae). In some instances, as in the Sphagnum and Polytrichum, the male organs may be seen in constant motion in the early spring months, and appear like two thread-like bodies, with one extremity thin and attached, and the other enlarged and free, inclosed within a distinct cell-wall. The same kind of motion is also found in other members of the class, and is due in some degree to hygrometric influence, as has before been described in reference to the Urn Mosses.

The Crystalworts are amongst the most diminutive members of the class, and swim or float upon small collections of shallow water, or attach themselves to the mud. They are but few in number. The Liverworts are found very abundantly in damp unfrequented places, on the uncovered ground, inclosed by the walls of ruined castles. They consist of a broad frond, which lies upon the soil, and emits roots from its under surface, possessing antheridia and pellate receptacles. They differ from Crystalworts in having elaters and involucrate spore-cases.

The Scale Mosses (Jungermannia, Figs. 294 and 295), possess a far higher degree of organization, having well and symmetrically expanded leaves, and, in many, a long stalk supporting the simple fruit. They abound in tropical regions.

The Horse-tails (Equisetum) possess a fistular articulated stem, surrounded by
a layer of hard woody tubes. There are no leaves; but the external articulated organs much resemble them. The fruit is borne on the top of the stem, and consists of a number of masses sessile upon the common rachis. They are widely distributed, and have the peculiarity of containing a large quantity of silex or flint in their cuticle; so much so, that the Equisetum hyemale and other genera are used in the polishing of metals and furniture.

The Osm Mosses are small, terrestrial, or aquatic plants, with an axis of growth and minute imbrocated leaves, and differ from all other Mosses in the structure of their two kinds of reproductive organs. They are an interesting and extensive division of the family of Mosses, and are more commonly found in temperate than in tropical climes. Wherever there is moisture, even if soil be almost absent, they will grow, and they are the first to cover a barren coast, as they are the last to linger when the atmosphere ceases to be capable of affording nourishment to vegetation. The Sphagnum, Polytrichium, and almost all plants vulgarly known as Mosses, belong to this division.

**FERNS.**

The highest division of the Cryptogams is that known as Ferns (Filices), a division which, in the degree of its organization, far exceeds that of any yet mentioned. They consist of "leafy plants producing a rhizome, which creeps below or upon the surface of the earth, or rises into the air like the trunk of a tree." When a stem exists it is usually simple, and of even diameter throughout, and bears a tuft of leaves on its apex, after the fashion of Palms and other endogenous plants, and is composed of cellular, woody, and scalariform tissues. The reproductive organs are spore cases, arising from the veins on the under surface, or other part of the leaves; or they are situate beneath the cuticle, which they thus throw up in the form of an indusium.

This class is divided into three portions—the Ophioglossus or Adder's-tongues, the Polypodiaceae or true Ferns, and the Danseaeae or Danaeants; and of these the middle one, or that of true Ferns, contains nearly the whole of the members of the class. We regret that our space does not permit us to enter into detail into this beautiful, varied, and very interesting tribe of plants; and the more so, that at the present moment the Ferns and the Orchis have attained to an enviable popularity.

The Adder's-tongues are minute plants, closely allied to the Club Mosses (Lycopodiaceae), with a hollow pithless stem, containing woody fibre, and possessing leaves with netted veins.

Its reproductive organs consist of spores contained within spore-cases, which are arranged on a spike on the sides of a contracted leaf. The Danseaeae, on the other hand, are true dorsiferous Ferns, with reproductive organs sunk within or seated upon the back of the leaflets. There is also, as in the Adder's-tongue, an absence of the elastic ring, which is indicative of true Ferns. Both of these divisions of Ferns are very small, containing together only nine genera.

The true Ferns or Polypodiaceae (vaguely designated Filices) are distinguished by the presence, on the spore-case, of a ring or band of coarse meshes distinctly different from the tissue of their sides, and too strong to be broken through, when the case opens to discharge its spores. A few genera are considered edible, as, for example, the Pteris esculenta, Cyathæa medullaris, Diplazium esculentum, and Gleichenia Hermanni. The Java Fern is also nutritious, whilst the Aspidium fragrans has been employed as a substitute for tea, and the Pteris Aquilina and Aspidium Filix-mas have been used in the manufacture of beer. The genera are very variously distributed over the face of the
earth, and in different localities bear very various relations to the total genera of plants; but it is certain that the most elegant, as well as the most lofty specimens, are not indigenous to our islands. Amongst the English genera we find the Polypodium, Wood-sia, Aspidium or Shield Fern, Cystea or Bladder Fern, Asplenium or Spleen Wort, Scolopendrium or Hart’s Tongue, Blechnum or Hard Fern, Pteris or Brake, Adiantum or Maidenhead, Trichomanes, Hymenophyllum, and Osmunda or Flowering Fern.

Before quitting the Linnaean arrangement, it may be advantageous to our readers if we give a few simple directions as to the proper mode of examining a plant under this system.

The first aim of the botanist will be to determine the class and order in which the plant under examination is arranged. He will, therefore, at once direct his attention to the flower (if the plant do not belong to the last order, or that of Cryptogamia), and see if both stamens and pistils are present together. If he find such to be the case, the plant is bisexual; but since, in the twenty-third class, or that of Polygamy, both unisexual and bisexual flowers exist on the same plant, he will glance at other flowers on the same stem, and ascertain if such be the case on the plant in question. If all the flowers are bisexual, he will then attend to the number, length, and position of the stamens, which, in a majority of instances, will at once direct him to the class sought for. Thus, if there be two long and two short stamens in all the flowers, the plant is Didynamous; and if there be four long and two short stamens universally, he will refer it to Tetradynamia. He must not, however, expect that in any plant all the stamens shall be of precisely equal length; but although such be the case, this will constitute no important source of fallacy, since half-a-dozen examinations of the stamens of a Didynamous and a Tetradynamous plant would enable him to perceive that the diversity in length is not an accidental circumstance, but one which, from its constancy and relative proportions, is very characteristic. Let him select the common Mint or Fox-glove, as an example of Didynamia, and the Mustard or Water-cress as an illustration of Tetradynamia.

This point having been passed, and having found that all the stamens are of nearly equal length, he will next ascertain if they are separate from each other down to their point of insertion. We will first suppose that their foot-stalks or filaments are connected together through a distance more or less great, but yet so restricted that the anthers are free; the plant will belong to one of the three classes—Monodelphia, Diadelphia, or Polydelphia. He will next seek to determine if they form one set, or two or more sets. To this end, he should take away the corolla, and any other parts which may interfere with a due inspection of the base of the stamens; and then with the fingers try if any part of the mass of stamens will come away naturally, as it were, from other parts. Thus the Hypericum, or St. John’s-wort, possesses a large number of stamens, which, on being gently pulled asunder at their bases, are readily detached in three or four masses; the stamens in each mass being still adherent, and each mass attached to its neighbour simply by the cohesion of apposition. Such a plant, then, belongs to the order Polydelphia. Again, the Pea, Bean, or Vetch presents the stamens arranged precisely as exhibited in Figs. 221 and 351, except that the single stamen is not so much detached from the mass as represented in these drawings; and by examining the concavity of the mass of stamens with the finger-nail, or any pointed instrument, the odd stamen will be discovered lying close to the mass, but not connected with it. This indicates the class Diadelphia. This class of plants has almost universally the
papilionaceous form of corolla, which, on being appreciated, will, in the great majority of instances, alone suffice to indicate the class. Lastly, when the stamens are united together by their filaments, as above indicated, but cannot be divided into distinct bodies, as in the Geranium and Mallow, the plant is Monadelphous.

There may, perhaps, be some little difficulty to the young botanist in determining whether plants belonging to the Monadelphia and Polydelphian classes have really their filaments so united; but a very little attention and practice will show that the filaments are not separate on both sides down to their base, and, moreover, the characteristic appearance of the stamens as a whole will soon be appreciated by the student.

If the filaments be free, but the stamens united together, the plant will belong to the order Syngenesia; but as all this great class of plants have aggregated florets placed as a capitulum (Figs. 354, 355), their appearance is so characteristic, that, after a very short space of time, the student will not need to examine the stamens to determine the classification of the plant.

The only other exceptional class is that of Gynandria; and it is not one which can be very intelligibly described upon paper. It is composed of the Orchis tribe of plants, and those closely associated with it; and if the student will regard attentively the combined stamens and pistils, and the toute ensemble of the flower of any Orchis, as of those growing in our moist meadows, or those now universally found in hot-houses, he will speedily learn how to distinguish this class in an instant, without, however, being so readily able to explain it to another.

We have considered the foregoing exceptional cases first, not because they are the most numerous in the great assemblage of plants, but because they have readily recognised characteristic peculiarities, and because, having excluded them from consideration, the student may give undivided attention to the greater number which yet remain. If the stamens are free from each other throughout, and are nearly of equal size (differing somewhat according to the progressive development of the season), and are not more than ten in number, the plant may be at once referred to its proper class, as Monandria, &c.; but if the number should be indefinite—say fifteen, or any larger number—the plant may be either Icosandrous or Polyandrous. To determine to which of the two classes it is to be referred, simply tear away the corolla and calyx piece by piece; and if the stamens come away with the pieces—as would be the case in the Rose, Hawthorn, and Apple—the plant is Icosandrous. This indicates that the stamens are Epigynous; whilst the Hypogynous mode of insertion is characteristic of the class Polyandria. The Rose may illustrate Icosandria, and the Crow-foot (Ranunculus) Polyandria.

The small class of Dodecandria is not so easily recognised by its stamens, since the number is considerable, but somewhat indefinite.

The foregoing directions will suffice as a guide to the student, except in the comparatively few instances in which the number of stamens has been unduly increased or diminished. The increase is less common than the decrease; and is chiefly restricted to the classes Triandria and Pentandria, or all the classes below Pentandria, and is usually to the extent of a duplicate of the original number. Thus a Triandrous plant occasionally has six stamens, and a Pentandrous one has ten stamens. This little difficulty is overcome by examining other flowers on the same plant, or on a similar plant growing near to it, when the normal number of stamens will be found on a majority of them.
When there is a decrease in the number of stamens, it is usually accompanied by a corresponding and equal increase in the number of the petals, and is for the most part restricted to the two classes Icosandria and Polyandria. If in either of these cases the petals are more than five in number, it may be inferred that the innermost rows have been produced at the expense of the outermost rows of stamens. This, however, constitutes no sort of difficulty, since a sufficiently large number of stamens remain to enable the student to determine the class, except in the case of cultivated plants, when the whole of the stamens may have been converted into petals, as in the perfect Rose (Fig. 207). We therefore advise the beginner to avoid all garden flowers, and examine only those which are met with in their wild and uncultivated state.

The classes Monœcia and Dioœcia are not so readily discovered by a reference to the stamens of the flower, since for the most part the flowers are small, and without gay colours, and the stamens are indistinct. He will first strive to ascertain if the flower under examination has stamens or pistils (since it is unisexual), and will find that the pistils occupy a central position, and have an expanded base or ovary, whilst the stamens are usually arranged in a circle, leaving a central vacuity, and are surmounted by a swollen part or anther. This is not at all times an easy diagnosis in practice; but it will aid the student to remember that, for the most part, the members of these classes are large wooded trees. There are many exceptions to this rule, as in the cases of the Stinging Nettle and the Sedges; but the exceptions are perhaps less difficult of diagnosis than the members which may constitute the rule.

Having thus discovered the Class to which the plant belongs, he will next seek the Order; and to this end will chiefly regard the pistils. This will apply perfectly to all plants having the stamens separate from each other, and of equal size; and in such cases it suffices to count the number of pistils only. The orders of the first fourteen classes are determinable in this way; but beyond these, the pistil is not regarded in determining the class. If, therefore, the plant belong to the class Polyandria, or any other preceding class, simply count the number of pistils in order to find the order; but if it be Didynamous, or Tetrodynamous, the student must notice the character of the seed-vessel or pod. Thus, when a Didynamous plant has an evident more or less conical ovarium, as in the Digitalis and Scrophularia, the order is Angiosperma; but if, after tearing away the corolla, he look deeply to the bottom of the calyx, and find a flattened ovarium with one or two transverse lines on its surface, indicating a division of the ovarium into two or four parts, as in the Mint, the plant belongs to the order Gymnosperma. The diagnosis of the two orders in Tetradynamia is somewhat more arbitrary; for it depends simply upon the size of the pod. A long pod, as of the Pea, indicates the order Siliquosa; and a short, and for the most part a comparatively broad one, marks the order Siliculosa.

The orders found in the classes Monodelphia, Diadelphia, and Polydelphia, and also Gynandria, Monœcia, and Dioœcia, are determined by counting the number of the stamens; whilst those of Polygamy are simply Monœcia or Dioœcia. The numerous class Syngenesia is divided into orders without exclusive reference to its stamens or pistils, but simply by the arrangement of the florets upon the capitulum. Thus, in the order Polygamy Æqualis, all the florets are equal, and all possess both stamens and pistils; whilst the term Superflua indicates that the florets are divided into those of the ray and of the disk, and that the former have pistils only. In the third order, or that of Frustranca, the florets of the ray are destitute of both stamens and pistils.

Thus we have not been able to give such directions as shall enable the student to
determine the order of a plant without having first discovered the class in which it ought to be placed; for such was not the intention of Linnaeus when he founded his arrangement. He will, therefore, first find the class and then the order; but, in the great majority of instances, both will be perceived by the same glance.

But both the class and the order are alike dependent upon the presence of a flower; and therefore it will be in vain for the inexperienced student to attempt to discover them, except at the proper season of the year, when the plant is in flower, and whilst the flower remains perfect.

These two preliminary circumstances are usually got over without any difficulty; but the next stages in the investigation require a far wider range of observation. It is now necessary to examine, more or less minutely, every part of the plant. Thus its height, and the size and form of its stem and root, must be noticed, distinguishing between herbaceous or annual plants and woody, or those which are more or less perennial. If the plant be herbaceous, it is necessary to ascertain if the stem be hollow, and if it have any flutings or other markings upon its external surface; and in all cases it is requisite to glance hastily at the general arrangement of the leaves upon the stem or plant. In reference to the root of herbaceous plants, it may further be observed that its form must be noticed—that is, as to whether it is tuberous or fibrous, or prae-morse, or any other of the forms previously indicated.

The leaves and the parts constituting the flower are, however, those parts from which the distinguishing features of plants are usually drawn.

The form of the leaf is a prime consideration; and the student must notice if it is round, oval, pointed, or otherwise, and if equally so on each side of the midrib, and also whether its edge is entire or divided in various ways. The size, thickness, and colour should be regarded, and also the character of its surface, as to whether it is smooth or rough, and if the hairs are distributed evenly over the two surfaces, or only over one or over a part of one; and also the precise characters of the hairs, as to whether they are like bristles or down, or otherwise. Lastly, its venation demands attention in order to show if the plant be an exogen, as indicated by the reticulated venation, or an endogen, as shown by its parallel veins. The petiole, in like manner, must be examined, and afterwards the inquiry made if the leaf is caducous or permanent, and if it altogether falls off the stem or withers upon it, as is the case in the indurate condition referred to in its proper place. The points in which leaves differ from each other are wonderfully numerous, probably extending to some hundreds; and all of these are made use of in describing the characters of plants. Most of them are happily recognisable by the very apt terms with which this science, above all others, has been supplied; so that any inexperienced student, with a descriptive manual in his hand, would scarcely fail to understand the terms which are employed to enable him to refer any plant to its proper place.

The flower is, as we have already shown, a compound organ, and offers a great many objects to the student's attention. First, regard the general arrangement of the flowers upon the plant, and inquire if they are placed in the axils of leaves (axillary) or otherwise, and if they terminate a branch rendering it determinate. Then somewhat restrict the range of observation, and notice that arrangement of the flowers upon the stem which constitutes the inflorescence, and afterwards proceed to consider an individual flower, regarding the envelopes from without inwards. The calyx and corolla may both be monosepalous or polysepalous. If they are monosepalous, the form must be noticed as to whether it is rotate or bell-shaped, or otherwise, and its free border inspected, to ascer-
tain if it is entire or variously divided; and if divided, the figure, number, and depth of its divisions will require attention. When a tube exists, as is common in mono-petalous corollas, its length, width, and general proportions must be observed, and also any hairs or other organs which may defend the entrance into it. When these envelopes are polypetalous, the same degree of attention must be given to each sepal and petal as above directed with regard to the leaves, except that these organs are usually of more delicate organization than leaves. But whether they consist of one or of many pieces, it will be equally necessary to notice their texture, colour, and relative length (that is, whether the corolla is longer or shorter than the calyx), and whether either or both are caduceous or permanent; and, if caduceous, to ascertain whether it falls early, and in one or in many pieces. Should there be any appendages to these parts—as the corona of the Narcissus, or the nectarium of the Ranunculus—they must be carefully noticed and examined. It will further be proper to notice the relations which these parts are said to bear to the ovary,—that is, as to whether they are superior or inferior; and also their relation with the stamens, as to whether those latter organs are attached to them or not.

In these directions we have already referred, to some extent, to the stamens and pistils; but further detail is now necessary. Thus, in reference to both, the presence or absence of the foot-stalk (filament and style) must be determined; and if it be present, its length, figure, and colour should be observed. In but few instances is it coloured; but in many the figure is not uniformly cylindrical, but tapering upwards, or awl-shaped; and in some instances it assumes a foliaceous character.

The anther demands minute attention, in order to show the mode of its attachment to the filament, its figure, and the number of the cells into which it is divided. The pollen seldom calls for examination under the Linnean system of classification; but if the examination be made at a period when the pollen is ripe, and lying loose upon the anther and other parts of the flower, there can be no difficulty in ascertaining its colour, size, and general configuration. Its minute anatomy is a subject of great difficulty, and one into the consideration of which it is not needful that the inexperienced student should enter.

The style offers perhaps fewer points for observation than the anther, since its structure is more simple. It will be proper first to notice its divisions, and the mode in which those divisions, if any, are arranged; and then to observe carefully its general configuration, and the precise nature of the exposed free surface upon which the pollen is destined to fall. Its internal anatomy, or that of its conducting tissue, is not of importance to this part of our subject. The ovary must be minutely examined; and in order to do that it will be needful to cut it through transversely, and then ascertain the number of the cells of which it is composed, and that of the seeds lying within each cell. It is not uncommon to find fewer seeds than cells, owing to abortion, and that also must be ascertained. The external configuration of that organ will, of course, call for attention, and also any bodies which are sometimes met with, as the disk at or near to its base.

The seed is to be observed chiefly on account of its external configuration, and its number in relation to the cells in which it lies. The Linnean arrangement calls but little for any account of its internal anatomy; and, with the exception of the number and general nature of its Cotyledons, and some slight reference to the albumen, it will not be necessary for the student to regard it. The fruit must be noticed in a general manner—that is, as to whether it is succulent or otherwise; and the names which have
been referred to when considering that organ, as well as those of more popular employment, committed to memory.

All the foregoing particulars are not necessary to enable the student to determine the genus of any plant, since the characteristic of a genus is, that it possesses only certain (perhaps but few) features which are common to a number of other most closely allied plants, which are thence termed species. But if any number of plants, say ten, agree in certain features, so that they may be associated under one head, each of these will differ from the others in features of greater minuteness; and, consequently, a more minute acquaintance with all the parts of a plant is more necessary to determine the species than the genus.

In order practically to apply these directions, we will give one or two familiar examples, by way of illustration. Let us first examine the Myosotis, or Forget-me-not. This plant will be found to have five stamens and one pistil, and consequently is at once referable to the class Pentandria, and order Monogyinia. Having referred to any synopsis of the Linnaean arrangement, the student will find no fewer than forty genera described under Pentandria Monogyinia, and therefore will need further characteristics, in order to prevent the necessity of comparing this plant with the descriptions of all these genera. This is effected by noticing that a certain number of these genera have an inferior monopetalous corolla, and two or four naked seeds; and on referring to the Myosotis he will find that such is the case with that plant also. This, then, limits his investigation to ten genera, and it will be his duty to read the description of each, beginning with the first, until he finds that one with which the plant in question corresponds. The following are the characters of the genus Myosotis:

"Calyx inferior, of one leaf, deeply five cleft; segments acute, equal. Corolla of one petal, salver-shaped; mouth half closed, with five small valves. Filaments very short; anthers small, oblong. Ovary, four. Style, thread-shaped, central, as long as the tube; stigma obtuse. Seeds egg-shaped, pointed, smooth."

This description having been found to correspond with the plant under examination, the next step will be to determine the precise species. The student will now find that there are seven species described under that genus, and it will be his duty to compare his plant with the first, and all others, until he finds the one with which it corresponds. This will probably be far less tedious than it at first sight appears, since, immediately he discovers in the description of any of the species any feature which differs clearly from the specimen in his hand, he will not continue the comparison, but at once proceed to the description of the next species. In this way it is possible to examine a dozen species in three or four minutes. Having, however, noticed that the description of the genus and species Myosotis palustris corresponds with his plant, he has then discovered that which he had been seeking for—viz., the class, order, genus, and species. The characters of the species are thus described:

"Calyx funnel-shaped, with short broad segments; leaves oblong, roughish, with close-pressed bristles, root creeping. Roots very long, creeping; stem from six to twelve inches high; clusters many-flowered; two or three together; limb of the corolla sky blue, the valves of the mouth yellow. Perennial; flowers in June and July; grows in marshy places and ditches: common."

The student will thus be able readily to appreciate the different degrees of minuteness needful to the determination of a genus and a species; he will observe that the difficulty of determining the genus and species is usually in proportion to the number of genera found in the same class and order, and of species under the same genus.
We will now take a more difficult illustration—viz., that of the Stinging Nettle (Urtica). We first notice that the flower is deficient in stamens or pistils, and thence that it is not bisexual. We then examine other flowers, and ascertain that this is not a mere coincidence, but is universal; and, further, that all the flowers are unisexual, and that on the same tree there are flowers only male, and others only female. Thus we refer the plant to the class Monoeica. We now select a male flower—that is, one having stamens only; and finding that there are four stamens, we refer the plant to the order Tetandria. In this order there are but five genera, and of these one is a tree—the Alder—and another is the common Box (Buxus), with both of which the student will be familiar, and know at once that they cannot refer to the plant in question. Moreover, two others, Littorella and Eriocaulon, are found, by the description of their solitary genus, to grow in lakes and marshy places; and as his plant grew on a bank, or on some waste dry land, he may exclude them, and thus find that he is referred to the only remaining genus, that of Urtica. This careless mode of exclusion will not, however, suffice beyond the point of directing immediate attention to the remaining genus, and therefore he will at once proceed to compare the description of the Urtica with the characters of the plant in his hand. The following description will suffice to indicate the genus Urtica:


The term nectary is here used in the indefinite sense in which Linnaeus employed it, when he assembled very various structures, situate at or about the base of the ovary, under that appellation, and in the sense in which it is still used by systematic works on classification. It is not the true nectary found upon the short claw of the petal of the Ranunculus, since the Urtica has no petals.

The determination of the species is not difficult, since there are but three species of Urtica, all of which have venomous stinging or secreting hairs, and opposite leaves, and the distinguishing features are referred to only two or three points. Thus we will suppose that the plant under examination is the small Nettle, or Urtica urens, and that the following description will indicate its characters:

"Leaves opposite, broadly elliptical, with about five longitudinal ribs; clusters simple. From one to two feet high; bright green, with venomous stings. Annual; flowers from June to October; grows on cultivated ground and waste places."

Having given these two illustrations, we think that the attentive student will find no difficulty in proceeding with the examination and classification of plants; but we think it needful to append one caution. Do not be discouraged if you have difficulty in referring an unknown plant to its proper place amongst the genera and species; but having given due attention and failed, lay the plant aside, or invite the assistance of some one who may have made further progress in the science. There is no royal road to learning, and the first steps will ever be toilsome and difficult; but, as the student proceeds, he will find that the difficulties gradually and insensibly recede, until, in a short time, he wonders that he ever regarded them for a moment. Do not at first fatigue the mind, and discourage the spirits; but be assured that you, like others, will overcome them.
NATURAL SYSTEM OF PLANTS.

The Natural System of Plants differs from the artificial system now detailed; for it takes into account the whole organization of the plant, with its habits and properties, and is not restricted to one or two particular features. The contrast of the two plans of classification is thus concisely stated by the author of the "Vegetable Kingdom": "The natural system of Botany being founded on these principles, that all points of resemblance, between the various parts, properties, and qualities of plants, shall be taken into consideration; that thence an arrangement shall be deduced in which plants must be placed next each other, which have the greatest degree of similarity in those respects; and that, consequently, the quality of an imperfectly-known plant may be judged of by that of another which is well known. It must be obvious that such a method possesses great superiority over artificial systems, like that of Linnaeus', in which there is no combination of ideas, but which are mere collections of isolated facts, having no distinct relation to each other. The advantages of the natural system, in applying botany to useful purposes, are immense, especially to medical men, who depend so much upon the vegetable kingdom for their remedial agents. A knowledge of the properties of one plant enables the practitioner to judge scientifically of the qualities of other plants naturally allied to it; and therefore the physician, acquainted with the natural system of botany, may direct his inquiries when on foreign stations, not empirically, but upon fixed principles, into the qualities of the medicinal plants which have been provided in every region for the alleviation of the maladies peculiar to it. He is thus enabled to read the hidden characters with which nature has labelled all the hosts of species that spring from her teeming bosom."—We do not need therefore to hesitate when we confidently recommend this plan of classification in preference to the simple one already given.

As the component parts of a plant are very various, and their relative importance is somewhat a matter of opinion, and, moreover, as plants resemble and differ from each other in so many and minute particulars,—it is no matter for wonder that various natural systems have been devised. Indeed it is not possible for any ten of the most learned men existing to prepare each an original scheme, independent of each other, without producing ten systems instead of one system of classification. There have been already about thirty distinct systems (many of which, however, were simply modifications of one or more preceding); and it is probable that the best one, at the present moment, is so imperfect that it must be amended yearly. The great Linnaeus himself gave the outline of a natural system, in which he arranged all the then known plants under sixty-eight heads; but he attached little importance to it. Since his day several others have appeared, which were original, and which have had great influence in the world. The first is that of Adrien de Jussieu, who, in 1789, published an admirable system on the outlines given by our great countryman Ray, in 1703; and to this day De Jussieu's system is held in high estimation. The next great writer on classification was A. P. de Candolle, and he compiled one hundred and sixty-one natural orders out of the three great divisions of plants,—Dicotyledons, Monocotyledons, and Acotyledons, before described. These two systems have been the foundation of all those of more modern
date, including those of Endlicher, who was De Jussieu's great successor, Brogniart, and Lindley.

The difficulty, at the present day, is to make a good selection, and more particularly in a work of this nature, which is to be the handbook of botany to so many thousands of readers—both scientific and non-scientific. Our aim must be to obtain that which, with simplicity, will give the most recent and the most valuable information. On careful consideration we are of opinion that we shall be doing an injustice to our readers, if we fail to make them acquainted with the last one above-mentioned—the system of a distinguished countryman, which, as it is based upon most extensive and usually accurate information, is deservedly supplanting others in the botanical teaching of the British schools.

THE NATURAL SYSTEM, ACCORDING TO DR. LINDLEY.

Before commencing an examination of this system we must beg our readers to bear in mind that a close attention is necessary to the minute parts of the plant, and more particularly of the seed; since, of all organs, that is one possessed of the greatest degree of constancy. We must also give some degree of encouragement to the student by stating, that although this system is not so simple as that previously described, it is yet less difficult than it appears to be. Its difficulty lies at the threshold; and to overcome it the student will have the gratification of gaining much interesting information.

We cannot enter at length into the subject, but shall give an outline of the whole scheme, and such illustration as may be interesting and useful to the reader, and necessary to a comprehension of so extensive a subject. The following is a condensation of Professor Lindley's scheme ("Vegetable Kingdom," p. lv., et seq.)

CLASSES.

Asexual, or Flowerless Plants.

Stems and leaves undistinguishable . . . . . . . I. THALLOGENS.

"A Thallus is a fusion of root, stem, and leaves, into one general mass, and Thallogens are also destitute of flowers; they are equally without the breathing pores, so abundantly formed in the skin of more complex species; and they multiply by the spontaneous formation in their interior, or upon their surface, of reproductive spheroids, called spores."

Stems and leaves distinguishable . . . . . . . II. ACROGENS.

"Beyond Thallogens are found multitudes of species, which, like Thallogens, are not furnished by nature with flowers, but which otherwise approach closely to the higher forms of structure, occasionally acquiring the stature of lofty trees. They have breathing pores in their skin; their leaves and stems are distinctly separated; in some of them those spiral threads, which form so striking a portion of the internal anatomy of a more perfect species, exist in considerable abundance; and finally, they multiply by reproductive spheroids or spores, either formed without the agency of sexes, or, if the contrary, shall be proved at all events not possessing bodies constructed like stamens on the one hand, and embryos on the other. Their stem, however, does not increase in diameter; it only grows at the end, and hence it has given to such plants the name of Acrogens."
Sexual, or Flowering Plants.

Fructification springing from a thallus

Foremost among the more perfect races comes a most anomalous collection of species called Rhizogens. These plants, leafless and parasitical, have the loose cellular organization of Fungi; a spiral structure is usually to be found among their tissues only in traces. Some of them spring visibly from a shapeless cellular mass, which stands in place of stem and root, and seems to be altogether analogous to the Thallus of the Fungi; and it is probable that they all partake in this singular mode of growth. Their flowers are like those of more perfect plants; their sexual apparatus is complete, but their embryo, which is not furnished with any visible radicle or cotyledons, appears to be a spherical or oblong homogeneous mass.

Fructification springing from a stem.

Wood of stem youngest in the centre; cotyledon single.

Leaves parallel-veined, permanent; wood of the stem always confused. IV. Endogens.

Endogens consist of species whose germination is endorrhizal, whose embryo has but one cotyledon, whose leaves have parallel veins, and whose trunk is formed of bundles of spiral and dotted vessels, guarded by woody tubes, which bundles are arranged in a confused manner, and are reproduced in the centre of the trunk.

Leaves net-veined, deciduous; wood of the stem, when perennial, arranged in a circle with a central pith. V. Dictyogens.

Dictyogens are Endogens, but with the peculiarity that the root is exactly like Exogens without concentric circles, and the leaves fall off the stem by a clean fracture, just as in that class.

Wood of stem youngest at the circumference, always concentric; cotyledons 2 or more.

Seeds quite naked. VI. Gymnogens.

Gymnogens are a division of Exogens which, in the sexual apparatus, have no style and stigma, but are so constructed that the pollen falls immediately upon the ovules, a peculiarity analogous to what occurs among reptiles in the animal kingdom.

Seeds inclosed in seed-vessels. VII. Exogens.

The class of Exogens is composed of innumerable races, having an exorrhizal germination, an embryo with two or more cotyledons, leaves having a net-work of veins, and a trunk consisting of woody bundles, composed of dotted and woody tubes, or of woody tubes alone, arranged around a central pith, and either in concentric rings or in a homogeneous mass, but always having medullary plates forming rays from the centre to the circumference, and reproduced on the circumference of the trunk, whence their name of Exogens.

Class I.—Thallogens.—939 Genera; 8394 Species.

Alliances of Thallogens.

1. Algae.—Cellular flowerless plants, nourished through their whole surface by the medium in which they vegetate; living in water or very damp places; propagated by zoospores, coloured spores, or tetraspores. 283 Gen.; 1994 Sp.

Natural Orders.—1. Diatomaceae, or Brittleworts. 2. Convergenses, or Convergenses. 3. Fucales, or Seaweeds. 4. Ceramiales, or Rosetangles. 5. Characeae, or Charadas.
2. **Fungi**.—Cellular flowerless plants, nourished through their thallus (spawn or mycelium); living in air; propagated by spores, colourless or brown, and sometimes inclosed in asc; destitute of green gonia. 383 Gen.; 4000 Sp.

Natural Orders.—5. Hymenomycetes, Agaricaceae, or Toadstools. 7. Gasteromycetes, Lycoperdaceae, or Puffballs. 8. Coniothyriaceae, Uredinaceae, or Blights. 9. Hyphomycetes, Botrytaceae, or Mildews. 10. Ascomycetes, Helvellaceae, or Morels. 11. Phycomycetes, Mucoraceae, or Moulds.

3. **Lycophyta**.—Cellular flowerless plants, nourished through their whole surface by the medium in which they vegetate; living in air; propagated by spores usually inclosed in asc; and always having green gonia in their thallus. 38 Gen.; 2400 Sp.


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**Class II.**—**Acrogens**—310 Genera; 4868 Species.

Alliances of Acrogens.

4. **Muscales.**—Cellular (or vascular). Spore-cases immersed or calyptrate (i.e., either plunged in the substance of the frond, or inclosed within a hood having the same relation to the spores as an involute to a seed-vessel). 113 Gen.; 1822 Sp.


5. **Lycopodiales.**—Vascular. Spore-cases axillary or radical, one or many-celled. Spores of two sorts. 6 Gen.; 224 Sp.

Natural Orders.—21. Lycopodiaceae, or Clubmosses. 22. Marsileaceae, or Pepperworts.

6. **Filicales.**—Vascular. Spore-cases marginal or dorsal, one-celled, usually surrounded by an elastic ring. Spores of but one sort. 192 Gen.; 2040 Sp.

Natural Orders.—23. Ophioglossaceae, or Adders' Tongues. 24. Polypodiaceae, or Ferns. 25. Danaceae, or Dianes.

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**Class III.**—**Rhizogens.**—21 Genera; 53 Species.

Alliance The Same as the Class.

Natural Orders.—26. Balanoporaecae, or Cynomoriinae. 27. Cytinaceae, or Cistusrupes. 28. Rafflesiacae, or Rafflesias.

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**Class IV.**—**Endogens.**—1420 Genera; 13864 Species.

Alliances of Endogens.

- **Flowers glumaceous (that is to say, composed of bracts not collected in true whorls, but consisting of imbricated colourless or herbaceous scales).**

7. **Glaumes.** 439 Gen.; 6186 Sp.

Natural Orders.—29. Graminaceae, or Grasses. 30. Cyperaceae, or Sedges. 31. Desvauxiaceae, or Bristleworts. 32. Restiaceae, or Restiads. 33. Eriocaulaceae, or Pipeworts.

- **Flowers petaloid, or furnished with a true calyx or corolla, or with both, or absolutely naked; ♀ ♂ (that is, having sexes altogether in different flowers, without half-formed rudiments of the absent sexes being present).**

- The following signs are employed in this scheme:—
  - □□ Signifies a bisexual, or hermaphrodite plant.
  - □♂ An unisexual, or male plant.
  - ♀♂ An unisexual, or female plant.

Flowers having two coverings, as calyx and corolla, are said to be **Dicalymydeous**; and one covering, **Monoclamydeous**. If they vary so that some have one and others two coverings, they are called **Monodicalymydeous**.
8. Arales.—Flowers naked, or consisting of scales, 3 or 3 together or numerous, and then sessile on a simple naked spadix; embryo axile; albumen mealy or fleshy. (Some have no albumen.) 41 Gen.; 278 Sp.

Natural Orders.—34. Pistia, or Lemnads, or Duckweeds. 35. Typhaceae, or Typhads, or Bulrushes. 36. Araceae, or Arads. 37. Pandanae, or Screw-pines.

9. Palmales.—Flowers perfect (with both calyx and corolla, sessile on a branched scaly spadix; embryo vague, solid; albumen horny or fleshy. Some Palms are תן. 73 Gen.; 460 Sp.

Natural Orders.—38. Palmae, or Palms.

10. Hydras.—Flowers perfect or imperfect, usually scattered; embryo axile, without albumen—aquatics. (Some are תן.) 26 Gen.; 48 Sp.

Natural Orders.—39. Hydrocharitaceae, or Hydrocharads. 40. Naiadaceae, or Naiads. 40 bis. Triurids, or Triurids. 41. Zosteraceae, or Seawracks.

* * * Flowers furnished with a true calyx and corolla, adherent to the ovary; תן.

11. Narcissales.—Flowers symmetrical; stamens 3 or 6 or more, all perfect; seeds with albumen. (Some Bromellaceae have a free calyx and corolla.) 163 Gen.; 1238 Sp.

Natural Orders.—42. Bromeliaceae, or Bromeliads. 43. Taccaceae, or Taccads. 44. Hemodoraceae, or Bloodroots. 45. Hypoxidaceae, or Hypoxids. 46. Amaryllidaceae, or Amaryllids. 47. Iridaceae, or Irids.

12. Amomales.—Flowers unsymmetrical; stamens 1 to 5, some at least of which are petaloid; seeds with albumen. 39 Gen.; 427 Sp.

Natural Orders.—48. Musaceae, or Musads. 49. Zingiberaceae, or Gingerworts. 50. Marantaceae, or Marants.

13. Orchidales.—Flowers unsymmetrical; stamens 1 to 3; seeds without albumen. 404 Gen.; 3035 Sp.

Natural Orders.—51. Burmanniaceae, or Burmanniads. 52. Orchidaceae, or Orchids. 53. Apostasiaceae, or Apostasiads.

* * * Flowers furnished with a true calyx and corolla, free from the ovary; תן.


Natural Orders.—54. Philydraceae, or Waterworts. 55. Xyridaceae, or Xyrids. 56. Com-melynaceae, or Spiderworts. 57. Mayaceae, or Mayacs.

15. Juncales.—Flowers herbaceous, dry, and permanent, scarious if coloured; albumen copious. (Some Callas have no albumen.) 27 Gen.; 260 Sp.

Natural Orders.—55. Juncaceae, or Rushes. 59. Orontiaceae, or Orontiads.

16. Liliales.—Flowers hexapetaloid; succulent, and withering; albumen copious. 171 Gen.; 1355 Sp.

Natural Orders.—59. Gillesiacae, or Gillesiads. 61. Melanthaceae, or Melanths. 62. Liliaceae, or Lilyworts. 63. Pontederaceae, or Pontederads.

17. Alismales.—Flowers 3-6-petaloid; apocarpal; albumen none. (Some Alismads are absolutely enefit.) 14 Gen.; 101 Sp.

Natural Orders.—64. Butomaceae, or Butomads. 65. Alismaceae, or Alismads. 66. Juncas-cinaceae, or Arrow-grasses.

Class V.—Dicyogens.—17 Genera; 268 Species.

Natural Orders.—68. Dioscoreaceae, or Yams. 69. Smilaceae, or Sarsaparillas. 70. Phile-siaceae, or Philsiads. 71. Trilliaceae, or Farids. 72. Roxburghiaceae, or Roxburgh-worts.
CLASS VI.—GYMNOCENS.—37 Genera; 210 Species.

Natural Orders.—73. Cycadaceae, or Cycads. 74. Pinaceae, or Conifers. 75. Taxaceae, or Taxads. 76. Gnetaceae, or Joint Firs.

CLASS VII.—EXOGENS.—6191 Genera; 66225 Species.

ALLIANCES OF EXOGENS.

SUB-CLASS I.—DICLINOUS EXOGENS.

Flowers $\varphi$, without any customary tendency to $\sigma$.

18. AMENTALES.—Flowers in catkins, aehlamydeous or monochlamydeous; carpels superior; embryo small, with little or no albumen. 19 Gen.; 358 Sp.

Natural Orders.—77. Casuarinaceae, or Beefwoods. 78. Betulaceae, or Birchworts. 79. Altingiaceae, or Liquidambars. 80. Salicaceae, or Willowworts. 81. Myricaceae, or Gallworts. 82. Elaeagnaceae, or Oleasters.

19. URTICALES.—Flowers scattered, monochlamydeous; carpel single, superior; embryo large, lying in a small quantity of albumen. 61 Gen.; 372 Sp.

Natural Orders.—83. Stilaginaceae, or Antidesmads. 84. Urticaceae, or Nettleworts. 85. Ceratophyllaceae, or Hornworts. 86. Cannabinaceae, or Hempworts. 87. Moraceae, or Morads. 88. Artocarpaceae, or Artocarpads. 89. Platanaceae, or Planes.


Natural Orders.—90. Euphorbiaceae, or Spurgeworts. 91. Scrophulariaceae, or Scopulads. 92. Calitrichaceae, or Starworts. 93. Empetraceae, or Crowberries. 94. Batidaceae.

21. QUERNALES.—Flowers in catkins, monochlamydeous; carpels inferior; embryo amygdaloid, without albumen. 12 Gen.; 292 Sp.

Orders.—95. Corylaceae, or Mastworts. 96. Juglandaceae, or Juglands.

22. GARRYALES.—Flowers monochlamydeous, sometimes amentaceous; carpels inferior; embryo minute, in a large quantity of albumen. 3 Gen.; 7 Sp.

Natural Orders.—97. Garryaceae, or Garryads. 98. Helwingiaceae, or Helwingians.

23. MENISPERMALES.—Flowers monodichlamydeous; carpels superior, disunited; embryo surrounded by abundant albumen. 39 Gen.; 281 Sp.

Natural Orders.—99. Monimiaceae, or Monimiads. 100. Atherospermaceae, or Plume-Nutmegs. 101. Myristicaceae, or Nutmegs. 102. Lardizabalaceae, or Lardizabalads. 103. Schizandraceae, or Kadsurads. 104. Menispermacae, or Menispermads.

24. CUCURBITALES.—Flowers monodichlamydeous; carpels inferior; placenta parietal; embryo without albumen. 61 Gen.; 433 Sp.

Natural Orders.—105. Cucurbitaceae, or Cucurbits. 106. Datisaceae, or Datiscads. 107. Begoniaceae, or Begoniads.

25. PAPAYALES.—Flowers dichlamydeous; carpels superior, consolidated; placenta parietal; embryo surrounded by abundant albumen. 11 Gen.; 29 Sp.

Natural Orders.—108. Papayaceae, or Papayads. 109. Pangiacaeae, or Pangiadiads.
SUB-CLASS II.—HYPOGYNOUS EXOGENS.

Flowers $\frac{1}{2}$, or $\frac{1}{2}$ $\frac{1}{2}$; stamens entirely free from the calyx and corolla.

26. VIOLALES.—Flowers monodichlamydeous; placentae parietal or sutural; embryo straight, with little or no albumen. 98 Gen.; 1282 Sp.

Natural Orders.—110. Placouriaceae, or Bixads. 111. Laciistemaceae, or Laciestmans. 112. Samydasceae, or Samyds. 113. Passifloraceae, or Passionworts. 114. Malesherbiaceae, or Crownworts. 115. Moringaceae, or Moringads. 116. Violaceae, or Violetworts. 117. Frankeniaceae, or Frankenias. 118. Tamaricaceae, or Tamarisks. 119. Sauvagesiacese, or Sauvageads. 120. Crassulaceae, or Houseleeks. 121. Turneraceae, or Turnerads.

27. CISTALES.—Flowers monodichlamydeous; placentae parietal or sutural; embryo curved or spiral; with little or no albumen. 214 Gen.; 2166 Sp.

Natural Orders.—122. Cistaceae, or Rock Roses. 123. Brassiaceae, or Crucifers. 124. Resedaee, or Weldworts. 125. Capparraceae, or Capparads.

28. MALVALES.—Flowers monodichlamydeous; placentae axile; calyx valvate in aestivation; corolla imbricated or twisted; stamens definite or 00; embryo with little or no albumen. 160 Gen.; 1933 Sp.

Natural Orders.—126. Stereuliacese, or Stereulias. 127. Byttneriaceae, or Byttneriads. 128. Vivianiacese, or Vivianads. 129. Tropoealaceae, or Indian Crosses. 130. Malvaceae, or Mallowworts. 131. Tiliaceae, or Lindenblooms.

29. SAPINDALES. Flowers monodichlamydeous, unsymmetrical; placentae axile; calyx and corolla imbricated; stamens definite; embryo with little or no albumen. (Stamens rarely 00.) 132 Gen.; 1656 Sp.

Natural Orders.—132. Tremendraceae, or Foreworts. 133. Polygalaceae, or Milkworts. 134. Vochyaeeae, or Vochyas. 135. Staphyleaceae, or Bladder Nuts. 136. Sapindaceae, or Soapworts. 137. Petiveriaceae, or Petiveriads. 138. Aceraceae, or Maples. 139. Malpighiacese, or Malpighiads. 140. Erythroxylaceae, or Erythroxyls.

30. GUTTIFERALES.—Flowers dichlamydeous; placentae axile; calyx imbricated; corolla imbricated or twisted; stamens 00; embryo with little or no albumen. (Stamens sometimes definite in number.) 93 Gen.; 645 Sp.

Natural Orders.—141. Dipteraceae, or Dipterads. 142. Turnströniaceae, or Theads. 143. Rhizobiacese, or Rhizobols. 144. Clusiaceae, or Guttifers. 145. Maregraviaceae, or Maregraviads. 146. Hypericaceae, or Tutsans. 147. Reaumuriaceae, or Reaumuriads.

31. NYMPHales.—Flowers dichlamydeous; placentae axile or sutural; stamens 00; embryo on the outside of a very large quantity of mealy albumen. (A part have no albumen.) 8 Gen.; 56 Sp.

Natural Orders.—148. Nymphaeeae, or Water-lilies. 149. Cabombaceae, or Water-shields. 150. Nelumbiaceae, or Waterbeans.

32. RANALES.—Flowers monodichlamydeous; placentae sutural or axile; stamens 00; embryo minute, inclosed in a large quantity of fleshy or horny albumen. 119 Gen.; 1703 Sp.

Natural Orders.—151. Magrollaceae, or Magnolads. 152. Anonaceae, or Anonads. 153. Dilleniaceae, or Dilleniads. 154. Ranunculaceae, or Crowfoots. 155. Sarraceniaceae, or Sarraceniads. 156. Papaveraceae, or Poppyworts.

33. BERBERALES.—Flowers monodichlamydeous, unsymmetrical in the ovary; placentae suttural, parietal, or axile; stamens definite; embryo inclosed in a large quantity of fleshy albumen. 79 Gen.; 804 Sp.

Natural Orders.—137. Droseraceae, or Sundews. 158. Fumariaceae, or Fumeworts. 159. Berberidaceae, or Berberids. 160. Vitaceae, or Vineworts. 161. Pittosporaceae, or Pittosporads. 162. Olaeeaceae, or Olaeads. 163. Cyrillaceae, or Cyrilids.

34. ERICALES.—Flowers dichlamydeous, symmetrical in the ovary; placentae axile; stamens definite; embryo inclosed in a large quantity of fleshy albumen. (Stamens occasionally adherent to the corolla.) 89 Gen.; 1215 Sp.

Natural Orders.—164. Humiriaceae, or Humiriads. 165. Epacridaceae, or Epacrids. 166. Pyroliaceae, or Winter-greens. 167. Francoaceae, or Francoads. 168. Monotropaceae, or Fir-rapes. 169. Ericaceae, or Heathworts.
35. Rutaless.—Flowers monochlamydeous, symmetrical; placenta axile; calyx and corolla imbricated, if present; stamens definite; embryo with little or no albumen. (Occasionally ♂ ♀). 236 Gen.; 1233 Sp.


36. Geraniaceae.—Flowers monochlamydeous, symmetrical; placenta axile; calyx imbricated; corolla twisted; stamens definite; embryo with little or no albumen. 19 Gen.; 1033 Sp.

Natural Orders.—183. Linaceae, or Flaxworts. 184. Cheniaceae, or Chenads. 185. Oxaliaceae, or Oxalids. 186. Balsaminaceae, or Balams. 187. Geraniaceae, or Cranesbills.

37. Sileneales.—Flowers monochlamydeous; placenta free, central; embryo external, curved round a little mealy albumen; carpels more than one, completely combined into a compound fruit. (Some slightly perigynous, others ♂ ♀). 118 Gen.; 1829 Sp.

Natural Orders.—188. Caryophyllaceae, or Silenads. 189. Illecebraceae, or Knotworts. 190. Portulacaceae, or Purslinads. 191. Polygynomaceae, or Buckwheats.

38. Chenopodiaceae.—Flowers monochlamydeous; placenta free, central; embryo external, either curved round or applied to the surface of a little mealy or horny albumen; carpels solitary, or if more than one, distinct. (Some slightly perigynous, others ♂ ♀). 125 Gen.; 803 Sp.


Natural Orders.—196. Piperasceae, or Pepperworts. 197. Chloranthaceæ, or Chloranths. 198. Saururaceae, or Saururads.

Sub-Class III.—Perigynous Exogens.

Flowers ♂, or ♂ ♀; stamens growing to the side of either the calyx or the corolla; ovary superior, or nearly so.

40. Ficoidales.—Flowers monochlamydeous; placenta central or axile; corolla, if present, polypetalous; embryo external, and curved round a small quantity of mealy albumen. 24 Gen.; 466 Sp.


41. Daphniales.—Flowers monochlamydeous; carpel solitary; embryo amygdaloid, without albumen. 129 Gen.; 1499 Sp.

Natural Orders.—203. Thymelaceæ, or Daphnads. 204. Proteaceæ, or Proteads. 205. Lauraceæ, or Laurels. 206. Caseithaceæ, or Dodder-laurels.

42. Rosales.—Flowers monochlamydeous; carpels more or less distinct: placenta sutural; seeds definite; corolla, if present, polypetalous; embryo amygdaloid, with little or no albumen. 551 Gen.; 7491 Sp.


43. Saxifragales.—Flowers monochlamydeous; carpels consolidated; placenta sutural or axile; seeds 60; corolla, if present, polypetalous; embryo taper, with a long radicle, and a little or no albumen. 89 Gen.; 761 Sp.

44. **Rhamnales.**—Flowers monoeichamydeous; carpels consolidated; placenta axile; fruit capsular, berried, or drupaceous; seeds definite; embryo amygdaloid, with little or no albumen. 223 Gen.; 1034 Sp.


45. **Gentianales.**—Flowers dichlamydeous, monopetalous; placenta axile or parietal; embryo minute, or with the cotyledons much smaller than the radicle, lying in a large quantity of albumen. 221 Gen.; 1580 Sp.


46. **Solanaceae.**—Flowers dichlamydeous, monopetalous, symmetrical; placenta axile; fruit 2-3-celled; embryo large, lying in a small quantity of albumen. (Occasionally aehlamydeous or polypetalous). 238 Gen.; 3934 Sp.

**Natural Orders.**—237. Oleaceae, or Oliveworts. 238. Solanaceae, or Nightshades. 239. Asclepiadaceae, or Asclepiads. 240. Cordiaceae, or Sebestens. 241. Convolulaceae, or Dodders. 242. Cuscutaceae, or Phloxworts.

47. **Cortusiaceae.**—Flowers dichlamydeous, monopetalous, symmetrical; placenta free, central; embryo lying among a large quantity of albumen. (Occasionally monochlamydeous, or polypetalous). 86 Gen.; 380 Sp.

**Natural Orders.**—244. Hydrophyllaceae, or Hydrophyls. 245. Plumbaginaceae, or Leadworts. 246. Plantaginaceae, or Ribworts. 247. Primulaceae, or Primworts. 248. Myrsinaceae, or Ardisiads.

48. **Echialceae.**—Flowers dichlamydeous, monopetalous, symmetrical, or unsymmetrical; fruit nuementaceous, consisting of several one-seeded nuts, or of clusters of them, separate or separable; embryo large, with little or no albumen. (Very rarely hypogynous!) 280 Gen.; 4158 Sp.


49. **Bignoniaceae.**—Flowers dichlamydeous, monopetalous, unsymmetrical; fruit capsular or berried, with its carpels quite consolidated; placenta axile, or parietal, or free central; embryo with little or no albumen. 48 Gen.; 3508 Sp.


**Sub-Class IV.**—**Epigynous Exogens.**

Flowers \( \text{♀} \), or \( \text{♂} \): stamens growing to the side of either the calyx or corolla; ovary inferior, or nearly so.

50. **Campagnolae.**—Flowers dichlamydeous, monopetalous; embryo with little or no albumen. 1102 Gen.; 10491 Sp.


51. **Myrtales.**—Flowers dichlamydeous, polypetalous; placenta axile; embryo with little or no albumen. (Occasionally monochlamydeous). 253 Gen.; 3340 Sp.

CONCLUDING SUMMARY.

52. CACTALES.—Flowers dichlamydeous, polypetalous; placentae parietal; embryo with little or no albumen. 39 Gen.; 900 Sp.

Natural Orders.—284. Homaliaceae, or Homallads. 285. Loasaceae, or Loassads. 286. Cactaceae, or Indian Figs.

53. GROSSALES.—Flowers dichlamydeous, polypetalous; seeds numerous, minute; embryo small, lying in a large quantity of albumen. 22 Gen.; 208 Sp.

Natural Orders.—287. Grossulariaceae, or Currantworts. 288. Escalloniaceae, or Escallonias. 289. Cnoctaceae, or Indian Figs.

54. CINCHONALES.—Flowers dichlamydeous, monopetalous; embryo minute, lying in a large quantity of albumen. 305 Gen.; 3243 Sp.


55. UMBELLALES.—Flowers dichlamydeous, polypetalous; seeds solitary, large; embryo small, lying in a large quantity of albumen. 322 Gen.; 1790 Sp.


56. ASARALES.—Flowers monochlamydeous; embryo small, lying in a large quantity of albumen. 49 Gen.; 652 Sp.

Natural Orders.—301. Santalaceae, or Sandalworts. 302. Loranthaceae, or Loranthis. 303. Aristolochiaceae, or Birthworts.

Had our space permitted, we should now proceed to consider the various alliances and natural orders in detail, so as to lay before our readers a complete account of the whole kingdom of plants; but we must content ourselves with the extended scheme which we have now inserted.

We have but little to add to the directions which we gave for the prosecution of the study of classification under the Linnæan system; but it is important to bear in mind, that under the natural arrangement the stamens and pistils play a subordinate part, and are only accounted as a portion of the whole constitution of the plant. But very minute and constant attention is directed to the ovule and the seed; so that a pocket magnifier of moderate power is at all times necessary.
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