ELEMENTARY

BOTANY

EDMONDS.

Longmans' Elementary
Science Manuals.

Cornell University Library.

THE GIFT OF
LONGMANS, GREEN & CO.,

14 April, 1889.

Cornell University Library
arV19095

Elementary botany :

3 1924 031 230 042
olin,anx

Cornell University Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

ELEMENTARY BOTANY

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
1 LONDON

ELEMENTARY BOTANY

THEORETICAL AND PRACTICAL

A TEXT-BOOK DESIGNED PRIMARILY FOR STUDENTS OF SCIENCE CLASSES

CONNECTED WITH THE SCIENCE AND ART DEPARTMENT OF

THE COMMITTEE OF COUNCIL ON EDUCATION

BY HENRY EDMONDS, B.Sc. (LOND.)

HONOURS IN BOTANY, SOUTH KENSINGTON

LECTURER ON NATURAL SCIENCE AND CHEMISTRY AT THE BRIGHTON SCHOOL
OF SCIENCE AND ART

SCIENCE LECTURER TO THE EVENING RECREATIVE CLASSES, BRIGHTON
ETC.

NEW AND REVISED EDITION

LONDON

LONGMANS, GREEN, AND CO.

AND NEW YORK . 15 EAST 16th STREET

1888

All rights reserved

PREFACE

TO
THE NEW EDITION.

THE favour with which the previous editions of this work have been received has necessitated a reprint. Some changes and modifications having been made this year in the syllabus issued by the Science and Art Department, the opportunity has been taken of thoroughly revising the work.

Chapters have been added on the movement of water in plant tissue, on the influence of heat and light upon growth, and the irritability of plants. The orders Boraginaceæ, Primulaceæ, and Amaryllidaceæ have also been substituted in the new syllabus for the Chenopodiaceæ, Orchidaceæ, Graminaceæ, and Cyperaceæ.

In the present edition, whilst the old orders are retained, the new ones, to meet the requirements of the Department, have been added.

H. EDMONDS.

BRIGHTON : *October* 1888.

P R E F A C E.

THE object of this text-book is as far as possible to cover the subject of Elementary Botany as provided in the syllabus of the elementary stage issued by the Science and Art Department, and at the same time to avoid being a mere cram work, but to give a general idea of the fundamental facts and principles of the science.

In many elementary works the greater part of the book is taken up with mere structural details, the Physiology of the Plants being relegated to a short chapter at the end. I have endeavoured, whilst tracing up the growth and development of the plant from the seed, to treat of the functions of each organ at the same time as its description.

Through the liberality of the publishers the book is well supplied with diagrams. It will not do, however, for the student to trust to these alone. No science can be properly studied from mere book-work, and this is especially true of such a science as Botany, which deals with various forms of natural objects. The student is strongly urged from the first to carefully examine specimens. A sharp penknife and a simple lens, which will only cost a few shillings, are all the apparatus required for dissecting and examining most flowers, and the commonest plants around us will well serve the student's purpose.

For some parts of the subject—as, for instance, the examination of Cellular Tissues—a microscope is needful. An excellent instrument can be obtained at any of the well-known makers' for about five or six pounds.

The student should also especially accustom himself to writing out descriptions of plants according to the model given at the close of the book.

H. EDMONDS.

BRIGHTON : *May* 1882.

CONTENTS.

CHAPTER	PAGE
I. INTRODUCTORY	1
II. STRUCTURE OF THE SEED	3
III. CELL STRUCTURE	6
IV. CELL GROWTH, SHAPE, AND FORMATION	15
V. GERMINATION, ROOT GROWTH, STRUCTURE, AND FUNCTIONS	25
VI. STEM STRUCTURE AND FUNCTIONS	40
VII. BUDS AND RAMIFICATION	59
VIII. LEAF STRUCTURE AND FUNCTIONS	69
IX. BRACTS AND INFLORESCENCE	92
X. FLOWER STRUCTURE AND FUNCTIONS	100
XI. FRUIT AND SEED	135
XII. MOVEMENT OF WATER IN THE PLANT TISSUES	145
XIII. INFLUENCE OF HEAT AND LIGHT UPON GROWTH	148
XIV. IRRITABILITY OF PLANTS	151
XV. CLASSIFICATION	153
QUESTIONS	193
INDEX	199

ELEMENTARY BOTANY

CHAPTER I.

INTRODUCTORY—DEFINITION AND SCOPE OF THE SCIENCE.

BOTANY is the science which deals with those special forms of living organisms known as Plants. This at once raises the question—What do we mean by a plant? The higher forms of animal and vegetable life can be easily distinguished the one from the other ; but when we descend to the lower forms we find it most difficult, if not impossible, to draw a line of demarcation between them.

The old distinction between the three kingdoms of nature was a simple one : minerals grow—plants live and grow—animals move, live, and grow. Putting aside for the moment the question as to whether minerals really grow, the phenomena of motion cannot be accepted as defining the difference between the two groups of living beings. Many plants, especially amongst the lower forms, are capable of motion at some time or other during their life. As an example, if we examine rain-water that has been standing for some days, we generally find minute green masses floating about in it. These on inspection under a microscope prove to be true plants (*Protococcus pluvi-
alis*), each being a little rounded mass containing green particles. After watching for some time, however, it will be seen that some of these plants change their form, becoming more pear-shaped, at the same time giving off two very minute threads or cilia. These are thrown into rapid motion, propelling the plant

through the water in which it floats. In this mode of motion the *Protococcus* cannot be distinguished from many of the low forms of animal life.

A better distinction is to be found in the **food** that is assimilated. **Plants**, like animals, require food ; but they, as a rule, possess the power of **obtaining it from the mineral kingdom only**, whilst **animals require** for their food **either vegetable or animal substances**. There are, however, exceptions to this rule, and, as we have said, the two kingdoms appear to merge gradually the one into the other in their lower forms.

Botany, then, being the science which treats of plants, has several branches. *Morphology* deals with the forms of the organs of plants. *Anatomy* treats of their internal structure ; and *Histology* of the minute appearance they present under the microscope. *Physiology* deals with the functions of the various organs, and the phenomena attendant upon life. *Classification* has to do with the grouping of plants according to their relation one to another. *Geographical Botany* deals with the distribution of plants in space ; and *Palæontological Botany* with their distribution in time. Of these we shall omit the two latter branches in the present work, merely taking up in an elementary form the remaining departments.

CHAPTER II.

FLOWERING AND FLOWERLESS PLANTS—STRUCTURE OF THE SEED.

ALL the **higher forms of plant life** are distinguished as being able, at some time or other of their existence, to **produce flowers**.

It is this fact which causes the Vegetable Kingdom to be divided into the two subkingdoms of **Flowering Plants** or **Phanerogams**, and **Flowerless Plants** or **Cryptogams**.

In the present work we shall deal entirely with the Phanerogams.

The point in which **all of these plants** agree is that they **spring originally from seeds**. To understand a seed thoroughly, it is well to commence with a large specimen, as, for instance, a Broad Bean, Haricot, or a Pea.

If we examine a Broad Bean carefully, we notice that it has an elongated shape. At one end there is a scar or mark. This is the point by which the seed is attached to the fruit, and is known as the **hilum**. At one end of this there is a minute hole. This can be readily seen by allowing the bean to soak in hot water for a short time; then on taking it out and squeezing it a drop of water is seen to escape through the aperture. This hole, which leads into the interior of the seed, is called the **micropyle**.

Next, taking a sharp penknife, we find that we can peel

FIG. 1.— Broad Bean. A, seed, with one cotyledon removed: *c*, remaining cotyledon; *kn*, the plumule; *w*, the radicle; *s*, the spermoderm. B, germinating seed: *s*, spermoderm, a portion torn away at *l*; *n*, hilum; *st*, petiole of one of the cotyledons; *k*, curved epicotyledonary portion of axis, *i*; *he*, short hypocotyledonary portion of axis; *h*, main root; *wus*, its apex; *kn*, bud in axil of one of the cotyledons. (After Sachs.)

the skin from off the seed, leaving a whitish fleshy mass within. This **skin** is really, however, double, as can easily be proved by peeling from the interior a thin pellicle.

These coats are collectively known as **spermoderm** ; the **outer** being called the **testa**, and the **inner** the **tegmen**.

The mass within the spermoderm forms the **nucleus** of the seed. In the case of the Broad Bean this nucleus is entirely made up of the young plant or **embryo**. At one end there is a pointed portion which is directed towards the micropyle. This is destined on germination to be prolonged to form the root, and is known as the **radicle** (fig. 1).

FIG. 2.—Longitudinal section of a seed of Oat: A, endosperm; C, the single cotyledon; G, plumule; R, radicle; T, testa; O, hairs.

FIG. 3.—Germination of the Oat: a, cotyledon; b, axis of the embryo; c, plumule; d, radicle; f, plumule.

The great mass of the nucleus is made up of two fleshy lobes, which can easily be separated from one another—the **cotyledons** ; and between these at the top of the radicle there is a little portion curved over and divided at the end in a plume-like manner. This, which is known as the **plumule**, will, under favourable circumstances, grow into the stem and leaves of the future plant.

In some seeds, as, for instance, those of the varieties of corn and grass, there is in the nucleus a substance, **albumen**, in addition to the embryo of the plant (fig. 2). This albumen

may originate from two different parts of the ovule or unripe seed, and hence is known either as **endosperm** or **perisperm**. This will be more apparent when we have dealt with the growth of the ovule.

The term **albumen** is rather a misleading one, as it might lead the student to imagine that the substance contained within the seed is identical in chemical composition with animal albumen, such as is found in the white of an egg, whereas it differs in its characteristics in various plants. In cereals it is *mealy* or *farinaceous* ; in the Barberry and Heart's-ease it is *fleshy* ; in the Poppy and Cocoonut it is *oily* ; in the Mallow, *mucilaginous* ; in the Vegetable Ivory and Coffee, *horny*.

Seeds containing albumen are spoken of as **albuminous**, whilst those **destitute of it** are **exalbuminous**.

We may tabulate the structure of the most perfect seed as follows :—

Spermoderm	{	Testa Tegmen	Nucleus	{	Albumen	{	Radicle
					Embryo	{	Plumule
						{	Cotyledons

There is another point in which seeds differ. On examining a grain of Wheat, or of an allied cereal, we find that there is only one cotyledon present, instead of, as in the case of the Bean, two. Several plants resemble the Bean in having two cotyledons present in their embryos ; whilst others, like Oats, have but one. This causes the division of the sub-kingdom of Flowering Plants into two groups: **Dicotyledons** include those **Phanerogams with two** (or in some Conifers more) **cotyledons** ; whilst **Monocotyledons** are **those with only one**. As we proceed further we shall find that there are other differences between these two great classes.

CHAPTER III.

CELL STRUCTURE.

THE substance of the Bean seed is not homogeneous. The **whole of the various organs** of plants are **made up of** a large number of component parts—**cells**, so minute as a rule as to be invisible separately to the naked eye. If a little brewer's Yeast be examined under a hand magnifying glass, it is seen to present a granular appearance. If it be more highly magnified, it is found to consist of a large number of minute rounded particles (fig. 4); these are separate cells. We recognise in them the outer pellicle or cell wall and the cell contents.

FIG. 4.—Beer Yeast (*Saccharomyces* [*Torula*] *Cerevisiae*).

FIG. 5.—A cell from the root of the Lizard Orchis (*Orchis hircina*): *a*, the cell-wall, consisting of cellulose; *b*, the protoplasm, contracted by alcohol; *c*, the nucleus with a nucleolus.

The **cell wall** may be absent during a portion of the cell's existence; it is simply inert, not-living matter; but in the Vegetable Kingdom it is always sooner or later produced. The principal substance contained in it is **cellulose**, a compound of carbon, hydrogen, and oxygen, having the chemical composition $(C_6H_{10}O_5)^3$.

Cellulose is not coloured blue by means of iodine alone, although it is so changed by the action of iodine and sulphuric acid, thus being distinguishable from starch, which has the same percentage composition, but is turned blue by iodine. Schultze's solution¹ will also stain it.

Cellulose is insoluble in water, both cold and boiling ; also in alcohol, ether, and dilute acids. If it be treated with cold concentrated sulphuric acid, it is converted first into dextrine or British gum, which is the same composition as cellulose, and then into grape sugar, $C_6H_{12}O_6$. It is found almost pure in Cotton wool, but generally the cell wall contains mineral ash and water in addition.

During the growth of the cell the cellulose is often converted into substances which are of an allied composition, but which differ from it in various physical and chemical properties.

The chief of these are—

1. **Suber, or Cuticularised Cellulose.**—This is highly elastic and almost impermeable to water ; when treated with iodine or Schultze's solution it turns yellow ; when warmed (not boiled) in concentrated solution of potash it is stained bright yellow. It is met with in Cork, epidermis cells, and pollen grains.

2. **Lignin.**—In this case the cell wall is hard, inelastic, and permeable to water. Treated with a solution of aniline sulphate acidulated with a few drops of sulphuric acid, it is stained yellow. It is met with in wood cells.

3. **Mucilage.**—When dry it is hard and horny, but it very readily absorbs water, swelling and becoming gelatinous. The reactions are the same as those of cellulose. Examples are to be found in Linseed and Quince mucilage.

The **cell contents** are very various ; we will note some of the principal :—

Protoplasm.—It is of this substance that the whole of the

¹ Schultze's solution :—Dissolve zinc in hydrochloric acid ; permit the solution to evaporate in contact with metallic zinc until it has attained a syrupy consistence. Saturate the syrup with potassic iodide, and then add enough iodine to make a dark sherry-coloured solution. The object to be stained must be placed in a little water, and then some of the above solution added.

young cell is at first made up. It is very complex in its chemical constitution, but always contains nitrogen. Iodine colours it brown, and concentrated sulphuric acid rose-red; whilst it is also stained by magenta. It is soft and jelly-like in consistency, never truly fluid. At times it is homogeneous and transparent; more often it is granular. It forms the vital portion of the cell, and possesses considerable power of movement. It readily absorbs water, which, however, forms drops or vacuoles in its interior.

The movements of protoplasm may be grouped under two heads :—

1. Movements of protoplasmic masses destitute of a cell wall.

(a) Swimming by means of cilia, as in the case of *Protooccus* (p. 1).

(b) Amœbiform movements, where a naked mass of protoplasm emits irregular projections (*pseudopodia*) at various parts of its surface; the rest of the mass flowing after the processes. This is seen in the remarkable animal the *Amœba*, or *Proteus animalcule*, and is met with in some of the lower forms of plant life.

2. Movements of protoplasm within the cell wall.

In many cases the protoplasm contained within the cellulose wall shows a tendency to rotate or circulate in various directions through the cell, often carrying with it substances which may be imbedded in it. This is especially well seen in the cells of many water plants. (See fig. 19.)

Chlorophyll is the substance to whose presence the green colour of plants is due. It occurs (in the higher plants) in the form of granules imbedded in the protoplasm of various parts of the plant. These granules really consist of two parts—a colourless more or less solid portion, which is formed out of the protoplasm and builds up the chlorophyll granules; and a green colouring matter diffused through and colouring it. The exact chemical composition is not yet known, but there appear to be two separate colouring matters, the one yellow, *phylloxanthin*, and the other blue, *phyllocyanin*, which by their union give the green tint.

The colouring matter of the chlorophyll is soluble in alcohol, ether, chloroform, benzine, and essential oils and fats.

The chlorophyll granules are **produced** in the protoplasm **under the influence of light**, except in the case of the germinating seeds of some Conifers and the fronds of Ferns, in which cases high temperature alone appears to be necessary for their formation.

If a growing plant be placed in **perfect darkness no chlorophyll will be formed**; the leaves and other organs which would naturally have a green colour present a pale and sickly appearance. Such organs are said to be *etiolated*. An example is to be found in the leaf-stalks of Celery. In the natural state they are green, but when cultivated, earth is heaped up so as to remove them from the influence of the light. The result of this is to produce the white leaf-stalk of the edible varieties, this change of colour being accompanied by change of flavour.

Chlorophyll plays a most important part in the plant economy, which we shall notice when we treat later on of the food supply of the plant.

Starch has the same percentage composition as cellulose, but appears to have a simpler molecule, its chemical formula

FIG. 6.—Chlorophyll granules in cells of leaf of *Funaria hygrometrica*. *A*, granules of chlorophyll, with contained starch grains imbedded in the protoplasm of the cells. *B*, separated chlorophyll granules containing starch: *a*, *b*, young granules; *b'*, *b''*, chlorophyll granules dividing; *c*, *d*, *e*, old chlorophyll granules; *f*, granule swollen up by action of water; *g*, starch granules remaining after chlorophyll destroyed by action of water. (After Sachs.)

being $C_6H_{10}O_5$. It differs from it, however, in many of its properties. It is insoluble in cold water, but swells up very strongly on the addition of boiling water, forming a paste. It is readily turned a dark blue by the addition of iodine. As this blue colour, however, is removed by heat, the starch re-

FIG. 7.—Various forms of starch grain from the Potato.

quires to be cold, or nearly so, for its production. Exposed to heat for some time, or to dilute sulphuric acid for a shorter period, starch is converted into dextrine or British gum.

Starch occurs in the plant in the form of granules varying in their size. Amongst the smaller are those of Rice starch,

FIG. 8.—I. Starch grain from the Scarlet Runner. II. *a*, *b*, Starch grains from Rye. III. Starch grain from the stem of the Sarsaparilla (*Smilax Sarsaparilla*).

which are frequently under $\frac{1}{5000}$ of an inch in diameter, whilst those of the 'Tous-les-mois' are often as much as $\frac{1}{3000}$ of an inch in length. In external form they vary very much, but they usually present a central portion, the hilum, or nucleus, round which the starch substance is arranged in concentric

layers. Probably this striated appearance is due to a varying quantity of water in the different parts of the granule.

The starch substance seems to be separable into two parts, which are allied if not identical in composition, but which differ in properties. The one, known as *farinose* or *starch cellulose*, appears to form the skeleton of the granule, and is either stained brown by iodine, or, as in some cases, remains unstained; whilst the other part, *granulose*, which forms 94 to 96 per cent. of the granule, is coloured blue.

Granulose is readily soluble in saliva, and is thus separated from the skeleton. The same change takes place by

FIG. 9. — Starch grains from the latex of *Euphorbia splendens*.

FIG. 10.—Cell of endosperm of *Zea Mais*, Maize. Thin plates of protoplasm separating the polygonal starch grains. *a-g*, granules from germinating seed of Maize becoming dissolved and disintegrated. (After Sachs.)

the action of *diastase*, a substance occurring in germinating seeds, whereby the starch stored up in the seed as a food supply is rendered soluble.

Starch granules, like those of chlorophyll, require *light* for their formation; the quantity needed, however, is greater than that for the production of the green colouring matter. The granules are at first formed within those of the chlorophyll; then in the dark they are converted into soluble substances which are transferred to other parts of the plant, where they are again fixed as reserve food materials in the form of starch.

Cell Sap.—In the young cell the whole of the wall, with the protoplasm and other contents, is saturated with a watery fluid containing various mineral and other substances in solution. This constitutes the cell sap. As the cell increases in age this sap collects in drops (*vacuoli*), which gradually run together

FIG. 11.—Cells from the root of *Fritillaria imperialis*. *A*, very young cell from near apex. *B*, from 2 mm. above the apex. *C*, from about 8 mm. above the apex: *h*, cell wall; *p*, protoplasm; *k*, nucleus; *kk*, nucleoli; *s*, vacuoles and cell-sap cavity. (After Sachs.)

FIG. 12.—Crystals of calcium oxalate in the cell wall. *Welwitschia mirabilis*. (After Sachs.)

until the whole of the interior of the cell is filled with sap, presenting the appearance of being surrounded by two coats—viz., within, the layer of protoplasm; and without, the cell wall. This sap is most important, as it contains much of the food material of the plant.

Raphides or Crystals.—Very often some of the mineral substances contained in the sap become crystallised out, and make their appearance either within the cell or in the wall. In some plants the amount of these crystals is very great. In the Old-Man Cactus, as much as 80 per cent. of the dried tissue consists of them. Professor Bailey found in a square inch of Locust bark no thicker than writing paper, as many as a million and a half of these crystals. The root of Turkey Rhubarb contains so many as to give a gritty character to it when chewed. As a rule the raphides are found in cells where there are no

FIG. 13.—Cell from the stem of *Aloe retusa*, with raphides.

FIG. 14.—Crystalloid, *kr*, in a parenchymatous cell of the Potato tuber; *k*, nucleus.

other granular contents, but this is not universal. In chemical composition they consist of phosphate of calcium, or more often of oxalate of calcium. Carbonate or sulphate of calcium is sometimes met with. In shape they are either cubical, octohedral, or needle-like (hence the name of *raphides*, from the Greek name for a needle).

Crystalloids.—In some cells, especially those of fatty seeds like the Brazil nut, bodies are found which are crystal-like in appearance, but instead of being mineral in composition, consist of proteinaceous or nitrogenous material closely allied to

protoplasm. They are insoluble in water, but break up in a peculiar manner so as to appear to be composed of several layers.

Aleurone Grains are minute rounded grains found in the cells of many seeds just before ripening. They often contain crystalloids. They are soluble in caustic potash. They are often oily, and appear to be used as food reservoirs by the plant.

FIG. 15.—Cells of cotyledon of *Pisum sativum*, Pea. *St*, starch granules with central hilum and concentrated striæ; *a*, granules of aleurone; *i*, intercellular spaces (After Sachs.)

FIG. 16.—Sphere crystals of inuline in a parenchymatous cell from a tuber of the *Dahlia* preserved in alcohol, after addition of nitric acid.

Inuline is a peculiar substance found in the roots of *Compositæ*, and now and then in stems. It is very closely related to starch and sugar, and in the living plant is only found in solution in the sap; but by the addition of alcohol or glycerine it separates out, either in a frothy condition or as beautiful spherical masses known as *sphere crystals*.

CHAPTER IV.

CELL GROWTH, SHAPE, FORMATION, AND TISSUES.

CELLS grow by the process of **intussusception**. This is a term which requires some amount of explanation. We must look upon the cell wall as consisting, not of a continuous homogeneous layer of cellulose, but of an immense number of isolated, minute, solid particles or molecules, which are comparatively speaking unalterable.

Between these it is supposed that water percolates so that each molecule is surrounded by a layer of liquid. The neighbouring molecules may vary in size, so that, if the aqueous envelope remains the same, larger molecules will form a denser, smaller a less dense, substance.

This hypothesis (for it is but an hypothesis, as the molecules are too minute to be perceived even by the strongest lens) was first suggested by Nägeli, and it is supposed that these molecules are held in their places by three forces, viz. :
 1. The *cohesion* of the particles of which each individual molecule is made up. 2. The *mutual attraction* which exists between the adjacent molecules, and which gives them a tendency to approach one another. 3. The *attraction* of their surfaces for the *watery envelope* which counteracts this tendency.

When fresh food material is brought to the cell, the new molecules are intercalated between those already existing there, and thus they cause an increase in the size of the cell wall. Such a process of increase by means of intussusception is very characteristic of the growth of organic beings, and is totally different from the manner in which minerals increase in size. If a crystal, say of alum, be suspended in a vessel containing a

strong solution of the same substance, it enlarges by a process of *accretion*—that is, a series of fresh layers form upon its exterior.

FIG. 17.—I. Spherical cell from the flesh of the Peach. II. Ellipsoidal cell from the flesh of the Peach. III. Hour-glass-shaped cell from the flesh of the Peach.

FIG. 18.—I. Fusiform cell from the wood of the Spruce Fir, with bordered pits. II. Fusiform bast-fibre of the Larch.

Growth by intussusception often produces a change in the shape of the cell. The normal form is more or less spherical; this, however, is rarely preserved except in the case of unicellular plants. If the wall grows more vigorously at the two extremities than at the sides, the cell will become *oval* or *elliptical* (fig. 17), then *elongated* (fig. 19), and lastly *fusiform* or *spindle-shaped* (fig. 18).

On the other hand, if a very vigorous growth takes place at certain parts whilst the rest of the cell wall is but slightly developed, several protuberances will be produced upon the surface, and a *stellate* or *star-shaped* cell is formed (fig. 20).

Another cause modifying the shape of individual cells is to be found in their mutual pressure the one upon the other during

growth. By this means they may become flattened or tabular (fig. 21), or polyhedral (fig. 22).

Other forms of cells are shown in figs. 23, 24, and 25.

FIG. 19.—Circulation of protoplasm in an elongated cell of the Celandine : *k*, the nucleus with a nucleolus. The arrows indicate the direction of the currents.

FIG. 20.—Stellate cell from the horizontal septum of the air-passages of the Flowering Rush (*Butomus umbellatus*).

FIG. 21.—Tabular cell from the epidermis of *Callitriche*.

FIG. 22.—Polyhedral cell from the pith of *Acacia lophantha* : *a*, seen in transverse ; *b*, in longitudinal section.

At first the cell wall appears as a thin layer of cellulose perfectly permeable to liquids. In some cells but little thickening takes place during growth ; in many others, however, very soon layers of secondary deposit are formed lining their interior

surfaces. At first these layers are complete and continuous like the original coat, but soon they are developed but slightly or not at all at certain points, thus causing perforations in their substance. As the holes thus produced in the contiguous

FIG. 23.—I. Disc-shaped cell; a unicellular Alga, *Coscinodiscus*. II. Crescent-shaped cell of a stoma (guard-cell).

FIG. 24.—Tetrahedral cells; spore of a Fern in various positions.

layers correspond with one another, canals are gradually formed leading towards the centre of the cell cavity.

Such cells, when seen under a microscope, transmit the light differently through their pore canals and through the thickened walls, and hence they present a pitted or dotted

FIG. 25.—Branched bast-cell of the Larch.

FIG. 26.—Moderately thickened pitted parenchyma from the pith of the Beech.

appearance as though pierced by a number of holes (fig. 26). These cells are known as **pitted** or **dotted cells**.

In other cases the secondary deposit takes the form of a spiral band round the wall, thus producing a **spiral cell**

(fig. 28). Or else it is deposited as separate rings, when an **annular** cell is formed (fig. 29). When the thickening is arranged in an irregular manner, producing a perfect network over the wall, the cell is said to be **reticulated**.

FIG. 27.—Transverse section of a cell of the pith of *Clematis vitalba*: *p*, primary cell wall; *t*, innermost thickening layer; *P*, pore-canal; *i*, intercellular space.

FIG. 28.—A spiral cell from a Cactus, *Opuntia Tuna*, with strongly thickened spiral band.

Very often there is in the cell a gradual passage from a spiral to an annular or reticulated marking (fig. 31). At other times there is a spiral or reticulate marking in addition to the

FIG. 29.—Annular cell from *Arundo donax*, with strongly thickened rings placed at different distances and different angles.

FIG. 30.—Reticulately thickened cell of the Touch-me-not (*Impatiens noli-me-tangere*).

FIG. 31.—Annular cell from an *Opuntia* with rings passing over into a spiral band.

pits or dots. Such cells as these are known as **tracheïdes** (fig. 32).

Fig. 33 shows another form of thickening, known as **scalari-form**, or ladder-like. In this case the secondary deposit is

arranged in transverse layers like the rungs of a ladder. Such cells are well seen in the stems of Ferns.

A very important form of pitted cell is met with, especially in the wood of the Fir trees and their allies. In these cases the pit is *funnel-shaped*, being wide on the outside and gradually tapering till it forms a tube or pore canal leading into the centre of the cell.

FIG. 32.—Piece of a reticulately pitted tracheide from the Lime (*Tilia grandifolia*).

FIG. 33.—Scalariform cell from the underground stem of the Brake (*Pteris aquilina*).

FIG. 34.—Longitudinal section of wood of *Pinus sylvestris*. Bordered pits, *t t'*, increasing in age; *a-e*, wood cells, *e*, eldest, *a*, youngest; *cb*, wood cells of cambium; *st*, large pits, where medullary rays touch wood cells. (After Sachs.)

On examining these cells by means of a microscope, they present the appearance of a central pit surrounded by a border, and they are called **cells with bordered pits**. This appearance is caused by a varying amount of light being transmitted through the central pore which forms the pit, and the funnel-shaped upper portion which forms the border.

Very often the cell wall between the two 'borders' becomes absorbed, in which case a complete passage is made between the two cells.

Besides these appearances due to secondary deposit, there is, especially in older cells, a striation or stratification of the cell wall, which appears to be due to the varying amount of water in the different parts of the wall.

Another important change in the history of the cell is the formation of *vessels*, or cell fusion.

Vessels are formed by the union of several cells (vascular cells), the walls between them being either partially or entirely absorbed.

FIG. 35.—Two cells from the wood of the Scotch Fir in transverse section, each with a pore, *p*, widened at its base. By the disappearance of the original cell wall the two widenings have united to form the 'border,' *h*; *i*, intercellular space.

FIG. 37.—I. Portion of a scalariform vessel from the Brake (*Pteris aquilina*): *s, s*, the transverse division wall broken through in a reticulate manner. II. Pitted vascular cell from the stem of a Grass, *Phragmites communis*, with numerous small bordered pits.

When several cells standing one over another have the walls separating them simply perforated in a sieve-like manner, **sieve-tubes** or **bast-vessels** are formed. These are found in various

parts of plants, and contain nutritive materials necessary for the nourishment of the plant. When the disappearance of the separating walls is more complete, so that the cells form more or less long tubes, true vessels are produced, and these are known, according to the nature of their component cells, as pitted, spiral, annular, reticulate, or scalariform vessels.

These true vessels usually possess a considerable quantity of secondary deposit, and are seldom branched. As a rule

FIG. 38.—Fusiform bast fibre of the Larch.

FIG. 39.—Vesicular vessel in longitudinal section of scale of bulb of Onion (*Allium Cepa*): *e*, epidermis with cuticle (*c*); *p*, parenchyma; *sg*, coagulated contents contracted to show the porous walls. (After Sachs.)

they contain nothing but air; but in the early spring, when the stem is gorged with sap, they are often partly filled with liquid.

Bast tubes or bast fibres are generally more pointed and sometimes branching (fig. 25). The coalescence between the component parts is so complete that the separate cells cannot be distinguished when the fibres are examined by means of the microscope. Bast fibres do not often communicate directly

with one another; when they do so it is by means of their lateral branches.

Very closely related to the sieve-tubes mentioned above, especially in containing like them nutrient fluids, are **vesicular vessels** and **laticiferous vessels**. The former consist of elongated cells containing a milky juice and bundles of needle-shaped crystals.

Laticiferous vessels are tubes more or less branching, often forming a complete network, and containing a fluid known as *latex*, which is often milky, sometimes coloured, and varies in its composition in different plants.

FIG. 40.—Transverse section of phloëm of root of *Scorzonera hispanica*, showing branching and anastomosing laticiferous vessels.

Cells do not grow indefinitely; the size of the adult cell varies. **Prosenchymatous cells** vary from $\frac{1}{40}$ to $\frac{1}{12}$ of an inch in length, and from $\frac{1}{1500}$ to $\frac{1}{3000}$ of an inch in diameter. **Parenchymatous cells** vary as a rule from $\frac{1}{250}$ to $\frac{1}{1200}$ of an inch in diameter, whilst some in the pith of plants, in succulent parts, and in water plants, are as much as $\frac{1}{50}$ or even $\frac{1}{30}$ of an inch in diameter.

As the plant increases in size, fresh cells are produced, being formed out of those already existing. This process is known as **cell formation**. There are several modes by which this takes place, but in the formation of the vegetative cells of higher plants it is always by means of **cell division**. Vitaly active cells always contain a portion of the protoplasm more or less distinctly separated from the general mass, known as the nucleus, and which often contains small granules or nucleoli.

When cell division is about to take place, two nuclei are formed either by the division of the original one, or by its disappearance, and the formation of two fresh ones.

The whole mass of the protoplasm now aggregates around these nuclei, and a cell wall is formed between the masses thus produced, growing inwards from the circumference to the centre, thus dividing the mother cell into two daughter cells, each of which may grow to the size of the mother cell, and itself undergo division. The formation of reproductive cells we shall have to notice later on (page 117).

Except in a few cases, cells do not remain through life individually separate, but are united together to form 'tissues.'

FIG. 41.—Cells of stem of *Vicia Faba*. Meristem cells in process of division: *k*, nucleus; dividing, *a*; fully divided, *b*. (After Prantl.)

These may be grouped according to either their *function*, or their *structure*. Under the former method of division we have two kinds, viz. **meristem**, which is a tissue where the cells remain vitally active and capable of division, and **permanent tissue**, where the cells are no longer able to divide. If we arrange them according to their structure, we distinguish those tissues which consist of elongated cells overlapping one another, and which are known as **prosenchyma**, and those which are formed of shorter cells placed end to end, or **parenchyma**. These two forms of tissues, however, pass the one into the other by endless gradations.

Sometimes the term **sclerenchyma** is used to denote either prosenchymatous or parenchymatous tissues, where the walls of the cells have become very thick and hard, and often dark coloured.

CHAPTER V.

GERMINATION, ROOT GROWTH, STRUCTURE,
AND FUNCTIONS.

IF a living seed be placed in the soil and be supplied with moisture and warmth, and exposed to fresh air, germination will ensue. The range of temperature between which this is

FIG. 42.—*Ricinus communis*. I. longitudinal section of ripe seed. II, germinating seed, the cotyledons still within the spermoderm, shown more distinctly in A and B: *s*, spermoderm; *e*, endosperm; *c*, cotyledon; *hc*, hypocotyledonary portion of axis; *w*, primary root; *w'*, lateral rootlets; *x*, the caruncle (or aril), a peculiar appendage to the seeds of *Euphorbiaceae*. (After Sachs.)

FIG. 43.—Germinating seed of cabbage: *b*, axis; *c*, *d*, the two cotyledons, which have risen above the soil, the testa *a* not being yet completely thrown off.

possible varies with different plants, but it may be stated generally as being between 5° or 6° C. and 40° C.

Either the roots at once lengthen and grow out through the micropyle, or, which is more often the case, the lower part of the cotyledon, known as the *hypocotyledonary* portion of the stem, becomes elongated, pushing the end of the root before it out of the seed.

If we sow in some soil specimens of the following seeds—Broad Bean, Acorn, Beech, Cress, Cabbage, Castor Oil, Pine, Date, and Wheat—and watch the germination as it takes place,

FIG. 44.—Seeds of *Pinus Pinca* in different stages of germination. *I*, ripe seed in longitudinal section: *s*, spermoderm; *c*, endosperm; *w*, radicle of embryo; *c*, the cotyledons; *y*, the micropyle end of seed, with the rootlet directed towards it. *II*, germination commencing: *A*, spermoderm, *s*, ruptured, and rootlet, *w*, protruding; *r*, red membrane inside spermoderm; *x*, ruptured embryo sac: *B*, portion of spermoderm removed; *e*, endosperm; *C*, longitudinal section; *c*, cotyledons: *D*, transverse section. *III*, germination complete, the cotyledons, *c*, unfolding, and the hypocotyledonary part of stem, *hc*, elongated, the main root, *w*, developing lateral rootlets, *w'*. (After Sachs.)

FIG. 45.—Germination of *Phoenix dactylifera*. *I*, transverse section of seed before germination. *II*, *III*, *IV*, different stages of germination. *A*, transverse section of seed at *x, x*, in *IV*; *B*, at *xy*; *C*, at *zz*. The following letters refer to all the figures: —*c*, endosperm; *s*, sheath of cotyledon; *st*, its stalk; *c*, apex, forming an organ of absorption by which the endosperm is entirely removed, the growing end occupying the place of the absorbed endosperm; *w*, primary root; *w'*, secondary root; *b'*, *b''*, leaves succeeding the cotyledon; *b''*, the first foliage leaf; *h*, pileorhiz. In *B*, *C*, the folded lamina is seen cut across. (After Sachs.)

we shall find that there is a great difference with regard to the growth and development of the cotyledon during the process.

In *exalbuminous* seeds, where the cotyledons are thick and

fleshy, as in the Bean (fig. 1) and Acorn, they remain within the seed during germination, finally perishing after the food-material contained in them has been used up for the growth of the embryo. In the case of the Cress, Cabbage, and Beech we have an *exalbuminous* seed where the cotyledons are thin, and here they rise out of the soil to form the first leaves, carrying the testa with them (fig. 43). The Castor-oil plant has an *albuminous* seed ; in this case the cotyledons are not liberated until after the *endosperm* has been all absorbed (fig. 42). In the case of the Pine we have an analogous growth (fig. 44),

FIG. 46.—Longitudinal section of fruit of *Zea Mais*. *c*, pericarp; *n*, remains of the stigma; *fs*, base of the fruit; *eg*, hard yellowish part of endosperm; *ew*, white softer portion of endosperm; *sc*, scutellum (cotyledon) of embryo; *ss*, its apex; *e*, its epidermis; *k*, plumule; *w* (below), the main root; *ws*, sheath covering main root; *w* (above), lateral rootlets springing from the first internode of the stem, *st*. (After Sachs.)

FIG. 47. — Germinating embryo of Oat (the endosperm removed). *p*, the plumule; *s*, the scutellum; *r*, *r*, the rootlets; *co*, the coleorhiza.

the cotyledons (which are numerous) appearing above ground after the absorption of the albumen, the peculiarity here being the development of *chlorophyll* in the cotyledons before they rise above the surface. All these are *dicotyledonous* seeds. The remaining two illustrate the germination of *monocotyledons*.

In the Date Palm (fig. 45) the lower part of the cotyledon lengthens, pushing the root and plumule out of the seed, whilst the rest of it remains in contact with the albumen absorbing it.

In the Wheat (fig. 46) the cotyledon is developed to form a plate where it is in contact with the endosperm, and is known as the *scutellum*. This serves the purpose of absorbing the

FIG. 48.—Germinating Bean : *a, b*, cotyledons ; *c, d*, leaves ; *e*, terminal bud ; *h*, primary root ; *g*, lateral roots.

FIG. 49.—Longitudinal section through the apex of a root of *Aspidistra elatior* : *wh.*, root-cap ; *M*, pith ; *o*, epidermis ; *G'*, narrow spiral vessels ; *G''*, broad reticulate vessels.

albumen. In this case there is at once a growth of the root causing a rupture of the sheath surrounding it, which remains attached to the axis forming the *coleorhiza* (fig. 47). In some few monocotyledonous plants, where there are exalbuminous seeds (as in the natural orders Naiadaceæ, Alismaceæ, &c.), the

cotyledon is freed from the integuments, and is raised up through the soil.

When the cotyledons remain beneath the soil they are said to be **hypogeal**, when they rise above **epigeal**.

There is also a great difference between dicotyledons and monocotyledons with regard to the formation of the young root. In dicotyledons the radicle is directly prolonged, and no branching takes place until after the young root has left the seed (fig. 48), so that the first root is a direct prolongation of the radicle, and is known as a *normal* root. Such a mode of root development is called **exorhizal**. In monocotyledons, on the other hand, there is a branching within the seed (fig. 47), and the radicle is not directly produced. Such roots are known as **adventitious**, and the growth is said to be **endorhizal**.

The term *adventitious* is applied to all roots which are not developed by the direct growth of the radicle ; hence in dicotyledons adventitious roots may be developed later on from various parts of the plants (as from stem, as seen in the Ivy, &c.), so that it is only the first-formed roots which are always normal in this group.

ROOT STRUCTURE.

Even whilst the radicle is within the seed a change of shape and condition has come over some of the cells, which, however, is more apparent after the young root has commenced to grow (fig. 49). The outer layer of cells becomes more or less flattened, forming a complete protective coat known as the **epidermis**. At the extremity the cells are thickened in such a manner as to produce what is known as the root-cap or **pileorhiza**, which is intended to protect the growing extremity of the root during its prolongation. Just behind the root-cap there is a mass of meristem tissue, which forms the growing point of the root. This by the constant subdivision of its cells produces on its outer sides additions to the root-cap, thus making up for portions that have become worn off by the growth of the root, whilst on its inner side it forms fresh tissue, thus causing the root to increase in length. Roots, then, increase in length only by growth near the apex. The upper part of the root is

made up of permanent tissue, consisting principally of a mass of parenchymatous cells forming the ground tissue, and in this there are developed, more or less completely, bundles of prosenchymatous cells and vessels, forming what are known as fibro-vascular bundles, running from the base of the root towards the apex.

These bundles consist of xylem and phloëm, very similar to that which exists in the stem (see Chapter VI.). Each

FIG. 50.—Transverse section of root of *Phaseolus*. M, pith; s, endodermis or sheath of fibro-vascular bundles, with parenchyma of the ground tissue externally; pc, pericambium layer; b, primary phloëm of bast fibres; g, primary xylem, with vessels; c, cambium. (After Sachs.)

bundle contains prosenchymatous cells or fibres, vessels and parenchyma, but they differ from the bundles of the stem and leaves, in that the vessels are, as a rule, first formed near the circumference of the bundle, and the xylem and phloëm masses (which vary in number in different plants) alternate instead of being placed the one outside the other. The bundles thus form an irregular star of three, four, or six rays.

In Dicotyledons there is, as a rule, a small number of such bundles, whilst in the roots of Monocotyledons the number is considerably larger.

Surrounding the bundles there is a ring of specially modified meristem cells known as the **pericambium**, and outside this an enveloping layer of cells forming the bundle-sheath or endodermis. Branches of the root are formed by outgrowths of the pericambium which push their way through the adjacent tissue, and thus form rootlets, which repeat the structure of the original root (fig. 51).

Roots increase in thickness by the formation of a ring of

FIG. 51.—Longitudinal section of main root of *Vicia Faba*. *r*, *r*, cortex of main root; *f*, fibro-vascular bundles; *n*, *n*, lateral rootlets developing from pericambium, and breaking through cortical tissue; *h*, pileorhiza of side rootlets. (After Prantl.)

FIG. 52.—Epidermis of root with hairs.

meristem between the xylem and phloëm bundles, and which, by the repeated division of its cells, produces new xylem and phloëm.

The cells of the epidermis often possess prolongations or hairs (*trichomes*), which tend to increase the amount of surface in contact with the soil (fig. 52).

FORMS OF ROOTS.

There are certain terms which are used in the description of the form of the root. When it is broad at its base and

tapers towards the apex, as in the Carrot (fig. 53) or Monkshood, it is **conical**. When it is broadest in the centre and tapers towards the two ends, as in the Radish (fig. 54), it is **fusiform**,

FIG. 53.
Conical root
of the Carrot.

FIG. 54.
Fusiform root
of the Radish.

FIG. 55.
Napiform root of
the Radish.

FIG. 56.
Fibrous root of
a Grass.

or spindle-shaped. When it has become somewhat globular with a tapering extremity, as in the Turnip, or some varieties of Radish (fig. 55), it is said to **napiform**; whilst the term **placentiform** is applied to it if the tapering apex be absent, as

FIG. 57.—Double tuber, *a, b*,
of *Orchis Morio*.

FIG. 58.—Double palmate tuber, *a, b*,
of *Orchis odoratissima*.

in the Sow-bread. If a number of slender branches be given off, as in the Grass (fig. 56), the root is **fibrous**. When some of these fibres become swollen in an egg-shaped manner, as in

Orchis Morio (fig. 57), the term **tuberculated** is employed ; whilst if the tuber is divided so as somewhat to resemble the

FIG. 59.—Tuberous fasciculated root of the Dahlia.

FIG. 60.—Nodulose root of *Spiraea filipendula*.

fingers of a hand outstretched, as in *Orchis odoratissima* (fig. 58), it is called **palmate**.

The term **fasciculated**, or tufted, is used where there are a number of tubercles or fleshy branches arranged in a bunch, as in the Dahlia (fig. 59).

When the fibres are enlarged only at their extremities, as in the Dropwort (fig. 60), the root is **nodulose**, or knotted ; whilst if there be several swellings arranged like beads on a necklace, as in *Pelargonium triste*, it is said to be **moniliform**, or necklace-shaped.

In Ipecacuanha the root is called **annulated**, it being marked with several ring-like expansions upon its surface.

FIG. 61.—*n*, a piece of branch of an Apple tree cut through lengthwise, into which a young Mistle-toe plant, *m*, has driven its sucking roots, *s*.

ROOT FUNCTIONS.

1. The root is a great **organ of support**, tending to hold the plant fixed in the soil or other situation in which it may be growing.

2. It is an **organ for the absorption of food**.

This raises three questions, viz. the source of the food, the nature of the food, and the manner of its introduction into the plant.

A. *The source of the food*.—The roots, as a rule, enter the ground, and hence receive the plant-nourishment from that source. In the case of some aërial plants the roots absorb the food with the moisture present in the air, whilst in the case of many parasites, as the Mistletoe (fig. 61), the sucking roots penetrate into the stem of the plant upon which it grows, thus obtaining their nourishment second-hand.

B. *Nature of the food*.—A chemical analysis of the substance of a plant shows it to be composed of the following elements:—

Carbon, C.	Phosphorus, P.	Potassium, K.
Hydrogen, H.	(Silicon, Si.)	Calcium, Ca.
Oxygen, O.	(Chlorine, Cl.)	Magnesium, Mg.
Nitrogen, N.		Iron, Fe.
Sulphur, S.		(Sodium, Na.)

The five placed in the first column are sometimes called the organic elements, as they are required for the building up of the protoplasm and cellulose. Those placed in brackets are not so necessary or so universally met with as the rest.

Since, then, the plant body is built up of these elements, it is evident that they must enter into the composition of its food. They are not, however, absorbed in their elementary condition, being obtained from various compounds which contain them.

Carbon is obtained by green plants from **carbon dioxide**, called also carbonic anhydride, and formerly known as carbonic acid gas, CO_2 , a gaseous compound of carbon and oxygen; perhaps partly by means of the roots; but especially, as we

shall see later on, through the pores of the leaves, these pores performing the part of both lungs and mouths for the plant. Carbon is one of the most important substances present, building up portions of all the plant-tissues, and usually forming one-half of the dried plant by weight.

Hydrogen, another element present in every organic compound, is obtained from **water**, H_2O , which is taken up in large quantities by the roots, and also, to a slight extent, from **ammonia**, NH_3 .

Oxygen.—The sources of this element are to some extent the two compounds H_2O and CO_2 already noted, and also the various **oxygen salts** of the metals, such as sulphates, phosphates, nitrates, &c. Besides this, the free oxygen of the atmosphere enters the plant, combining with the tissues, as we shall have to notice further on under the head of **Respiration**.

Nitrogen, which is an essential element of protoplasm, the albuminoids, and allied bodies, is obtained from **ammonia**, NH_3 , and **nitric acid**, HNO_3 , which latter, with the metals, forms the salts known as nitrates. It must be borne in mind that, although nitrogen exists to a very large extent in the air in a free or uncombined state, yet that plants are only able to absorb it from its compounds.

Sulphur is taken up as **sulphates**, that is, salts of sulphuric acid, H_2SO_4 ; probably chiefly calcium sulphate or gypsum, $CaSO_4$. This element also is required for the protoplasm and albuminoids.

Phosphorus is obtained from **phosphates**, principally calcium phosphate, $Ca_3,2PO_4$.

Silicon is taken in as **silica**, SiO_2 , which is often largely present in the soil; whilst the sources of **chlorine** are the **chlorides** of the various metals, especially of sodium, the chloride of which is common salt. The metals mentioned above are all obtained as salts combined with the acids we have noticed.

c. Method of introduction of the food substances into the plant.—Before any **food** can be absorbed it is necessary for it to be in a **state of solution**. The water present in the soil

dissolves up the various food materials, and thus brings them into a fit state to be taken.

The outside surface of the root is entire, not perforated by holes, hence the solution of food has to be absorbed into the cells of the plant itself. This is accomplished by means of the

process of **osmosis**. If two liquids be separated by a membrane permeable to both, they will flow through it and intermingle.

This can be very easily demonstrated by means of a simple experiment. If a vessel is closed below by a piece of bladder, whilst a tube is tightly fastened in the neck (fig. 62), and if a concentrated solution of cupric sulphate is placed in the vessel so that it stands a short way up the tube, and then the whole apparatus is plunged into a vessel of water as shown in the diagram, the two liquids will interchange, some of the cupric sulphate passing through the bladder into the outer water, whilst some of the latter enters the vessel. The two liquids do not, however, flow with equal rapidity. The law in all such cases is that the denser liquid flows more slowly than the less concentrated. As cupric sulphate solution is denser than water, a larger amount of the latter passes through the membrane than of the former, and therefore the liquid will rise in the glass tube. The passage inwards is called *endosmose*, whilst that outwards is termed *exosmose*. Sugar syrup may be used in the above experiment instead of cupric sulphate.

FIG. 62.—Apparatus for measuring osmose: *b*, a vessel filled with cupric sulphate closed below by a permeable membrane, and placed in a vessel of water. As the water passes through the bladder to mingle with the cupric sulphate, the level of the fluid will rise in the tube *r* in connection with the vessel *b*, but will fall at *n* in the outer vessel.

Let us apply this process to the root. Within the cells there is the sap, without there is the water with mineral salts in solution; we have here two liquids of different densities separated by a permeable membrane, the cell wall. As a consequence osmosis ensues, some of the external water passing

into the cell, and some of the sap being excreted into the soil. As, however, the sap is much denser than the water without, the flow of this latter is more rapid. By the same means the food material thus absorbed is transferred up the root from cell to cell towards the stem. The sap is densest in the upper cells, owing to the evaporation which is going on, and hence the flow is maintained. This passage of food takes place especially by means of the prosenchymatous cells or fibres, whilst absorption goes on most actively in those cells which are near the growing point and by means of the hairs.

The various food materials are not, however, taken up indiscriminately by the plants. It is found, if plants are grown in water containing equal amounts of the salts necessary for food, that the quantities removed are very different.

There is what is known as *selective power*, each plant removing from the soil those substances which are more especially necessary for its life, leaving other foods behind. Thus leguminous plants remove especially lime salts; potatoes and turnips, compounds of potash; cereals and grasses, silica; and so on.

If the same plant be grown year after year in the same soil it gradually impoverishes the ground, whilst food materials needful for other plants will be accumulated. Hence is brought about what is known as rotation of crops—that is, growing a well-chosen selection of plants in succeeding years in the same soil.

The exact plan of rotation varies with the nature of the soil and the plants desired to be grown. The following is an example of what is known as the Norfolk or four-course rotation:—

1	2	3	4
Fallow. Turnips and Swedes	Barley	Clover	Wheat

That is, the farm will be broken up into four portions. The first will undergo thorough tillage and be planted with root

crops, which need especially potash and lime, and, having short roots, take their food near the surface, or are surface-feeders. Division No. 2 has barley, which takes up very little lime and potash but much silica, and is also a surface-feeder. Clover, in division 3, takes much the same food as the root crops, but is a subsoil-feeder—that is, sends its roots deeply into the ground. The wheat in division 4 is also a subsoil-feeder, but like barley takes up much silica.

The next year the position of the crops is changed. Barley is grown on division 1, clover on division 2, wheat on 3, and so on ; so that once every four years each part of the soil has each kind of plant growing on it, and the full rotation is thus shown :—

	1st Year	2nd Year	3rd Year	4th Year
1st Division	Root crops	Barley	Clover	Wheat
2nd „	Barley	Clover	Wheat	Root crops
3rd „	Clover	Wheat	Root crops	Barley
4th „	Wheat	Root crops	Barley	Clover

At the same time various manures are employed to supply the place of the different materials removed from the soil.

3. The root is also, as we have seen, an **organ of excretion**; some of the sap, by osmosis, passes out into the soil, whilst the food enters the root. This is most important, as the sap is found to possess, as a rule, an acid reaction (that is, it turns vegetable blues, such as litmus, red), and hence it aids the root by dissolving up some of the materials present in the soil. Many of these substances, which are very needful for the food of the plant, are insoluble in water, but the acid sap dissolves them readily.

This can be easily shown by means of an experiment. Take a piece of perfectly smooth marble, and cover it with sand to the depth of about a quarter of an inch ; sow in this some seeds of mustard or cress, and place in a position favourable for germination. When the young plants have grown for a short time, clear the whole off, and it will be found that the rootlets will have eaten their way into the marble, dissolving the substance, and forming minute grooves where they had been.

This explains how it is that we sometimes see large trees with their roots sunk into the solid rock. They have sprung up in that position from seeds, and as the roots have grown the acid sap has gradually eaten a passage for them until they have attained their present firm condition. Added to this, the root exerts a mechanical force, splitting the rock in the direction of pre-existing grooves, and thus helping to form a passage for their growth. On the high road between Buxton and Longnor, at a village called Sterndale, several large trees are close to the road-side, growing through immense blocks of limestone, which blocks have been split by the expansive force of the tree.

4. The preceding functions belong more or less to all roots; there is, however, a fourth, which is only occasionally seen. In some cases the root acts as a **storehouse of food**.

Let us take the case of a biennial plant, such as a Turnip. During the first year there are no flowers, but plenty of leaves. Food materials are absorbed and converted by means of the leaves into starch and other substances, which are stored up in the root, which latter becomes swollen. The next year the plant flowers and fruits, and this reserve of food is used up during the process, so that by the end of the second year the root has become shrivelled and fibrous.

CHAPTER VI.

*DEVELOPMENT OF THE PLUMULE—FORMATION,
STRUCTURE, AND FUNCTIONS OF THE STEM.*

WHILST the radicle grows downwards to form the root of the plant, the plumule is elevated above the soil, and produces the stem, bearing leaves and other appendages.

Popularly the **stem** is looked upon as differing from the root in growing above the ground, but botanically there is a wider difference. Underground portions of many plants, as the Onion and Potato, which are generally called roots, are in reality stems.

The characters of stems as distinguished from roots are as follows :—

1. Their **growing points** are not covered with a root-cap, but are **surrounded by young leaves** (buds).
2. They have developed upon them **appendages**, variously modified, but which differ in structure from the stems themselves ; whilst roots simply branch, the branches being repetitions of the structure of the original root.
3. Whilst, as we have seen, the branches of the root have their origin in the deep-seated layers of the pericambium (endogenous growth), the **branches** and appendages of stems take their rise from more superficial layers (**exogenous growth**).

If we make a transverse section across the young stem during the first year of its growth, we find that there is a great difference in the appearance it presents in the two great groups of Dicotyledons and Monocotyledons.

Fig. 63 shows the section of a portion of a young dicotyledonous stem. On the exterior there is an **epidermis** of flattened cells.

At first this is like the epidermis of the root, consisting of a number of similar cells, always completely in contact ; but after a while some of these become separated from one another, leaving an opening or **stoma** (plural, *stomata*) between them (fig. 64).

These stomata are always surrounded by two or four cells, which are generally smaller than the epidermal cells, are crescent-shaped, and contain chlorophyll. These are known as *stomatal* or *guard cells*.

FIG. 63.—Transverse section of petiole of *Hel-leborus*, showing the three systems of tissues : *e*, epidermal ; *f*, fibro-vascular ; *x*, xylem ; *c*, *b*, phloëm—*c*, soft bast ; *b*, bast-fibres ; *g*, ground or fundamental tissue. (After Prantl.)

FIG. 64.—I. Horizontal section through the epidermis of the under side of the leaf of *Euonymus japonicus* looked at from below : *sp*, stoma. II. Course of development of the stoma of *Arthropodium cirrhatum* : *spm*, mother cell ready for division ; *sp'*, *sp''*, *sp'''*, successive stages of division. III. Mature stoma.

More towards the interior of the stem there are developed some **bundles of cells** (fig. 63). At first these bundles consist of meristem tissue, known as **procambium**, forming a string of similar and growing cells. Very soon, however, the greater part of this passes into the form of permanent tissue, which is separated into an outer or **phloëm** and an inner or **xylem**

portion, leaving a band of meristem (**cambium**) between them (fig. 65).

The bundles, which now consist of fibres and vessels, with a few parenchymatous cells, are spoken of as **fibro-vascular bundles**. In many cases the fibres and vessels become very much hardened by the thickening of the secondary deposit, and the fibro-vascular bundles can then be easily separated from the surrounding portions of the stem. In other cases there is very little hardening in the bundles, and they cannot be thus separated.

FIG. 65.—Transverse section through a young internode of *Bahmeria argentea*: o, epidermis; co, outer cortex (collenchyma); r, inner cortex; s, intercellular space; c, cambium of the vascular bundle; c', cambium of the thickening ring; b, bast portion; h, xylem portion of the vascular bundle; b', the bast formed from the intermediate cambium; z, medullary ray.

which separate the fibro-vascular bundles and unite these two portions, the **medullary rays**.

The next change is in the cells which lie between the fibro-vascular bundles and the epidermis. Here are produced flattened cells filled with air, possessing flexible and elastic walls forming a close tissue without interspaces. These are *cork cells*. They are rarely (as in the Willow) developed from the epidermis itself; sometimes (as in the Poplar) from the

The rest of the stem in its young state is made up of parenchymatous cells, forming what is known as **fundamental** or **ground tissue**, which is divided into three parts—a portion in the centre of the stem, the pith or **medulla**; a ring underlying the epidermis, from which the **cortex** or bark is developed; and, lastly, masses of cells

cells immediately beneath it, more often from the more deeply lying cells.

On the inner side there is developed a ring of meristem, known as **phellogen** or cork cambium, whilst within this there is a layer of cells containing chlorophyll, the **phelloderma** or green layer. Sooner or later all the cells outside the cork tissue dry up and shrivel, forming the outermost layer of the bark.

FIG. 66. —Transverse section of one-year-old stem of *Ailanthus glandulosus*: *e*, epidermis withered; *k*, cork cells, formed by the inner cells with protoplasm, the cork cambium or phellogen; *r*, inner green cells, the phelloderma. (After Prantl.)

The dicotyledonous stem now consists of the following parts :—

1. *A ring of epidermis* and cells with it becoming dried and dead.
2. *A ring of cork tissue*, the outer bark or epiphloëum, with the cork cambium within.
3. *A ring of phelloderma*, the middle bark or mesophloëum.
4. *A ring of phloëm*, interrupted by the passage of the medullary rays, and forming the bast, liber, inner bark, or endophloëum.

5. *A ring of cambium*, also interrupted by the passage of the medullary rays.

6. *An interrupted ring* of xylem or wood.

7. *A central pith* or medulla.

8. *The medullary rays*, uniting the pith with the middle bark. (See fig. 65.)

In the monocotyledonous stem (fig. 67) there is quite a different arrangement. On the exterior there is no differentiated

FIG. 67.—Diagrammatic representation of the distribution of the fibro-vascular bundles in the transverse section of a Palm stem.

bark ; within, no separation into pith and medullary rays ; but a number of bundles of procambium scattered amongst the general ground or fundamental tissue. These bundles differ in their development as well as in their arrangement from those of the dicotyledonous stem. Instead of leaving a layer of vitally active cambium, they are entirely converted into xylem and phloëm.

Dicotyledonous bundles which contain cambium are spoken of

as **open**, whilst those bundles which are destitute of this formative tissue, as those of **monocotyledons**, are known as **closed**.

We must now note a little more fully the structure and functions of the various parts of the dicotyledonous stem.

1. The **medulla** or **pith** consists entirely of parenchymatous cells, generally dodecahedral in shape, and it forms a cylindrical axis at or towards the centre of the stem. In the earlier stages the cells usually contain a little chlorophyll, and are filled with nutrient substances ; later on they become dry and colourless, and filled with air, and no longer serve any purpose in the life of the plant, so that the stem may be hollowed, all the pith having disappeared, and yet the plant may be living vigorously.

The amount of pith varies much in different plants. In hard-wooded plants, as the Ebony, it is very small ; whilst in soft-wooded plants, as the Elder, it is much larger. Again, we often find in many rapidly growing herbaceous plants, as

the Hemlock, the pith, not being able to keep up in growth with the other parts, has left the stem hollow, with a rugged attachment of pith at the sides; whilst in the Walnut and Jessamine it has become broken up into thin discs (*discoid* pith).

2. Surrounding the pith there is a layer of spiral vessels (the **medullary sheath**), which is in reality the commencement of the wood or xylem. The function of these vessels, as indeed of all true vessels, is to serve as air carriers. Like the wood, cambium, and liber, the medullary sheath is pierced by the medullary rays.

FIG. 68.—Portion of the transverse section through a shoot of Ivy four years old: R, cortex; B, bast bundles; H, wood, in which the four annual rings are distinctly visible; M, pith; S', medullary rays; F, bast fibres; Cb, cambium; S'', primary, S''', secondary bundles.

3. Outside the medullary sheath comes the **xylem** or wood, arranged in the form of concentric rings. These rings are formed as follows. During the first year the cambium cells by their division have caused the wood and liber to increase in thickness. During the winter the cambium remains dormant, but as soon as spring returns the cells once more become vitally active, and form a fresh ring of wood on its interior *outside* the old xylem, and a fresh ring of liber on its exterior *inside* the old

phloëm. Thus year by year fresh rings of wood and liber are formed (fig. 68), the oldest wood being towards the centre of the tree, whilst the oldest bark is towards the exterior. Growth such as this is sometimes spoken of as **exogenous**, and dicotyledonous plants are sometimes termed *exogens*. It is, however, only the wood which is exogenous in growth; the liber is endogenous.

As fresh rings of wood are as a rule formed every year, the age of a tree can generally be approximately ascertained by counting the number of the rings. The annual rings of various trees differ very much in the extent of their thickness, much depending not only on the nature of the plant itself, but also on its age and the atmospheric conditions of the climate. Also in the same plant the rings are not of equal thickness all round, so that the pith instead of being geometrically in the centre of the tree is generally more or less excentric.

When these wood rings are fully developed they consist of three elements, viz. :—

- a. Wood fibres or wood prosenchyma.
- b. Vessels, either spiral, annular, pitted, or otherwise.
- c. A variable quantity of wood parenchyma.

These three elements are variously arranged, and any one of them may be absent. Generally there is plenty of secondary deposit, so that the cells have become hard. The inner wood is, as we have seen, the oldest, and hence the hardest, and is often coloured by the secondary deposit having colouring matter. This is especially well seen in such wood as Ebony, Mahogany, Rosewood, &c. In other cases, as in the Poplar and Willow, the old wood is nearly as colourless as that of the exterior. This inner wood is known as the **duramen** or heart-wood.

The xylem on the exterior, which is younger, is permeated with sap, and is known as the **alburnum** or sap-wood.

The heart-wood is principally useful in supporting the plant, so that it may be absent as well as the pith without interfering with the vital activities of the tree.

In the sap-wood the vessels are air carriers, whilst the fibres are sap distributors carrying a current of sap from the root up towards the leaves (see Chapter XII.).

4. Outside the xylem there is the interrupted ring of **cambium**, consisting of prosenchymatous cells dormant during the winter, and in full activity on the return of spring. After the first year cambium is formed between the fibro-vascular bundles

FIG. 69.—Diagrammatic view of the structure of a dicotyledonous stem with circumferential growth as seen in transverse section. A—M, R, ground tissue forming pith (M) and cortex (R), the external ring representing the epidermis. Six fibro-vascular bundles separate—x the xylem, and p the phloem of each bundle. B—older stem: the bundles now united by cambium ring of fascicular (fc) and interfascicular (ic) cambium; b, b, the primary bast fibres of the phloem. C—still older stem. By the activity of the cambium new wood and bast have been formed. fh, wood formed by fascicular cambium; ifh, wood formed by interfascicular cambium; ifp, interfascicular phloem; x, y, medullary sheath. The shaded upper part shows medullary rays. (After Sachs.)

(*interfascicular cambium*), thus making the cambium ring complete (see figs. 65 and 69, B). By means of this interfascicular cambium, not only are the medullary rays lengthened as the

stem increases in thickness, but also fresh phloëm and xylem are produced between the original bundles.

5. Outside the cambium there is the interrupted ring of **phloëm**, liber, or inner bark. Like the wood this consists of

three elements, viz. :—

a. The bast vessels or sieve-tubes (fig. 36).

b. Bast fibres (fig. 38).

c. Bast parenchyma or soft bast.

The separate annual layers of the liber cannot, as a rule, be so readily distinguished as those of the wood, they being much thinner and compressed together by the growth in thickness of the tree. In some cases, however, the liber can be separated into thin plate-like layers.

A good example of this is to be seen in the Lace-bark tree (*Lagetta linlearia*) of Jamaica, where the inner bark separates into thin sheets having the appearance of lace, the holes in it being the perforations for the passage of the medullary rays.

The fibres of the bast act as sap circulators, bringing down the elaborated sap from the leaves.

6. The *green layer*, or

phelloderm, consists of chlorophyll-containing cells, often inter-mixed with laticiferous vessels.

7. The *outer* or **cork layer** with its formative phellogen immediately beneath it. These two last layers form a pro-

FIG. 70.—Part of a transverse section through the bast of the Wild Lettuce (*Lactuca scariola*): Bf, bast fibres; Bp, bast parenchyma; M'' outer, M' inner laticiferous vessels; Rp, cortical parenchyma; Hlf, wood-fibres.

protective coat to the exterior of the stem. After a short time the cells generally become dead, and very often peel off under the expanding influence of the growth of the stem.

FIG. 71.--Longitudinal tangential section of stem of *Ailanthus*, showing secondary xylem of fibro-vascular bundles: *g, g*, wood vessels; *p*, wood parenchyma; *t, lf*, wood prosenchyma, of two varieties; *t*, tracheides, with pitted and spiral markings, and *lf*, libriform or bast-like wood fibres; *st*, medullary rays cut across. (After Sachs.)

This, as is seen in the Elm or Cork Oak, gives a rugged appearance to the bark. In other cases, as in the Beech,

owing to its capability of distension, the bark presents a smooth appearance.

8. The **medullary rays** uniting the pith with the middle bark, and separating the fibro-vascular bundles. They are generally made up of flattened, six-sided cells, arranged like bricks in a wall (*muriform parenchyma*).

The rays are rarely continuous from the top to the bottom of the stem, being separated by the fibro-vascular bundles (*st*, fig. 71).

The medullary rays form what is known as the 'silver grain' of the cabinet makers. The use of the rays is to distribute the elaborated sap from the liber through the other parts of the stem.

In most cases the fibro-vascular bundles are continuous with those which form the veins of the leaves, and are known as '**common bundles**,' *i.e.* common to leaf and stem. At the nodes (the point of attachment of the leaf to the stem) these bundles enter the stem and run down parallel to one another, usually through two or three internodes. At the nodes the bundles branch and interlace in various ways, whilst they thin out the further they descend. In some few water plants, as the Hippuris or Mare's tail, the Myriophyllum or Milfoil, and a few others, the fibro-vascular bundles run simply through the stem, or are **cauline**, the foliar originating later.

The direction of the fibro-vascular bundles can be readily traced by making a longitudinal section of a young stem, taking care to cut through at least two nodes, and then soaking it for five or ten minutes in a solution of aniline sulphate acidulated with a few drops of sulphuric acid; the lignin of the bundles will be stained yellow, and hence their position can be noted.

STRUCTURE AND FUNCTIONS OF THE PARTS OF A MONOCOTYLEDONOUS STEM.

Even in their external form monocotyledonous stems present a different appearance from the dicotyledonous stems described. In this country we possess no indigenous monocotyledonous tree (the Butcher's Broom is the only indigenous shrub), but

the exotic Palms (fig. 72), instead of having tapering stems like our forest trees, possess them of much the same diameter from top to bottom.

FIG. 72.—*Livistonia australis*, a Fan Palm.

Within there is no separation into pith or bark. On the exterior there is an epidermis and a cortex, or false rind made up of the ends of the fibro-vascular bundles. These bundles

enter the stem from the bases of the leaves being continuous with the bundles present in them. At first they are narrow. They grow inwards, and then pass down the interior of the stem, gradually increasing in diameter. At length, having attained their largest size, they begin to curve outward again, thinning as they do till they end at the exterior (fig. 73).

FIG. 73.—Course of the vascular bundles of *Iris* in longitudinal section (diagrammatic).

FIG. 74.—Transverse section of fibro-vascular bundle of *Zea Mais*: *p*, thin-walled parenchyma of ground tissue of, *a*, outer and, *i*, inner part of stem, with thick-walled prosenchymatous ground tissue internal to it; *g*, *g*, large pitted vessels; *s*, spiral vessel; *r*, isolated ring of annular vessel; *z*, air cavity; *v*, *v*, cambiform tissue or soft bast. (After Sachs.)

The bundles are closed, containing no cambium, hence after their formation they cannot increase in size. A section across the stem will show the younger bundles within and the older ones without. Such a mode of growth is often termed **endogenous**, but it must be borne in mind that it is only at a part of their passage that this is true, as at the commencement and end they grow outwards.

In annual and herbaceous monocotyledons the ground tissue

is soft and delicate ; but in trees, as Palms, it is much hardened by secondary deposit, forming *woody parenchyma*.

It follows from this structure that it is impossible for such a stem to increase in thickness after the outer rind has become thoroughly hardened.

In some Monocotyledons of the Lily tribe, as the Aloe and Dragon-tree (fig. 75), there is a provision for the exogenous formation of new bundles, but in a different manner from that which takes place in Dicotyledons.

A layer of meristem is formed in the outer part of the ground tissue, by means of which the stem is increased in thickness, and in which new fibro-vascular bundles are formed.

In Monocotyledons the sap rises to the leaves through the xylem of the bundles, and descends through the phloëm, and apparently partly by the parenchymatous tissue.

FIG. 75.—Transverse section of stem of *Dracena*, near apex : *e*, epidermis ; *k*, cork ; *r*, cortical portion of ground tissue ; *b*, fibro-vascular bundle to leaf ; *m*, ground tissue of centre of stem ; *g*, fibro-vascular bundles ; *x*, meristem zone, developing new fibro-vascular bundles (*g'*) and new ground tissue (*st*). (After Sachs.)

EXTERNAL FORMS OF STEMS.

A section of the stem usually shows it to be more or less cylindrical in shape ; at other times it is angular, being either triangular, square, five-ribbed, etc. (fig. 76).

When the stem is herbaceous, and dies down annually, it is

called a **caulis** ; when woody and perennial, a **trunk** ; and when jointed, as in Grasses, a **culm**.

Generally stems are able to support themselves in an upright position, and are **erect** ; if they trail on the ground they are **prostrate** ; if, whilst thus reclining, they rise towards their extremities, they are **decumbent** ; or if they gradually rise from near the base, **ascending**.

FIG. 76.—I. Section of triangular stem. II. Section of square stem. III. Section of five-ribbed stem.

Some stems are **climbing**, attaching themselves to some object of support either by *root-lets* (as in the Ivy), or by *tendrils* (as in the Passion Flower and Sweet Pea). At other times they are **twining** around the object of support (as in the Bind-weed and Hop, fig. 77).

FIG. 77.—I. Stem of *Convolvulus arvensis* twining to the left. II. Stem of Hop twining to the right

There are certain terms which are applied to various forms of stems, some of which describe the aerial or above ground, and others the subterranean stems.

1. Aerial Stems.

a. The Runner.—This is well seen in the Strawberry, where a branch springing from a plant creeps along the ground (often with a modified leaf or scale upon it), and ultimately strikes in the soil, producing leaves and roots, and forming a new plant (fig. 78).

FIG. 78.—Runner of Strawberry (*Fragaria vesca*).

FIG. 79.—The offset of the Houseleek (*Sempervivum*).

b. The offset, seen in the Houseleek, much resembling the runner, but shorter and thicker (fig. 79).

c. The stolon, as in the Gooseberry and Currant, is really a branch given off above the ground striking into the earth and giving off roots and leaves, forming a fresh plant. This is often imitated by gardeners in the process of layering, when they bend down a branch into the soil, thus causing it to take root and produce a fresh plant.

FIG. 80.—Stolon.

d. The Sucker.—This differs from the last in being a branch springing from beneath the soil, and after proceeding for a short time in a horizontal direction; giving off roots as it does so, turns up and grows out of the ground, forming a new plant. The Rose and Mint are examples.

2. Subterranean Stems.

e. The rhizome or rootstock is a thickened stem creeping either at the surface of the soil or just below it, giving off leaves from the upper surface, and roots from the lower. As the leaves fall off year by year, they leave scars marking where

they had been. These, together with other subterranean stems, are popularly termed roots, but are distinguished from true roots in the manner already indicated. Examples are to be found in the Iris, Sweet Flag, Ginger, Solomon's Seal, etc.

FIG. 81.—Sucker.

FIG. 82.—Rhizome of Solomon's Seal (*Convallaria Polygonatum*): *a*, terminal bud from which is developed the next year's stem; *b*, this year's stem; *c*, *d*, scars of the stems of previous years.

FIG. 83.—Creeping rhizome of *Carex*.

f. The **soboles** or **creeping stem** is thinner than the rhizome, but otherwise resembles it. It is met with in the Sand Sedge (Fig. 83) and Couch Grass. In the former plant it is often of great use in binding together the loose sands of the sea shore, whilst in the latter it is a pest to the farmer.

g. The **tuber** is an underground stem or branch, which is much swollen by the deposition of a large quantity of starch and other food materials. It possesses leaves which are more or less modified. In the Potato (which is a good example of the tuber) the eyes are the modified leaf buds. It is a well-known fact that if the aerial branches of a Potato plant are earthed, their growth will be arrested and tubers will be formed.

FIG. 84.—A six-weeks-old Potato plant, developed from the seed, the upper branches, *a, b*, being cut off: *d*, cotyledons; in the axils of the cotyledons are developed the underground branches, *e, e*, which penetrate into the ground and form tubers, *f, g*, at their apex or in the axils of small leaves. The tubers are formed only on the branches which are produced in the axils of the cotyledons, never on the true roots *h*.

FIG. 85.—Single tuber of the Pig Nut (*Carum bulbocastanum*).

Other examples of tubers are to be seen in the Jerusalem Artichoke and in the Pig Nut.

The two following modifications of stem are only to be met with amongst monocotyledonous plants.

h. The **bulb** consists of a more or less flattened disc-like stem, giving off roots below, and scale-like leaves, together with stem and flowers, above.

The scale-like leaves have the power of developing in their

axils smaller bulbs or buds known as *cloves* or *bulbils* (*a*, fig. 86). There are two forms of bulb. When the inner scales are fleshy, and are covered by thin membranous ones, the bulb is said to be *tunicated*, as in the Onion. If there be no outer tunic, as in the Lily, the bulb is said to be *scaly* or *naked*.

FIG. 86.—Scaly (squamosa) bulb of the Onion: *b*, plate or disc; *a*, bulbils.

FIG. 87.—Corm of *Gladiolus segetum*. A, longitudinal section: *a*, last year's, *b*, this year's bulb; *c*, scape; *d*, scales; *x*, roots; B, after removal of the enveloping scales: *y*, bud, which will develop into next year's corm; *z*, bulbil.

i. The **corm** differs from the bulb in being much more solid, consisting of a larger disc and fewer scale-leaves. Examples are to be met with in the *Gladiolus*, *Snowdrop*, *Crocus*, *Colchicum*, etc.

CHAPTER VII.

BUDS AND RAMIFICATION.

BRANCHES of the stem first make their appearance as **buds**. These as a rule do not appear indiscriminately but at certain definite parts of the plant, viz., at the extremities of the stem

FIG. 88.—*a*, terminal bud ; *b*, axillary bud, the leaf in the axil of which it was produced having been removed.

FIG. 89.—Diagram of a longitudinal section of the apex of the stem of a dicotyledonous plant ; *m*, pith ; *f*, fibro-vascular bundles, both developed from the pleurome (*pl*), the bundles sending branches to the leaves ; *r*, corticle tissue ; *e*, epidermis ; *b*, *b*, young leaves, two showing their origin from protomeristem (*p*) ; *kn*, axillary bud. (After Prantl.)

and branches, when they are called **terminal buds** ; and in the axils of the leaves, that is to say, the angle formed between the leaf and the stem, when they are termed **axillary buds**.

If they grow from any other part of the plant they are said to be **adventitious**.

At first the bud consists entirely of parenchymatous tissue connected with the parenchyma of the stem. There is a central conical mass around which, after a while, vessels and wood cells are developed; outside these, parenchymatous tissue which forms bark, and which is covered with little scales of parenchyma variously overlapping one another, forming the rudimentary leaves.

The portions of the young stem to which these leaves are attached are known as **nodes**, whilst the stem between the nodes forms the **internodes**.

FIG. 90.—Branch spines of the Sloe (*Prunus spinosa*).

FIG. 91.—Prickles of the Rose.

In cold and temperate climates, where the buds remain dormant during the winter, unfolding during the following spring, the outer surface is protected by modified scales, which sometimes, as in the Horsechestnut and Poplar, possess resinous secretions, and at other times, as in Willows, are covered with hairs. These scales protect the young bud from the cold and frosts of the winter, and fall off when it begins to develop in the following spring.

The commencement of the development of the bud is by the growth of the internodes, by which the young leaves become gradually separated from one another and the branch is formed.

If all the normal buds of the plant were developed, the branching would follow regularly the arrangement of the leaves.

This uniformity is often interfered with : 1st, by the non-development of buds ; 2nd, by the formation of adventitious buds.

Sometimes many of the buds remain entirely undeveloped. At other times, instead of being developed into leaf-bearing branches, they form subsidiary organs.

1. **Spines** are often modified branches. They are met with in the Sloe or Blackthorn. At times they are small and destitute of leaves ; often they bear leaves, and under cultivation they become developed into leaf-bearing branches. Thus, whilst the Sloe is spiny, the cultivated Plum bears only leafy branches.

There is a great difference between spines (as in the Sloe and Locust-tree) and prickles (as in the Rose and Bramble). In the former case the spines are modified branches, and as such are connected with the internal parts of the stem ; in the latter case the prickles are simply hairs of the epidermis which have become hardened by the deposition of secondary deposit.

2. **Tendrils.** — Sometimes the buds become developed as tendrils or cirrhi, as in the Grape Vine, enabling the plant to hold on to the object of support.

Both spines and tendrils *may* be modifications of parts of leaves. The spines of the Barberry, and of some species of Acacia (fig. 129), and the tendrils of the Sweet Pea (fig. 93), are examples.

FIG. 92.—Stem tendrils of the Grape-vine : *v*, in the normal state ; *v*, bearing a bunch of grapes.

We can tell, however, which they are by their position. If they are in the axils of leaves they are modified branches ; if upon the stem or forming part of the leaf they are modified leaves.

In some cases adventitious buds are formed beneath the

FIG. 93.—Sweet Pea (*Lathyrus odoratus*).

bark, and are not developed externally. In such cases they produce considerable variations in the figure and grain of the wood. Bird's-eye Maple is a very good example of this.

Buds are often capable of being removed from one plant and made to grow upon another of the same family. Upon this fact depend the important operations of **grafting** and **budding**.

In grafting, a branch of a superior variety, possessing buds, is taken and implanted on a wild stock (fig. 94). The formative cambium round the wound grows, forming a protective succulent cushion of tissue known as a *callus* (fig. 95). The graft grows independently of the stock, receiving, however, its nourishment through it.

In budding, a bud, together with the surrounding bark, is

FIG. 94.—Grafting: *d*, the stock to which the graft is attached.

FIG. 95.—Diagrammatic representation of a longitudinal section through a graft: *cl*, the callus; *r*, bark; *m*, pith.

removed from a superior variety, and a T-shaped incision is made in the stock, beneath which the bark of the bud is inserted, the whole being bound round to protect it from the action of the atmosphere (fig. 96).

The bud grows in the same way as the graft.

The terms **vernation** and **præfoliation** are employed to express the way in which the young leaves are arranged in the bud. We have two things to notice, viz., 1st, the arrangement

of each individual leaf; 2nd, the disposition of the several leaves in the bud.

1. *The arrangement of the separate leaves.*—In the buds of the Firs they are **flat**. In other cases they are variously bent.

FIG. 96.—The various elements in the process of budding.

If the apex approaches the base, as in the Tulip-tree (fig. 97, I.), it is **reclinate**. If the two edges meet together, leaving the midrib in the centre, as in the Oak and Magnolia (II.), it is

FIG. 97. — Various methods of leaf-folding in buds.

conduplicate. If each side be folded several times like a fan, as in the Lady's Mantle, Beech, Sycamore, and Vine (III.), it is **plicate**. When the apex of the leaf is rolled up towards the base, as in the Sundews, Ferns, and Cycads (IV.), it is **circinate**.

When the leaf is rolled on itself, one margin being rolled towards the midrib, and the other margin rolled over it, as in the Apricot and Banana (v.), the folding is **convolute**. When the two margins are rolled towards the midrib on the under side of the leaf, as in the Dock and Rosemary (vi.), it is **revolute**. When the margins are rolled in the opposite way, that is, towards the upper surface of the leaf, as in the Violet and Water Lily (vii.), it is **involute**.

(The diagrams of vernation are often at first hard to understand, unless we remember they represent *sections* cut across the leaves. A good plan is to cut out a large leaf in paper and to bend it in the forms described, after which an examination should be made of actual specimens.)

FIG. 98.—Forms of leaf-arrangement in bud.

2. *The disposition of the several leaves in the bud.*—In this case the leaves are either flat, or only slightly convex, or they are bent or rolled.

(a) *Leaves flat or only slightly convex.*—The vernation is **valvate** (fig. 98, i.) when the leaves are placed in the same level and simply touch one another by their edges. If they are placed at different levels and overlap one another like tiles of a roof, as in the Lilac (ii. and iii.), it is **imbricate**. When the

overlapping is carried further (as in fig. iv.), it is said to be **spiral** or **twisted**.

(b) *The separate leaves bent or rolled*.—When, as in the Columbine, involute leaves touch by their edges without overlapping (v.), the vernation is **induplicate**. When, as in the Privet, conduplicate leaves are bent around one another (vi.), it is **equitant**; whilst when, as in the Sage, they are only half folded over one another (vii.) they are **obvolute** or **half equitant**.

When, as in the Apricot, a convolute leaf has another rolled outside it (viii.), the vernation is **supervolute**.

In considering branching, whether of root, stem, or leaf, we must carefully distinguish the main **axis**, **foot** or **podium**, and the branches. This, however, is not always easy.

1. In some cases the main axis ceases to grow when the branches are formed. Such branching is called **dichotomy** or **dichotomous branching**. The podium has at its extremity two growing points, each of which develops a branch. Sometimes both of these grow equally vigorously, each bifurcating in its turn, and a true **dichotomy** or **forked system** is produced (fig. 99, A). Sometimes one branch becomes more strongly developed than the other; the system now

FIG. 99.—Diagrams of dichotomous branching. A, normal dichotomy, the forked branches equally developed, and becoming the podia of new dichotomies. B, Bostrychoid dichotomy, one fork-branch only becoming the podium of a new dichotomy: in this case the left (l). C, cincinnal dichotomy; one fork branch, alternately left (l) and right (r), becoming the podium of a new dichotomy. B and C are sympodial arrangements. (After Sachs.)

becomes **sympodial**, the successive strong branches looking as though they were the continuous axis, and the weaker branches appearing to be lateral ones. If the stronger bifurcation is

always on the same side, a **helicoid** or **bostrychoid dichotomy** is formed (fig. 99, B). If the stronger bifurcation alternates, first to the right and then to the left, we have a **scorpioid** or **cicinnal dichotomy** (fig. 99, C).

2. If the axis is prolonged beyond the branch, a **monopodial** branching is produced. If the main axis continues to develop more strongly than the branches, the branching is said to be **racemose**; in other cases the main axis soon ceases to grow, and the shoots become strong; the branching is now said to be **cymose**.

There are two varieties of this:—

a. When two or more shoots arise near the apex of the podium and develop more strongly than the main axis, which soon ceases to grow. This is called **false dichotomy** (or if three branches, **trichotomy**, or if more than three, **polytomy**) (fig. 100, C).

FIG. 100.—Diagrams of sympodial varieties of monopodial branching. A and B, cicinnal monopodia. C, dichasium, or false dichotomy. D, bostrychoid monopodium. The axes are numbered in succession from 1 to 7. (After Sachs.)

b. When only one shoot grows it forms a **pseud-axis** or **sympodium**, which may form a **scorpioid** or **cicinnal cyme** if the branches come off on opposite sides (fig. 100, A, B), or a **helicoid cyme** if they all come off on the same side (fig. 100, D).

SUMMARY OF FORMS OF BRANCHING.

True Dichotomous branching is very rare, being seldom met with in leafy shoots. It may be seen in the roots of Lycopods, in the shoots of Selaginella, and in the fronds of some ferns. Racemose branching is met with in the stem of conifers, also in the compound leaves of umbellifers and in the roots of dicotyledons. A false dichotomy is seen in the inflorescence of chickweed and other plants of the order Caryophyllaceæ, also in the stem of Mistletoe. The sympodial cyme is to be met with in the annual shoots of many of our forest trees, such as the Elm, Beech, and Hazel.

CHAPTER VIII.

STRUCTURE AND FUNCTIONS OF LEAVES.

WHEN a leaf is perfectly complete, it consists of three parts :—
 1. The flat expanded portion which is popularly called the leaf. This is the **lamina**, or **blade**. 2. The stalk, which attaches

FIG. 101.—Oval leaf of the Apple, with two free stipules.

FIG. 102.—Sessile leaves of Shepherd's-purse (*Capsella bursa-pastoris*).

this to the stem, the **petiole** or **leaf-stalk**. 3. The little leaf-like projections at the point of union between the petiole and the stem, the **stipules**.

In very many cases, however, there are only one or two of these parts present. If the petiole be absent, the leaf is said to be **sessile**; if the stipules, **exstipulate**.

The Wallflower and Shepherd's-purse (fig. 102) are examples of plants with leaves which consist of lamina only. In some of the leaves of the Australian Acacias (fig. 103), we have only the petiole developed. It grows in a flattened leaf-like expansion know as a **phyllode** (fig. 103, *a*, *b*).

FIG. 103.—Leaf of *Acacia melanoxylon*, showing phyllodes *a*, *b*.

In the *Lathyrus Aphaca* (fig. 104) the stipules are the only parts which are developed in a leaf-like manner, the lamina and petiole being converted into a tendril.

In structure the leaf consists of parenchyma, which is intimately connected with the outer parenchyma of the stem, and prosenchyma forming the veins, and which is in like manner connected with the xylem and phloëm.

In a vertical section through the leaf we find the following parts (fig. 105):—

1. A flattened **epidermis** coating the upper (*b*) and under (*e*) sides. As a rule, the under surface possesses a greater number of stomata than does the upper.

FIG. 104.—*Lathyrus Aphaca*: *r*, tendril; *b*, flower; *f*, fruit; *s*, stipule.

FIG. 105.—Diagrammatic section of leaf: *a*, cuticle of upper, *f*, of lower side; *b*, epidermis of upper, *e*, of lower side; *c*, cells of upper side; *d*, stellate cells of lower side; *g*, *g*, stomata; *h*, *h*, hairs.

Professor Bentley gives the following table of the number of stomata found in a square inch of the two surfaces respectively of the various plants:—

	Upper Surface.	Under Surface.
Mezereon	None	4,000
Pæony	"	13,790
Vine	"	13,600
Olive	"	57,600
Holly	"	63,600
Laurustinus	"	90,000
Cherry Laurel	"	90,000
Lilac	"	160,000
Hydrangea	"	160,000
Mistletoe	200	200
Tradescantia	2,000	2,000
Houseleek	10,710	6,000
Garden Flag	11,572	11,572
Aloe	25,000	20,000
Yucca	40,000	40,000
Clove Pink	38,500	38,500

Besides stomata, the epidermis is very frequently provided with hairs of various kinds.

These are simply prolongations of the epidermal cells, sometimes unicellular (fig. 106, I.), sometimes multicellular (fig. 106, II.).

They vary much in their shape, sometimes being simple and at other times branched.

An interesting modification is seen in glandular hairs which contain various secretions ; of these stinging hairs, as are found in the stinging-nettle, are good examples. In this case there is a little bag at the base of the hollow hair, containing an acrid fluid, and surrounded by a number of elastic cells. The point of the hair is sharp, and is protected by a little cap. When the nettle is touched lightly, the cap is broken off, the point of the hair pierces the skin, and a drop of the stinging juice is forced into the blood. If the nettle be grasped firmly the sting is broken lower down, and hence there is no sharp point to pierce the skin, and the juice is simply poured out upon the exterior.

2. The surface of the epidermis is generally covered with a thin structureless layer, the **cuticle** (fig. 105, *a* and *f*).

3. The parenchyma of the interior of the leaf consists of cells containing chlorophyll.

There is a difference, however, in their arrangement in the different parts of the leaf. Towards the upper surface the cells are packed closely together (*c*, fig. 105), whilst towards the under surface we find examples of stellate parenchyma, leaving air spaces between the cells (*d*, fig. 105). This is the cause of the fact that in most leaves the under surface is lighter in colour than the upper, as there is less chlorophyll packed there.

The upper parts of the veins are in direct communication with the wood of the stem, whilst the lower parts are connected with the liber. At the edges of the leaves there is a passage between the upper and lower sides, so that the sap which passes up the wood flows out through the upper part of the veins, back through the under surface to the liber, and so down the stem.

There is a great difference in the **venation** or arrangement

FIG. 106.—Simple hairs: I. Unicellular hair from the leaf of a *Pelargonium*. II. Multicellular hair from the stem of *Geranium pratense*.

FIG. 107.—Stinging hair of the nettle (*Urtica dioica*): the corroding fluid flows out of the hair when the virreous knob-shaped apex is broken off.

of the veins of the leaves in the two great groups of flowering plants.

In Dicotyledons the smaller veins run together, forming a complete network known as **reticulate venation** (fig. 108)

FIG. 108.—Reticulately veined leaf of *Acer acutifolium*.

In Monocotyledons, as a rule, there is no network formed between the principal veins, and the venation is said to be

FIG. 109.—Parallel venation.

parallel (fig. 109). (Some Monocotyledons, however, as the Aroids, have net-veined leaves.)

There are varieties of both net-veined and parallel-veined leaves.

If we take the net-veined leaves, we find that there is either a single principal vein or midrib, as in the Guelder Rose (fig. 110), when the leaf is said to be **unicostate**, or there are several principal veins, as in the Maple (fig. 108), when the leaf is **multicostate**.

Again, amongst unicostate leaves in some cases the smaller veins curve towards the apex (fig. 110), when we may term the leaf **curved-veined**; in other cases they run more at right angles from the midrib to the margin (fig. 111), when it is said to be **feather-veined**.

FIG. 110. — Dentate ovate leaf of the Guelder Rose, with unicostate venation (*Viburnum Opulus*).

FIG. 111. — Runcinate leaf of the Dandelion, feather-veined.

FIG. 112. — Converging veined leaf of Cinnamon.

There are also two varieties of the multicostate leaves. In some cases, as in the Maple (fig. 108), the diverging ribs never meet again. The venation of the leaf is then said to be **diverging** or **palmate**. In other cases, as in the Cinnamon (fig. 112), they meet again at the apex, and the leaf is **converging veined**.

Of the parallel-veined leaves there are three varieties. When, as in the Grass (fig. 109), the veins all run from the base to the apex, it is **straight veined**. When, as in the Banana, there is a central midrib, and the side veins run off to the margin, it is **transverse veined**. When, as in the Fan Palm (fig. 72), there are several veins diverging from a common centre, it is **radiating veined**.

We may tabulate these forms of venation as follows :—

FIG. 113.—Lyrate-crenate leaf of the White Mustard (*Brassica alba*).

In describing leaves, besides the venation, we have to take into account the following points :—1. Composition ; 2. Margin ; 3. Incision ; 4. Apex ; 5. General Outline.

1. **Composition**.—Leaves are either **simple** or **compound**. In simple leaves, as in the Apple (fig. 101), there is only a single lamina ; in compound leaves, as the Acacia (fig. 103), the lamina is divided into a number of leaflets articulated to the common petiole.

2. **Margin**.—The condition of this depends upon the extent to which the parenchyma is developed between the veins. The margin may be **entire**, as in Grasses. More often there are indentations.

If the teeth thus formed are rounded (fig. 113), the margin is **crenate**. If they are sharp, and point straight outwards (fig. 110), it is **dentate**. If sharp and pointing

towards the apex, like teeth of a saw (fig. 101), **serrate**.

Sometimes the teeth are themselves divided, and we get **bicrenate**, **duplico-dentate**, and **biserrate** margins.

If the margin of the leaf be covered with numerous hairs (fig. 114), it is **ciliate**. If there be alternate concavities and convexities larger than crenated indentations, the margin is **sinuate** (fig. 115).

When the teeth are very long and sharp, the margin is **spiny** (fig. 116), and when the margin is very irregular, as in the garden Endive and curled Dock, it is **crisped**.

FIG. 114.—Ciliate leaf of the Beech.

FIG. 115.—Sinuate leaf of the Oak.

FIG. 116.—Spiny leaf of the Holly.

3. **Incision**.—We apply this term if the margin be more deeply indented than in the instances already described. If the indentations reach to midway between the margin and the midrib or petiole, we speak of them as **fissures**, and the portions of leaf between them as **lobes**, and the leaf is said to be *bi-*, *tri-*, etc., *-fid*. If the divisions go nearly to the base, or midrib, they are **partitions**, and the leaf is *bi-*, *tri-*, &c., *-partite*. If quite down to the midrib or base **segments**, the leaf is *bi-*, *tri-*, &c., *-sected*. (For further remarks on this point see under the head of Outline.)

4. **Apex**.—If the apex of the leaf be rounded (fig. 115), it is **obtuse** or **blunt**. If it be sharp pointed (fig. 110), it is **acute**, and if it gradually tapers to a point (fig. 117), it is **acuminate**. When there is a rounded head, and a broad shallow notch in it, the apex is **retuse**, and when the notch is more triangular

(fig. 118), it is **emarginate**. When the apex is very abrupt as though cut off, it is said to be **truncate**.

FIG. 117. — Acuminate leaf of the Pellitory (*Parietaria*).

FIG. 118. — Leaf of *Oxalis micrantha*, with three obcordate leaflets.

FIG. 119. — Mucronate leaflet of the Lucerne.

FIG. 120. — *Pinus sylvestris*, the Scotch Fir, with acerose leaves.

FIG. 121. — Lanceolate leaf of the Privet.

When the apex is flattened and has a sharp point projecting (fig. 119), it is called **mucronate**.

5. **General Outline**.—Various terms are employed for the description of the general outline.

If, as in the Grasses (fig. 109), the two margins of the lamina are nearly parallel and the lamina itself is narrow, the leaf is **linear**.

If the leaf be sharp pointed and needle-like, as in many Conifers (fig. 120), it is **acero**se. When the leaf is somewhat broad in the centre, and tapers towards the two extremities, as in the Privet, it is **lanceolate** (fig. 121). If more rounded at the extremities and broader in the centre, it is **oval**, or **elliptical** (fig. 101), and **oblong** when rather long. When, as in the Guelder Rose (fig. 110), the leaf is broad and rounded at the base, tapering to a point at the apex, it is **ovate** or egg-shaped; and if the reverse, **obovate**, or inversely egg-shaped.

FIG. 122.—Orbicular leaf of *Malva rotundifolia*.

FIG. 123.—Cordate leaf of *Lanium*.

When the leaf is nearly round (fig. 122) it is **orbicular** or **subrotund**. When, as in the case of the *Lanium* (fig. 123), the leaf is somewhat hollowed out at the base, and pointed at the apex, so as to be roughly like a heart in a pack of playing cards, it is **cordate** or heart-shaped, and when the reverse (fig. 118), **obcordate**.

If the apex is rounded, instead of pointed, whilst the base is hollowed, as in the Ground Ivy (fig. 124), the outline is **reniform** or kidney-shaped.

When the apex is rounded, and the leaf gradually tapers to the base (fig. 125), it is **spathulate** or spoon-shaped; or if it is more tapering, as in the leaflets of the Horse-chestnut (fig. 126), the outline is said to be **cuneate** or wedge-shaped.

When the leaf is somewhat of the form of an arrow-head (fig. 127), it is called **sagittate** or arrow-shaped ; or if the barbs of the arrow point out more at a right angle to the blade, the leaf is **hastate** or halbert shaped (fig. 128).

There are also several terms which are applied to the outlines of compound and much divided leaves. Thus, if a compound leaf has two leaflets it is **bi-nate** ; if three, **ternate** (fig. 118). A **quadrifoliate** leaf has four, a **quinate** five, a **septenate** seven, and a **multifoliate** leaf more than seven leaflets springing from a common

FIG. 124. — Reniform leaf of the Ground Ivy (*Nepeta Glechoma*).

FIG. 125. — Spathulate leaf of the Ox-eyed Daisy (*Chrysanthemum leucanthemum*.)

FIG. 126. — Cuneate leaflet from the leaf of the Horse-chestnut.

FIG. 127. — Sagittate leaf of *Convolvulus arvensis*.

FIG. 128. — Hastate leaf of *Rumex acetosa*.

point. When the leaflets are arranged on either side of the central stalk, like barbs on a feather, the leaf is said to be **pinnate**. Of these leaves there are two varieties, viz., **impairipinnate** or unequally pinnate, when there is an odd lobe at

the extremity (fig. 129), and **paripinnate**, or equally pinnate, when the number of lobes present is even (fig. 130).

FIG. 129.—Imparipinnate leaf of the 'Acacia' (*Robinia Pseudacacia*) with opposite leaflets (and spinous stipules).

FIG. 130.—Paripinnate leaf of *Lathyrus macrorhizus* (with auriculate or ear-shaped stipules), the rachis ending in a point.

FIG. 131.—Pinnatisect leaf of the Common Poppy (*Papaver Rhæas*).

When a simple leaf is divided in a pinnate manner, it is **pinnatifid**, **pinnatipartite**, or **pinnatisect** (fig. 131), according to the depth of the incisions. When a pinnatifid leaf

has its terminal lobe large and rounded, and the side lobes gradually getting smaller towards the base (fig. 113), it is **lyrate** ;

FIG. 132.—Bipinnate leaf of *Gleditschia triacanthos*.

whilst if the terminal lobe is triangular, and the lobes are also angular (fig. 111), it is **runcinate**.

When each of the pinnæ of a pinnate leaf is itself pinnate.

FIG. 133.—Tripinnate leaf of *Thalictrum*.

the leaf is said to be **bipinnate**. If the division be carried a step further, it is **tripinnate** (fig. 133).

When the divisions of the leaf spread out like the fingers

of a hand, the leaf is **palmate** (fig. 134), **palmatifid** (fig. 108), **palmatipartite** and **palmatisected** (fig. 135).

When a palmatisected leaf is itself cut up into segments, it is **dissected** or **laciniate** (fig. 136).

FIG. 134.—Palminerved leaf of *Geranium pratense* (nature printed).

FIG. 135.—Palmatisect leaf of the Monkshood (*Aconitum*).

FIG. 136.—Heteromorphic leaves of the Water Crowfoot (*Ranunculus aquatilis*): the floating leaves trilobed, the submerged leaves lacinate.

FIG. 137.—Pedate leaf of the Christmas Rose (*Helleborus niger*).

Sometimes the lateral lobes of a palmate leaf are themselves divided, giving the whole somewhat the appearance of a bird's foot (fig. 137). The leaf is then **pedate**.

There are certain terms which are applied to the attachment of the leaves to the stem. Thus when placed one above the other upon opposite sides of the stem, they are **alternate**. If placed in pairs on opposite sides, they are **opposite**. If the alternate pairs of opposite leaves are placed at right angles to

FIG. 138.—Decussate leaves of the Scarlet Pimpernel (*Anagallis arvensis*), with axillary flowers.

FIG. 139.—Verticillate leaves of the Madder (*Rubia tinctorum*).

FIG. 140.—Connate leaves of the Honeysuckle.

one another (fig. 138), they are **decussate**. When there are more than two leaves forming a whorl round the stem (fig. 139), they are said to be **verticillate**. When two opposite leaves have their bases so united as to form apparently but one (fig. 140), often thus producing a cup, as in the Teasel, they are **connate**. If the base of the leaf, whether petiole, lamina, or

stipules, embraces the stem, the leaf is **amplexicaul**, the part surrounding the stem being called the **vagina** or **sheath**.

If the stem grows through the leaf, the latter is said to be **perfoliate** (fig. 141), whilst, if any part of the leaf adheres to the stem, causing the latter to be winged (fig. 142), the leaf is said to be **decurrent**.

FIG. 141.—Perfoliate leaf of *Bupleurum rotundifolium*.

FIG. 142.—Decurrent leaf of *Symphytum officinale*, the stem hence becoming winged on one side.

If the leaves grow from the point of junction of the root and stem, or if the stem be so reduced as to be almost obliterated, they are said to be **radical**. Leaves growing from the main stem are called **cauline**, and those from the branches, **ramal**.

FUNCTIONS OF THE LEAVES.

1. **To absorb food for the plant.**—We have already seen how the roots take up from the soil the various substances needed for the life of the plant. One very important substance, however, is not taken up by the roots of green plants, and this is carbon.

This element exists in the atmosphere in the form of carbon dioxide or carbonic acid gas, a compound of carbon and

oxygen, CO_2 . It is produced wherever breathing, burning, and decay of organic bodies are taking place.

The composition of a thousand parts, by volume, of atmospheric air is as follows :—

Nitrogen	779'50.
Oxygen	206'10.
Water (variable)	14'00.
Carbon dioxide	40.
Various gases	traces.
	<hr/> 1,000'00.

That is to say that a thousand cubic feet of air contain not quite half a cubic foot of carbonic acid. Small as this quantity may appear to be, it is the source of the carbon of the plant.

The carbon dioxide enters with the other constituents of the air by means of the stomata into the interior of the leaf, there to serve for the nourishment of the plant.

2. To assimilate the food absorbed.—The food materials which are taken up by the root are not changed as they are carried up to the leaves. The sap becomes thicker by evaporation, but when it enters the leaves it still contains simply mineral substances. In the leaves, however, it is brought into contact with the carbon dioxide, and a marvellous change takes place. In the presence of the chlorophyll and under the action of light, the carbonic acid gas is decomposed: its oxygen is restored to the atmosphere, whilst the carbon is chemically united with the water and the mineral substances, to build up new and organic compounds. These changes will only take place in the light, and go on in all the green parts of the plants. It is owing to this that the amount of carbonic acid in the atmosphere is kept down, and the air purified and rendered fit for man to breathe; hence the importance of open spaces with trees in the midst of our cities.

One of the first substances formed is generally oxalic acid, which unites with the lime of the sulphate of lime, setting free the sulphur which is required for the manufacture of the various albuminoids. Other organic substances soon follow, and the

food which passes down the liber is in a fit state to be absorbed by the plant.

(It is generally stated that the presence of chlorophyll is necessary to the decomposition of carbon dioxide. Recent observations, however, have raised the suggestion that chlorophyll may be the *result*, not the *cause*, of the decomposition. The question needs further investigation, but the presence of chlorophyll and the decomposition of carbonic acid always go together.)

A very important point to remember is, that the plant does not absorb free nitrogen from the atmosphere. All the nitrogen required by the plant is taken in either as ammonia or nitrates.

3. **As a breathing organ.**—Plants, like animals, carry on a process of respiration, *i.e.* they take in atmospheric oxygen, which combines with the carbon and hydrogen of the tissues forming carbon dioxide and water, which are restored to the air. The respiration, however, of plants is much less than that of animals ; it differs in its amount in various plants, and in the different parts of the same plant. The more energetic the growth, the greater the amount of respiration : hence it is especially well seen in quickly germinating seeds, and unfolding leaf and flower buds.

The oxygen passes into the interior of the plant by means of the stomata, and by the same openings the carbonic acid gas is passed out into the atmosphere. This change goes on continually, irrespective of the presence or absence of light. During the daytime the feeding by the decomposition of carbon dioxide and assimilation of the carbon is so greatly in excess of the respiratory act, that it completely overshadows it, and apparently nothing is going on but the decomposition of the carbonic acid ; but in the night time, when, owing to the absence of the light, no assimilation is taking place, the breathing can be perceived.

4. **As an organ of transpiration.**—A large portion of the water which is taken in by the roots of the plant escapes by the leaves. By means of this evaporation the sap becomes thickened as it ascends the stem. The transpiration takes place by means of the epidermis, and especially through the

stomata. The amount which is evaporated depends upon certain conditions, viz. :—

a. The state of the atmosphere. All other things being equal, more moisture will be given off in dry than in moist atmosphere.

b. The amount of light. The greater the light, the greater the transpiration.

c. The structure of the epidermis. In many succulent plants the epidermis is very thick, thus preventing an excess of evaporation.

d. There is a greater evaporation from the lower than the upper sides of the leaves.

The amount of water transpired is often very great, as is shown by experiments which were first performed by Hales in 1724. A Sunflower plant, $3\frac{1}{2}$ feet high, weighing 3 lbs., and with a surface of 5,616 square inches, exhaled a pint of water a day ; a Cabbage plant with 2,736 square inches, 19 fluid ounces ; a Lemon tree with 2,557 square inches, 6 fluid ounces.

The action of Wardian cases depends upon this continual evaporation. By this means the water which evaporates collects on the glass, and running down once more, waters the plants.

The transpiration of plants also plays an important part in determining the humidity of the atmosphere where they grow. We always find that if there are forests of trees the atmosphere in the neighbourhood is moist ; whilst, on the other hand, there have been numerous cases where the clearing of a tract of country has materially interfered with the rainfall, producing droughts.

5. As organs of circulation.—From the fact of transpiration follows the next, that the leaves tend to produce a flow of sap upwards. As evaporation takes place there is a continual flow of water up the wood to take its place : the greater the evaporation the more rapid the sap circulation. (See Chapter XII.)

The foregoing functions are performed by all leaves ; the following, however, are exceptional.

6. In some cases the leaves act as carnivorous organs.—
Some plants seem to possess the power of absorbing their

FIG. 143.—Venus's Fly-trap (*Dionaea muscipula*).

nitrogen by means of organic compounds containing it. Good examples are to be seen in Venus's Fly-trap (fig. 143), and the Sundews of our own country. If we examine the leaves of

either of these plants, we find that their upper surfaces are covered with glandular hairs which, when touched, exude a few drops of a sticky liquid which adheres to the fingers, and will be drawn out into a fine thread.

If an insect settles upon the leaf it becomes arrested, and gradually the leaf folds over, enclosing it. It thus remains closed for a short time, and on opening again there is found merely the outer shell of the insect, all the nutritive part having been absorbed by the plant. The leaf seems to contain a substance analogous to, if not identical with, the pepsine of the animal stomach, which possesses the power of rendering nitrogenous substances soluble. Other carnivorous plants have the same power of absorbing organic food materials by their leaves in various ways.

7. In some cases the leaves act as organs of support.—We have already seen that parts of the leaf may be converted into tendrils (figs. 93 and 104), thus twining round the organ of support and sustaining the stem. In the *Tropæolum* the leaf-stalk itself twines and supports the plant.

Parasites.—It has been noted (page 34) that some plants obtain their food through the medium of others. Such plants are known as parasites. We may divide them under three heads.

(a) **Semi-Parasites.**—These can obtain some food from the soil, but not sufficient to enable them to grow in a luxuriant manner.

If some seeds of Yellow Rattle be allowed to germinate in earth they will grow, but the plants will not be fully developed. If, however, the seeds be sown amongst some grass, strong, well-developed Rattles will be obtained. The Rattle sends its roots into the roots of the grass and draws sap out of them, which is afterwards elaborated in its own leaves.

(b) **Green parasites.**—Mistletoe (fig. 66) is a type of this class. It cannot obtain any nourishment for itself out of the soil, and has to depend entirely upon the tree into whose stem it sends its roots. At the same time its leaves contain chlorophyll, and hence it can decompose the carbon dioxide of the atmosphere, and assimilate food for itself.

(c) **Perfect parasites.**—Of this group the Broom-rape and Dodder are types. These plants possess no chlorophyll, hence they cannot decompose the atmospheric carbon dioxide, so they obtain from the plants on which they live sap which is already elaborated.

In the case of the Broom-rape the leaves are modified into scales destitute of chlorophyll, whilst in the Dodder leaves are entirely absent.

CHAPTER IX.

BRACTS AND INFLORESCENCE.

THE term **bract** is employed for those leaves in whose axils flower buds instead of leaf buds arise, or for any appendage growing upon the flower-stalk below the flower.

In some cases, as in the White Dead-nettle, bracts cannot be distinguished, except by their position, from the true leaves of the plant; in other cases, whilst still leaf-like, they differ in shape from the other leaves of the same plant. In all these cases the bracts are said to be foliaceous or leafy bracts.

FIG. 144.—Capitulum of Marigold, with imbricate involucre.

Sometimes the bracts are coloured, being then often mistaken for the true flowers, as in the *Hydrangea*, and in some species of *Euphorbia*. In other cases the bracts are small and scale-like.

When several bracts surround a single flower as in the *Pink*, or a head of flowers as in the *Marigold* (fig. 144), they form an **involucre**.

When a single bract is enlarged and ensheaths a single flower whilst in the young state, as in the *Narcissus* and *Snowflake*, or a head of flowers, as in the *Cuckoo-pint* or *Palm*, it is called a **spathe**.

When bracts are scaly, they are said to be *squamous*, and

the special scaly bracts which enclose the flowers of the Grass and Sedge tribes are *pales* and *glumes*.

If the bracts fall before, or soon after, the flower opens, they are *deciduous* ; whilst if they remain (sometimes even to the ripening of the fruit), *persistent*.

If bracts be present, the plant is said to be *bracteate* ; if absent, *ebracteate*.

FIG. 145.—Simple raceme of *Antirrhinum majus*.

FIG. 146.—Longitudinal section through the capitulum of the Burdock (*Arctium Lappa*).

The term **inflorescence** is employed to describe the arrangement of the flowers upon the stem. In some cases, as in the Tulip, there is a single flower at the top of the stalk, no others being formed below. The inflorescence is then said to be single-flowered. More often there are several flowers variously arranged. Inflorescences are divided under two heads.

If we examine such a bunch of flowers as the Snapdragon (fig. 145), or Wallflower, or Stock, we find that the oldest flowers are towards the base, the younger ones being towards the apex. Such an inflorescence is said to be **indefinite**. Sometimes in the indefinite inflorescences, as in the Burdock (fig. 146), or Thistle, or Dandelion, the flowers instead of being arranged

one above another are side by side. In this case the younger flowers are towards the centre, and the older ones around them, and hence the indefinite inflorescence is also spoken of as **centripetal**, or centre-seeking. In the Pink, on the other hand (fig. 147), the stalk is capped by a flower which is the first to open, the younger ones budding below it. This is termed **definite inflorescence**, or (since, when the flowers are

FIG. 147.—*Dianthus Caryophyllus* : portion of plant with definite inflorescence.

FIG. 148.—Simple spike of *Verbena officinalis*.

on the same level, the older ones will be towards the centre, and the younger ones outside) **centrifugal**.

Of each of these forms there are several varieties.

Indefinite or Centripetal Inflorescence.—In the case of the indefinite inflorescence the axis may either be lengthened as in the Snapdragon, or arrested as in the Burdock and Dandelion ; and in either case the flowers may be sessile or stalked.

A **spike** is an indefinite inflorescence with a lengthened

axis and sessile flowers, as in the Verbena (fig. 148), Plantain, or Wheat.

A **raceme** is an indefinite inflorescence with a lengthened axis and stalked flowers, as in the Snapdragon (fig. 145) and Currant (fig. 149).

A **capitulum** is an indefinite inflorescence with shortened axis and sessile flowers, as in the Marigold (fig. 144), Burdock (fig. 146), and Dandelion.

An **umbel** is an indefinite inflorescence with shortened axis and stalked flowers, as in the Cherry (fig. 150). If

FIG. 149.—Simple raceme of the Currant.

FIG. 150.—Simple umbel of the Cherry.

FIG. 151.—Compound umbel of Fool's Parsley (*Ethusa Cynapium*); common involucre wanting; involucl. of three leaves each.

each branch of the umbel be itself branched, the *compound umbel* is produced, as in the Fool's Parsley (fig. 151). Generally the capitulum and umbel are surrounded by an involucre of bracts, and sometimes the secondary branches of the compound umbel have a special involucre which is called the *involucl.*

Special names are given to varieties of some of these forms.

VARIETIES OF SPIKE.

A **catkin** or **amentum** is a deciduous spike of unisexual flowers, as in the Oak (fig. 152), Hazel, or Willow.

A **spadix** is a fleshy spike bearing several unisexual flowers, the whole enveloped in a spathe, as in the Arum (fig. 153).

A **strobilus** is a spike of unisexual flowers with membranous bracts, as in the Hop.

FIG. 152.—Catkin or amentum of the Oak.

FIG. 153.—Spadix of Arum: *a*, barren stamens; *b*, stamens; *c*, pistils.

FIG. 154.—Cone of the Scotch Fir.

A **cone** is a spike of unisexual flowers with lignified bracts, as in the Fir (fig. 154).

VARIETIES OF RACEME.

A **corymb** is a raceme where the stalks or pedicels are of different lengths, the lower ones being the longest, so that the flowers form a flat-topped head, as in the Hawthorn and some species of *Cerasus*.

A **panicle** is a compound raceme, that is, one where each branch is itself branched, as in some *Yuccas*.

A **thyrsus** is a panicle with very short pedicels, as in the Horse-chestnut and Lilac.

VARIETY OF CAPITULUM.

The **hypanthodium** has the end of the stalk hollowed out, the flowers growing within, as in the Fig (fig. 155).

FIG. 155.—I. Longitudinal section through the hypanthodium of a Fig, exposing the flowers in its interior. II. A piece with five female flowers : *s*, pistil ; *b*, perianth.

We may tabulate the forms of indefinite inflorescence as follows :—

Indefinite Inflorescence.			
With lengthened axis.		With shortened axis.	
With sessile flowers.	With stalked flowers.	With sessile flowers.	With stalked flowers.
SPIKE.	RACEME.	CAPITULUM.	UMBEL.
Amentum.	Corymb.	Hypanthodium.	Compound umbel.
Spadix.	Panicle.		
Strobilus.	Thyrus.		
Cone.			

Varities {

Definite or Centrifugal Inflorescence.—The general name for these is **Cyme**. We cannot well tabulate them in the same way that we do the indefinite. In many cases we employ the name of the indefinite inflorescence as an adjective to qualify the term *cyme*. Thus we have a **spiked cyme** in *Sedum*,

racemose cyme in Campanulas, **panicled cyme** in Privet, **corymbose cyme** in Laurustinus, etc.

The **dichotomous cyme** (fig. 156) is one where two branches spring from beneath the terminal flower, each in its turn capped by a flower and developing two branches just below it, as in the Chickweed and Centaury. If there be three stalks the cyme is *trichotomous*.

FIG. 156.—Dichotomous cyme of *Cerastium*.

FIG. 157.—Cymose inflorescence of *Myosotis*.

If but one stalk be given off, which is again branched on the same side, and this again repeated a number of times always on the same side, so that the young flowers become coiled like a scorpion's tail or a shepherd's crook, the **scorpioid cyme** is formed, as in the Forget-me-not, and many of the Boraginaceæ (fig. 157).

The **fascicle** is a cyme which has a large number of flowers on short stalks, as in the Sweet William.

The **glomerulus** is a cyme with a large number of sessile flowers, as in the Box.

The **verticillaster** consists of two cymose bunches placed on opposite sides of the stem, so as apparently to produce a whorl, as in the *Lamium album* (fig. 158), and other members of the Labiatae.

FIG 158.—Verticillaster of *Lamium album*.

Mixed Inflorescences.—Sometimes in a plant there is a mixture of the two kinds of inflorescence. Thus in the Dead-nettle, whilst each separate inflorescence is definite, being a verticillaster, yet, taking the whole plant, the arrangement is indefinite, the lower verticillasters opening first. On the other hand, in most of the members of the natural order Compositae, whilst each capitulum is itself indefinite, yet, taking the plant as a whole, the arrangement is definite, for the terminal capitulum is the first to open.

Such an inflorescence is said to be mixed.

CHAPTER X.

STRUCTURE AND FUNCTIONS OF PARTS OF THE FLOWER.

THE **flower** is that part of the plant which **suberves** the **purposes of reproduction**.

When complete, the flower consists of four whorls or series of organs. The two outer ones are merely coverings, whilst the inner ones form the essential organs.

Commencing at the exterior, the outer coat is known as the **calyx** (fig. 159, *K*), and each division of which it is made up is a **sepal**. The inner coat is the **corolla** (fig. 159, *B*), and each separate part of it a **petal**.

FIG. 159.—Flower of *Sisymbrium Alliaria* : *K*, calyx ; *B*, corolla ; *S*, stamens ; *St*, pistil.

If both coats be present, as in the Buttercup, the flower is said to be **dichlamydeous** ; if only one, as in the Anemone, **monochlamydeous** ; if both be absent, as in the Ash, **achlamydeous**.

The outermost whorl of the essential organs of the flower is the **androecium** (fig. 159, *S*), consisting of one or more **stamens** ; whilst within there is the **pistil** or **gynoecium** (fig. 159, *St*), consisting of one or more **carpels**.

This will be a convenient place to note the distinction that is drawn between a complete and a perfect flower.

For a flower to be **complete**, all four of the whorls must be present ; if any one be absent, the flower is **incomplete**. On the other hand, the term **perfect** is applied to all those flowers in which both androecium and pistil are present, although, as in the Anemone, one of the coats may be wanting, or even, as

in some flowers of the Ash, both coats may be absent. An **imperfect** flower is one where there is only one whorl of the essential organs, as in the Hazel and Oak.

It follows that every complete flower must be perfect, but every perfect flower is not necessarily complete ; on the other hand, every imperfect flower must be incomplete, but every incomplete flower is not imperfect.

Perfect flowers are sometimes spoken of as **hermaphrodite**.

Imperfect flowers are either **staminate** (fig. 160) if the pistil be absent, or **pistillate** (fig. 161) if the stamens be absent.

FIG. 160.—Staminate (♂) flower of *Callitriche verna*, with two sickle-shaped bracts.

FIG. 161.—Pistillate (♀) flower of *Callitriche verna*.

FIG. 162.—The Hazel (*Corylus Avellana*); branch with male and female flowers.

If staminate and pistillate flowers grow upon the same plant, as in the Hazel (fig. 162), Oak, and Birch, the plant is

said to be **monœcious** ; if they grow upon separate plants, as in the Willow (fig. 163), Juniper, and Poplar, it is **diœcious** ; whilst if on the same plant are to be found hermaphrodite, staminate, and pistillate flowers, as in the Ash, it is **polygamous**.

We must now notice each part of the flower more particularly.

FIG. 163.—Sallow (*Salix caprea*). I. Male catkin. II. Female catkin.

FIG. 164.—Flower of the Strawberry, with calyx in two rows.

FIG. 165.—Longitudinal section through the flower of *Ranunculus acris*, showing the hypogynous calyx, corolla, and stamens.

CALYX.—The sepals are generally arranged in one whorl, but in some cases, as in the Strawberry (fig. 164), there may be two (or even, as in the Cotton, three) whorls.

Generally the sepals are green, but sometimes, as in the Fuchsia, Larkspur, and Garden Nasturtium, they are coloured, or petaloid.

When the calyx is inserted beneath the ovary upon the end of the flower-stalk (which is known as the **thalamus**), it is said to be **inferior**, and the ovary is **superior**, as in the *Ranunculus* (fig. 165, and fig. 166, H and P).

FIG. 166.—Diagrammatic section of hypogynous (H), perigynous (P), and epigynous (E) flowers. *a*, axis, forming convex or concave receptacle, or wall of ovary; *k*, calyx; *c*, corolla; *s*, stamens; *f*, carpels; *n*, stigma; *sk*, ovules. (After Prantl.)

In other cases the calyx is adherent to the sides of the ovary, only the free limb springing from its upper part (or the calyx springs entirely from the top of the ovary). It is then said

FIG. 167.—Spurred calyx of *Tropaeolum*.

FIG. 168.—Caducous calyx of Poppy

to be **superior**, and the ovary is **inferior** (fig. 166, E), as in the *Fuchsia*, *Willow-herb*, *Apple*, etc.

When the sepals of the calyx are distinct from one another,

as in the Strawberry (fig. 164), it is said to be **polysepalous**. If the sepals be united together (fig. 170), as in the Primrose, the calyx is **gamosepalous**.

When the sepals are alike, as in the Buttercup (fig. 165), or Primrose, the calyx is said to be **regular**; if some be differently developed from the rest, the calyx is **irregular**, as in the Garden Nasturtium (fig. 167).

If, as in the Poppy (fig. 168), the calyx falls off as soon as the flower-bud opens, it is said to be **caducous**; if, as in the Ranunculus (fig. 165), it remains after the flower opens, but falls off before the fruit ripens, it is **deciduous**; whilst if it remains after the fruit has ripened, it is **persistent**, as in the Strawberry (fig. 164).

FIG. 169.—Tubular calyx.

FIG. 170.—I. Turbinate. II. Urceolate calyx (represented diagrammatically).

FIG. 171.—Saccate calyx of *Lunaria*.

Sometimes the persistent calyx becomes very much enlarged around the fruit; it is then **accrescent**, as in the *Physalis*.

There are also certain terms which are used in describing the shape of the calyx which are of great importance in Descriptive Botany.

Thus it may be **tubular** (fig. 169), as in the Centaury; **urceolate** (fig. 170, II.) or urn-shaped, as in the Campion; **inflated** or swollen, as in the Bladder Campion; **turbinate** or top-shaped (fig. 170, I.); **funnel-shaped** or **infundibuliform** (fig. 176), as in the Deadly Nightshade; **saccate** (fig. 171), if there are four sepals, two of which are prolonged at the base, as in most cruciferous plants; **rotate** (fig. 164), as in the Strawberry; **bilabiate** or **two-lipped** (fig. 177), as in the Dead-nettle;

spurred (fig. 167), as in the Tropæolum ; **galeate** or **hooded** (fig. 172), as in the Monkshood.

When the calyx is polysepalous, it should be described as **bisepalous**, **trisepalous**, etc. If gamosepalous, it may be described as **toothed**, **lobed**, or **incised**, according to the depth to which it is cut.

FIG. 172.—Monkshood (*Aconitum Napellus*).
Part of plant, showing galeate calyx.

FIG. 173.—Pilose sessile pappus of
Senecio.

FIG. 174.—Pilose stipitate pappus
of Dandelion.

A remarkable form of calyx known as **pappus** is met with amongst the composite and some other flowers. In this case the sepals are converted into numerous hairs, which crown the ovary, and are often very much enlarged upon the fruit, as is seen in the head of the Dandelion after flowering.

The hairs may be either simple when the pappus is **pilose**

(figs. 173 and 174), or feathery when it is **plumose** (figs. 175 and 178). Again, they may be sessile upon the ovary (figs. 173 and 175), or stalked, when they are said to be **stipitate** (figs. 174 and 178); so that there are four forms of pappus, viz. :—

Pilose sessile, as in Groundsel.

Pilose stipitate, as in Dandelion.

Plumose sessile, as in Salsify or Goatsbeard.

Plumose stipitate, as in Thistles.

FIG. 175.—Plumose sessile pappus of *Tragopogon*.

FIG. 176.—Deadly Nightshade (*Atropa Belladonna*): flower.

FIG. 177.—Bilabiate five-toothed calyx of *Lamium*.

FIG. 178.—Pappus of *Carlina vulgaris*. the feathery rays united below into several bundles and coherent at the base into a ring.

FIG. 179.—Fruit, *f*, of the Tansy (*Tanacetum vulgare*), surmounted by the coronate pappus.

In the Chicory and Tansy (fig. 179) the pappus is **coronate**, forming a crown of broad hairs above the fruit.

COROLLA.—The second enveloping layer of the flower is generally more delicate in its structure than the calyx, and is

often highly coloured and possesses odour. If there be only one coat present, as in the Anemone and Marsh Marigold, whatever its appearance, it is spoken of as calyx.

The corolla is either **gamopetalous** or **polypetalous**—**regular** or **irregular**.

If the petals are attached with the calyx beneath the ovary (fig. 166, H), the corolla is said to be **hypogynous**; if the ovary be superior, but the petals, instead of being inserted under it, are attached upon the calyx, forming a ring round the ovary, the corolla is **perigynous** (fig. 166, P). When the ovary is inferior and the corolla springs from the top of it with the calyx (fig. 166, E), it is **epigynous**.

The corolla never remains to form a part of the fruit as the calyx does sometimes.

FIG. 180.—Unguiculate petal of *Dianthus*, with toothed lamina.

FIG. 181.—Bifid unguiculate petal of *Lychnis*, with ligule.

FIG. 182.—Tubular corolla from the disc of the capitulum of *Centaurea Cyanus*

Terms are also employed to describe the shape of the corolla, and of the individual petals.

When the petals are broad above and form a narrow limb below, as in the Pink (fig. 180) and *Lychnis* (fig. 181), they are said to be **unguiculate** or **clawed**.

When each petal is notched at its free edge, as in the *Lychnis* (fig. 181), it is described as **bifid**. If there are several notches it is **toothed** (fig. 180), or, if very much divided, **frimbriated**, as in *Dianthus plumarius*.

Again, the corolla may be **tubular**, as in the Bluebottle and other composite plants (fig. 182); **campanulate** or bell-shaped,

FIG. 183.—Campanulate corolla of the Canterbury Bell.

FIG. 184.—Urceolate corolla of *Vaccinium Myrtillus*.

FIG. 185.—Globose corolla of *Erica Tetralix*.

FIG. 186.—Infundibuliform corolla of *Convolvulus arvensis*.

FIG. 187.—Hypocrateriform corolla of the Jasmine.

FIG. 188.—Rotate corolla of the Borage (*Borago officinalis*).

FIG. 189.—Cruciform flower of *Lunaria*, with unguiculate petals.

FIG. 190.—Ligulate corolla of *Globularia Alypum*,

FIG. 191.—Bilabiate ringent corolla of *Lamium album*,

FIG. 192.—Bilabiate personate corolla of *Antirrhinum majus*.

as in the Campanula (fig. 183); **urceolate** or urn-shaped, as in the Bilberry (fig. 184); **globose**, as in many Heaths (fig. 185); **infundibuliform** or funnel-shaped, as in the Convolvulus (fig. 186); **hypocrateriform** or salver-shaped, with the petals flattened above, as in the Jasmine (fig. 187); **rotate** or wheel-shaped, as in the Borage (fig. 188); **cruciform** or cross-shaped, when there are four petals arranged like a Maltese cross, as in the Wallflower, Stock, or Lunaria (fig. 189); **ligulate** or strap-shaped, when the lower part of the corolla forms a tube and the upper part is flattened out, as in the Globularia (fig. 190), and the ray florets of the Daisy and florets of the Dandelion; **spurred**, as in the Violet and many Orchids; **bilabiate**

FIG. 193.—Papilionaceous corolla of Laburnum. I. Seen laterally. II. In front. III. Standard. IV. Left wing seen from without. V. Keel.

or two-lipped, as in the Dead-nettle (fig. 191). Of this there are two forms: if the lips are wide apart, as in the Dead-nettle, it is **ringent**; if closed, as in the Snapdragon (fig. 192), it is **personate**; **papilionaceous** or butterfly-shaped, as in the Laburnum and other members of the Pea-flower tribe (fig. 193). In this case there are five petals, one overlooking the rest, the *standard* or *vexillum* (fig. 193, III.); one standing out on each side, the *wings* or *ala* (fig. 193, IV.); and two united surrounding the stamens, the *keel* or *carina* (fig. 193, V.).

In some cases, as in many of the Orchids, there is a most irregular shape of corolla which has received no special name. The term **caryophyllaceous** is applied to the corolla as it is met with in the Pink tribe (figs. 194 and 195), when there are five

petals attached by claws to the base of a tubular calyx ; whilst if there are five petals, not clawed, and attached in a perigynous manner (fig. 196), the corolla is **rosaceous**.

FIG. 194.—Caryophyllaceous corolla of *Lychnis vespertina*, with corona.

FIG. 195.—Longitudinal section through the caryophyllaceous corolla of *Dianthus*.

There are sometimes attached to the corolla subsidiary organs, which are variously arranged, and which, owing to their not being universally present, are not treated of as separate organs. They form the **corona** or **paracorolla**, and are petaloid

FIG. 196.—Longitudinal section through the rosaceous flower of the Rose ; the pistil seated in the base of the urceolate calyx.

FIG. 197.—Petaloid perianth of *Narcissus*, with 6-partite limb and campanulate corona.

and well developed in the *Narcissus* (fig. 197), or small as in the *Lychnis* (fig. 194), or consist of several hairs as in the Passion Flower and Dead-nettle, or scales with glandular hairs attached

as in the Grass of Parnassus (fig. 199), or scales known as **staminodes** closing the tube of the corolla as in the Borage (fig. 198).

NECTARIES, or glands for the secretion of honey, are sometimes spoken of as subsidiary organs, but various parts of the

FIG. 198.—Longitudinal section through the flower of the Borage; each bifid stamen bears the anther on its inner half, while the other half forms an erect scale.

flower may be specially developed for this function. Thus, there may be scales between the stamens as in the Grape Vine (fig. 200), or spurs either of the calyx as in the *Tropæolum* (fig. 167), or of the corolla as in the Valerian (fig. 201), or of

FIG. 199.—I. Longitudinal section through the flower of *Parnassia palustris*.
II. One of the petals; a glandular scale belonging to the corona attached to it in front.

both as in the Larkspur (fig. 202), or of the stamens as in the Violet (fig. 204). There may be specially developed petals, as in the Monkshood (fig. 203); or glands in hollows at the base of the petals, as in the Buttercup.

PERIANTH.—The term **perianth** is generally employed in

FIG. 200.—Stamens and pistil of the Grape Vine, with a honey gland (nectary) between each pair of stamens.

FIG. 201.—Spurred corolla of *Valeriana*.

FIG. 202.—Longitudinal section of flower of Larkspur, with spurred calyx and corolla.

FIG. 203.—Monkshood (*Aconitum Napellus*). Flower, the coloured calyx having been removed, showing the two petals, *a*, developed into nectaries, the remaining petals being reduced to scales or altogether abortive.

those cases where the calyx and corolla resemble one another, being both green or both petaloid, especially when it occurs among monocotyledonous plants. In this case we speak of it as being **gamophyllous** or **polyphyllous**. (Some botanists use the term perianth for describing the flowers which possess only one floral envelope.)

ÆSTIVATION.—Just as the terms *vernation* and *præfoliation* are applied to the arrangement of the foliage leaves in the bud, so the terms **æstivation** and **præfloration** are employed to describe the arrangement of the leaves in the flower-bud. The same terms already employed (see Chapter VII.) can also be used in this case. Besides these, however, we apply the term **vexillary** to the æstivation as seen in a papilionaceous plant (fig. 205), and **crumpled** when the petals are crumpled up as in the Poppy.

FIG. 204. — Spurred stamens of Violet.

FIG. 205. — Vexillary æstivation of Papilionaceæ.

FIG. 206. — Monadelphous stamens of *Malva*.

FIG. 207. — Diadelphous stamens of *Lathyrus*; nine filaments united into a sheath at the base, one free.

FIG. 208. — Polyadelphous stamens of Orange.

ANDRÆCIUM.—We now come to the first whorl of the essential organs of the flower. Each **stamen** of which the andræcium is composed consists, when complete, of **three parts**, viz., the stalk which attaches it to the rest of the flower, and

which is known as the **filament**; the knob on the summit, which is in reality a little box, the **anther**; and within this a fine powder, the **pollen**, which is the essential part of the stamen.

These stamens may be either distinct, when they are said to be **free**, as in the *Ranunculus* (fig. 165), or they are more or less united.

If they are united by means of their filaments into one bundle, whilst their anthers are free, as in the Mallow (fig. 206), they are said to be **monadelphous**.

FIG. 209. — Syngenesious anthers of Thistle; the filaments free.

FIG. 210. — Stamens of *Aristolochia* sessile upon the stigma.

FIG. 211. — Section of corolla of Honeysuckle, with epipetalous stamens.

If there be two bundles, as in the Sweet-pea (fig. 207), the androecium is **diadelphous**; and if more than two bundles, as in the Orange (fig. 208), **polyadelphous**. If the stamens are attached together by means of their anthers, whilst the filaments are free, as in the Thistle and other composite plants (fig. 209), they are **syngenesious**. If the anthers are attached immediately upon the pistil, as in the Birthwort (fig. 210) and various Orchids, they are **gynandrous**.

With regard to the attachments of the stamens, we apply the same terms which we used in describing the position of the

corolla. Thus the stamens may be **hypogynous** (fig. 166, H), **perigynous** (fig. 166, P), or **epigynous** (fig. 166, E). In addition to these positions the stamens may be upon the corolla, when they are said to be **epipetalous** (or **epiphyllous** when there is a perianth), as in the Honeysuckle (fig. 211). If the filament of the stamens be absent, as in the Verbena (fig. 212), the anthers are said to be **sessile**.

More often there is a filament present which is generally thin and thread-like, but sometimes, as in some of the stamens of the Water-lily, it is broad and flat. Generally the various filaments are about the same length, but in some cases there is a constant difference between the stamens on this point. Thus

FIG. 212. -- Section of corolla of *Verbena*, with sessile epipetalous anthers.

FIG. 213. --Tetradynamous stamens and pistil of *Brassica nigra*; a shorter, b longer stamens.

FIG. 214. -- Flower of *Lamium*, with didynamous stamens.

in the Mustard (fig. 213), and allied plants of the natural order Cruciferae, there are four long and two short stamens, when they are said to be **tetradynamous**; whilst in the Dead-nettle and most other plants of the order Labiatae there are two long and two short, and the stamens are **didynamous** (fig. 214).

If the anthers are attached immediately upon the top of the filaments they are said to be **innate**, or **basifixed**, in their attachment. If the filament is prolonged up behind the anthers they are **adnate** or **dorsifixed**; and if it be attached loosely to the centres of the anthers, so that they swing upon the point of attachment, as in the Wheat (fig. 215), they are **versatile**.

The portion of the filament to which the anthers are attached is called the **connective**. Usually this is not developed to a noticeable degree, but in the Herb Paris it is prolonged beyond the anthers, giving them the appearance of being placed half-way down the stamen.

In the Hornbeam the connective is divided into two equal branches, each of which bears an anther lobe (fig. 216), whilst in the Sage (fig. 217) the branches of the connective are unequal in length; the long one bears a perfect anther lobe, whilst the short one has an abortive anther, or one destitute of pollen.

FIG. 215.—Stamen of Wheat, with versatile anther, *b*, lightly fixed at the extremity of the filament, *a*.

FIG. 216.—Stamen of Hornbeam (*Carpinus Betulus*), with branching connective.

FIG. 217.—Stamen of *Salvia*, with connective branching into two arms of very unequal length, the right-hand arm bearing an abortive anther.

The anther lobes are hollow, possessing cells or loculi, of which there is generally one for each lobe, so that the anther is two-celled or **bilocular**. In the early stage of its development there are four cells, two in each lobe; but generally the partition between the loculi in each anther lobe is absorbed, producing the bilocular anther. In some plants, as the Flowering Rush, this division never disappears, and the anther remains four-celled or **quadrilocular** through life. In some few plants, as the Mallow and Milkwort, there is but one cell, and the anther is then said to be **unilocular**.

The surface of the anther to which the connective is attached is known as its **back**, whilst the other side is called the **face**. This is generally grooved, showing the point of attachment of the lobes. When the face is turned towards the pistil the stamens are said to be **introrse**; when towards the petals, **extrorse**.

Within the anther lobes there are developed the **pollen grains** (fig. 218). In the early stages of the growth of the anthers there are a large number of cells forming the central part of each lobe. These are the *parent* or *mother cells* of the pollen grains. Each of these, by cell division, becomes divided into four *special parent cells*, and in each, by a process known as free cell formation, a pollen grain is formed. In free cell formation the protoplasm aggregates around the nucleus of the mother cell, a cellulose coat is formed around it, and thus for a while we have a cell within a cell. As the pollen grains grow the walls of the special mother cells and mother cells generally become absorbed and disappear, and the grains thus become

loose in the cavity of the lobe. Sometimes, however, the wall of the special parent cells is not quite absorbed, and there is formed a component body of four pollen cells united, whilst in the Orchids the pollen cells of each lobe are completely united together, forming a pollen mass or **pollinium** (fig. 218, v.). Each pollen grain possesses two coats: the inner one, the **intine**, is complete; the outer one, the **extine**, is pierced by several openings, and is often variously ornamented by spines, protuberances, or reticulations (see fig. 218). The protoplasmic contents of the cell, known as **fovilla**, contain sulphur and fat globules. In form the pollen granules are generally round; in the Chicory they are polyhedral; in the Evening Primrose, triangular; in the Basella, cubical; in the Tradescantia, cylindrical; and in the Zostera, thread-like.

FIG. 218.—Pollen grains
I. *Cucurbita*. II. *Passiflora*. III. *Cuphea platycentra*. IV. *Dipsacus fullonum*.
V. Pollen-masses (pollinia) of *Cynanchum lincetoxicum* (Asclepiadææ).

In size they vary from $\frac{1}{200}$ to $\frac{1}{1000}$ of an inch. Generally the grains are yellow, in species of Mullein they are red, in some Willow-herbs blue, black in the Tulip, and in other plants green or of a whitish colour.

When the pollen is ripe the anther lobes open to let it fall out. They open or dehisce in various ways.

1. *Longitudinal dehiscence*, as in the Pine (fig. 219) or Tulip, when there is a slit running along the face of the anther from top to bottom. This is the commonest form.

2. *Transverse dehiscence*, generally met with in unilocular anthers, as the Lady's-mantle.

FIG. 219.—Stamen of *Pinus sylvestris*, with longitudinal dehiscence.

FIG. 220.—Stamen of Barberry, the anther opening by recurved valves.

FIG. 221.—Stamen of *Rhododendron*, each anther-lobe opening by a pore.

FIG. 222.—Stamen of Bay (*Laurus nobilis*), with two glands at the base of the filament, the anther opening by recurved valves.

3. *Porous dehiscence*, openings being produced either at the apex of the lobe, as in the Rhododendron (fig. 221); or in the side, as in the Heath (fig. 223).

4. *Valvular dehiscence*, when a portion of the anther lobe lifts up like a trap-door, as in the Barberry (fig. 220) or Bay (fig. 222).

GYNÆCIUM OR PISTIL.—Each of the **carpels** of which the pistil is made up consists, when complete, of a swollen basal portion, the **ovary**; above this a stalk or **style**, which is capped by the **stigma**. The ovary is a hollow box containing one or more rounded bodies, the **ovules**. Generally the carpels of the

pistil are united together, either entirely, as in the Lily (fig. 224), or, as is often the case, the ovaries are united whilst the styles and stigmas are free, as in the Sea-lavender (fig. 225). In these cases the pistil is said to be **syncarpous**. When the ovaries are distinct, as in the Buttercup (fig. 165), it is **apocarpous**

FIG. 223. — Stamen of *Erica*, the anther opening by pores and bearing two appendages at its base.

FIG. 224. — Pistil of Lily, with ovary, style, and stigma.

FIG. 225. — Papillose stigma of *Statice*.

(when there is only one carpel to the pistil, as in the case of the Pea, it is also said to be **apocarpous**). If there is but one carpel, the pistil is said to be **monocarpellary**. A **bicarpellary** pistil has two carpels, a **tricarpellary** three, a **polycarpellary** pistil more than three.

In a syncarpous pistil we can often tell the number of carpels present by the separate stigmas (or styles) (fig. 225). In other cases we find on making a section that the syncarpous ovary possesses several cells or loculi, each corresponding with a single carpel, so

that from them we can count the number of carpels (fig. 226). Sometimes we find that there is but a single loculus in the ovary, and we can then often tell the number of carpels by

FIG. 226. — Capsule of *Colchicum*; transverse section.

FIG. 227. — Section of ovary of *Viola*.

noticing in how many places the ovules are arranged (fig. 227).

In some few cases it is difficult or almost impossible to be able to say definitely in an individual plant how many carpels are present. The ovary, as we have seen, may be either *inferior* or *superior*. In the former case it is either inserted in the fleshy end of the flower-stalk, known as the *thalamus* or *receptacle*, so that the calyx springs from above it; or the calyx tube is adherent to the wall of the ovary, the free limb springing from the top. We often find two lines running down the ovary from apex to base. These are known as the *sutures*: the one towards the centre of the flower is the *ventral suture*, whilst the one turned towards the perianth is the *dorsal suture*.

FIG. 228.—Diagrammatic sections of ovaries: *p*, the placenta, to which the seeds are attached; *A*, monocarpellary unilocular; *B*, polycarpellary unilocular; *C*, polycarpellary falsely multilocular; *D* polycarpellary multilocular; *r*, dorsal suture, or midrib; *b*, ventral suture, or margins of carpel. (After Prantl.)

When the pistil is apocarpous, each ovary contains but one cell, or is **unilocular**, although sometimes there are false partitions growing partially across the cell.

In syncarpous ovaries there are often numerous cells agreeing with the numbers of the carpels (fig. 228, *D*), when the ovary is **bi-**, **tri-**, or **multi-locular**. In other cases there is but one cell (fig. 228, *B*), the ovary being **unilocular**. Sometimes there are partial dissepiments formed by an infolding of the edges of the carpels (fig. 228, *C*). In some few cases there are actual divisions; thus the ovary of the Labiatae and Boraginaceae is originally bilocular, but by a subsequent division it becomes divided into four cells. The ovules are not, as a rule, distributed indiscriminately over the surface of the ovary, but are arranged on certain parts of the wall, each of which is called a **placenta**, whilst the arrangement of the ovules is spoken of as **placentation**.

In the case of apocarpous pistils, where there are more than one ovule, they are generally arranged along the ventral suture, and the placentation is said to be *marginal* (figs. 229 and 228, A). In the multilocular syncarpous pistil the ovules are generally arranged in the central axis, where the cells of the ovary meet (fig. 228, D), and the placentation is **axile**.

When the ovary is unilocular the ovules are arranged either upon the wall (fig. 228, B), or upon slight projections (fig. 228, c), and the placentation is **parietal**.

In some cases of a unilocular ovary, as in the Primrose and Pink, the ovules are attached to the end of the flower-stalk which grows up into the ovary (fig. 230). In this case, which

FIG. 229.—Marginal placentation.

FIG. 230.—Unilocular ovary of *Hottonia*, with free central placentia.

FIG. 231.—Lateral style of Strawberry.

FIG. 232.—Basilar style of *Alchemilla*.

is known as **free central placentation**, the walls of the ovary are perfectly free from the ovules, as can be seen by cutting the pistil of a Pink or Primrose, when the walls can be cut away, leaving the column of ovules in the centre.

The **style**, when present, forms a conducting tube from the stigma to the ovary. In the Violet and Flowering Rush it consists of a perfectly hollow tube; more often, although hollow at first, it becomes afterwards filled up by the growth of 'conducting tissue,' so that at the time of fertilisation no channel is evident. As a rule the style grows from the top of the ovary, when it is said to be **terminal**. If it springs out from the side, as in the Strawberry (fig. 231), it is **lateral**; if from the base, as in the *Alchemilla* (fig. 232), it is **basilar**.

Very often the style is absent, in which case the stigma is said to be *sessile* upon the ovary.

The **stigma** is intended to receive the pollen grains, and hence its presence is necessary in the perfect pistil. It varies much in appearance. In some cases it is merely an opening at the top of the style, upon which is secreted some glutinous fluid. In other cases it is variously enlarged. It is **capitate**, or forming a head, in the Primrose and Lily (fig. 224) ; **petaloid** in the Iris (fig. 233) ; **penicillate**, with a number of hair-like arms, in the Peltitory of the Wall (fig. 234) ; **peltate**, or shield-like, in the Poppy (fig. 235).

FIG. 233.—Petaloid stigmas of *Iris*.

FIG. 234.—Pistil of *Parietaria*, with penicillate stigma.

FIG. 235.—Peltate stigma of Poppy, with hypogynous stamen.

The **ovule**, when in a young state, consists simply of a mass of parenchymatous cells ; these soon become surrounded by coats, the **primine** (*ai*, fig. 236) and the **secundine** (*ii*, fig. 236). These coats are not complete, leaving an opening, the **micropyle** (fig. 236, *m*), leading into the interior of the ovule, which is composed of the original cellular mass forming the **nucleus** (*k*), amongst which is one cell, the **embryo-sac** (*em*), larger than the rest.

The ovule is generally attached to the placenta by a short stalk, the **funiculus** (*f*), but at other times it is sessile upon the ovary. The point by which the ovule is attached to the funiculus (or placenta) is the **hilum**, whilst the point by which the nucleus is attached to the integuments is the **chalaza** (*c*).

There are three forms of ovules, differing in the arrangement of their parts :—

Orthotropous ovule (fig. 236, A). In this case the nucleus is straight, the chalaza and hilum are in proximity, and the micropyle is removed to a distance from the funiculus. This form is rare, being met with in the Rhubarb and its allies in the natural order Polygonaceæ.

Anatropous ovule (fig. 236, B). In this case the nucleus is straight, but is inverted upon the funiculus, so that the micropyle is brought down into close proximity with the stalk, whilst the hilum and chalaza are separated, being united by a prolongation of the funiculus known as the *raphe*. This form is well seen in the Dandelion and White Water-lily.

FIG. 236. —Diagrammatic longitudinal sections of ovules: A, orthotropous or straight; B, anatropous or inverted; and C, campylotropous or bent ovule. *ai*, outer integument or primine; *ii*, inner integument or secundine; *m*, the micropyle; *k*, the nucleus, with the embryo-sac, *em*; *c*, the chalaza or base of the nucleus; *f*, the funiculus; *r*, the raphe of the anatropal ovule, formed by the fusion of the outer integument and funiculus. (After Prantl.)

Campylotropous or bent ovule (fig. 236, c). In this case the nucleus is bent, so that whilst the micropyle is brought near the funiculus, as in the anatropous form, the chalaza and hilum are in close proximity as in the orthotropous form, and there is no need of a raphe. The Wallflower and Mallow are examples of this kind. These three forms are united by many modifications.

Thalamus and Disc.—The thalamus, or end of the flower-stalk upon which the various floral organs are inserted, is often specially modified. Thus in all plants with a free central

placentation it is prolonged into the ovary, bearing the ovules. In other cases, as in the Umbelliferae and Geraniaceae, it is prolonged between the carpels and beyond the ovary, and is known as the **carpophore** (see page 139).

In other cases, as in some forms of *Lychnis*, Pink, and Passion-flower, it is prolonged beyond the calyx, forming a stalk for the ovary (fig. 237), and it is known as the **gynophore**. In many plants it is much swollen, and the ovaries are sunk or embedded in it, often giving them a syncarpous appearance when they are truly apocarpous.

FIG. 237. — Section of *Lychnis Flos-Jovis*, with gynophore, g.

We sometimes find between the calyx and pistil a body or bodies which are not universal among flowers, and which cannot be referred to any of the organs above described. To this body the name of **disc** is applied. In the Mignonette and Orange it forms a fleshy swelling below the pistil; in umbelliferous plants it surmounts the ovary, adhering to the styles. In other cases it is variously developed.

Cohesion and Adhesion.—When the similar parts of a flower are united together in growth, we speak of it as **cohesion**;

FIG. 238. — Floral diagram of the Rose.

FIG. 239. — Floral diagram of Potato (*Solanaceae*).

FIG. 240. — Floral diagram of Sweet-pea.

when dissimilar parts are united, as **adhesion**. Thus the formation of a gamosepalous calyx, a gamopetalous corolla, or a monadelphous stamen would be cohesion; whilst the growth of

the calyx to the ovary, or the epipetalous or gynandrous arrangement of stamens, would be due to adhesion.

It will often give an idea of how the parts of a flower are arranged with regard to cohesion and adhesion to make a floral diagram of it. Figs. 238, 239, and 240 are examples of how this should be done. In fig. 238 we have in a Rose a poly-sepalous polypetalous apocarpous regular flower, whilst in the Potato (fig. 239) we have a gamopetalous syncarpous flower. The diagrams show the different way that the petals and carpels are represented in the two cases. Fig. 240 shows an irregular flower, as seen in the Sweet-pea.

Fertilisation.—In order that the ovary and ovules may properly perform their functions, it is necessary that they should be fertilised by the pollen. The pollen grains adhere to the stigma (fig. 241, *b*), and being nourished by the viscid secretion present, a portion of the intine protrudes either through an opening already existing in the extine, or forcing its way through a part where the outer walls are thinner. The prolongation thus formed is known as a **pollen-tube** (fig. 242). These tubes grow down the loose conducting tissue of the style and enter the ovary.

The time necessary for this varies from a few hours to several weeks. In the Crocus it takes from twenty-four to seventy-two hours; in the Arum over five days, and in the Orchids even some months. Just previous to this, or about the same time, a change has been going on in the embryo-sac of the ovule. Usually one or two cells are produced within the embryo-sac at the end away from the micropyle. These are

FIG. 241. — Longitudinal section through the uniovular ovary of *Polygonum convolvulus* at the time of flowering: *a*, stigma; *b*, pollen grains; *c*, pollen-tube; *d*, wall of the ovary; *gm*, the erect orthotropous ovule; *se*, its embryo-sac; *ch*, chalaza: two pollen-tubes have penetrated through the conducting tissue of the style, one of which has entered the micropyle of the ovule, the other not.

known as **antipodal cells** (fig. 243, *g*), and their function is unknown. Soon after their formation two nuclei are produced at the other end of the embryo-sac, round which the protoplasm becomes aggregated, forming two **embryonic** or **germinal vesicles** or cells (fig. 243, *k*). These vesicles appear to be

FIG. 242.—Pollen grains putting out their pollen-tube; A, *Dipsacus fullonum*; B, *Cucurbita*.

FIG. 243.—Upper part of the nucleus of the ovule of *Crocus*: *p*, the embryo-sac with its nucleus, *zk*; *k*, the embryonic vesicles; *g*, the antipodal cells.

FIG. 244.—The process of fertilisation in *Gladiolus segetum*. I. The two embryonic vesicles at the apex of the embryo-sac; *x' x''*, the filiform apparatus; *y' y''*, the balls of protoplasm ready for fertilisation; *se*, the wall of the embryo-sac. II. A pollen-tube, *tp*, which has just fertilised the two embryonic vesicles in contact with it; the cell-walls which surround the balls of protoplasm are still very thin. III. A somewhat later stage; the cell walls are thicker; the fertilised vesicle *y'* is beginning to develop and to divide into two.

membraneless before fertilisation, but on the approach of the pollen-tube a cellulose coat is formed round each. The pollen-tube passing into the ovary enters the micropyle of one of the ovules, and, arriving at the apex of the embryo-sac, comes in contact with one of the embryonic vesicles, fertilising it by the passage of the fovilla of the pollen into it by osmosis (figs. 244

and 245). The first change that takes place (after the surrounding of the embryonic vesicle by a cellulose coat) is the division of the vesicle into two (fig. 244, II., *k*); the upper cell being developed into a suspending cord, the **suspensor** or **pro-embryo** (fig. 246, *et*), at the end of which the **embryo** or young plant, formed by the division of the lower cell, is attached (fig. 246, *e*). At the same time a number of cells are produced within the embryo-sac by free cell formation; these are filled with nutritive materials, and are known as **endosperm**. Sometimes nutritive cells are produced within the

FIG. 245.—Fertilisation of *Canna*. I. Apex of the embryo-sac, *e*, at the time when the pollen-tube, *ps*, has just come into contact with the embryonic vesicle, *k*. II. Fertilised embryonic vesicle separated.

FIG. 246.—Formation of the embryo of *Heliotropium*: *ed*, endosperm; *et*, suspensor; *e*, rudiment of the embryo, its enveloping membrane being already formed; *a*, cells developed out of the two embryonic vesicles.

nucleus outside the embryo-sac. In this case the term **perisperm** is employed. Very often as the embryo increases in size the nutritive cells around are absorbed, until, as we have seen is the case with the Broad Bean, the young plant occupies the whole of the nucleus. In other cases a part of the endosperm,

or of the perisperm, or of both, persists, forming the so-called **albumen**, so that this latter may consist of endosperm, or of perisperm, or of both.

In the fertilisation of the Fir trees and their allies there is a modification of this process. In the first place the pollen

FIG. 247.—*Viola tricolor*. A, longitudinal section of anatropous ovule after fertilisation: *pl*, placenta; *w*, swelling on the raphe; *a* outer, *i*, inner integument; *p*, pollen-tube entering micropyle; *e*, embryo-sac, with the fertilised germinal vesicle at the micropyle end, and numerous endosperm cells at the other. B, apex of embryo-sac, *e*, with young embryo, *eb*, of three cells, and one cell forming the suspensor or pro-embryo. C, same, further advanced. (After Sachs.)

grains divide into two cells before pollination, and the tube, instead of being formed from the entire grain, is produced by one of the cells (fig. 249). In the next place the ovules, instead of

FIG. 248.—*Viola tricolor*. Posterior part of embryo-sac: *e*, wall; *S*, cavity of the cell; *K*, *K*, young endosperm cells formed by free cell formation in the protoplasm, *pr*. (After Sachs.)

being enclosed in an ovary, are naked (whence the plants are said to be **gymnosperms**, or naked-seeded plants, whilst other flowering plants are **angiosperms**, or enclosed-seeded plants), so that the pollen falls direct upon the micropyle (fig. 250).

The embryo-sac soon after pollination is filled with endosperm, which disappears after a short while, and a second quantity is subsequently formed. In the upper part of this

there are several cells which enlarge and form **secondary embryo-sacs** or **corpuscula**. These split up into two cells, the upper or neck cell breaking up into several, which form a tube

FIG. 249.—Fertilisation of *Cupressus sempervirens* (Coniferæ). I. A pollen grain with its two cells: *a*, extine; *b*, intine. II. Pollen grain in which the pollen-tube, *c*, has been formed.

FIG. 250.—Fertilisation of *Abies excelsa*: *p*, pollen grains; *ps*, pollen-tubes; *c*, two corpuscles in the embryo-sac, *e*.

or neck leading into the lower cell, which enlarges, forming the **oosphere**. The pollen-tube grows down to the oosphere, fertilising it and causing it to break up into a **pro-embryo** or **suspensor**, which forces its way through the embryo-sac, and at the end of which the embryo is produced.

Recent investigations seem to point out that in the fertilisation of Angiosperms there is a certain approach to this process as seen amongst the Gymnosperms. In 'Nature' for July 1879 an interesting paper appeared, giving an account of the researches of Messrs. Strasburger and Elfving at Jena. They treated pollen grains with osmic acid so as to render the contents more visible, and then they grew them artificially in sugar solutions. In a number of the cases observed there seemed to be a breaking up into two or three cells previous to the emission of

FIG. 251.—Pollen of Tulip, A, B; and of Flowering Rush, C.

the tube, which latter was given off from one of the cells (fig. 251), as we have seen is the case with Gymnosperms. It is a question which requires further investigation.

As a general rule the pollen is not capable of fertilising the ovules of the *same* flower, and hence has to be taken to another, and the process known as **cross-fertilisation** is brought about. The pollen is carried from flower to flower by various means. The first agency we shall notice is the wind. In the Hazel, for example, we have a monoëcious plant with unisexual flowers. It is evident that the pollen must be transferred from one flower to another. The male and female catkins are on the same plant (fig. 162), the former pendulous with numerous anthers and a large quantity of pollen, the latter erect with the red stigmas appearing through the enveloping bracts. When the pollen is fully ripe it is shed from the anther cells and scattered by the wind; the greater portion is wasted, but some falls upon the stigmas, fertilising them. Such a plant is said to be **anemophilous**, or wind-fertilised. Other examples of anemophilous plants are to be found in the Oak, the Fir, the Yew, and various Grasses and Cereals. In all these cases the flowers are small and inconspicuous and destitute of odour, whilst the pollen is produced in a far larger quantity than is actually needed for fertilising purposes. Often in Fir forests the pollen is given off into the air in such enormous quantities that it is washed down by the rain as a yellow powder, and is popularly known as *sulphur rain*.

More important agents in the fertilisation of flowers are insects. In all cases of insect-fertilised (**entomophilous**) plants the flowers possess either rich and variegated colours, or sweet odours, or have both qualities. These serve to attract the insect, whilst in some part of the flower honey is stored up in a nectary. Whilst endeavouring to obtain this the insect comes into contact with the anther, and the pollen is scattered over portions of its body, and, being carried away, adheres to the glutinous stigma of the next flower visited.

The mechanical contrivances and arrangements to ensure this proper distribution of the pollen are very numerous. In an elementary book such as this it is only possible to notice a few typical forms.

In many cases it is impossible for the flowers to be self-fertilised, as either the anthers are ripened before the stigmas, or the stigmas before the anthers. This is known as **dichogamy**, and in the former case the flower is **protandrous**, and the pollen has to fertilise the pistil of a flower which preceded it in opening ; whilst in the latter case the flowers are **protogynous**, and the pollen fertilises a later flower.

A good example of a protandrous plant, and one which at the same time shows mechanical arrangements for ensuring the delivery of the pollen upon the right part of the insect's body, is to be found in the Sage. Fig. 252 shows in diagrammatic form the arrangement of the parts in *Salvia officinalis*. The corolla is bilabiate, the lower lip forming a convenient resting-place for the insect to stand upon, whilst the upper lip protects the stamens and pistil from the rain.

The stamens, two in number, have branched connectives ; the lower lobes are abortive and united together (*b*), so that if either be pushed it affects both stamens. The upper lobe is full of pollen, and is poised upon the movable connective in such a manner that if the abortive lobes are pushed backwards and upwards the upper ones come downwards and forwards. In

FIG. 252.—Sage fertilisation.

the corolla tube honey is secreted. The style and stigmas at first are placed well back against the upper lip, and are not matured until after the pollen. When they are matured, however, the style bends forward (*d*), bringing the stigmas near the

centre of the mouth. If a bee visits one of the flowers which has its pollen matured, in order to seek for honey, it will, on entering the flower and plunging its proboscis into the tube, strike its head against the lower anther lobes, bringing the fertile lobes down against its sides, covering its body with pollen (*c*).

If it now visits another flower in the same condition, it will simply have its stock of pollen increased; but if it visits a flower which has its pistil bent over, evidently the stigmas will strike against the insect's back, and some of the pollen scattered there will adhere to the glutinous stigmatic surface.

Other protandrous flowers are met with in the Mallows, the Geraniums, many Campanulas, the Pinks and other members of the Caryophyllaceæ, many Compositæ, Umbelliferæ, and others.

Protogynous flowers are much less common, but they are met with amongst the Plantains, the Scrophularias, the Magnolias, and other species of plants.

Another arrangement is known under the name of **heterostylism**, where the pistils and stamens of different flowers are of various lengths. A good example of a heterostylic flower is to be found in the common Primrose. If we examine a bunch of common Primroses we shall find the flowers of two different kinds. Some have a little knob filling up the mouth of the corolla tube, and others a rosette. On making a vertical

FIG. 253.—Dimorphic flower of *Primula*. I. Long-styled, II. Short-styled form: *a*, corolla; *b*, anthers; *c*, ring of hairs; *d*, pistil.

section of one of each kind of flower, we find the arrangement as shown in fig. 253. In the first case we have the pistil with a long style (253, I.), the stigma of which forms the 'knob' filling up the corolla tube, whilst the stamens are placed low down in the tube. In the other case the stamens are high up, forming the 'rosette' (253, II.), whilst the

style is short and the stigma at about the same height as the stamens in the preceding variety. Such a flower is said to be **dimorphic**, and we can speak of the 'long-styled' and 'short-styled' varieties of Primrose. There is a slight difference in the

pollen and the stigmas in the two cases. The pollen grains of the short-styled flowers are larger than those of the long-styled flowers, and the stigma in the latter case is globular, whilst in the former it is depressed in the centre. A number of careful experiments by Professor Darwin and others show that long-styled flowers are fertilised by the pollen from short-styled, and *vice versâ* the short-styled are fertilised by the pollen from the long-styled. Such a cross Mr. Darwin calls *legitimate union*, whilst the term *illegitimate union* is applied to the union of long-styled pollen with long-styled stigma. This illegitimate union will not produce seeds to the extent that the legitimate will, and in some dimorphic flowers none at all are formed.

FIG. 254.—Trimorphic forms of *Lythrum*.

In some species of *Lythrum* we have **trimorphic** flowers : one with long style, six medium stamens, and six short stamens ; one with medium style, six long stamens, and six short stamens ; and one with short style, six long stamens, and six medium stamens. In such cases we always find that the long style is fertilised by the long stamens, the medium style by the medium stamens, and the short style by the short stamens, as shown by the lines in the diagram.

Whilst these provisions for cross-fertilisation are the rule amongst flowers, in some few cases there is a special arrangement for self-fertilisation. The Sweet Violet is a good example. The well-known flowers that appear in the spring do not,

although fertilised by insects, bear fruit. They are followed in the summer by small inconspicuous apetalous flowers, where the stamens and pistil are enclosed in a calyx which does not open. The result is, the flowers are fertilised by their own stamens. Such flowers are said to be **cleistogamous**. Besides this there are other examples where self-fertilisation is specially provided for.

RELATION OF FLOWER TO OTHER PARTS OF THE PLANT.

The parts of the flower must be looked upon as modified foliar organs. This is pretty evident in the calyx and corolla, but not so well seen at first in the stamens. We have proof, however, in the facts, 1st, of the tendency in double flowers to form petals instead of stamens; and 2nd, the gradual transition from petals to stamens as seen in the white Water-lily, or *Rosa centifolia* (fig. 255).

FIG. 255.—Stages of transition between the petals and stamens of *Rosa centifolia*.

In some cases the filament appears to represent the petiole, the connective the midrib, and the anther the blade, when the pollen would represent the general internal tissue of the leaf. In other cases the filament appears to be the leaf-blade, and the anthers and pollen appendages upon it.

We must regard the carpels as leaves (carpellary leaves), either folded over so that their edges meet, when the dorsal suture marks the midrib, and the ventral the margin of the leaves, or, in a unilocular polycarpellary pistil, the carpellary leaves unite by their margins. The placenta is developed on the margin of the carpellary leaves, or in the free central placentation on the prolongation of the stem. The ovules are appendages of the carpellary leaves, or, in the case of the free central placentation, buds upon the prolonged axis.

CHAPTER XI.

FRUIT AND SEED.

AFTER fertilisation a change takes place in the ovary ; it enlarges and changes very much in appearance, forming the fruit. Botanically the **fruit** is the **ripened ovary**. Many so-called fruits, however, have in addition to the ovary some other part of the flower attached. Thus, in the Strawberry and Apple, the fleshy edible part is the enlarged receptacle or thalamus, the pips of the Strawberry and the core of the Apple being the true fruits. In these cases the term **pseudocarp** is applied. Sometimes the whole inflorescence will be matured into a single fruit-like mass, when the term **syncarp** is used ; whilst if the bracts or any other part of the floral organs are added in so as to produce a pseudocarp, as in the Pineapple and Mulberry, the term **pseudosyncarp** is employed (fig. 256).

FIG. 256.—Multiple pseudocarp of the Mulberry.

(Care must be taken not to confound the terms *syncarp* and *syncarpous* pistil or fruit; the latter term being, as we have seen, restricted to those ovaries and fruits where the carpels are united together, whilst the former term is used for matured inflorescences even if the pistil be apocarpous.)

The walls of the ovary consist of three layers : hence in the fruit we find three layers present—the outer or **epicarp**, the middle or **mesocarp**, and the inner or **endocarp**. Often these three layers cannot easily be distinguished from one another ; at other times they are very evident. The number of cavities or loculi in the fruit generally corresponds to that in the ovary ; sometimes, however, some of the partitions disappear, so that the fruit possesses fewer loculi than the ovary.

We may divide fruits into those which are **dehiscent** or break, and those which are **indehiscent** or do not break, when ripe.

DEHISCENT FRUITS.

When a dehiscent fruit opens so that the seeds fall out, it is known as a **capsule**. The dehiscence may take place longitudinally or from top to bottom of the fruit, breaking it into several valves; it is then said to be *valvular*. Or it may take place in a transverse manner, opening off like a lid, when it is

FIG. 257.—Capsule of *Primula* dehiscing by ten teeth.

FIG. 258.—Capsule or pyxis of *Anagallis*, with circumscissile dehiscence.

FIG. 259.—Capsule of Poppy dehiscing by pores beneath the peltate stigma.

described as *transverse* or *circumscissile* dehiscence (fig. 258). Or, lastly, there may be small openings or pores, when the dehiscence is *porous* (fig. 259).

FIG. 260.—I. Diagram of a loculicidal capsule. II. Diagram of a septicidal capsule. III. Diagram of a septifragal capsule.

If the longitudinal dehiscence is partial, so as to only take place at the top of the fruit by means of a number of teeth, it is *dehiscent by teeth* (fig. 257).

If the dehiscence is complete, it may either take place by

the ventral suture, or by the dorsal suture, or by both. Again, in some cases the walls of the loculi split open, leaving the septa attached to them, as in the Lily and Iris; the dehiscence is then said to be *loculicidal*. It is *septicidal* when the fruit breaks up into its separate carpels, the dehiscence taking place

FIG. 261.—Septifragal capsule of *Datura*.

FIG. 263.—Legume of Pea split lengthwise: E outer, EN inner layer of the pericarp; L, placenta; F, funiculus; o, seed.

FIG. 262.—Capsule or pyxis of *Plantago*, with circumscissile dehiscence.

FIG. 264.—Fruit of *Illicium* or Star-Anise, consisting of a number of follicles.

down the septa themselves, as in the *Rhododendron* and *Colchicum*; and it is *septifragal* when, the carpels opening by their dorsal sutures, the dissepiments separate from the valves, being still attached in the centre, as in the Thorn-apple (see figs. 260 and 261).

Some forms of capsules have received special names. A

pyxis is a capsule dehiscing transversely, as in the *Anagallis* (fig. 258) and *Plantago* (fig. 262).

A **legume**, or **pod**, is a unilocular monocarpellary capsule dehiscing by both dorsal and ventral sutures, as in the *Pea* (fig. 263).

FIG. 265.—Fruit of *Peony*, consisting of two follicles.

FIG. 266.—Wallflower (*Cheiranthus Cheiri*). Siliqua.

FIG. 267.—Silicle of *Cochlearia*, open and showing the seeds attached to the replum.

FIG. 268.—Cremocarp of the *Fennel*: *a*, carpopore.

the seeds. An example is seen in the fruit of the Wallflower (fig. 266).

A **silicle** resembles the last, except that, instead of being long and narrow, it is short and broad (fig. 267).

When a dehiscent fruit breaks up into several portions which are usually one-seeded and remain closed, although they do in some few cases open to allow the seeds to fall out, it is called a **schizocarp**, the divisions being called mericarps.

There are also several varieties of schizocarp.

A **cremocarp** is a bicarpellary schizocarp dehiscing into two mericarps attached to a central carpophore. Examples are found in the Fennel (fig. 268) and the other members of the order of Umbelliferae.

A **samara** is a winged fruit : in some cases, as in the Maple (fig. 269), it is a schizocarp breaking up into two one-seeded

FIG. 269.—Bipartite schizocarp of the Maple, consisting of two samaræ.

FIG. 272.—Quadripartite schizocarp of *Ajuga*, consisting of four nucules.

FIG. 273.—Tripartite schizocarp of *Tropæolum*.

FIG. 270.—Bract of the Birch (*Betula*), with three samaræ in its axis.

FIG. 271.—Lomentum of *Hedysarum*.

II.

FIG. 274.—Quinquepartite schizocarp of *Geranium Robertianum*. I. The immature pistil. II. The mature fruit.

portions ; in other cases, as in the Birch (fig. 270), it is an indehiscent fruit.

A **lomentum** is a schizocarp dehiscing transversely into two or more one-seeded mericarps, as in the *Hedysarum* (fig. 271) and Radish.

A **carcerulus** is a quadripartite schizocarp, as seen in the

Bugle (fig. 272) and other labiate plants. Each of the four divisions is often called a *nucule*. In other cases the schizocarp may be *tripartite* (divided into three mericarps) as in the Indian Cress (fig. 273), *quinquepartite* (five mericarps) as in the Geranium (fig. 274), or *multipartite* (many mericarps) as in the Mallow (fig. 275).

FIG. 275.—Multipartite schizocarp of *Malva*.

INDEHISCENT FRUITS.

The **drupe**, or **stone fruit**. In this case the three layers of the fruit are always distinct. The endocarp is hard, forming the so-called stone. The epicarp and mesocarp differ in their

FIG. 276.—I. Longitudinal section through the unilocular drupe of the Peach. II. Through the bilocular drupe of *Cornus*.

FIG. 277.—Longitudinal section of Coconut : *a*, epicarp ; *b*, endocarp ; *c*, testa ; *d*, endosperm or albumen ; *e*, embryo ; *f*, cavity in the endosperm which contains the milk.

consistency. In the Plum, Cherry, and Peach (fig. 276) the epicarp forms the skin, and the mesocarp the succulent edible portion. In the Coconut (fig. 277) both epicarp and mesocarp are dry and fibrous, whilst in the Almond and Walnut they are leathery. In some few cases, as in the Cornel (fig.

276, II.), there are two loculi in the drupe, usually there is but one.

The **berry**, as seen in the Gooseberry (fig. 278), Grape, or Currant, has the endocarp soft and succulent as well as the

FIG. 278.—Transverse section through a Gooseberry; the firmer outer layer of the pericarp encloses the succulent flesh; the seeds lie imbedded in the latter, and are attached by long funiculi to two opposite parietal placentæ.

FIG. 279.—Longitudinal section through an Apple: c, dry persistent calyx limb; e, loculi with cartilaginous pericarp; t, mesocarp.

FIG. 280.—Achene.

mesocarp, whilst the epicarp forms a skin. In the Gourd and Cucumber we have a fruit much resembling the true berry, but the outer layers are firmer and harder; such a variety of berry

FIG. 281.—I. Acorn of *Quercus sessiliflora*, with two empty cupules. II. Longitudinal section through the fertilised pistillate flower, with the cupule in an early state.

is known as a **pepo**. The fruit of the Orange, known as a **hesperidium**, is a multilocular berry; whilst in the Apple we have a berry-like pseudocarp, the fleshy edible portion being the enlarged thalamus, and the scales above forming the re-

mains of the calyx, whilst the core is the true fruit. This variety is known as a **pome**.

In the **achene** (fig. 280) all three layers of the fruit are dry ; whilst if they are lignified, as in the Nut and Acorn (fig. 281), the term **glans** is employed.

Sometimes we have several fruits produced from the ripening of the apocarpous pistil of a single flower, and the name of **etærio** is applied.

FIG. 282. — Fruit of Dewberry (*Rubus cæsius*). I. Natural size.

II. A single drupelet.

FIG. 283. — Pseudocarp of the Strawberry.

FIG. 284. — Section of fruit of Rose.

Thus in the Raspberry, Blackberry, and Dewberry (fig. 282) we have an etærio of drupes. In the Buttercup and Strawberry we have an etærio of achenes (in the latter case, as we have seen, the edible portion is the enlarged thalamus).

In the Rose (fig. 284) we have an etærio of achenes contained within a hollow receptacle, and the whole pseudocarp is called a **cynarrhodum**.

THE SEED.

We have already, in Chapter II., described the seed in a general manner ; there are, however, a few details which it is necessary to note at this point. Various terms are used to describe the arrangement of the radicle and cotyledons in the embryo. When the two cotyledons lie flat upon one another, and the radicle is placed upon the line which separates them, as is the case with many cruciferous plants (fig. 285), the embryo is **pleurorhizal**.

When the cotyledons are flat upon one another, but the radicle is placed upon the back of one of them (fig. 286), the embryo is **notorhizal**.

When the two cotyledons are folded upon one another leaving a hollow channel in which the radicle is placed (fig

FIG. 285.—Pleurorhizal embryo of *Lunaria*. I. Transverse, II. Longitudinal section through the seed.

FIG. 286.—Seed of *Neslea paniculata*. I. Entire. II., III. Sections in two different directions, showing the notorhizal embryo.

FIG. 287.—Seed of *Eruca sativa*. I. Entire. II., III. Sections in two different directions, showing the orthoplozic embryo.

FIG. 288.—Spiral embryo of *Bunias Erucago*.

FIG. 289. — Peripheral endosperm surrounding the central embryo in the Pansy.

FIG. 290. — Peripheral embryo surrounding the central endosperm in *Mirabilis Jalapa*.

FIG. 291. — Lateral embryo of *Menispermum canadense*.

287), the embryo is **orthoplozic**. When, lastly, the flat cotyledons are spirally coiled (fig. 288), the embryo is **spiral**.

Again, in albuminous seeds, if the embryo is in the centre

surrounded by the endosperm, as in the Pansy (fig. 289), the former is said to be **central**, and the latter **peripheric**.

The case is just reversed in the *Mirabilis Jalapa* (fig. 290), where the peripheric embryo is bent round the central endosperm.

At other times the embryo and albumen are placed more side by side, when they are said to be **lateral**.

FIG. 292.—I., II., III. Development of the arillus of the Yew. IV. Longitudinal section through the ripe seed.

In some plants a peculiar appendage is developed from the hilum of the ovule after fertilisation, and, growing up round the seed, forms either a complete coat as in the Yew (fig. 292), a perforated coat as in the 'mace' of the Nutmeg, or hairs as in the case of the Willow. This is known as the **arillus**.

CHAPTER XII.

*THE MOVEMENT OF WATER IN THE PLANT
TISSUES.*

IN the tissues of a living plant there is a continual movement of water, the amount of movement being governed by various circumstances. This movement may be readily described under three heads.

1. **Slow Movement.**—Wherever cells are growing water is needed to aid their growth. Again, during the process of assimilation, water is the chief source of the hydrogen which is required for the formation of the organic materials. Also water is needed in the reservoirs where the assimilated food is stored up in order to re-dissolve that food and convey it to the growing parts. All of these necessities cause a flow of water towards these parts. This flow, like the growth and assimilation, is slow. It is caused by osmosis, the growing cell absorbing water from the next, and so on till the source of water is reached. It takes place in the parenchyma and meristem of the stem. It is greatest during the spring and early summer—the time of most rapid growth.

2. **Rapid Movement.**—In plants which grow entirely under water the slow movement is the only one which exists. In all ordinary plants there is, however, another kind of movement going on due to the transpiration which we have seen takes place in the leaves. As water thus escapes a fresh supply has to be obtained, and this passes up entirely through the lignified cells of the xylem. If the supply is not sufficient to replace the loss, the leaves droop and wither. This is the reason why a branch cut from a tree so soon withers, as there is no water to compensate for evaporation. If such a branch is placed in

water it cannot, as a rule, obtain a sufficiency of the needed liquid, owing to the fact that cutting the stem in the air acts upon the cut surface in such a way as to diminish its absorbing power. If, however, the stem is cut under water, absorption takes place as usual. That the current does take place through the wood can be shown—(1) If a ring of bark is cut off the stem of a growing plant, as long as the wood is uninjured the leaves will not droop; and (2) if the plant is watered with some coloured solution it is found to rise in the wood, staining it. The amount of the flow of water in the wood depends upon the amount of transpiration. It is greatest in the summer, when the transpiration is most rapid. At this time

the wood cells and vessels are full of air, hence the water must pass not through the cell cavities, but in the cell walls.

Trees can be much more readily transplanted in the late autumn and winter than in the summer, because at the former times they are not so full of sap as when the leaves are fully expanded, and when they are transplanted at first the roots do not take up much water.

3. **Root-pressure.**—We may regard both of the movements of water of which we have been speaking as due to suction. There is, however, a third movement which is due to root-pressure, and which depends neither upon growth nor evaporation. If the stem

FIG. 293.—Apparatus for measuring root-pressure.

of a plant is cut, and the surface is protected from evaporation, water is found to ooze out. This is caused by the pressure of the root. The amount can be measured by means of a

manometer (fig. 293). Sometimes this root-pressure causes an exudation of water in various parts of plants. Examples are to be seen in many Grasses, Aroids, and *Alchemilla*, where the water escapes in drops along the margins and at the tips of the leaves.

It is especially in spring that this root-pressure is noticeable. In summer, when active transpiration is going on it is reduced to a minimum.

CHAPTER XIII.

INFLUENCE OF HEAT AND LIGHT UPON GROWTH.

THE various vital phenomena can only be carried on within a certain range of temperature. There is a minimum below which and a maximum above which the activity ceases. The maximum and minimum vary with different plants and for the different processes of the same plant. Roughly speaking, however, from 0°C. to 50°C. may be looked upon as the range. Between the maximum and minimum there is always a temperature, the optimum, at which the vital function is most active.

Thus, taking the germination of Maize, 9.5°C. is the lowest temperature at which it is possible ; as the temperature is increased the Maize germinates more readily until the optimum is reached at 33.7°C. Beyond this the germination is less and less active until the maximum is reached at 46.2°C.

Comparing Wheat with this, we find that the minimum of germination is 5°C. , the optimum 28.7°C. , and the maximum 37.7°C.

The injurious action of high and low temperatures upon plants depends to a great extent upon the amount of water present. Dry peas do not lose their power of germination even if exposed to a temperature of 70°C. for an hour, whilst if wet a temperature of 54°C. will kill them. In the case of low temperatures the injury is due to the water being separated from the protoplasm. It never freezes within the cell, but is separated and forms crystals of ice outside the cell wall. These crystals often considerably injure the tissues. If afterwards the thawing is gradual the tissues may recover, but if it is too rapid the water cannot be reabsorbed, and either rotting ensues, or the water evaporates and the plant dries up.

A curious effect of cold upon some plants is to change the colour of the chlorophyll. Thus the leaves of Yew, Pine, Juniper, Box, and other plants turn red or reddish brown under the influence of cold.

Light also plays an important part in the life and growth of plants. We may divide the effects of light under two heads.

1. **Chemical Action of Light.**—This is seen in the formation of chlorophyll and in the decomposition of the carbon dioxide of the atmosphere, the assimilation of carbon, and the production of starch and other organic compounds. These changes can only take place in the light. A plant grown in perfect darkness will, as we have seen, be etiolated, and no starch will be formed. A very slight amount of light—the diffused light at the back of a room—will be sufficient to produce the green colour ; but for the production of starch much brighter light is necessary. Metastasis, that is, the conversion of one kind of organic material into another (such, for instance, as the conversion of starch into sugar during the germination of many seeds), can go on without the aid of light. A plant that contains a large reservoir of food material will grow, nay even produce flowers and fruit, in the dark ; losing, however, instead of increasing in weight. The growth of tubers and bulbs in the dark and the germination of seeds are cases in point.

2. **The Mechanical Action of Light.**—Upon the development of the internodes of growing shoots light exerts a retarding influence. If a plant, such as a Broad Bean, is grown in darkness, it is found that not only does it present an etiolated appearance, but that the internodes are much longer than those of a corresponding plant grown in the light.

Again, if a plant is grown in a window, so that the sunlight falls upon only one side of it, very soon the stem will be found to bend over to the window. Such a bending is known as **heliotropism**. It is produced by the retarding influence of the light upon that side of the plant which is turned towards it. In some few cases the bending is in exactly the opposite direction. When the bending is towards the light it is called positive, and when away from it negative heliotropism.

The mechanical and chemical actions of light are brought

about by different series of rays. The least refrangible, those towards the red end of the spectrum, have the greatest chemical effect ; the most refrangible, those towards the blue end of the spectrum, possess the greatest retarding influence.

Sachs gives the following table as the result of his experiments upon the amount of carbon dioxide decomposed by the various rays of the spectrum (that decomposed by the yellow being reckoned 100) :—

Red	25·4
Orange	63·0
Yellow	100·0
Green	37·2
Blue	22·1
Indigo	13·5
Violet	7·1

If plants are grown surrounded by glass vessels, in the one case filled with a solution of potassium bichromate, which only allows red, orange, and yellow rays to pass through, and in the other case with a solution of ammoniacal copper oxide, which only allows green, blue, and violet rays to pass, in the former case no bending takes place, whilst in the latter case the heliotropism is as great as in the light.

CHAPTER XIV.

IRRITABILITY OF PLANTS.

Nor only is there a movement of plants or parts of plants during growth, but also certain fully formed organs of plants are motile, especially under the influence of an external stimulant. One of the best known examples is the Sensitive Plant (*Mimosa pudica*) (fig. 298). The leaves of this remarkable plant are bipinnate, and are articulated to the stem. The four pinnæ and the separate leaflets are also articulated. Spontaneously at evening, or under the influence of any irritant, the leaflets fold upwards, whilst the leaf-stalk as a whole bends downwards. The movement is due to the presence at the base of the stalk and of each leaflet of a mass of succulent parenchyma—the pulvinus. The cells are saturated with water, rendering them turgid. On irritation some of the water escapes into the intercellular spaces, and the elastic cell walls contract, producing the movement. When the irritation is removed the sap flows again into the tissue, causing the return of the leaf to its normal position.

The movement only takes place between the temperatures of 15° C. and 40° C. Oxygen appears to be necessary, as under the exhausted receiver of an air-pump, or in an atmosphere of hydrogen, nitrogen, or carbonic acid, the leaves of *Mimosa* cease to move. Anæsthetics, as chloroform, also cause a cessation of the movements.

The leaves and leaf-hairs of Venus's Fly-trap (fig. 143) and Sundew are irritable. When a fly alights upon the surface of the leaf it causes a bending over of the sides of the leaf to enclose it.

The stamens of many flowers are irritable. The Barberry

is a good example. There are six stamens surrounding the pistil. If one is touched it springs forward towards the ovary. At the base of the stamens are honey glands ; insects visiting the flowers in search of honey strike against the stamens, causing them to fall forward, scattering the pollen over the intruders' bodies.

In the *Centaurea* and some other Compositæ the stamens contract on touching. Some leaves, although they are not sensitive to touch, close at the approach of night. The leaflets of Wood-sorrel fold down, those of Clover fold up. Changes of temperature and variation in the amount of light produce these movements.

The opening and closing of flowers at certain hours of the day is a phenomenon due to similar causes.

CHAPTER XV.

CLASSIFICATION.

UNDER the head of Classification we include the grouping of plants into classes according to their affinities. There are two great systems of classification, the *Artificial*, or (as it is often called) the Linnæan, and the *Natural*. In the former case the plants are arranged simply according to the number, position, and relation of their stamens and carpels ; in the second case the general structure and arrangement of the plant as a whole is taken into account. The result is that although the Artificial system is a most useful one for the purpose of tracing out a flower whose name we may wish to discover, yet since it depends solely on the arrangement of one set of organs, it often separates plants which are evidently closely allied, and on the other hand unites those which possess no common properties beyond the structure of their flowers. For these reasons, for the purposes of classification, the Natural system is now always employed.

The sub-kingdom of Flowering Plants is divided into two classes, the **Dicotyledons** and **Monocotyledons**, most of the distinctive characteristics of which we have already noted, and hence it will only now be necessary to tabulate them as follows.

DICOTYLEDONS.

Embryo with two cotyledons.
 Primary root-growth exorhizal.
 Growth of wood with open bundles, exogenous.
 Leaves net-veined.
 Parts of the flower arranged (as a rule) in fours or fives.

MONOCOTYLEDONS.

Embryo with one cotyledon.
 Primary root-growth endorhizal.
 Growth of wood with closed bundles, endogenous.
 Leaves parallel-veined.
 Parts of the flower arranged in threes.

Each of these classes is divided into sub-classes, of which

there are four in the Dicotyledons, and two in the Monocotyledons.

If we examine four such flowers as the Buttercup, Rose, Dead-nettle, and Hazel, we shall easily be able to understand the grouping.

In the first three specimens the flowers are **complete** ; in the Hazel **incomplete**, the calyx and the corolla being absent. The Hazel stands, then, as a representative of the sub-class **Incompletæ**.

In the first two specimens the flowers are **polypetalous** ; in the Dead-nettle the corolla is **gamopetalous**. The latter, therefore, is an example of the sub-class **Corollifloræ** or **Gamopetalæ**.

In the Buttercup the petals and stamens are **hypogynous**, which characterises the sub-class **Thalamifloræ** ; whilst in the Rose they are **perigynous** (in some members of the group they are **epigynous**), and the sub-class is known as the **Calycifloræ**.

We may tabulate these results thus :—

Dicotyledons	Complete	Polypetalous	Petals and stamens		THALAMIFLORÆ
			hypogynous	.	
		Incomplete	Gamopetalous	Petals and stamens	
	perigynous or epigynous			.	
	.		.	.	.
.	.	.	.	INCOMPLETÆ	

The Monocotyledons are divided into two sub-classes : the **Petaloidæ**, which, like the Lily or Tulip, possess an evident perianth ; and the **Glumaceæ**, which, like the Grasses, have their flowers arranged in those peculiar bracts known as glumes.

Each of these sub-classes is divided into several natural orders ; in this work we shall deal with a few of the principal.

DICOTYLEDONS.

THALAMIFLORÆ.

Pistil apocarpous.	Petals few, stamens many .	RANUNCULACÆÆ.
Pistil syncarpous	Corolla cruciform, stamens	
	tetradynamous . .	CRUCIFERÆ.
	Leaves opposite, stem	
	swollen at nodes, sepals	
	and petals 5. Free	
	central placenta . .	CARYOPHYLLACÆÆ.

CALYCIFLORÆ.

Pistil apocarpous	{	Flowers papilionaceous, stamens 10, mono- or diadelphous, pistil monocarpellary	LEGUMINOSÆ.
		Flowers regular, petals 5, stamens and carpels numerous	ROSACEÆ.
Pistil syncarpous	{	Flowers arranged in umbels, petals and stamens epigynous, fruit a cremocarp	UMBELLIFERÆ.

COROLLIFLORÆ.

Flowers compound (in a capitulum)	{	Stamens syngenesious . . .	COMPOSITÆ.
		Stem square, leaves opposite, corolla bilabiate, stamens didynamous, ovary 4-lobed	LABIATÆ.
Flowers simple	{	Stamens didynamous, ovary 2-lobed	SCROPHULARIACEÆ.
		Stamens five, ovary 2-lobed, inflorescence scorpioid . .	BORAGINACEÆ.
		Stamens five. Free central placentation	PRIMULACEÆ.

INCOMPLETEÆ.

Flowers not in catkins	{	Calyx present, stamens opposite sepals, ovary 1-celled .	CHENOPODIACEÆ.
Flowers in catkins. Trees or shrubs			AMENTACEÆ

MONOCOTYLEDONS.

PETALOIDÆ.

Flowers irregular, ovary inferior, stamens gynandrous	ORCHIDACEÆ.
Flowers regular, ovary superior, 3-celled ; perianth 6 divisions, stamens 6	LILIACEÆ.
Flowers regular, ovary inferior, 3-celled ; perianth 6 divisions, stamens 6	AMARYLLIDACEÆ.

GLUMACEÆ.

Stems solid, sheaths of leaves not split, no ligule present	CYPERACEÆ.
Stem hollow, leaf-sheath split, ligule present	GRAMINACEÆ.

Each of these orders contains numerous plants, which are arranged in *genera* and *species*. A genus is an assemblage of plants which resemble one another more closely in general structure and appearance than they do other species of plants. Thus, if we examine a Sweet Violet, a Dog-violet, and a Pansy, we find that although they differ in many minor points of detail, yet there is a great resemblance between them which causes them all three to be grouped under the genus *Viola*. By a species we mean an assemblage of individuals which whilst possessing the characteristics of the genus, possess in addition distinctive characters which separate them from the allied plants of the same genus. Thus the points in which the Sweet Violet, Dog-violet, and Pansy agree would be their generic characters; whilst the points in which they differ are their specific characters. When the seed of a plant is grown it always reproduces the same species as the parent. In giving the name of a plant we place the generic name first, followed by the specific name. Thus the Sweet Violet is *Viola odorata*, the Dog-violet *Viola canina*, and the Pansy *Viola tricolor*.

Sometimes the pollen of one species will fertilise the ovule of a closely allied species, and a plant is thus obtained which combines the properties of both. Such a plant is said to be a *hybrid*.

We will now give a detailed account of the various orders, in each case mentioning a typical plant that should be carefully examined and compared with the description of the order.

DICOTYLEDONS.

THALAMIFLORAL ORDERS.

RANUNCULACEÆ.

Plant for examination, Buttercup (there are several species any of them will answer for the purpose).

Note that the plant is an **herb** (the Clematis is a **shrubby climber**; otherwise the plants of the order are all herbs). If you have a specimen with leaves on the stem, they are arranged in an **alternate** manner (in the Clematis they are **opposite**). Often the bases of the leaves sheath around the stem. Examine the flower, making a vertical section through one (fig. 165),

and removing the parts of another. The **sepals** are **five** (in the order they vary from three to six, usually five), inferior. **Corolla** usually of **five petals** (varies in order from three to fifteen), **hypogynous**. (In some plants of the order, as Marsh-marigold (fig. 287) and Anemone, the corolla is absent.) **Stamens numerous, hypogynous; carpels distinct, numerous, superior** (sometimes in the order they are few). Fruit, an *etærio* of *achenes*. Some Ranunculaceæ have follicles (figs. 265 and 294, II.). The flowers in the case of the Buttercup are

FIG. 294.—Marsh-marigold (*Caltha palustris*). I. Part of plant.
II. Fruit, consisting of follicles.

regular; in other cases, as in the Aconite (fig. 172) and Larkspur (fig. 202), they are *irregular*. Plants of this order contain a watery acrid juice which is often poisonous. They grow in damp and marshy places, especially in the temperate regions.

Principal Plants of the Order.

Aconitum. The British plant, *A. Napellus*, the Monkshood, is easily recognised by its hooded calyx (fig. 172), the petals being small and developed as nectaries (fig. 203). The plant is very poisonous: the root has been mistaken for Horse-radish with fatal results; it is, however, much more conical in shape. It is most useful for medicinal purposes.

Adonis, Pheasant's-eye (fig. 295). Much like the Buttercup, but the petals are bright scarlet and have no nectaries at the base. Flowers in the summer and early autumn in corn-fields.

Anemone, Wind-flower. No corolla present, the calyx either coloured as in the Pasque-flower, or white as in the Wood-anemone. Flowers in the spring; several species cultivated in our gardens for their showy colours.

Aquilegia, Columbine, with its five sepals petaloid, and five petals with spurs twisted up in a horn-like manner. Grown in gardens.

Caltha, Marsh-marigold (fig. 294). A marsh plant with large flowers, yellow sepals, and no petals.

(Note, although this and other plants of the order are incomplete, the corolla being absent, yet we place them in this thalamifloral order because their general affinities resemble those of the other plants of the group. The same remark is true of many incomplete plants of other orders.)

FIG. 295.—Pheasant's-eye (*Adonis*). I. Longitudinal section through achene.
II. Longitudinal section through flower.

Clematis, Old Man's Beard, or Traveller's Joy. A shrubby climber with opposite leaves. The sepals are petaloid (greenish white in the British species), and petals absent. Many exotic *Clematis* are cultivated for their beautiful flowers.

Delphinium, Larkspur (fig. 202). Flowers with one sepal spurred. Two petals small and united within the spurred sepal. Stavesacre is obtained from an exotic *Delphinium*.

Helleborus, Hellebore. Sepals large and petaloid, petals small and tubular. The Christmas Rose is an exotic *Helleborus*.

Myosurus, Mousetail. Small clawed petals, and carpels arranged in a dense cylindrical spike, whence the name.

Pæonia, Peony. Large showy flowers with deep red petals, and stamens inserted in a prominent disc.

Ranunculus, Crowfoot or Buttercup. A numerous genus, the flowers usually yellow, in some few cases white, but all characterised by the presence of nectaries at the base of the petals.

CRUCIFERÆ.

Typical plant, Wallflower (*Cheiranthus Cheiri*) (fig. 296). Note, the stem is **shrubby** below and **herbaceous** above (the

FIG. 296. — Wallflower (*Cheiranthus Cheiri*), Siliquosæ. Part of plant.

FIG. 297. — I. Schizocarps of *Isatis tinctoria*. II. Transverse section of angustisept silicle of *Capsella*. III. Transverse section of latisept silicle, *a*, of *Camelina*; *b*, four seeds. IV. Lomentum of *Raphanus*.

plants of the order are generally herbs, sometimes under-shrubs). **Leaves** alternate and **exstipulate**; flowers are arranged in a **raceme**; **calyx** four sepals, **saccate**; **corolla** four petals, **cruciform**; **stamens** six in number, **tetradynamous** (fig. 213) (note, in cultivation there is always a tendency for the stamens to become the same length); pistil with single ovary and two stigmas; fruit a **siliqua**. (Besides the siliqua there is also met with in the order the *silicle*, the *lomentum*, and an indehiscent fruit as seen in the Woad, figs. 271 and 297.) This is a large and

widely distributed order, easily recognised by the cruciform corolla and tetradynamous stamens. **No plant of this order is poisonous.** Many are used for food purposes. Many of the plants contain sulphur and are pungent in taste.

Principal Plants of the Order.

Brassica. A large and important genus. Leaves irregularly pinnate; flowers yellow; fruit a siliqua, often beaked at the end. Principal species are—*B. Sinapis*, Mustard; *B. oleracea*, which yields all the varieties of Cabbage, Cauliflower, Broccoli, Brussels Sprouts, and Savoy; *B. Napus*, Rape; *B. campestris*, Swedish Turnip, the seeds of which with some other species yield colza oil; *B. Napa*, Turnip.

Capsella (fig. 102), Shepherd's-purse. One of the commonest weeds, and a good example of a silicula-bearing crucifer. Flowers small, white; fruit a silicula with replum running across the narrow diameter (*angustisept*) (fig. 297, II.).

Cheiranthus, Wallflower.

Cochlearia. Fruit a silicula with replum running across the broad diameter (*latisept*) (fig. 297, III.), so that the fruit is nearly globose. There are two British species, the Horseradish and the Scurvy-grass.

Crambe, Sea-kale. Fruit two-jointed, upper joint with one seed indehiscent, lower joint forming a stalk above the calyx; might be mistaken for a gynophore.

Iberis, Candytuft. Petals unequal, the two exterior petals larger than the interior ones; fruit silicula, *angustiseptate*.

Isatis, Dyer's-woad. Small numerous yellow flowers; fruits pendulous, flattened, indehiscent. The plant yields a blue dye.

Lepidium, Cress. Numerous small white flowers, petals equal; fruit silicula, *angustiseptal*, one seed in each cell.

Matthiola, Stock. Plants hoary from minute hairs; large purple flowers; fruit a cylindrical siliqua.

Nasturtium, Watercress. Small yellow or white flowers; fruit a siliqua, generally somewhat curved. (This must not be confounded with the garden *Nasturtium*, which is a *Tropæolum*, belonging to quite a different order.)

Raphanus, Radish. Fruit a lomentum.

CARYOPHYLLACEÆ.

Typical plant, the Greater Stitchwort (*Stellaria Holostea*).

Note, the plant is **herbaceous**; the **leaves** are **opposite, exstipulate**; in some few genera there are small scarious (scaly) stipules. The **stem** is **swollen** at the **nodes**. **Inflorescence** a **dichotomous cyme** (fig. 156), usually to be found in the order; calyx five separate sepals (in some genera calyx is gamosepalous); corolla five petals notched (this is often met with in the order, and in many cases the petals are unguiculate, figs. 180, 181, and 195); stamens ten, seldom in the order fewer; pistil with *syncarpous* ovary, *three styles* (in the order the number varies from two to five); **free central placentation**, very characteristic of order. A very wide-spread order, found in all parts of the temperate regions, especially in the Northern Hemisphere.

Principal Plants of the Order.

Cerastium, Mouse-ear Chickweed (fig. 156). A numerous genus. Flowers with separate sepals, two-cleft petals, five styles; the fruit often prolonged in a horn-like manner, and opens by ten valves or teeth.

Dianthus, Pink (fig. 147). Calyx gamosepalous, with two or more scales (bracts) outside, two styles. There are several species cultivated, such as the Clove Pink or Carnation, Maiden Pink, Cheddar Pink, Sweet-william, &c.

Lychnis (fig. 194). Gamosepalous calyx, ebracteate; ovary with five styles. Several species grow as common weeds, such as Ragged Robin, Evening Campion, and Corn-cockle.

Silene. Differs from the *Lychnis* in having three or four styles. Several species of Campion and Catchfly.

Stellaria. Differs from *Cerastium* in having three styles, and capsule opening by six valves or teeth. Several species of Chickweed and Stitchwort.

We now come to the—

CALYCIFLORAL ORDERS.

LEGUMINOSÆ.

Typical plant, Sweet-pea (*Lathyrus odoratus*, fig. 93.

Note, the plant is *herbaceous* (in the order there are also shrubs and trees); leaves *alternate*, *stipulate*, often compound and pinnate, as in this case; calyx *gamosepalous*, with five teeth; corolla **papilionaceous**; **stamens** ten, **diadelphous** (in several genera they are **monadelphous**); pistil *monocarpellary*; fruit a *legume*.

FIG. 298.—Sensitive Plant (*Mimosa pudica*).

There are three sub-orders of this important order. All the British plants, however, belong to one of these, the *Papilionaceæ*, which is distinguished by having papilionaceous flowers, and hence can be easily recognised.

In the other two sub-orders, which are exclusively extra-European, the flowers are regular, the petals being imbricated in the *Cæsalpineæ*, and valvate in the *Mimoseæ* (fig. 298). The order is a very large one and widely distributed, very varied in its properties, some of the plants being most useful as food and fodder plants, others as drugs, whilst others again are poisonous.

Principal British Plants.

Astragalus, Milk Vetch. Leaves imparipinnate; stamens diadelphous; keel of corolla blunt; legume not jointed, but more or less divided into two cells by a partition. A good fodder plant.

Genista, Greenweed and Dyer's-weed. Leaves simple; stamens monadelphous; calyx bilabiate. The Dyer's-weed (*G. tinctoria*) yields a yellow dye.

Lathyrus, Peas and Vetchlings. Leaves imparipinnate, ending in tendrils, with few leaflets, and sagittate or half-sagittate stipules; stamens diadelphous, style flattened above. Several species used as fodder plants. The Sweet-pea (*L. odoratus*) and Everlasting Pea (*L. latifolius*) are exotic species. The edible Pea is separated into another genus, *Pisum*.

Lotus, Bird's-foot Trefoil. Leaves trifoliate, with large leaf-like stipules; stamens diadelphous; calyx with five equal teeth; legume imperfectly many-celled. A good fodder plant.

Medicago, Medick or Lucerne. Leaves trifoliate; stamens diadelphous; legume more or less spirally twisted (fig. 299),

FIG. 299.—Twisted legume of Lucerne (*Medicago sativa*).

FIG. 300.—Abbreviated inflorescence of Clover.

sickle-shaped, indehiscent. Much cultivated as a fodder plant, especially *M. sativa*, the Lucerne.

Melilotus, Melilot. Leaves trifoliate; flowers in long loose racemes; stamens diadelphous; legumes with one or very few seeds, longer than the calyx. Fodder plants.

Onobrychis, Sainfoin. Leaves imparipinnate; stamens diadelphous; legume flat, hard, one-seeded, and indehiscent. A valuable fodder plant.

Sarothamnus, Broom. Leaves trifoliate, three digitate leaflets; stamens monadelphous; calyx campanulate, with two lips, minutely toothed; legume flat, many-seeded.

Trifolium, Trefoil or Clover. Leaves trifoliate; flowers in abbreviated heads (fig. 300); stamens diadelphous; legume few

seeds, concealed within calyx and often indehiscent. Many species are very largely cultivated as fodder plants.

Ulex, Furze. Leaves simple and acerose; two sepals; stamens monadelphous.

Vicia, Vetch and Tares. Leaves imparipinnate, ending in tendrils and with many leaflets; stamens diadelphous; style thread-like. Very useful fodder plants. One exotic species, *V. Faba*, gives us the Broad Bean.

The following are important exotic plants belonging to this sub-order:—Used for food purposes: *Arachis*, Ground-nuts; *Ervum*, Lentils; *Phaseolus vulgaris*, the French Bean; and *P. coccineus*, the Scarlet Runner; *Pisum*, Pea. Used for various purposes: Balsam of Tolu, Indigo, Kino, Laburnum, Liquorice, Ordeal Bean, Rosewood, Tonquin Bean.

The following important plants belong to the other two sub-orders:—Braziletto-wood, Cassia, Copal, Copaiba Balsam, Locust-tree, Logwood, Sandal-wood, Sanders-wood, Sensitive Plant, Tamarind.

ROSACEÆ.

Typical plant, Bramble (*Rubus fruticosus*); also compare with it Blackthorn or Sloe, Rose, and Apple.

Note, the plant is a *shrub* (in the order there are also herbs and trees); leaves *alternate*, stipules present, adhering to the

FIG. 301.—Longitudinal section through the flower of the Pear.

petiole (stipules are seldom absent in the order); calyx *gamosepalous*, five *divisions*, *inferior* (there may be but four divisions to the calyx—in the Rose it forms a cup-like tube enclosing the carpels [fig. 196], and in the Apple and Pear it is adherent to the carpels, figs. 301 and 279); corolla **poly-petalous**, **five petals**, **perigynous** (in a few cases there are four petals, and in some cases none); **stamens numerous**, **perigynous**; **carpels numerous** (in the Blackthorn there is but one), **apocarpous**; fruit an *etærio* of

*drupe*s. (In the order the fruit is very various. Thus it may be a single *drupe*, Blackthorn; *etærio* of *achenes*, Straw-

berry ; *cynarrhodum*, Rose ; *follicles*, Meadow-sweet ; or *pome*, Apple.)

This large and important order is widely distributed, especially in the temperate regions. Many of the plants very much resemble those of the Ranunculaceæ, but a careful examination will show the great distinction from that order in the perigynous stamens and petals.

The Rosaceæ are divided into four sub-orders :—

1. DRUPACEÆ or AMYGDALÆ. Trees or shrubs with simple leaves ; fruit a drupe. Many parts of the plants contain hydrocyanic or prussic acid.

Prunus is the only British genus of this sub-order. It has the nut of the drupe smooth or slightly seamed. The native species include the Sloe, Wild Plum, and Cherry. Amongst exotic species of the same genus which are largely cultivated are the Apricot, Cherry Laurel, and Portuguese Laurel.

Amygdalus is the exotic genus which yields us Almonds, both bitter and sweet, Peaches, and Nectarines.

2. ROSEÆ. Shrubs or herbs ; stipules adherent ; ovaries one or more, not adherent to calyx ; fruit etærio or folliclès.

Principal British Plants.

Agrimonia, Agrimony. Flowers in loose spikes ; calyx five-cleft, top-shaped, with hooked bristles ; stamens not more than fifteen ; carpels two. The plant was formerly used by herbalists.

Fragaria, Strawberry. Calyx ten-cleft, in two rows ; fruit an etærio of achenes on an enlarged and fleshy receptacle.

Potentilla differs from the Strawberry principally in the fruit being on a dry receptacle ; *P. Tormentilla* has but four petals.

Rosa. Calyx urn-shaped ; fruit a cynarrhodum. There are several species of wild Roses and Briars, from which many of our cultivated Roses are obtained ; others come from exotic species.

Rubus, Bramble. Calyx five-cleft ; fruit etærio of drupes. The genus includes the Raspberry, Blackberry, Dewberry, and Cloudberry.

Spiræa. Calyx five-cleft ; fruit three to twelve follicles. Several species of Meadow-sweet. Some of the exotic plants are cultivated for their flowers.

3. SANGUISORBEÆ. Herbs or under-shrubs ; flowers often unisexual ; petals absent (fig. 302) ; carpel solitary ; fruit an achene (fig. 302, II.).

FIG. 302.—*Sanguisorba officinalis*. I. Flower. II. Fruit

British Plants.

Alchemilla. Calyx eight-cleft, in two rows ; stamens one to four. The species of Lady's-mantle and Parsley Piert are used as fodder plants.

Poterium, Salad Burnet. Calyx four-cleft, petaloid ; flowers unisexual ; stamens numerous. A good salad plant.

Sanguisorba, Great Burnet. Calyx four-cleft, petaloid ; stamens four. Grown in Germany as a fodder plant.

4. POMEÆ. Trees or shrubs ; carpels one to five, adhering more or less to one another, and sunk in the receptacle, thus becoming inferior ; fruit a pome.

British Plants.

Cratægus, May or Hawthorn. Fruit hard or bony ; calyx divisions sharp.

Mespilus, Medlar. Differs from the May in its larger flowers and foliaceous calyx divisions.

Pyrus. Calyx divisions small ; fruit fleshy. Its species include the Apple, Pear, Rowan-tree or Mountain Ash, and

Wild Service-tree. The exotic genus *Cydonia* yields us the Quince.

From many of the plants of this sub-order also prussic acid is obtainable.

UMBELLIFERÆ.

Typical plant, Cow-parsnip (*Heracleum Sphondylium*).

Note, the stem is **herbaceous**, *hollow*, except at the nodes ; leaves *alternate*, *sheathing at base*, *bi- or tri-pinnate* (leaves in the order are generally much divided) ; flowers in **compound umbels** (in *Hydrocotyle* the umbels are simple, in *Sanicula* and *Eryngium* the flowers are arranged in tufted heads) ; **calyx adherent** to ovary, free limb absent, or as five *small teeth* ; corolla **polypetalous**, **five petals**, **epigynous** ; **stamens five**, **epigynous** ; pistil *inferior*, *two cells*, *two styles* ; fruit a **cremocarp**.

This is a very large and wide-spread order, easily recognisable by its umbellate flowers and two-celled ovary with cremocarp. The plants of the order are, however, very difficult to identify, as the distinctions of the genera and species depend principally upon small points of detail in the structure of the seed and the fruit.

The properties of the order are very various ; some members yield us food plants, others are very poisonous ; and again others yield useful drugs.

Principal British Plants.

Angelica. Fruit two flattened carpels united by their faces, with three sharp ridges at the back of each, and two at the

FIG. 303.—I. *Aethusa Cynapium* (Fool's-parsley). II. Fruit. III. Section of fruit.

side expanding out. The leaf-stalks are used candied as sweet-meats.

Æthusa, Fool's-parsley (fig. 303). Fruit nearly globose; no general bracts, but three partial bracts to each secondary umbel, which hang down (figs. 303 and 151). A very poisonous plant, liable to be mistaken for true Parsley; distinguished by its bracts.

Apium, Celery. Fruit roundish egg-shaped, the carpels flattened and united by the narrow edge, five slender ridges on each; no bracts. In the wild state poisonous; when blanched by etiolation, fit for eating.

Bunium, Earth-nut. Oblong fruit of flattened carpels united by narrow edge with five blunt ridges; no general involucre, but a slight partial one. The tuberous root is esculent.

Carum, Caraway. Oblong fruit of flattened carpels united by narrow edge with five slight ridges; no bracts, or at most but one general bract. Roots and leaves are edible, and fruit used under the name of Caraway-seed.

Chærophylum, Chervil. Fruit contracted at sides, with short beak, five blunt ridges on each carpel; several partial bracts. Formerly cultivated as a culinary herb.

Cicuta, Water-hemlock. Fruit of two globose carpels united by narrow edge with five broad flattened ridges. A most virulent poison.

FIG 304.—I. Fruit of Coriander (*Coriandrum sativum*). II. Transverse section.

Conium, Hemlock. Fruit egg-shaped, with five wavy ridges on each lobe. Plant emits, when bruised, a nauseous 'mousy' smell. A most poisonous plant, useful medicinally.

Coriandrum, Coriander. Fruit globose (fig. 304), scarcely prominent ribs, very aromatic. Fruit used under name of Coriander seed.

Crithmum, Samphire. Leaves succulent; fruit elliptical, with spongy lobes. The plant is edible, being used as a pickle.

Daucus, Carrot. Fruit slightly flattened, prickly (fig. 305), there being rows of prickles between the bristly ridges. The root is edible, forming the cultivated Carrot.

Eryngium, Sea-holly. Flowers in dense prickly heads.

Fœniculum, Fennel. Fruit elliptical (fig. 268), carpels with five bluntly keeled ridges. Leaves much divided. Plant esculent.

Helosciadium, Marshwort, or Fool's Watercress. Plant much resembling Watercress, but leaves more pointed and serrate. No general bracts, five partial. Very poisonous, hence importance of distinguishing it from Watercress.

Heracleum, Cow-parsnip. Very common weed. Flowers white, the outer petals of umbel larger than the inner ones, else very like the true Parsnip. Might be used as an esculent herb.

Hydrocotyle, White-rot. A marsh plant with simple umbels and peltate leaves.

Ligusticum, Lovage. Fruit elliptical, not flattened, the five ridges to each lobe sharp and winged. Used as a vegetable in many parts.

Myrrhis, Sweet Cicely. Very aromatic; fruit large, with deep furrows between carpels, and five sharply keeled ridges. Potherb.

Œnanthe, Water-dropwort. Fruit egg-shaped, with five blunt ridges; petals notched. Very poisonous plant.

Pastinaca, Parsnip. Fruit very flat, with broad border; flowers yellow, all small. Root edible.

Petroselinum, Parsley. Fruit very much like Celery; numerous partial bracts. Esculent plant.

Pimpinella, Burnet Saxifrage. Fruit much like Celery, but ribs less prominent. Aniseed is obtained from an exotic species of this genus.

FIG. 305.—I. Fruit of Carrot (*Daucus Carota*). II. Transverse section: the four secondary ridges are conspicuous; of the primary ridges the two lateral ones are scarcely visible, the median (carina) and intermediate ones are spiny.

Sanicula, Sanicle. Flowers in tufted heads, imperfect, the outer pistillate, inner staminate. Was formerly supposed to possess healing qualities.

The following exotic plants belong to this important order:—*Anethum*, Dill ; *Anthriscus*, Chervil ; *Cuminum*, Cummin ; *Dorema*, which yields gum ammoniacum ; *Ferula*, yields asa-fœtida ; and *Opoponax*, yielding the gum resin of that name.

COROLLIFLORAL ORDERS.

COMPOSITÆ.

Typical plant, Dandelion (*Taraxacum dens-leonis*) ; also compare with it a Daisy.

Note, the plant is **herbaceous** (some exotic Compositæ are shrubby) ; leaves exstipulate ; flowers arranged in a **capitulum**, surrounded by an **involucre** of bracts ; calyx **superior**, a **pappus** (note, the pappus absent in the Daisy) ; corolla **gamopetalous**, **epigynous**, **ligulate** (note, in the Daisy the florets of the disc have **tubular** corollas, whilst those of the ray have **ligulate** corollas), *five teeth* ; androecium **five stamens**, **epipetalous**, **syngenesious** ; pistil **syncarpous**, **single style**, and bifid stigma.

The plants of this order are easily recognised by their flowers being arranged in capitula with *syngenesious* stamens, the latter characteristic distinguishing them from the allied Teasel family.

It is the largest of all natural orders, containing one-tenth of the known plants of the world. The members of the group differ much in their properties and uses.

The British plants are divided into two sub-orders :—

TUBULIFLORÆ, which have all their florets (as the Corn Blue-bottle), or inner ones only (as Daisy), tubular.

LIGULIFLORÆ have all their florets ligulate (as Dandelion).

Principal British Plants.

TUBULIFLORÆ.

Anthemis, Chamomile. Flowers arranged on a convex receptacle, with tubular perfect florets in disc, and ligulate pistillate

flowers in ray ; the receptacle has scales between the flowers. Used medicinally.

Arctium, Burdock. All flowers tubular, perfect, and in a convex head ; a globose involucre present, with hooked points to the bracts ; pappus short. Various parts of this plant may be eaten, either as a salad or cooked (fig. 146).

Artemisia, Wormwood. All flowers tubular, perfect, in a flat head ; no pappus ; only few flowers in the head. A very bitter plant, used in the manufacture of *absinthe*.

Bellis, Daisy. Flowers as in *Anthemis*, but without scales on receptacle ; involucre of two rows of equal bracts.

Carduus, Thistle. All florets tubular, perfect, in a convex head ; involucre swollen below, with thorn-like scales.

FIG. 306.—Common receptacle of *Anthemis arvensis*, with paleæ between the flowers.

FIG. 307.—Neuter flower of *Centaurea Cyanus*.

Centaurea, Knapweed and Bluebottle. Florets tubular, inner perfect, outer large and neuter, somewhat irregular (figs. 182 and 307).

Chrysanthemum. Disc florets tubular and perfect, ray florets ligulate and pistillate ; involucre flat ; receptacle naked, and no pappus.

Inula, Elecampane. Disc florets tubular and perfect, ray ligulate, all yellow ; pappus present ; many-rowed involucre. Formerly used as a sweetmeat.

Senecio, Ragwort and Groundsel. Disc florets tubular and perfect, ray ligulate and pistillate (latter wanting in Groundsel), all yellow ; simple pappus ; scales outside the involucre.

Tussilago, Coltsfoot. Flowers appear in spring before the leaves ; flower-stalks covered with scale-like bracts ; few disc

florets, tubular, perfect ; many narrow ray florets, ligulate, pistillate ; all yellow. Often used as a remedy for colds and coughs.

LIGULIFLORÆ.

Cichorium, Chicory. Flowers blue, sessile, upon tough stems ; involucre of two rows. It is the root which is used to mix with coffee.

Lactuca, Lettuce. Few florets, with hairy pappus and oblong imbricated involucre. The garden Lettuce is an exotic species of this genus.

Taraxacum, Dandelion. Lyrate leaves, radical ; flower-stalk hollow, leafless ; outermost bracts of the involucre recurved ; receptacle dotted. The young plant forms a good salad, and is often used by herbalists as a tea.

The following exotic genera yield important plants :—*Arnica*, used medicinally in case of bruises ; *Calendula*, Marigold, also used as an external remedy for cuts, and to adulterate saffron ; *Carthamus*, Safflower, or Bastard Saffron, often used instead of true Saffron to yield the pink dye ; *Cynara*, Artichoke ; *Helianthus*, Jerusalem Artichoke and Sunflower.

LABIATÆ.

Typical plant, White Dead-nettle (*Lamium album*, fig. 158).

Note, the plant is **herbaceous** ; stem **square** ; leaves **opposite** ; flowers in **verticillasters** ; calyx **inferior**, five-toothed (it may be ten-toothed in the order) ; corolla (figs. 308 and 191) **bilabiate**, **ringent** (in some cases the corolla is almost regular, fig. 309) ; stamens **didynamous**, **epipetalous**, fig. 214 (in the Sage there are only two stamens with branched connective, fig. 217 ; and in the Mint the four stamens are equal, fig. 302) ; pistil **superior**, **four-lobed** ; fruit a **carcerulus** (fig. 272).

The four-lobed ovary is a most important point, as it distinguishes the order from the next, where there are only two lobes. **No plant of the order is poisonous.** Many contain aromatic essential oils, and are used for flavours and perfumes. It is chiefly distributed in temperate regions,

Principal British Plants.

Calamintha, Wild Basil and Basil Thyme. Calyx with thirteen nerves upon it ; corolla longer than calyx, lower lip with three broad lobes ; outer stamens longest, but not diverging from inner ones.

Lamium, Dead-nettle. Calyx ten ribs and five teeth ; corolla with upper lip arched, lower lip with large middle lobe, two side ones small.

Marrubium, White Horehound. Stamens shorter than the tube of the corolla ; calyx with five or ten teeth and ribs ; upper lip of corolla deeply notched. Used as a remedy for coughs.

FIG. 308.—*Lamium album*. Longitudinal section of flower.

FIG. 309.—Nearly regular flower of Peppermint (*Mentha piperita*).

Mentha, Mint. Corolla nearly regular ; stamens four, equal. There are many species used as flavours and odours ; principal are Spear-mint, Peppermint, and Pennyroyal.

Origanum, Marjoram. Flower in panicles or corymbs ; a bract under each flower. Used as a potherb.

Salvia, Sage or Clary. Two stamens with branched connectives.

Teucrium, Germander. Upper lip of corolla apparently wanting, but appearing as two small teeth, one on each side of the lower lip.

Thymus, Thyme. Calyx bilabiate, upper lip three-toothed,

lower two-toothed ; corolla with upper lip flat and erect, lower spreading ; outer stamens diverging from the inner ones.

Amongst exotic genera we have *Hyssopus*, Hyssop ; *Lavandula*, Lavender ; *Melissa*, Balm ; *Ocimum*, Basil ; *Pogostemon*, Patchouly ; *Rosmarinus*, Rosemary ; *Satureia*, Savory.

SCROPHULARIACEÆ.

Typical plant, Great Snapdragon (*Antirrhinum majus*, fig. 145).

Note, the plant is **herbaceous** ; leaves **opposite** (rarely alternate) ; corolla **bilabiate**, **personate**, fig. 192 (it may be almost regular, as in the Foxglove, fig. 310 ; or ringent, as in the *Scrophularia*) ; stamens **epipetalous**, **didynamous** (only two in *Veronica*, and five in Mullein) ; pistil **superior**, **two-lobed** ; **dumb-bell-shaped placenta** (fig. 311).

It is most important to note the two-lobed ovary, which distinguishes this order from the last, as many

FIG. 310.—Flower of Foxglove (*Digitalis purpurea*).

FIG. 311.—Bilocular ovary of *Antirrhinum*, with axile placentæ.

plants of the Scrophulariaceæ are poisonous. Distributed all over the world.

Principal British Plants.

Antirrhinum, Snapdragon. Corolla personate, not spurred, but with a protuberance at base.

Digitalis, Foxglove. Corolla irregularly bell-shaped ; leaves alternate. Very poisonous ; used medicinally.

Euphrasia, Eyebright. Calyx four-cleft ; corolla ringent, upper lip two-lobed, spreading.

Linaria, Toadflax. Differs from Snapdragon in having spurred corolla.

Melampyrum, Cow-wheat. Calyx four-cleft ; corolla ringent, upper lip compressed laterally.

Rhinanthus, Rattle. Differs from the last in having the calyx much swollen, with four small teeth.

Scrophularia, Figwort. Calyx five-lobed ; corolla ringent, nearly globose ; flowers small. Poisonous.

Verbascum, Mullein. Corolla rotate, five-lobed ; five stamens.

Veronica, Speedwell. Corolla rotate, four-lobed ; two stamens.

BORAGINACEÆ.

Typical plant, Forget-me-not (*Myosotis palustris*, fig. 157).

Note, plant **herbaceous** (in many Boraginaceæ the herbage is very coarse and rough with numerous hairs—**hispid**) ; leaves **alternate** ; flowers in a **scorpioid cyme** ; calyx **inferior, gamosepalous, five-lobed** ; corolla **regular, gamopetalous, five-lobed**, the throat closed by five short notched scales (in some Boraginaceæ the corolla is almost irregular, and in some cases the scales are absent) ; stamens **five, epipetalous** ; pistil **superior, four-lobed**, composed of two carpels, each divided by its dorsal suture being bent inwards ; style **gynobasic**—that is, growing up between the four ovaries and looking as though it were a prolongation of the thalamus.

The plants of the order are chiefly natives of the temperate regions of the Northern Hemisphere.

Principal British Genera.

Anchusa, Alkanet. Corolla funnel-shaped with a straight tube, the throat closed by five blunt white scales. An exotic species, cultivated in S. Europe, has a dark blood-red root, which is chiefly employed to colour oils for perfumery and other purposes.

Borago, Borage. A very coarse hispid herb ; corolla rotate, with five broad notched scales (figs. 188 and 198). It contains nitrate of potash, which gives coolness to beverages in which it is steeped, hence is used in claret cup.

Echium, Viper's Bugloss. A very coarse hispid herb ; corolla unequally five-lobed, the throat naked ; stamens much protracted.

Myosotis, Forget-me-not and Scorpion-grass. Corolla small and rotate, the throat closed by five short notched scales.

Symphytum, Comfrey. Coarse herb ; stem more or less winged by the decurrent leaves (fig. 142) ; corolla campanulate, with five awl-shaped scales. The young leaves and shoots are sometimes eaten as a vegetable.

PRIMULACEÆ.

Typical plant, Common Primrose (*Primula vulgaris*).

Note, an herb with **radical leaves** (many plants of the order, however, possess cauline leaves) ; flowers **regular** ; calyx **gamosepalous, inferior, five-cleft** ; corolla **gamopetalous, five-cleft** ; stamens **five, epipetalous**, OPPOSITE THE COROLLA LOBES (the flowers being dimorphic, the stamens are sometimes inserted just in the throat of the corolla, sometimes some little distance down the tube) ; ovary **one-celled** ; **free central placentation, single style** ; stigma **capitate**.

The plants grow mostly in the north temperate zone, especially in mountainous districts.

Principal British Genera.

Anagallis, Pimpernel (fig. 138). Calyx split to the base ; corolla rotate ; hairy stamens ; capsule dehiscing transversely (fig. 258).

Cyclamen, Sow-bread. Calyx split halfway down ; corolla rotate, with reflexed segments ; capsule dehiscing by five teeth.

Hottonia, Water-violet. A water plant with submerged divided leaves ; calyx divided almost to the base ; corolla salver-shaped ; capsule dehiscing by five teeth.

Lysimachia, Loosestrife, Yellow Pimpernel, Moneywort, Creeping Jenny, &c. Calyx divided to the base ; corolla rotate ; stamens without hairs ; capsule dehiscing by valves.

Primula, Primrose, Cowslip, Oxlip. Calyx tubular, five-cleft ; corolla salver-shaped or funnel-shaped.

INCOMPLETÆ.

CHENOPODIACEÆ.

Typical plant, White Goosefoot (*Chenopodium album*).

Note, plant **herbaceous** (some plants are somewhat shrubby), **succulent** ; leaves **alternate** (often in the order very succulent) ; flowers inconspicuous (in many plants of the order we have separate staminate and pistillate flowers) ; calyx **inferior, five-lobed** (in the order it is from two- to five-lobed, usually five), persistent (often in the order it very much enlarges as it surrounds the fruit) ; corolla **absent** ; stamens **five, opposite the sepals** (rarely in order one or two) ; pistil **superior, syncarpous** ; two or three *styles*.

This order is widely distributed, the plants growing especially in salt marshes. Many of the plants are esculent, others were formerly much employed in the manufacture of soda, which was obtained from their ashes, known as *barilla*.

Principal British Genera.

Atriplex, Orache and Purslane. Flowers generally unisexual ; perianth five-cleft in staminate and two-cleft in pistillate flowers, very much enlarged round fruit, which is one-seeded. Several species of common weeds.

Beta, Beet. Fruit one-seeded, immersed in succulent base of calyx ; three small bracts beneath the calyx. Edible ; much cultivated for manufacturing sugar. Mangel-wurzel is a variety of the Beet.

Chenopodium. Flowers differ from above in having no bracts, and the perianth not becoming fleshy on fruiting. There are several species. *C. album* is the commonest, a plant which overruns gardens and grows on waste places. It may be used as a potherb. *C. Bonus-Henricus*, Good King Harry, or All-good, is also edible. *Spinacea oleracea*, Spinach, is an exotic genus with four styles cultivated for food purposes.

AMENTACEÆ.

Typical plant, Common Hazel (*Corylus Avellana*, fig. 162).

Note, the plant is a **shrub** or **small tree** (trees and shrubs are met with in the order); leaves **alternate**; flowers in **catkins**, **monœcious** (in many plants of the order, as the Willow, the flowers are **diœcious**); staminate catkins *pendulous*; numerous *wedge-shaped bracts*; no *perianth*; eight *stamens attached to each bract*, fig. 312 (in the order the number of stamens present varies from two upwards, and a slight perianth is sometimes present); pistillate inflorescence a bud-like catkin

FIG. 312.—The Hazel (*Corylus Avellana*). I. Male flower. II. Female flower. III. Fruit with lacinated spurious cupule.

with two flowers within surrounded by numerous bracts, each flower consisting of a two-celled ovary with two red stigmas (in the order the pistillate catkins are either pendulous like the staminate, with one, two, or three flowers on each scale-like bract, or in a bud-like head with two or three flowers in the centre); fruit a one-seeded nut (in some plants of the order a capsule). This is an important and extensive family, distributed all over the globe, especially in temperate regions, and yields a large number of timber trees as well as esculent plants.

It is divided into several sub-orders, four of which are represented in this country, viz. :—

SALICINÆ. Generally diœcious ; pistillate flowers in catkins ; fruit a capsule.

BETULINÆ. Flowers generally monœcious ; pistillate flowers in catkins ; fruit a flat nut.

MYRICEÆ. Flowers generally diœcious ; pistillate flowers in catkins ; fruit a false drupe from the scaly bracts becoming fleshy.

CUPULIFERÆ. Pistillate flowers in tufts or spikes ; bracts grow up around fruit to form a cup or cupule (figs. 281 and 312).

Principal British Plants.

SALICINÆ.

Populus, Poplar. Stamens eight to thirty ; stigmas deeply forked, slight ; perianth present. Several species grown as ornamental and timber trees.

Salix, Willow and Osier. Stamens one to five ; stigmas slightly forked ; no perianth present. Very numerous species.

BETULINÆ.

Alnus, Alder. Fruit not winged ; two flowers on each pistillate bract. The wood is very durable and yields good charcoal.

Betula, Birch. Fruit winged, three in each bract (fig. 270). The timber is utilised, and from the sap Birch wine, which is used medicinally, is obtained.

MYRICEÆ.

Myrica, Sweet-gale. Dioœcious ; four to eight stamens, two stigmas.

CUPULIFERÆ.

Carpinus, Hornbeam. Stamens twelve to each scale ; pistillate catkins slender and loose ; a three-lobed scale (perianth ?) to each pistil, which enlarges with the fruit (fig. 313). Used for timber.

Corylus, Hazel. Stamens eight to each scale ; two pink stigmas to each ovary ; fruit a nut in a leafy involucre. Filberts, Cobs, and Barcelona nuts are varieties of Hazel.

Fagus, Beech. Staminate flowers in a globose catkin; stamens five to fifteen; fruit two three-cornered nuts in a prickly involucre. The wood yields good charcoal.

FIG. 313.—Fruit of the Hornbeam (*Carpinus Betulus*), with its three-lobed perianth.

Quercus, Oak. Stamens five to ten; staminate flowers in a long drooping catkin; fruit surrounded with a cup-shaped involucre. The timber is most valuable for many purposes. Cork is the outer bark of *Q. suber*. Oak-galls and Oak-apples are also obtained from various species, whilst the bark is often used for tanning.

Exotic plants of interest belonging to this order are—*Carya*, Hickory; *Castanea*, Sweet Chestnut; *Juglans*, Walnut; *Liquidambar*, species of which yield resins known as storax and liquidambar; and *Ostrya*, Ironwood.

MONOCOTYLEDONS.

PETALOIDÆ.

ORCHIDACEÆ.

Typical plant, Spotted Orchis (*Orchis maculata*).

Note, the plant is **herbaceous**; flowers **very irregular** (fig. 314); perianth **superior** (note, the twisted ovary may be mistaken for a stalk), **six-lobed**; there are three outer and three inner segments, all petaloid; one of the inner lobes is flattened out, forming a **lip** or **labellum**, and is also prolonged below into a *spur*. Behind the labellum there is a short column terminating in a knob, the **rostellum** (fig. 314, II., R), and a single stamen with two anther lobes (fig. 314, II., L, P), containing not free pollen, but a mass united together and stalked, a **pollinium** (fig. 314, IV.). Below the rostellum and stamen is the stigma (fig. 314, II., ST), so that the arrangement is gynandrous. Below is the one-celled ovary with three parietal placentas.

Taking a flower which has but recently expanded, push gently a sharpened pencil into the spur. It is found that on touching the rostellum its pouch-like membrane is pushed down,

FIG. 314.—I. *Aceras anthropophora* (Man Orchis), whole plant. II. Flower of an Orchid looked at in front, the ovary being concealed: L, P, anther lobes, each containing a pollinium; ST, stigma; R, rostellum. III. Gynostegium of *Cypripedium*, seen laterally; above to the right the anther, to the left the stigma. IV. Pollinia of an Orchid, with their pedicels united by the rostellum. V. Burst capsule. VI. Transverse section of an ovary.

and the pencil comes in contact with the viscid substance at the base of the pollinia. On removing the pencil one or both of the pollinia are removed attached to it. It will be found after removal they gradually bend over towards the point of the pencil.

If an insect, such as a bee, visits the plant for the honey contained in the spur, it presses its head against the rostellum, and flies away with the two pollinia attached ; on visiting a second flower these have bent forward, so that instead of returning to the same place from which they were taken in the previous flower, they strike against the viscid stigma, and some of the pollen remains attached.

The exact method of fertilisation varies in the different plants of this order. It is very widely distributed, especially in tropical regions. Many of the plants are *epiphytes*, or air plants : clinging to the trunks of trees, their roots are green with stomata, and never reach the soil ; they absorb all their nourishment from the air. Many of the plants are remarkable for the singular shapes of their flowers, which simulate various natural objects, insects, birds, reptiles, &c. So much so that Dr. Lindley says, 'So various are they in form, there is scarcely a common reptile or insect to which some of them have not been likened.' Amongst our British genera we have the Fly Orchis (*Ophrys muscifera*), which presents the appearance of several flies growing up the stem ; Bee Orchis (*Ophrys apifera*) and Spider Orchis (*Ophrys aranifera*), each with the flowers like the insects named. There are various species of the genus Orchis, all of which have spurred flowers : *Aceras*, or Man Orchis (fig. 314, 1.) ; *Listera*, or Twayblade ; *Habenaria*, or Butterfly Orchis, and others. Though so numerous a family, the plants are not economically useful. Salep is a starchy esculent substance obtained from the roots of several species of Orchis ; and vanilla is a flavouring material obtained from the fruit of an exotic plant, *Vanilla aromatica*. The marvellous forms of the flowers cause them to be much cultivated in our greenhouses.

LILIACEÆ.

Typical plant, Bluebell (*Scilla nutans*, or *Agraphis nutans*).

Note, the plant is **herbaceous** (the Butcher's-broom is the only British plant which is shrubby, but exotics may be shrubs or trees) ; perianth **inferior, polyphyllous** (it may be *gamophyllous*), **six divisions** (in Herb Paris there are eight) ; **stamens six** (eight in Herb Paris) ; pistil **syncarpous, three-celled**, with *axile placentæ* and *numerous ovules* (four-celled in Herb Paris).

This large and important order is widely distributed throughout the world. It is divided into several sub-orders, some of which are sometimes raised to the dignity of orders.

The British genera may be grouped into the five following sub-orders :—

TRILLIDÆ. Leaves net-veined ; styles distinct ; fruit a berry.

(All the other sub-orders have parallel-veined leaves.)

CONVALLARIÆ. Fruit a berry ; styles united ; testa of seed membranous.

ASPARAGÆ. Fruit a berry ; styles united ; testa of seed hard and black.

LILIÆ. Fruit a capsule ; styles united.

COLCHICÆ. Fruit a capsule ; styles distinct.

*Principal British Plants.***TRILLIDÆ.**

Paris, Herb Paris. A remarkable plant with four net-veined leaves upon a short stem, and the parts of the flower arranged in fours, thus resembling Dicotyledons ; but otherwise a monocotyledonous plant.

CONVALLARIÆ.

Polygonatum, Solomon's Seal. Flowers axillary, drooping ; perianth gamophyllous, shortly six-cleft, tubular.

Convallaria, Lily of the Valley. Differs from last in flower-stalk being leafless ; perianth campanulate.

ASPARAGÆ.

Asparagus. Leaves small, subulate, surrounded by short scarios scales; flowers small, polyphyllous; two ovules in each of three cells of ovary; style single, and three-lobed stigma. The young succulent shoots are eaten.

Ruscus, Butcher's-broom. Shrubby plant. The branches

FIG. 315.—Leaf-like branch or phylloclade of *Ruscus aculeatus*: *a*, flower.

are leaf-like (fig. 315), and known as *phylloclades*, the true leaves being scales upon them. The flowers are small, sessile upon the phylloclades.

LILIÆ.

Allium, Garlic, Chives, &c. Flowers in an umbel, with two or three thin bracts at base; flower-stalk leafy. Amongst cultivated species of this genus are the Onion (*A. Cēpa*), Garlic (*A. sativa*), and Leek (*A. Porrum*).

Fritillaria, Fritillary. Flowers generally single on the stalk, polyphyllous; the three inner segments have each a nectary at the base; anthers attached above their bases; style three-cleft.

Ornithogalum, Star of Bethlehem. Flowers in racemes or corymbs; perianth persistent; a scarios bract at base of each flower-stalk.

Scilla, Squill, Bluebell, &c. Flowers blue or pink, in racemes or panicles; perianth not persistent. The medicinal Squill is an exotic species of this genus.

Tulipa, Tulip. Flowers solitary on leafy stalk; petals without a nectary; anthers innate; style absent.

COLCHICEÆ.

Colchicum, Meadow Saffron. Flowers with long tube, so that the ovary is underground, but superior ; styles three, very long and thread-like.

Amongst exotic plants of this order which are grown for ornamental purposes, or are variously employed, are several species of the genus *Lilium*, also *Hyacinthus*. The genus *Aloë* yields several species, some of which are used medicinally : *Dracæna Draco* is the famous Dragon-tree of Teneriffe ; *Phormium* yields New Zealand flax ; *Sansevieria* yields African hemp ; the buds of the *Xanthorrhæa*, or Grass-tree of Australia, are eaten like Asparagus ; and *Yucca* is the Adam's Needle.

AMARYLLIDACEÆ.

Typical plant, Lent Lily or Daffodil (*Narcissus pseudo-Narcissus*). Note the bulbous underground stem ; membranous bract ; perianth with **six divisions, superior** ; corona (not always present in the order) ; **six stamens, epiphyllous** ; ovary **inferior, three-celled**.

The plants of this order differ from the Liliaceæ in possessing an inferior ovary.

Principal British Genera.

Galanthus, Snowdrop. No corona ; three outer segments of perianth larger than three inner ; flowers solitary.

Leucojum, Snowflake. No corona ; all perianth divisions equal ; flowers two to six together.

Narcissus. Flowers with corona (fig. 197).

GLUMACEÆ.

CYPERACEÆ.

Typical plant, Common Cotton Sedge (*Eriophorum polystachyum*, see fig. 83).

Note, the stem is **herbaceous, solid** ; leaves **sheathing** ; the sheaths are entire, not split down the side of the stem, opposite to the free lamina ; flowers arranged in a spike with numerous scaly bracts (*glumes*), the outer of which are empty,

and the inner ones contain the bisexual flowers ; perianth consists of numerous hypogynous bristles, which elongate on fruiting (in some plants of the order no perianth is present) ; stamens *three* ; anthers *innate* ; ovary *one-celled*, with three simple stigmas. This order contains numerous grass-like plants. In the large genus of *Carex* (Sedges) there are unisexual flowers (fig. 316).

FIG. 316.—Flower of *Cyperus longus*, with the parts separated.

FIG. 317.—I. Male flower, II. Female flower of *Carex*.

The Sand Sedge (*Carex arenaria*) is very useful for binding together the loose sand by means of its creeping stems. The Lake Scirpus (*Scirpus lacustris*) is used for chair bottoms, baskets, mats, &c. Papyrus was obtained from the stems of an Egyptian *Cyperus*.

GRAMINACEÆ.

Typical plant, Common Wheat (*Triticum vulgare*).

Note, plant is **herbaceous** (some exotics are shrubby) ; leaves **sheathing**, sheath **split in front** ; an appendage on the leaf where it separates from the sheath known as the **ligule** (fig. 318, *a*) ; stem **hollow**, except at nodes.

Flowers arranged in a spike with glumes, as in Cyperaceæ. If we remove one of the spikelets from the centre of the spike

(fig. 319, I.) we find there are two outer bracts (*glumes*), G, G, containing several flowers, some fertile and others barren, rs. Each fertile flower is enveloped by two scales, one with a prolongation or *awn*, *a*, the flowering *glume*, or *outer pale*; the other, *Pi*, more delicate, the *inner pale*. Within these there are two minute scales, feathery above, the *lodicules*. These represent all there is of the perianth (see fig. 319, II.); then three stamens with *versatile anthers*, and lastly a single ovary with *two feathery stigmas*.

FIG. 318.—*a*, split leaf-sheath of a Grass; *b*, ligule; *d*, part of the lamina of the leaf; *c*, node of the culm.

FIG. 319.—I. Expanded spikelet of the Oat, with a fertile and a barren flower, rs; G, glumes; Pe, outer pale, with awn, A; Pi, inner pale; within are the feathery stigmas. II. Fertile flower with the outer pale removed.

This is the general structure of the plants of the order; here are, however, minor points of deviation. Thus, in the Sweet-smelling Vernal-grass there are four outer glumes to each spikelet, in the Rye-grass one, and in the Mat-grass none. Sometimes the pale is absent, as in the Foxtail; or the lodicules, as in the Vernal-grass, Mat-grass, and Foxtail. In the Rice there are six stamens, and in the Mat-grass only one stigma. The Indian Corn has monœcious flowers; the staminate flowers have two lodicules and three stamens; the pistillate flowers no lodicules and but one stigma.

This large and wide-spread order is one of the most import-

ant to man, yielding, as it does, the various cereals that he employs as food, and the Grasses used as food for cattle. Amongst the cereals the first place must be given to Wheat (*Triticum vulgare*). The origin of this important plant is entirely lost in the past. We are not acquainted with the wild stock from which it has been produced. Numerous varieties of Wheat are cultivated, some with awns to the flowering glumes and some without. Interesting experiments have been tried by Major Hallett in Sussex. By choosing the best ears and grains, and using these for sowing, and by repeating this process several times, the Wheat is greatly improved in character. By this process of artificial selection what is known as 'Pedigree Wheat' is obtained. The seeds in the case of all the plants of the Graminaceæ are albuminous, and flour is obtained from the crushed albumen.

Barley (*Hordeum vulgare*) is another important cereal, probably one of the first cultivated. Malt is prepared from Barley by allowing it to begin to germinate, and then heating it to 160° or 180°; by this means the starch of the grain is converted into sugar, which is capable of fermentation.

Oats (*Avena sativa*), Rye (*Secale cereale*), and Millet, which is obtained from several genera, are also cultivated. Indian Corn is obtained from *Zea Mais*, which is a native of the New World. Rice is obtained from *Oryza sativa*, a tropical plant.

Besides these food plants we have the important Sugar-cane (*Saccharum officinarum*), the clarified juice of which yields us sugar, whilst the residue produces molasses and treacle.

Numerous Grasses are grown for fodder purposes, whilst from some sweet essences are obtained. Lemon-grass oil is extracted from *Andropogon citratus*, citronelle oil from *Andropogon Nardus*, and some suppose that the spikenard oil of Scripture was obtained from *Andropogon Iwarancusa*.

The Bamboo is an arborescent genus of this order, used for many important purposes.

It will be well in conclusion to point out the differences between the two allied orders Cyperaceæ and Graminaceæ in a tabular form.

Cyperaceæ.

Stem solid.
 Leaf-sheaths entire.
 No ligule present.
 No lodicules.
 Anthers innate.
 Stigmas three, simple.

Graminaceæ.

Stem hollow.
 Leaf-sheaths split.
 Ligule present.
 Lodicules generally present.
 Anthers versatile.
 Stigmas two, feathery.

PLAN FOR DESCRIBING A PLANT.

Root.—Kind.

Stem.—*a.* Kind (herbaceous, shrubby, or woody).

b. Shape (rounded, angular, square, ribbed, &c.).

c. Direction (upright, spreading, creeping, climbing, &c.).

d. Surface (smooth, hairy, rough, &c.).

Leaves.—1. Insertion (opposite, alternate, radical, &c.).

2. Petiole (presence or absence, peculiarities).

3. Lamina.

a. Composition (simple or compound).

b. Venation.

c. Margin.

d. Incision.

e. Apex.

f. General outline.

g. Surface (smooth, hairy, &c.).

4. Stipules (present or absent, shape if present; also note if sheath).

Inflorescence.—Kind of inflorescence and bracts.

Flower.—1. Calyx.

a. Cohesion (gamosepalous or polysepalous).

b. Number of sepals or divisions.

c. Adhesion (inferior or superior).

d. Specialities (colour, shape, &c.).

2. Corolla.

a. Cohesion.	} As above.
b. Number.	
c. Adhesion.	
d. Specialities.	

Note. If perianth is present, describe it in same manner.

3. Corona or other appendages between corolla and andrœcium should be described here.

4. Andrœcium.

- a. Cohesion (free, monadelphous, &c.).
- b. Number.
- c. Adhesion.
- d. Specialities (if tetradynamous or didynamous ; also peculiarities of filament and anther).

5. Gynœcium.

- a. Cohesion (syn- or apo-carpous).
- b. Number of carpels.
- c. Adhesion (inferior or superior).
- d. Peculiarities of ovary, including—
 - α. Number of cells.
 - β. Placentation.
 - γ. Number of ovules.
- e. Peculiarities of style and stigma.

Fruit and Seed.

EXAMPLE.

SWEET VIOLET (*Viola odorata*).

Root.—Fibrous.

Stem.—Slightly shrubby, rounded, short, underground, forming a rhizome ; surface scarred.

Leaves.—Apparently radical, but really growing in a tuft at apex of stem. *Petiole* evident, covered with short scattered hairs. *Lamina* simple, net-veined, unicostate, curve-veined, crenate margin, apex either rounded or somewhat acute, cordate or

reniform, surface hairy, especially upon the margins and veins. *Stipules* present, slightly membranous, undivided, lanceolate.

Inflorescence.—Single-flowered, the flower-stalks growing from the axils of the leaves and bearing two small nearly opposite linear bracts about the centre.

Flower.—

Calyx.—Polysepalous ; five sepals, inferior, irregular, each sepal broad in centre and pointed towards the two extremities, green, hairy.

Corolla.—Polypetalous ; five petals, hypogynous. Irregular, either purple or white ; in the former case the lower petal has several darker lines converging towards interior of flower ; the lateral petals have a hairy tuft near mouth of tube ; the inferior petal is prolonged into a short blunt spur.

Andræcium.—Stamens free, five in number, hypogynous, almost sessile, the filament being very short ; connective prolonged beyond the anthers as an orange-coloured mass ; two of the stamens spurred, the spurs passing into the spur of corolla.

Gynæcium.—Syncarpous, three carpels, superior ; ovary one-celled, with three parietal placentas and numerous ovules ; surface of ovary hairy ; style curved ; stigma hooked.

QUESTIONS FOR EXAMINATION.

[*Those followed by a date are questions which have been set at previous examinations held in connection with the Science and Art Department, South Kensington.*]

1. How can you distinguish a plant from an animal?
2. Into what two great sub-kingdoms may plants be divided?
3. Describe fully the seed of a Bean. (1875 and 1878.)
4. Compare the seed of the Oat with that of the Bean.
5. Explain the terms 'albuminous' and 'exalbuminous,' and mention some albuminous seeds.
6. Describe the structure of a living parenchymatous plant-cell. What chemical elements enter into the composition (a) of the cell-wall, (b) of the protoplasm? (1887.)
7. What are the composition and properties of cellulose?
8. Enumerate and describe briefly the most important substances which are formed *within* the protoplasm of plant-cells.
9. Give an account of the general properties of chlorophyll, and of the conditions which are necessary to its formation.
10. What remarkable change do plants show when they are grown in the dark? (1876.)
11. Why does heaping earth round Celery cause the stalks to be white? (1877.)
12. What is the nature of starch? How is it formed, and what is its use? (1879.)
13. Explain the structure of a cell and the changes it undergoes in the growth of a plant. (1878.)
14. What conditions modify the shape of cells?
15. How are thickened cells produced?
16. In what respects does the wood of the stem of a Conifer (Fir Tree) differ from that of a dicotyledonous plant? Describe the development of 'bordered pits.'
17. What is meant by a vessel? How is it formed, and what is its use? (1878.)
18. How are the cells, say in the leaf of a plant, increased in number?
19. Give an account of 'parenchyma.' Explain how it is formed. (1875.)

20. Describe what happens in the germination of a Bean seed. (1878.)
21. What requisites are needed for germination?
22. Compare the germination of the following seeds:—Broad Bean, Acorn, Cress, Mustard, Pine, Date, and Wheat.
23. Compare the modes of germination of seeds of the Oak and of the Beech. In what important respects do they differ? (1884.)
24. Describe the way in which roots grow. (1877.)
25. The seeds of Mustard and Cress will germinate on flannel soaked with rain-water. Will they go on growing under these circumstances? and if not, why not? (1879.)
26. When any vegetable material is burned, what constituents go off as gas? What are left behind? (1877.)
27. What are the principal substances which form the food of plants? (1875.)
28. What part of the food of a plant is taken up by the roots? (1878.)
29. Explain how the food is absorbed by the roots.
30. Of what substances in the plant is nitrogen an essential ingredient? How does the plant obtain the nitrogen? (1876.)
31. Why do plants require nitrogen, and in what form do they take it in? (1880.)
32. Explain the 'rotation of crops.'
33. Explain why the root of a turnip first grows after than the stem, and then stops while the stem grows rapidly. (1877.)
34. What are the chief differences between a root and a stem? (1876.)
35. Suppose a piece of the axis of some flowering plant were shown to you, what appearances would enable you to decide whether it was part of a root or of a stem? (1882.)
36. Compare the appearance of a monocotyledonous and dicotyledonous stem as seen in transverse section.
37. What is the cause of the ring-like markings seen in the cross-section of a tree-trunk? (1876 and 1881.)
38. Describe and explain as much of the texture of a deal plank as can be made out with the naked eye. (1879.)
39. Explain the difference in the growth of the bark of a tree and that of the wood. (1880.)
40. What is the structure and use of cambium?
41. State generally what is the composition of a vascular bundle. Describe the longitudinal course of the vascular bundles in the stem of any Dicotyledon. (1887.)
42. Describe a 'runner,' a 'rhizome,' an 'offset,' and give examples.
43. Give a full account of a Potato, and explain as much as you can structure. (1875.)
44. Explain why a Potato is considered to be a stem. (1878.)
45. Describe and explain the structure of an Onion. (1876 and 1880.)

46. Give a botanical description of the part, in each of the following plants, which is commonly used as food :-- the Potato, the Onion, the Turnip, and the Carrot. (1887.)

47. What are the essential differences between a node and an internode? Illustrate your answer by examples. (1884.)

48. Describe a bud. To what structures do the outer coverings correspond? What is the origin and use of the resinous secretion with which they are often covered? (1877 and 1881.)

49. Why are some of our fruit-trees thorny in the wild state, but not when cultivated? (1879.)

50. Mention, with examples, the different members of the plant which may be modified into tendrils.

51. Explain precisely how a tendril acts. (1881.)

52. Explain the process of grafting. (1876.)

53. What is the structural difference between a prickly (as in the Rose, and a spine (as in the Blackthorn). (1881.)

54. What is a leaf? What is its use to the plant? (1877.)

55. Describe the general structure of a leaf.

56. What are stomata? Where are they found in the plant and what is their use? (1880.)

57. What is the general plan of arrangement of leaves on a stem? Why is it the most advantageous to the plant? (1881.)

58. What components of the atmosphere are taken from it by plants, and for what purpose? (1881.)

59. What is the cause of the green colour of plants? What is its use? (1875.)

60. State why absence of light is injurious to plants. (1881.)

61. Plants are said to 'starve in the absence of light.' Explain this statement. (1883.)

62. Why will a plant grown in a dwelling-room be less vigorous than one grown in the open air? (1879.)

63. What is meant by respiration? Describe an experiment for showing that plants respire. (1878.)

64. What is meant by transpiration? Under what circumstances do plants transpire most? (1879.)

65. What are the conditions, external and structural, which regulate the amount of evaporation from leaves?

66. Explain the action of the leaves of carnivorous plants.

67. Give instances in which leaves are only imperfectly developed. What useful purposes may they serve in such cases? (1882.)

68. Excluding the leaves forming the flower, we have three kinds occupying different positions on the stem in the higher plants. Briefly describe these.

69. What are bracts? Give some of their modifications.

70. What is meant by definite and indefinite inflorescence? Give examples and draw diagrams to explain your answer. (1875.)

71. If an inflorescence appears at the end of a branch of a tree, what is the effect on the future growth of the branch? (1879.)

72. Tabulate the principal indefinite inflorescences.

73. What is meant by 'mixed inflorescence'?

74. What is a flower? What structures compose it, and what are their use? (1877.)

75. Give the names and brief descriptions of the enveloping and essential organs of a flower. (1875.)

76. Some English plants have one, others have two, and even three kinds of flowers. Explain how this is possible. (1879.)

77. Explain the terms 'polygamous,' 'dioecious,' 'gynandrous,' 'syngenesious,' 'hypogynous,' 'perigynous,' 'inferior,' 'epigynous.'

78. Explain fully the various respects in which a petal differs from a leaf. (1880.)

79. How do you explain the fact that while the leaves of most plants are green their flowers are of some other colour? (1878.)

80. What is pollen? What is its use? (1875 and 1878.)

81. What is meant by an inferior ovary? Give examples. (1875.)

82. What is meant by placentation? Describe the various forms.

83. What is a placenta? Describe the placentation in the Cruciferae, the Leguminosae, and the Liliaceae.

84. Explain the terms 'monadelphous,' 'diadelphous,' 'adnate,' 'innate,' 'versatile,' 'introrse,' 'extrorse.'

85. Mention plants whose flowers contain nectar. What is its use? (1877.)

86. Describe the general structure of an ovule.

87. Explain the terms 'orthotropous,' 'anatropous,' 'raphe,' 'hilum,' 'micropyle.'

88. Draw a diagram showing the arrangement of the parts of the flower of a leguminous plant as seen in transverse section. Point out in what respects it differs from the arrangement typical of flowers generally. (1883.)

89. Draw a diagram showing the arrangement of the different parts of the flower of any Crucifer. (1882.)

90. Explain what is meant by an irregular flower. What is the advantage to a plant of having such flowers? (1878 and 1881.)

91. What provisions are made for cross-fertilisation?

92. What is a fruit?

93. Explain the terms 'syncarp,' 'pseudocarp,' 'drupe,' 'achene,' 'pome.'

94. Classify the dehiscent fruits.

95. What is a berry? What is the advantage to a plant to have this kind of fruit? (1877.)

96. Explain the essential differences of structure in the fruits of the Strawberry and Blackberry. (1881.)

97. How do the fleshy parts of the Strawberry, Blackberry, Apple, and Plum originate? (1876.)

98. Describe as fully as you can the structure of an Apple, and explain the origin of the different parts. (1879.)

99. Explain the terms 'epicarp,' 'mesocarp,' 'endocarp,' 'loculicidal,' 'septifragal,' 'circumscissile.'

100. Describe the fruits of a Buttercup and of a Pink. In what respects do they agree and in what respects do they differ? (1883.)

101. Describe, with sketches, the structures seen in transverse sections of the fruit of an Apple and of an Orange respectively. Point out, as far as you can, the parts in each case of which the structural value is the same. (1884.)

102. In what points of structure does an ovule differ from a seed? (1880.)

103. What are 'endosperm' and 'perisperm'? Also give the structure of the arillus.

104. There are three distinct modes in which water moves in the plant. State what they are, and describe the experiments by which you would prove their existence. (1884.)

105. What is the channel by which the leaves of a plant make up for the loss of water by transpiration? Where does the water come from?

106. Why can a tree be transplanted more safely in the winter than in the summer? (1877.)

107. When a branch of a tree is cut off, why do the leaves of the branch fade, while those of the tree remain fresh? (1876 and 1880.)

108. What constituents of sunlight are most effective in producing the chemical changes on which the nutrition of plants depends?

109. What is a hybrid? (1876.)

110. What are the characters of the two groups of flowering plants?

111. Describe the typical structure of a stamen. State the peculiarities characteristic of those of a Crucifer, a Composite, a Labiate, and a Grass. (1880.)

112. In what important respects does the fruit of a cruciferous plant (such as Shepherd's-purse) differ from that of a leguminous plant (such as a Pea)? How can the differences be accounted for? (1880.)

113. Describe the general structure of the ovary and of the fruit in Rosaceæ and Leguminosæ.

114. Compare the natural orders Labiatae and Scrophulariaceæ.

115. Give an account of the structure of the head of a Daisy. (1880.)

116. What is the difference between an annual and a perennial plant? (1875.)

INDEX AND GLOSSARY.

ABS

ABSORPTION of food by roots, 34 ; by leaves, 85

Accrescent calyx (Lat. *accresco*, to increase). Term used when the calyx forms a bladderly expansion round the fruit, 104

Accretion (Lat. *accresco*). Term applied to growth by a series of layers, 16

Aceras, 181

Acerose (Lat. *acer*, sharp). Term applied to leaves when sharp and pointed, 79

Achene (Gr. *a*, not ; *chaino*, to open). A dry fruit which does not open, 142

Achlamydeous (Gr. *a*, without ; *chlamus*, a cloak). Flowers destitute of both calyx and corolla, 100

Aconitum, 105, 111, 157

Acorn, germination of, 26

Action of chlorophyll, 86

Action of heat, 148

Action of light, 149

Acuminate (Lat. *acuminatus*, made pointed). Term applied to the gradually pointed apex of leaves, 77

Acute (Lat. *acutus*, sharpened). Term applied to the pointed apex of leaves, 77

Adam's Needle, 185

Adnate (Lat. *ad*, to ; *nascor*, natus, to grow). Where one part grows against another, applied to stamens where the filament grows up against the anther, 115

Adonis, 157

Adventitious (Lat. *adventicius*, foreign or extraneous). Applied to anything growing out of its ordinary place, as buds, 61, 62 ; and roots which are not direct prolongations of the radicle, 29

Aerial stems (Lat. *aer*, air). Stems growing above ground, 55

Æstivation (Lat. *æstivus*, relating to the summer). Term applied to the

ANA

arrangement of the parts of the flower in the flower bud, 113

Æthusa, 168

Agraphis, 183

Agrimonia, 165

Alæ (Lat. wings). Term used to describe two of the petals in the papilionaceous corolla, 109

Albumen (Lat. *albus*, white). Food material found in many seeds, 4

Albuminous seeds. Those containing albumen, 5

Albumum (Lat. *albus*, white). The outer wood of a dicotyledonous stem usually light in colour, 46

Alchemilla, 166

Aleurone (Gr. *aleuron*, fine meal).

Oily grains often found in cells, 14

Alkanet, 175

Allium, 184

Almond, 165

Alnus, 179

Alœe, 185

Alternate leaves, 84

Amaryllidaceæ, 105

Amentaceæ, 178

Amentum (Lat. a strap). A form of spike bearing unisexual flowers, 96

Ammonia. A compound of nitrogen and hydrogen, which forms a source of nitrogenous food to the plant, 35

Amœbiform movements (Gr. *amœbe*, change). Changes of form of protoplasm such as are seen in the Amœba or Proteus animalcule, 8

Amplexicaul (Lat. *amplexus*, encircling ; *caulis*, stem). Applied to leaves which encircle the stem at their base, 85

Amygdalææ (Lat. *amygdalum*, an almond). A division of the order Rosaceæ, 165

Amygdalus, 165

Anagallis, 176

Anatropous (Gr. *ana*, backwards ; *tropos*, a turn). An ovule which is turned

ANC

- over so that the micropyle is near the placenta, 123
- Anchusa*, 175
- Androecium (Gr. *andreios*, male; *oikos*, a house). Term applied to the collected stamens of the flower, 113
- Andropogon*, 188
- Anemone*, 158
- Anemophilous (Gr. *anemos*, wind). Plants which are fertilised by the wind, 130
- Anethum*, 170
- Angelica*, 167
- Angiosperms (Gr. *angos*, vessel; *sperma*, seed). Plants whose seeds are enclosed in vessels or ovaries, 128
- Annular cells (Lat. *annularis*, ringed). Cells with the secondary deposit arranged in rings, 19
- Annulated roots. Roots with several ring-like constrictions, 33
- Anthemus*, 170
- Anther (Gr. *antheros*, flowery). The hollow box at the summit of the stamen and which contains the pollen, 114, 115, 117
- Anthriscus*, 170
- Antipodal cells (Gr. *anti*, opposite; *pous*, *podos*, foot). Cells developed in the embryo-sac at the opposite end to the embryo-cell, 126
- Antirrhinum*, 108, 174
- Apex of leaves, 76, 77
- Apium*, 168
- Apocarpous (Gr. *apo*, from; *karpus*, a fruit). Pistils with separate carpels, 119
- Apple*, 135, 141, 164, 166
- Apricot*, 165
- Aquilegia*, 158
- Arachis*, 164
- Arctium*, 171
- Arillus (Lat. *areo*, to be dried up). A peculiar coat growing up around the ovule of some plants and remaining attached round the seed, 144
- Arnica*, 172
- Artemisia*, 171
- Artichoke*, 172
- Asparagææ*. A group of the order Liliaceæ, 183-184
- Asparagus*, 184
- Assimilation of food, 86
- Astragalus*, 162
- Atmosphere, composition of, 86
- Atriplex*, 177
- Avena*, 188
- Axillary buds (Lat. *axilla*, the arm-pit). Buds which grow in the angle formed between the leaf and stem, 59

BALM, 174

Balsam of Tolu, 164

Bark, 42, 48

Barley, 188

Basifixed, 115

Basil, 174

CAL

- Basil Thyme*, 173
- Bast. The inner bark, 48
- Bastard Saffron*, 172
- Bast fibres, 21, 48
- Bast tubes, 22
- Bast vessels, 21, 48
- Bean seed, 3
- Beech*, 180
- Beet*, 177
- Bellis*, 171
- Berry. A fleshy fruit which does not open, and which contains several seeds, 141
- Beta*, 177
- Betula*, 179
- Betulineæ*. A group of the order Amnataceæ, 179
- Bicrenate (Lat. *bis*, twice; *crena*, a notch). Term applied to leaves having their edges doubly notched, 77
- Birch*, 179
- Bird's foot Trefoil*, 163
- Biserrate (Lat. *bis*, twice; *serra*, a saw). Term applied to leaves when their edges are doubly toothed, 77
- Blackthorn*, 164
- Bluebell*, 183, 184
- Bluebottle*, 107, 171
- Borage*, 175
- Boraginaceæ*, 175
- Borago*, 175
- Bostrychoid (Gr. *bostruchos*, a curl). A term applied in branching when the successive branches come off on the same side, 66, 67, 68
- Botany, definition of, 1; divisions of, 2
- Bracts (Lat. *bractea*, a thin plate of metal). Organs, generally leaf-like, growing between the leaves and the flowers, 92
- Bramble*, 164
- Branching, 59, 66
- Brassica*, 160
- Broad Bean*, 164; seed of, 3; germination of, 27
- Broom*, 163
- Budding, 63
- Buds, 40
- Bulbils, 58
- Bulbs, 57
- Bunium*, 168
- Burdock*, 93, 94, 171
- Burnet Saxifrage*, 169
- Butcher's Broom*, 50, 183, 184
- Buttercup*, 102, 103, 111, 114, 119, 142

CABBAGE, 160

Caducous (Lat. *caducus*, falling). An organ which falls off early, especially applied to the calyx which falls off before the buds open, 104

Calamintha, 173

Calendula, 172

Callus (Lat. a hard skin). A growth of cambium which is formed when the stem is wounded, 63

Caltha, 15

CAL

- Calycifloræ*, a group of plants, the separate petals of whose flowers are arranged either around or upon the ovary, 162
- Calyx* (Gr. *kalux*, from *kalupto*, to cover). The outer covering of the flower, 100
- Cambium* (Lat. *cambio*, to change). The formative layer between the wood and the liber out of which new wood and new liber are formed, 42, 44, 45, 47
- Campanulate* (Ital. *campana*, a bell). Bell-shaped corolla, 107
- Campion*, 161
- Campylotropous* (Gr. *kampulos*, bent; *tropos*, direction). An ovule which is bent over, 123
- Candytuft*, 160
- Capitulum* (Lat. diminutive from *caput*, a little head). An indefinite inflorescence with shortened axis and sessile flowers, 95
- Capsella*, 160
- Capsule* (Lat. *capsula*, a small box). A form of fruit which opens to allow the seeds to fall out, 136
- Caraway*, 168
- Carbon of plants, whence obtained, 34, 86
- Carbonic acid or Carbon dioxide, 34, 86
- Carcerulus* (Lat. *carcer*, a prison). A fruit breaking up into four one-seeded nucules, 139
- Carduus*, 171
- Carina* (Lat. keel). Term applied to the innermost petals of the papilionaceous corolla, 109
- Carnation*, 161
- Carnivorous plants (Lat. *caro*, *carnis*, flesh; *vorare*, to eat). Plants which feed upon flesh, 89
- Carpels (Gr. *karpōs*, a fruit). The innermost parts of the flower which when ripened form the fruit, 100, 118
- Carpinus*, 179
- Carpophore* (Gr. *karpōs*, fruit; *phero*, to bear). A prolongation of the flower stalk growing between the carpels of the pistil or fruit, 124, 139
- Carrot*, 169
- Carthamus*, 172
- Carum*, 168
- Carya*, 180
- Caryophyllaceæ*, 161
- Cassia*, 164
- Castanea*, 180
- Castor-oil seed, germination of, 27
- Catkin (diminutive of *cat*), see *Amentum*.
- Cauline* (Lat. *caulis*, a stem). Leaves growing upon the stem, 85
- Caulis* (Lat. stem). A herbaceous annual stem, 54
- Celery*, 9, 168
- Cells, 6; contents, 6, 7; changes in wall, 7; division, 23; formation, 23, 117; growth, 15; sap, 12; shape, 16; size, 23; thickening, 17; tissues, 24

COL

- Cells with bordered pits, 20
- Cellulose. The substance of which the cell wall is built up, 6
- Centaurea*, 171
- Centrifugal inflorescence (Lat. *centrum*, centre; *fugio*, to flee from). Inflorescence where the oldest flowers are towards the centre, 94, 97
- Centripetal inflorescence (Lat. *centrum*, centre; *peto*, to seek). Inflorescence where the youngest flowers are in the centre, 93, 94
- Cerastium*, 161
- Chalaza* (Gr. a tubercle). The point by which the nucleus of the seed is attached to the integuments, 122
- Cheiranthus*, 159, 160
- Chenopodiaceæ*, 177
- Chenopodium*, 177
- Cherry*, 165
- Chervil*, 170
- Chickweed*, 161
- Chicory*, 172
- Chlorine of plant, whence obtained, 35
- Chlorophyll* (Gr. *chloros*, green; *phyllon*, leaf). The green colouring matter of plants, 8
- Christmas Rose*, 158
- Chrysanthemum*, 171
- Cicinal* (Gr. *kikinnos*, Lat. *cicinnus*, a curled lock of hair). A term used in branching when the successive branches come off on opposite sides, 67
- Cicuta*, 168
- Cilia* (Lat. *cilium*, an eye-lash). Hair-like prolongations of cells, 1, 8, 77
- Ciliate*. A term applied to the margins of leaves when they have a hairy fringe, 77
- Circinate* (Lat. *circino*, to make round). Term applied to the arrangement of the leaves in the bud when the apex is rolled towards the base, 64
- Circulation of sap, 145
- Circhi* (Lat. *cirrus*, a curl). Tendrils, 61
- Clary*, 173
- Classification, 153
- Cleistogamous (Gr. *kleistos*, closed; *gamos*, marriage). Flowers where the ovule is fertilised without the flower-bud opening, 134
- Climbing stems, 54
- Closed bundles. Woody bundles containing no cambium, 44
- Clover*, 163
- Cloves (Lat. *clavus*, a nail). The young bulbs developed by the side of the old ones, 58
- Cochlearia*, 160
- Colchicææ*, a group of the *Liliaceæ*, 183, 185
- Colchicum*, 185
- Coleorrhiza* (Gr. *koleon*, a sheath; *rhiza*, a root). The sheath around the base of the root in many monocotyledons, 29

COL

Coltsfoot, 171
Columbine, 158
Comfrey, 176
 Complete flowers. Those flowers which possess all four of the floral whorls, 100, 154
Compositæ, 155, 170
 Composition of air, 86
 Compound flowers, 155 ; leaves, 76, 80
 Conduplicate (Lat. *conduplico*, to double). When in the leaf bud the two edges of the leaf are doubled over, leaving the midrib in the centre, 64
 Cone (Lat. *conus*). A unisexual spike with woody bracts, 96
 Conical root, 32
Conium, 168
 Connate (Lat. *con*, together ; *nascor*, natus, to grow). When the bases of opposite leaves are united so that they appear to be one, 84
 Connective (Lat. *con*, together ; *necto*, to bind). The portion of the filament which unites the anther lobes, 116
Convallaria, 183
Convallariæ, a group of the Liliacæ, 183
 Convolute (Lat. *convolutus*, rolled up). When in the leaf bud the two edges of the leaf are rolled the one over the other, 65
Copaiba, 164
Copal, 164
Coriander, 168
 Cork cambium (*see* Cambium). The formative tissue below the cork cells, 43, 48
 Cork cells. The outermost cells of the bark, 42, 48
 Corm (Gr. *kormos*, a stem or trunk). An underground stem resembling a bulb but more solid, 58
Corn Cockle, 161
 Corolla (Lat. a small wreath). The second of the floral envelopes, 100, 106
Corollifloræ. A group of dicotyledonous plants with gamopetalous corollas, 148, 154, 170
 Corona (Lat. a crown). An extra organ sometimes present within the corolla of flowers, 110
 Corpuscula (Lat. *corpusculum*, a little body). Certain cells produced within the embryo-sac of conifers, 129
 Cortex (Lat. bark), 42
Corylus, 178, 179
 Corymb (Gr. *korumbos*, a cluster of fruit or flowers). An indefinite inflorescence where the flowers form a flat-topped head, 96, 97
 Cotyledons (Gr. *kotyledon*, a hollow vessel). The lobes within the embryo of the seed, 4, 5, 26, 153
Cow Parsnip, 167, 169
Cow Wheat, 175
Crambe, 160

DEF

Cratægus, 166
 Cremocarp (Gr. *kremnao*, to hang down ; *karpós*, a fruit). A fruit which breaks up into two halves hanging upon a central stalk, 139, 167
Cress, 160, germination of, 27
Crithmum, 168
 Cross fertilisation. The arrangement by which the pollen of one flower fertilises the ovule of another, 130
Crowfoot, 159
Cruciferae, 154, 159
 Cruciform (Lat. *crux*, a cross ; *forma*, a shape). Cross-shaped. Applied to the corolla when the petals are arranged in the form of a Maltese cross, 109, 154, 159
 Cryptogams (Gr. *kruptos*, hidden ; *gamos*, marriage). Flowerless plants, 3
 Crystalloids (Gr. *krystallos*, ice ; *eidos*, form). Nitrogenous materials in many cells presenting a crystalline appearance, 13
 Crystals, 13
 Culm (Lat. *culmus*, a stalk). The hollow jointed stem of grasses, 54, 186
Cumin, 170
 Cupule (Lat. *cupula*, a little cup). A peculiar growth of bracts forming a cup around the fruit, 141, 179
Cupulifera (Lat. *cupula*, a little cup ; *fero*, I bear). A group of the Amnataceæ, 179
 Cuticle (Lat. *cuticula*, the skin). The outer structureless layer of plants, especially of leaves, 72
Cyclamen, 176
Cydonia, 167
 Cyme (Gr. *kuma*, a wave). Definite inflorescence, 97
Cynara, 172
 Cynarrhodum (Gr. *knou*, *kunos*, a dog *rhodon*, a rose). The fruit of the rose. An assemblage of achenes within a hollow receptacle, 142, 165
Cyperaceæ, 155, 185, 189

DAISY, 109, 170, 171
Dandelion, 93, 109, 170, 172
Date, germination of, 28

Daucus, 169
Dead Nettle, 99, 109, 115, 154, 172, 173
 Deciduous (Lat. *de*, off ; *cado*, to fall). Falling off, especially applied to parts of the flower, leaves, etc., which fall early, 104
 Decurrent (Lat. *de*, down ; *curro*, to run). Leaves with base running along the stem, 85
 Decussate (Lat. *decussis*, the intersection of two lines crosswise). When two pairs of opposite leaves are arranged at right angles, 84
 Definite inflorescence. Inflorescence where the oldest flowers are above or in the centre, 94, 97
 Definition of botany, 1 ; of plant, 1

DEH

- Dehiscent fruits (Lat. *de*, apart; *hisco*, to gape). Fruits which break when ripe, 136
- Delphinium*, 158
- Development, of buds, 60; of plumule, 40; of root, 25
- Dextrine (Lat. *dexter*, to the right). British gum; an altered form of starch, so called because it turns the rays of polarised light to the right, 7, 10
- Diadelphous (Gr. *dis*, twice; *adelphos*, a brotherhood). Stamens arranged in two bundles, 114
- Dianthus*, 161
- Diastase (Gr. *diastasis*, a division). A ferment produced in germinating seeds and which acts upon starch, 11
- Dichlamydeous (Gr. *dis*, twice; *chlamus*, a cloak). Flowers with both calyx and corolla, 100
- Dichogamy (Gr. *dicha*, in two; *gamos*, a marriage). Plants where the pistil and stamens are ripened at different times, so that there must be cross fertilisation, 133
- Dichotomous (Gr. *dicha*, in two; *temno*, to cut). When branches divide continually into two, 66, 98
- Dicotyledons (Gr. *dis*, twice; *kotyledon*, a hollow vessel). Plants with two cotyledons in the embryo, 5, 153
- Dicotyledonous stem, 44, 153; leaves, 75, 153; root, 29, 153
- Didynamous (Gr. *dis*, twice; *dunamis*, power). Flowers with two long and two short stamens, 115
- Digitalis*, 174
- Dill*, 170
- Dimorphic (Gr. *dis*, twice; *morphe*, shape). Plants where the flowers differ, some having short pistil and long stamens, and others long pistil and short stamens, 132
- Diœcious (Gr. *dis*, twice; *oikos*, a house). Stamens and pistils upon separate plants, 102
- Discoid (Gr. *diskos*, a round plate; *eidōs*, form). A term applied to pith when it is broken up into a number of flat plates, 45
- Distinguishing characters of roots and stems, 40
- Dorema*, 170
- Dorsifixed, 115
- Dotted cells, 18
- Double flowers. Flowers in which stamens and pistils are converted into petals, 134
- Dracæna*, 185
- Dragon-tree*, 53, 185
- Drupeacæ*, a group of the Rosaceæ, 165
- Drupe (Lat. *drupa*, an over-ripe olive). Stone fruit, where the inner layer is hard and stony, 140, 164, 165
- Duramen (Lat. *durus*, hard). The inner, generally hard, layers of wood, 46
- Dyer's-weed*, 162
- Dyer's Woad*, 160

ETÆ

EARTH-NUT, 168

Echium, 176

Elecampane, 171

Elements in plants, 34

Elliptical cells, 16; leaves, 79

Embryo (Gr. *em* for *en*, in; *bruo*, to swell). The young plant in the seed, 4

Embryo-cell. The cell of the ovule which forms the embryo, 126

Embryo-sac. The cell of the ovule in which the embryo-cell is formed, 122, 125

Embryonic vesicles, *see* above, Embryo-cells

Endocarp (Gr. *endon*, within; *karpōs*, fruit). The inner layer of the fruit, 135

Endogenous growth. Growth from within, seen in roots, 40; in stems, 52

Endogens (Gr. *endon*, within; *gennao*, to produce). Plants where the new wood bundles are first of all produced within the older ones; monocotyledons, 52

Endophlœum (Gr. *endon*, within; *phloios*, inner bark). The internal bark or liber of dicotyledons, 43

Endorhizal (Gr. *endon*, within; *rhiza*, root). Applied to roots of monocotyledons which branch before leaving the seed, 29

Endosmose (Gr. *endon*, within; *osmos*, an impulse). The passage inwards of fluids through a membrane, 36

Endosperm (Gr. *endon*, within; *sperma*, a seed). The cells formed within the embryo-sac around the embryo, 5, 127

Entomophilous (Gr. *entoma*, insects). Flowers fertilised by insects, 130

Epicarp (Gr. *epi*, upon; *karpōs*, fruit). The outer layer of the fruit, 135

Epidermis (Gr. *epi*, upon; *dermis*, the skin). The outer skin of the plant, 29, 40, 71

Epigeal (Gr. *epi*, upon; *ge*, the earth). Seeds where, on germinating, the cotyledons rise above the soil, 29

Epigynous (Gr. *epi*, upon; *gynē*, woman). Attachment of petals and stamens above the pistil, 107, 115, 154

Epipetalous (Gr. *epi*, upon). Attachment of stamens to petals, 115

Epiphlœum (Gr. *epi*, upon; *phloios*, bark). The outer bark of dicotyledons, 43

Epiphyllous (Gr. *epi*, upon; *phyllon*, leaf). Attachment of stamens upon the divisions of the perianth, 115

Equitant (Lat. *equitans*, riding). Term used in veneration when two conduplicate leaves are bent round one another, 66

Eryum, 164

Eryngium, 167, 169

Etærio (Gr. *hetairos*, a companion). Fruits formed by the aggregation of several distinct ovaries, 142

ETI

Etiolation (Fr. *étioier*, to make slender).

Parts of plants blanched by being grown in the dark, 9

Euphrasia, 174

Evening Campion, 161

Exalbuminous seeds. Seeds destitute of albumen, 5, 27

Excretion (Lat. *ex*, from; *cerno, cretus*, to separate). The separation of materials from the plant by the roots, 38

Exogenous growth (Gr. *exo*, outside; *genmao*, to grow). Growth on the outside. Seen in stems, 40; characteristic of dicotyledons, 46, 153; seen in monocotyledons, 54

Exogens. Dicotyledons with exogenous growth, 46

Exorhizal (Gr. *exo*, without; *rhiza*, root). Roots which commence to branch outside the seed, 29, 153

Exosmose (Gr. *exo*, without; *osmos*, an impulse). The passage outwards of fluids through a membrane, 36

Exstipulate (Lat. *ex*, without; *stipula*, a stalk). Leaves destitute of stipules, 70

External forms of stems, 53

Extine. The outer coat of the pollen grain, 117, 125

Extrorse (Lat. *extra*, externally; *orsus*, originating). The opening of the anthers outwards towards the exterior of the flower, 116

Eyebright, 174

FARINOSE (Lat. *far*, a kind of grain). One of the components of starch, 11

Fascicle (Lat. *fascicula*, a little bundle). A cyme with a number of flowers on short stalks, 98

Fasciculated root. The swellings of the root arranged in a bundle, 33

Fennel, 169

Fertilisation, 125; by insects, 130; by the wind, 130; of conifers, 128

Ferula, 170

Fibres (Lat. *fibra*, a filament). More or less lengthened, generally thickened, cells, 22, 42, 46, 48

Fibro-vascular bundles. Bundles, consisting principally of fibres and vessels, found in the stems of plants, 42, 51

Figwort, 175

Filament (Lat. *filum*, a thread). The stalk which supports the anther of the stamen, 114, 116

Floral diagram, 125

Flow of sap, 36, 46, 48, 50, 53, 72, 88, 145

Flowering plants, 3, 153

Flowerless plants, 3

Flowers, general structure of, 100; relation of parts of, 134

Follicle (Lat. *folliculus*, a small leathern

GYM

bag). A capsule opening along only one of its edges, 138, 157

Food of plants, 3

Fool's Parsley, 168

Fool's Watercress, 169

Forget-me-not, 175, 176

Forms, of calyx, 104; of cells, 16; of corolla, 107; of fruit, 137; of inflorescence, 93; of leaves, 78; of roots, 32 or stems, 55

Fovilla (Lat. *foveo*, to support, assist). The protoplasmic contents of pollen grains, 117, 126

Foxtail, 187

Fragaria, 165

Free cell formation, 117

Free central placentation, 121, 154, 155, 161, 170

French Beans, 164

Fritillary, 184

Fruit, 135

Functions, of leaves, 85; of roots, 34; of stems, 44, 46, 48, 50, 53

Fundamental tissue, 412

Funiculus (Lat. a little rope). The stalk by which many ovules are attached to the placenta, 122

Furze, 164

Fusiform (Lat. *fuscus*, a spindle). Spindle-shaped, *i.e.* pointed at each end. Applied to cells, 16; and to roots, 32

GALANTHUS, 185

Galeate, Lat. *galeatus*, a helmed warrior). Helmet-shaped, 105

Gamopetalæ (Gr. *gamos*, a marriage). A group of dicotyledons with the petals united, 154

Gamopetalous. Union of the petals of the corolla, 107, 154

Gamosepalous. Union of the sepals of the calyx, 104

Garlic, 184

Genera, 156

Genista, 162

Germination, 25

Glans (Lat. an acorn). An achene with hardened walls, 142

Glomerulus (Lat. a little ball). A cyme arranged in a compact head, 98

Glumaceæ, 154, 155, 185

Glumes (Lat. *gluma*, husk). The scaly bracts in grasses and sedges, 93, 154, 185, 186

Good King Harry, 177

Goosefoot, 177

Grafting, 62

Graminaceæ, 186

Granulose (Lat. *granum*, a grain of corn). One of the constituents of starch, 11

Guard cells. The cells around the stomata of the epidermis, 41

Gymnosperms (Gr. *gymnos*, naked; *sperma*, a seed). Plants whose seeds are not contained in ovaries, 128

GYN

- Gynandrous (Gr. *gune*, a woman; *aner*, a man). Applied to flowers where the pistil and stamens are united together in a central column, 114, 180
 Gynæcium (Gr. *gune*, a woman; *oikos*, a house). The pistil or female organ of the flower, 100, 113
 Gynophore (Gr. *gune*, woman; *phero*, to carry). A prolongation of the flower stalk beyond the calyx, bearing the ovary, 124

HABENARIA, 182

Hairs, prolongation of the epidermis of plants, 31, 72

Hawthorn, 166

Hazel, 101, 178, 179

Heartwood. The inner wood of dicotyledons, 46

Helianthus, 172

Helicoid (Gr. *helix*, *helicos*, coiled). The same as bostrychoid, which *see*

Heliotropism (Gr. *helios*, sun; *trope*, a turn). The bending of plants towards the light, 149

Helleborus, 158

Helosciadium, 169

Hemlock, 168

Heracleum, 167, 169

Herb Paris, 116, 183

Hermaphrodite (Lat. *hermaphroditus*). Plants where stamens and pistil grow in the same flower, 101

Hesperidium (from the Lat. *Hesperides*). A multilocular berry, as seen in the orange, 141

Heterostylism (Gr. *heteros*, different from). Plants where the styles differ in length in the various flowers, 132

Hilum (Lat. a very little thing). The scar by which the ovule or seed is attached to the raphe or placenta, 3,

133

Hordeum, 188

Horse-radish, 160

Hottonia, 176

Hyacinthus, 185

Hybrid (Lat. *hybrida*, a mongrel). The common offspring of two distinct species, 156

Hydrocotyle, 169

Hydrogen of plant, whence obtained, 34

Hypocrateriform (Gr. *hupo*, under; *krater*, a goblet). Salve-shaped corolla; that is, a long tube with spreading lobes above, 109

Hypogeal (Gr. *hupo*, under; *ge*, the earth). Seeds whose cotyledons remain below the soil, 29

Hypogynous (Gr. *hupo*, under; *gune*, a woman). Attachment of petals and stamens below the pistil, 107, 115,

154

Hyssop, 174

INV

IBERIS, 160

Imbricate (Lat. *imbricatus*, overlapping). Arrangement of leaves in a bud where they overlap like tiles of a house, 65

Imparipinnate (Lat. *impar*, odd; *pinnatus*, winged). Leaves where the leaflets are arranged on each side of the central stalk like barbs of a feather, and an odd leaflet terminates the whole, 80

Imperfect flowers. Those where the pistil and stamens are on separate flowers, 100

Incomplete, 154, 177

Incomplete flowers. Those where any of the floral whorls are absent, 100

Indefinite inflorescence. Inflorescence where the youngest flowers are above or in the centre, 94

Indehiscent fruits (Lat. *in*, not; *dehisco*, to gape). Fruits which do not break when ripe, 136, 140

Indian Corn, 188

Indigo, 164

Induplicate (Lat. *in*, in; *duplicatus*, doubled). When in the leaf bud involute leaves touch by their edges without overlapping, 66

Inferior. Applied to the calyx when it is attached beneath the ovary, 108; and to the ovary when the calyx is above it, 103

Inflorescence (Lat. *infloresco*, I flourish). The general arrangement of the flowers upon the stem, 93

Influence of plants on climate, 88

Infundibuliform (Lat. *infundibulum*, a funnel). Funnel shaped: applied to the calyx or corolla, 109

Innate (Lat. *innatus*, inbred). When the anther lobes are attached immediately on top of the filament, 115

Inner bark, 48

Integument of seed. (Lat. *integumentum*, a covering). The outer coat of seeds, 3

Interfascicular cambium (Lat. *inter*, between; *fasciculus*, a little bundle). Cambium growing between the fibrovascular bundles, 47

Internodes (Lat. *inter*, between; *nodus*, a knot). The portions of the stem between the nodes, 60

Intine. The inner coat of the pollen grains, 117

Intussusception (Lat. *intus*, from within; *suscipio*, to beget). The peculiar method of growth seen in organic bodies, 15

Inula, 171

Inuline. A peculiar compound found in the roots of Compositæ, 14

Involucel. A partial or secondary involucre, 95

Involucre (Lat. *involutum*, a covering). A whorl of bracts forming a covering

INV

around a single flower or a head of flowers, 92, 95
Involute (Lat. *involutus*, wrapped up). Arrangement in the leaf bud when the margins of the leaves are rolled towards the upper surface, 65
Irregular. Applied to the calyx and corolla when the various parts are wanting in symmetry, 104, 107
Isatis, 160

JUGLANS, 180

KEEL. The innermost petals of a papilionaceous flower, 109
Kino, 164
Knapsweed, 171

LABELLUM (Lat. *labium*, a lip). The lower lip or petal of orchids, 180

Labiata, 155, 172

Labiate (Lat. *labium*, a lip). Applied to the calyx or corolla when arranged in a two-lipped manner, 104, 109, 172

Laburnum, 164

Laciniate (Lat. *lacinia*, a fringe). Applied to a leaf when it is very much cut up, 83

Lactuca, 172

Lamina (Lat. a blade). The blade of a leaf, 69

Lamium, 172, 173

Lanceolate (Lat. *lancea*, a lance). Applied to leaves which are narrow and pointed or lance-shaped, 79

Larkspur, 158

Latex (Lat. a liquid). A peculiar milky juice in the stems and leaves of many plants, 23

Lathyrus, 162, 163

Laticiferous vessels (Lat. *latex*, and *fero*, I bear). The vessels containing the latex, 23

Lavender, 174

Leaves, 69; forms of, 78; functions of, 85; margin of, 76; structure of, 71

Legume (Lat. *legumen*, pulse). A one-celled monocarpellary capsule opening by both edges, 138, 162

Leguminosa, 155, 162

Lemon Grass, 188

Lepidium, 160

Leucojum, 185

Liber (Lat. inner bark). The inner bark of dicotyledons, 44, 48

Lignin (Lat. *lignus*, wood). The changed condition of cellulose as seen in woody cells, 7

Ligulate (Lat. *ligula*, a strap). A membranous appendage at the top of the sheath of the leaves of grasses, 186, 189

Ligulifloræ, 170, 171

MES

Ligusticum, 169

Liliaceæ, 155, 183

Liliæ, 183, 184

Lilium, 184

Linaria, 175

Linear (Lat. *linea*, a line). Applied to leaves which are long and narrow with parallel edges, 79

Liquidambar, 180

Liquorice, 164

Listera, 182

Loculicidal (Lat. *loculus*, a cell; *cio*, I move). Applied to those capsules which, on dehiscing, open into the loculi or cells, 137

Loculus (Lat. a cell). The cell or internal cavity in the various organs of the plant, as the anther, 116; fruit, 137; or ovary, 120

Locust-tree, 61, 164

Logwood, 164

Lomentum (Lat. bean meal). A fruit which breaks up transversely into several portions, 139, 159

Lotus, 163

Lovage, 169

Lychnis, 161

Lyrate (Lat. *lyra*, a harp). A leaf with the terminal lobe rounded and several smaller lobes below, 82

Lysimachia, 176

MARGIN of leaves, 76

Marjoram, 173

Marrubium, 173

Marsh Marigold, 157, 158

Mat Grass, 187

Matthiola, 160

May, 166

Meadow Saffron, 185

Meadow Sweet, 166

Medicago, 163

Medulla (Lat. the interior part). The pith of dicotyledonous stems, 42-44

Medullary rays. The rays of parenchymatous tissue extending from the pith to the bark, 44, 50

Medullary sheath. The layer of vessels surrounding the pith, 45

Melampyrum, 175

Melilotus, 163

Melissa, 174

Mentha, 173

Mericaip (Gr. *meris*, a part; *karpós*, a fruit). When a fruit breaks up into pieces without the seeds falling out, each piece is called a mericaip, 138

Meristem (Gr. *meristes*, a divider). Growing tissue, the cells of which are continually dividing so as to produce fresh tissue, 24

Mesocarp (Gr. *mesos*, middle; *karpós*, fruit). The middle layer of the fruit, 135

Mesophloeum (Gr. *mesos*, middle; *phloios*, bark). The middle or green layer of the bark of dicotyledons, 43, 48

MES

- Mespilus*, 166
 Micropyle (Gr. *mikros*, small; *pule*, a gate). The opening which leads into the seeds and ovules, 3, 122
 Midrib. The central vein which runs from the base to the apex of the leaf, 75
Millet, 188
Mimoseæ, 162
Mint, 173
Mistletoe, growth of, 34, 90
 Mixed inflorescence. Inflorescence where there is a mixture of definite and indefinite, 99
 Molecular hypothesis, 15
 Monadelphous (Gr. *monos*, one; *adelphos*, a brother). Union of stamens into one bundle by means of their filaments, 114
 Moniliform (Gr. *monile*, a necklace). Applied to that form of root which has several contractions, making it look like beads on a necklace, 33
Monkshood, 157
 Monochlamydeous (Gr. *monos*, one; *chlamus*, a cloak). Flowers which have only one floral envelope, 100
 Monocotyledonous (Gr. *monos*, one; *kotyledon*). Possessing but one cotyledon in the embryo: characteristic of the leaves, 74; root, 29; stem, 44
 Monocotyledons, 5, 153, 155, 180
 Monœcious (Gr. *monos*, one; *oikos*, a house). Plants which have the stamens and pistil on different flowers but on the same plant, 102
 Monopodium (Gr. *monos*, one; *pous*, *podos*, a foot). In branching, where several branches grow from a common axis, 67
Mouse-ear Chickweed, 161
Mousetail, 158
 Movements of plants, 151
 Movements of protoplasm, 8
 Movements of water in plants, 145
 Mucilage, 7
 Mucronate (Lat. *mucronatus*, pointed). Applied to the leaf when the apex is flattened, with a sharp point growing out, 78
Mullein, 175
 Multicostate (Lat. *multus*, many; *costa*, a rib). A leaf with several principal veins, 75
 Multifoliate (Lat. *multus*, many; *folium*, a leaf). A leaf with many leaflets springing from a common point, 80
 Multilocular (Lat. *multus*, many; *loculus*, a cell). A cavity divided into several cells, as in several ovaries, 120; and fruits, 141
Mustard, 160
Myosotis, 175, 176
Myosurus, 158
Myrica, 179
Myricææ, 179
Myrrhis, 169

OST

- N**APIFORM (Lat. *napus*, a turnip). A root which is swollen in a turnip-like manner, 32
Narcissus, 185
Nasturtium, 160
 Natural system, 153
 Nectary (Lat. *nectar*, honey). Receptacles in the flower containing honey, 111
 Nitric acid and nitrates, 35
 Nitrogen of plant, whence obtained, 35
 Node (Lat. *nodus*, a knot). The points on the stem from which the leaves are given off, 60
 Nodulose (Lat. *nodus*, a knot). Applied to roots which have knot-like swellings, 33
 Normal root. The root which is formed by the direct prolongation of the radicle, 29
 Nucleus (Lat. a kernel) A mass of protoplasm aggregated at a certain point in the cell, 117; also the internal portion of the ovule in which the embryo is formed, 122; and therefore the portion of the seed within the seed coats, 4
 Nut (Lat. *nut*). An achene with hardened walls 42
- O**AK, 180
Oats, 188
 Obcordate (Lat. *ob*, inversely; *cor*, a heart). Inversely heart-shaped. Applied to the outline of leaves, 79
 Oblong. Applied to leaves, 79
 Obovate (Lat. *ob*, inversely; *ovatus*, egg-shaped). Applied to the outline of leaves, 79
 Obvolute (Lat. *obvolutus*, covered over). When the leaves in the bud are partly covered over one another, 66
Ocymum, 174
Oenanthe, 169
 Offset. A short thick branch whose terminal bud takes root, 55
Old Man's Beard, 158
Onobrychis, 163
 Oosphere (Gr. *oon*, an egg; *sphaira*, a globe). Cells formed within the embryo-sac of conifers, 129
 Open bundles. Fibro-vascular bundles which contain cambium, 44
Ophrys, 182
Opoponax, 170
 Opposite leaves, 84
Orache, 177
Orchidaceæ, 155, 180
Orchis, 180, 182; fertilisation in, 181
 Organic elements, 34
Ornithogalum, 184
 Orthotropous (Gr. *orthos*, straight; *trepo*, I turn). When the ovule is straight, 123
Osier, 179
 Osmosis (Gr. *ōsmos*=*ōsis*, an impulse). The passage of liquids through a permeable membrane, 36
Ostrya, 180

OUT

- Outline of leaves, 78
 Oval leaf, 79
 Ovary (Lat. *ovum*, an egg). The lowest part of the pistil, which, on ripening, forms the fruit, 118
 Ovate (Lat. *ovatus*, egg-shaped). Applied to leaves which are rounded and broad at the base and tapering at the apex, 79
 Ovule (Lat. diminutive of *ovum*, an egg). The unripened seed, 118, 122
 Oxygen of plant, whence obtained, 35

- PALES** (Lat. *palea*, chaff). The membranous bracts surrounding the flowers of grasses, 187
 Palmate (Lat. *palmatus*, palm-shaped). A leaf with divisions spreading out so as roughly to appear like an outspread hand, 83; root, 33
 Panicle (Lat. *panicula*, the down upon reeds). A compound raceme, 96
Papilionaceæ, 162
 Papilionaceous (Lat. *papilio*, a butterfly). A special form of irregular corolla as seen in the sweet pea, 109, 162
 Pappus (Lat. thistledown). The divided and hairy calyx as seen in Compositæ, which often grows into long hairs crowning the fruit, 105
 Paracorolla (Gr. *para*, besides, and *corolla*). An organ which sometimes grows between the corolla and stamens, 110
 Parallel venation. Venation of leaves of monocotyledons where there are no cross veins forming a network, 74
 Parasite (Lat. *parasitus*, a guest). A plant which obtains its nourishment by growing upon another, 90
 Parenchyma (Gr. *paregcheo*, to pour in besides). Cellular tissue where the cells are no longer than they are broad, 24
 Parietal (Lat. *paries*, a wall). Attachment of ovules upon the wall of the ovary, 121
 Paripinnate (Lat. *par*, equal; *pinna*, a feather). Pinnate leaves without an odd leaflet at the end, 81
Paris, 183
Parsley, 169
Parsnip, 169
Pastinacea, 169
Patchouly, 174
Pea, 163, 164
Peach, 165
 Pedate (Lat. *pedatus*, furnished with feet). A palmate leaf with the side lobes divided so as to roughly resemble a bird's foot, 83
Peony, 159
 Pepo (Lat. a gourd). A fruit resembling a berry, but with the outer walls firmer and harder, 141

PHY

- Perfect. Applied to flowers when both stamens and pistil are present, 100
 Perfoliate (Lat. *per*, through; *folium*, a leaf). Applied to the real or apparent growth of the stem through the leaf, 85
 Perianth (Gr. *peri*, around; *anthos*, a flower). Term applied to the calyx and corolla, especially amongst monocotyledons, when they are alike in appearance, 111
 Pericambium (Gr. *peri* and *cambium*). The cambium in roots from which the branches are produced, 31
 Perigynous (Gr. *peri*, and *gune*, woman). Applied to petals and stamens when attached around the ovary, 107, 115, 154, 164
 Perisperm (Gr. *peri*, around; *sperma*, a seed). The albumen formed within the ovule outside the embryo-sac, 5, 127
 Permanent tissue. That which is no longer dividing and increasing in the number of its cells, 24
 Persistent (Lat. *persistens*, remaining). Applied to any organ which remain beyond the usual time of such an organ on other plants, as the calyx when it remains after fruiting, 104
 Personate (Lat. *persona*, a mask). A two-lipped corolla with the two lips closed, 109, 174-175
 Petal (Gr. *petalon*, a leaf). One of the separate parts of the corolla, 100, 107
Petaloidæ, 155, 180
 Petiole (Lat. *petiolus*, a little foot). The stalk of the leaf, 69
Petroselinum, 169
 Phanerogams (Gr. *phaneros*, apparent; *ganos*, marriage). Flowering plants, 3
Phaseolus, 164
Pheasant's Eye, 157
 Phelloderma (Gr. *phellos*, cork; *derma*, skin). The middle bark of dicotyledons, 43, 48
 Phellogen (Gr. *phellos*, cork; *gennao*, to produce). The formative tissue from which the cork layer is increased in thickness, 43
 Phloëm (Gr. *phloios*, the inner bark of trees). The inner bark or liber, 41, 43, 48
Phormium, 185
 Phosphorus of plant, whence obtained, 35
 Phylloclade (Gr. *phullon*, a leaf; *klados*, a branch). A branch which is flattened in a leaf-like manner, 184
 Phyllocyanin (Gr. *phullon*, a leaf; *kuanos*, blue). The blue colour of chlorophyll, 8
 Phyllode (Gr. *phullon*, a leaf; *eidos*, form). A petiole which is flattened and leaf-like, 70
 Phylloxanthin (Gr. *phullon*, a leaf; *xanthos*, yellow). The yellow colour of chlorophyll, 8

PIL

Pileorhiza (Gr. *pilos*, a cap; *rhiza*, a root). The protecting layer of cells which covers the growing point of roots, 29
Pimpernel, 176
Pimpinella, 169
Pine, fertilisation of, 128
Pine, germination of, 27
Pink, 161
Pinnate (Lat. *pinnatus*, feathered). A leaf where the leaflets are arranged on each side like the barbs of a feather, 80
Pistil (Lat. *pistillum*, a pestle). The inner whorl of floral organs, 100, 118
Pistillate flower. A flower destitute of stamens, 101
Pisum, 163, 164
Pith (Anglo-Saxon *pitha*, marrow). The internal column of parenchymatous cells found in the stems of dicotyledons, 44
Pitted cells. Cells where the secondary deposit is arranged in little pits or channels, 18
Placenta (Lat. a cake). The part of the ovary to which the ovules are attached, 120
Placentation. Attachment of ovules to the placenta, 120
Placenticform. A flattened form of root, 32
Plant, definition of, 1
Plicate (Lat. *plicatus*, folded). The arrangement of the leaf in the bud when it is folded up like a lady's fan, 64
Plumule (Lat. *plumula*, a little feather). The undeveloped stem in the embryo, 4
Plumule, development of, 40
Pogostemon, 174
Pollen (Lat. fine flour). The fine dust within the anthers of the stamens, 177
Pollination. The act of pollen grains falling upon the stigma, 125
Polyadelphous (Gr. *polus*, many; *adelphos*, a brother). Union of stamens into several bundles, 114
Polygamous (Gr. *polus*, many; *gamos*, marriage). Where upon the same plant there are staminate, pistillate, and perfect flowers, 102
Polygonatum, 183
Polyhedral (Gr. *polus*, many; *hedra*, a side). Applied to cells of many sides or faces, 17
Polypetalous (Gr. *polus*, many; *petalon*, a leaf). Applied to the corolla where the petals are separate, 107
Polysepalous (Gr. *polus*, many; Low Lat. *sepalum*, a sepal). Applied to the calyx where the sepals are distinct, 104
Pome (Lat. *pomum*, an apple). A berry-like pseudocarp as seen in the apple, 142, 166
Pomea, 166
Poplar, 179

RAD

Portuguese Laurel, 165
Potato, structure of, 57
Potentilla, 165
Poterium, 166
Præfloration (Lat. *præ*, before; *flos*, *floris*, a flower). The arrangement of the parts of the flower in the bud, 113
Præfoliation (Lat. *præ*, before; *folium*, a leaf). The arrangement of the leaves in the bud, 63
Primine (Lat. *primus*, first). The inner coat of the ovule, 122
Primrose, 176
Primrose, fertilisation of, 132
Primula, 176
Primulaceæ, 176
Procambium (Gr. *pro*, before, and *cambium*). The formative tissue which first builds up the fibro-vascular bundles, preceding the true cambium, 41
Prosenchyma (Gr. *pros*, towards; *egcheo*, to pour in). Cellular tissue where the cells are long and pointed, 24
Protandrous (Gr. *protos*, first; *aner*, man). Flowers where the stamens are ripened before the pistil, 131
Protococcus, 1
Protogynous (Gr. *protos*, first; *gune*, woman). Flowers where the pistil is ripened before the stamens, 131
Protoplasm (Gr. *protos*, first; *plasma*, anything moulded). The living contents of the cell from which the new cells are produced, 7; movements of, 8
Prunus, 165
Pseudocarp (Gr. *pseudos*, false; *karpós*, a fruit). Applied when any part of the plant besides the ovary is united with the fruit, 135, 141
Purslane, 177
Pyrus, 166
Pyxis (Lat. a box). A capsule which dehiscs transversely, so that the upper part comes off like a lid, 138

QUADRIFOLIATE (Lat. *quadrans*, a fourth part; *folium*, a leaf). A leaf with four leaflets, 80
Quercus, 180
Quinate (Lat. *quinque*, five). A leaf with five leaflets, 80
Quince, 167

RACEME (Lat. *racemus*, a bunch). A form of indefinite inflorescence with lengthened axis and stalked flowers, 95, 96
Radiating veined (Lat. *radius*, a sun-beam), 76
Radical (Lat. *radix*, a root). Growing from a point close to the summit of the root, 85
Radicle (Lat. *radicula*, diminutive of *radix*, root). The part of the embryo

RAG

which forms the future root of the plant, 4
Ragged Robin, 161
Ragwort, 171
 Ramal (Lat. *ramus*, a branch). Growing upon the branches, 85
Ranunculaceae, 154, 156
Ranunculus, 156, 159
 Raphe (Gr. a cord). A cord running up the side of an anatropous ovule, 123
 Raphides (Lat. *raphis*, a needle). Crystals, often needle-shaped, contained within the cells of plants, 13
Rattle, 175
 Ray. The outer florets in the flower heads of Composite plants, 109, 170
 Recline (Lat. *reclino*, to lean backwards). When in the bud the apex of the leaf is bent towards the base, 64
 Regular : calyx, 104 ; corolla, 107
 Relation of the flower to the other parts of the plant, 134
 Reniform (Lat. *ren*, kidney ; *forma*, form). Kidney-shaped, that is, a leaf rounded at the apex and hollowed at the base, 79
 Replum (Lat. part of a door). The central part in the siliques and silicles which remains after the valves have fallen away, 138
 Respiration of plants, 87
 Reticulate (Lat. *reticulum*, a small net). Arranged in a net-like manner ; applied to cells, 19 ; to the venation of leaves, 74
 Retuse (Lat. *retusus*, blunted). A notch in the apex of a leaf, 77
 Revolute (Lat. *revolutus*, turned back). When in the bud the two edges are rolled towards the under side of leaf, 65
Rhinanthus, 175
 Rhizome (Gr. *rhiza*, a root). A creeping underground stem, thick and swollen, 55
Rice, 188
 Rind. The outer coat of monocotyledonous stems, 51
 Ringent (Lat. *ringens*, grinning). A bilabiate corolla where the lips are widely separated, 109, 172
 Rings of wood, 45
 Roots, 25 ; branches, 31 ; forms, 31 ; functions, 34 ; growth, 29 ; increase in thickness, 31 ; structure, 29
Rosaceae, 164
Rose, 165
Roseae, 165
Rosemary, 174
 Rotate (Lat. *rota*, a wheel). Wheel-shaped ; applied to a rounded corolla, 109 ; and calyx, 104
 Rotation of crops, 37
Rowan-tree, 166
Rubus, 164, 165
 Runcinate (Lat. *runcina*, a large saw). A pinnatifid leaf where the terminal lobe and side lobes are angular, 82

SEE

Runner. A slender prostrate stem as seen in the Strawberry, 55
Ruscus, 183, 184
Rye, 188
Rye Grass, 187
SACCATE (Lat. *saccus*, a sack). When two of the sepals have a swelling at their base, 104
Saccharum, 188
Safflower, 172
Sage, 173 ; fertilisation of, 131
 Sagittate (Lat. *sagitta*, an arrow). Arrow-shaped : applied to leaves which are pointed at the apex, and with two pointed lobes like barbs growing back at the base, 80
Salicineae, 179
Salix, 179
 Salver-shaped. See Hypocrateriform
Salvia, 173
 Samara (Lat. the fruit of the elm). A winged fruit, that is, one with a membranous expansion attached, 139
Sampshire, 168
Sandal-wood, 164
Sander's-wood, 164
Sanguisorba, 166
Sanguisorbeae, 166
Sanicula, 170
 Sap (Lat. *sapa*, sodden wine). A general term for the juices of the plant, 12
 Sapwood. The outer wood of dicotyledons, 46
Sarothamnus, 163
Satureia, 174
Savory, 174
 Scalariform (Lat. *scala*, a ladder ; *forma*, form). Term used when the secondary thickening of a cell is arranged like rungs of a ladder, 20
Scarlet Runner, 164
 Schizocarp (Gr. *schizo*, to split ; *karpós*, fruit). A fruit which splits into separate pieces each containing one seed, 138
 Schultze's solution, 7
Scilla, 183, 184
Scirpus, 186
 Sclerenchyma (Gr. *skleros*, hard). Tissue much hardened by formation of secondary deposit, 24
 Scorpoid (Gr. *skorpíos*, scorpion ; *eidos*, resemblance). Used in branching as equivalent to cincinnal, which see, 67 ; also a peculiar form of inflorescence, 98
Scorpion Grass, 176
Scrophularia, 175
Scrophulariaceae, 174
Sea Holly, 169
Sea Kale, 160
Secale, 188
 Secundine (Lat. *secundus*, second). The inner coat of the ovule, 122
Sedge, 185, 186
 Seeds, structure of, 3

SEL

- Selective power of roots, 37
 Sensitive Tree, 151, 164
 Sepal (Fr. *sepalé*; Low Lat. *sepalum*). A portion of the calyx, the outermost covering of the flower, 100, 102
 Septenate (Lat. *septem*, seven). A leaf with seven leaflets, 80
 Septicidal' (Lat. *septum*, a division; *cædo*, I cut). A capsule where dehiscence takes place along the septa, 137
 Septifragal (Lat. *septum*, a division; *frango*, I break). A capsule where, the carpels opening by their dorsal sutures, the septa separate from the valves, 137
 Serrate (Lat. *serratus*, sawed). Applied to the margin of the leaf when there are a number of sharp saw-like teeth pointing towards the apex, 76
 Sessile (Lat. *sessilis*, sitting). When any organ is destitute of a stalk, 70, 95, 115
 Sieve-tubes. Vessels with the separating walls perforated in a sieve-like manner, 21
Silene, 161
 Silica of plants, whence obtained, 35
 Silicula (Lat. a little pod). In structure like the siliqua, but shorter and broader, 138
 Siliqua (Lat. a bean pod). A bicarpellary capsule with a replum running up the centre; the two valves break away and leave the seeds attached upon the replum. It is long and narrow in shape, 138
 Silver grain, 50
 Sinuate (Lat. *sinuatus*, crooked). Applied to the margin of the leaf when there are alternate lobes and depressions of a larger form than in crenate leaves, 77
Sloe, 165
Snaydragon, 174
 Soboles (Lat. a sprout). An underground creeping stem thinner than the rhizome, 56
Solomon's Seal, 183
Sowbread, 176
 Spadix (Lat. a palm branch). A fleshy unisexual spike surrounded by a spathe, 96
 Spathe (Lat. *spatha*, the flowering branch of a palm tree). A bract enveloping one or a number of flowers, 92, 96
 Spathulate (Lat. *spathula*, diminutive of *spatha*). Spoon shaped; when a leaf is rounded at the apex and narrower towards the base, 79
 Species, 156
 Spermoderm (Gr. *sperma*, seed; *derma*, skin). The term used collectively for the coats of the seed, 4
 Sphere crystals, 14
 Spike (Lat. *spica*, an ear of corn). An indefinite inflorescence with prolonged axis and sessile flowers, 94, 96

SUP

- Spinacea*, 177
 Spine. A modified branch or leaf which is hard, stiff, and sharp-pointed, 61
 Spiny leaves. Leaves with sharp spines on their margins, as in the holly, 77
 Spiral cells, 18; vessels, 22; veneration, 66
Spiræa, 166
 Spur. A prolongation of the various parts of the flower, 111
 Stamen (Lat. a distaff). One of the divisions of the andrœcium, the outermost whorl of the essential organs of the flower, 100, 113
 Staminate flowers. Those with stamens but no pistil, 101
 Staminode (*stamen*, and Gr. *eidos*, resemblance). An abortive stamen.
 Standard. One of the petals of papilionaceous flowers, 109
Star of Bethlehem, 184
 Starch, 9
Stellaria, 161
 Stellate (Lat. *stella*, a star). Term used in describing cells with several star-like processes, 16
 Stems, 40; forms of, 53; growth of, 45, 52
 Stigma (Gr. a point). The portion of the pistil which receives the pollen, 118, 122
 Sting, 72
 Stipulate. Possessing stipules, 69
 Stipule (Lat. *stipula*, a blade). Foliaceous organs often attached at the base of the leaf, 69
Stitchwort, 161
Stock, 160
 Stolon (Lat. a shoot). A branch given off above ground and striking into the soil, 55
 Stomata (Gr. *stoma*, a mouth). The openings through the epidermis of plants, 41, 71
 Storehouse of food, 39
Strawberry, 165
 Striation of cell wall, 21
 Strobilus (Lat. a cone). An inflorescence differing from a cone in possessing membranous bracts, 96
 Style (Lat. *stylus*, a sharp-pointed instrument used for writing on waxed tablets). The stalk which supports the stigma upon the ovary, 118, 121
 Suber (Lat. cork). A changed condition of cellulose met with in cork, and epidermis cells, 7
 Subterranean stems, 55
 Sucker (Lat. *surculus*, a branch). A branch springing below the soil and growing up into the air, 55
 Sulphur of plant, whence obtained, 35
Sunflower, 172
 Superior. Applied to calyx when above ovary, 103; and to ovary when above calyx, 103
 Supervolute (Lat. *super*, upon; *volutus*, rolled). When in the leaf bud two

SUT.

- convolute leaves are rolled one around the other, 66
 Suture (Lat. *sutura*, a seam). The line of junction, especially used with regard to the ovaries and fruits, 120, 138
Sweet Cicely, 169
Sweet Pea, 162, 163
Symphytum, 176
 Sympodium (Gr. *sun*, together; *pous*, *podos*, a foot). Applied in branching where the branches become strong so as to form a false axis, 66, 67
 Syncarp (Gr. *sun*, together; *karpōs*, fruit). A compound fruit formed by the ripening of an inflorescence, 135
 Syncarpous (Gr. *sun*, together; *karpōs*, fruit). The union of the several carpels of one pistil, 119
 Syngenesious (Gr. *sun*, together; *genesis*, origin). Union of stamens by means of their anthers, 114

TABULAR (Lat. *tabula*, a table).

Term applied to flattened cells, 17

Tamarind, 164

Taraxacum, 170, 172

Tares, 164

Tegmen (Lat. *tego*, I cover). The inner coat of the seed, 4

Temperature necessary for germination, 148

Tendrils, 61

Terminal buds, 59

Ternate (Lat. *ternus*, three each). A leaf with three leaflets, 80

Testa (Lat. a covering). The outer coat of the seed, 4

Tetradynamous (Gr. *tetra*, four; *dynamis*, power). With four long and two short stamens, 115

Teucrium, 173

Thalamifloræ, 154, 156

Thalamus (Lat. a bed-chamber). The end of the flower-stalk, to which the flower is attached, 123

Thistle, 171

Thymus, 173

Thyrus (Lat. a stalk). A panicle with short stalks, 96

Tonquin Beans, 164

Tracheides (Lat. *trachea*, windpipe). Cells with both spiral markings and pores, 19

Transpiration of plants, 87, 145

Traveller's Joy, 158

Trefoil, 163

Trifolium, 163

Trillidæ, 183

Trimorphic (Gr. *treis*, three; *morphe*, shape). Plants where there are three different lengths of pistil and stamens in various flowers, 133

Tripinnate (Lat. *tres*, three; *pinna*, a feather). A pinnate leaf in which the leaflets are themselves pinnate, and these secondary divisions are again divided in a pinnate manner, 82

VER

Triticum, 186, 188

Truncate (Lat. *truncatus*, maimed).

When a leaf terminates abruptly, 78

Trunk (Lat. *truncus*, the stem of a tree), 54

Tuber (Lat. a swelling). A swollen underground branch, 57

Tuberculated. A root with tuber-like swellings, 33

Tubular (Lat. *tubus*, a pipe). Applied to the form of the calyx, 104; and corolla, 107

Tubulifloræ, 170

Turbinate (Lat. *turbineus*, top-shaped).

Applied to the form of the calyx 104

Turnip, 160; root of, 39

Twayblade, 182

Twining stems, 54

ULX, 164

Umbel (Lat. *umbella*, a sunshade).

An indefinite inflorescence with shortened axis and stalked flowers, 95

Umbelliferæ, 155, 167

Unicostate (Lat. *unus*, one; *costa*, a rib). Leaves with only one principal rib or vein, 75

Unilocular (Lat. *unus*, one; *loculus*, a cell). Containing only one cavity

Applied to anthers, 116; to ovaries 120; and to fruits, 138

Urceolate (Lat. *urceolus*, a little pitcher). Pitcher-shaped; applied to the shape of the calyx, 104; and corolla, 109

Use of insects in fertilising flowers, 130, 182

VACUOLI (Lat. *vacuum*, an empty space). The drops in which the cell sap first appears in the protoplasm, 12

Vagina (Lat. a sheath). Applied to the base of the leaf when it encircles the stem, 85

Valvate (Lat. *valvæ*, folding doors). Applied to the bud when the individual leaves touch without overlapping, 66

Vanilla, 182

Veins. The fibro-vascular bundles in the leaves, 72

Venation. The arrangement of the veins in the leaf, 72

Verbascum, 175

Vernal Grass, 187

Vernation (Lat. *ver*, spring). Arrangement of leaves in the bud, 63

Veronica, 175

Versatile (Lat. *versatilis*, revolving). Applied to an anther which swings on top of the filament, 115

Verticillaster (Lat. *verticillum*, a little whorl; *aster*, a star). Cymose bunches which give the appearance of whorled flowers, 99

VER

- Verticillate (Lat. *verticillum*). Whorled :
 applied to leaves, 84
 Vessels. Tubes formed by the fusion of
 cells, 21
Vetch, 164
 Vexillum (Lat. a standard). One of the
 petals of papilionaceous flowers, 109
Vicia, 164
Violet, 156, 190
Viper's Bugloss, 176

WALLFLOWER, 159, 160

- Walnut*, 180
 Wardian cases, 88
Watercress, 160
Water Dropwort, 169
Water Hemlock, 168
Water Violet, 176
Wheat, 186, 188; germination of, 28
White Rot, 169
 Whorl. An arrangement where the or-
 gans are placed in a circle round the
 central axis. Applied to leaves, 84 ;
 and to the parts of the flower, 100

ZEA

- Wild Service-tree*, 167
Windflower, 158
 Wing. One of the side petals of a
 papilionaceous flower, 109
Woad, 160
 Wood. The central part of the fibro-
 vascular bundles, especially when
 hardened by secondary deposit, 41 44
 45
Wormwood, 171

XANTHORRHOEA, 185

- Xylem (Gr. *xulon*, wood) The
 same as the wood, 41, 44, 45

YEAST, 6

- Yellow Loosestrife*, 176
Yellow Pimpernel, 176
Yucca, 185

ZEA, 188

LONGMANS' ELEMENTARY SCIENCE MANUALS.

Written specially to meet the requirements of the Elementary Stage of Science Subjects as laid down in the Syllabus of the Directory of the Science and Art Department, South Kensington.

SOUND, LIGHT, and HEAT. By MARK R. WRIGHT (Hon. Inter. B.Sc. London). With 160 Diagrams and Illustrations. Crown 8vo. 2s. 6d.

An INTRODUCTION to MACHINE DRAWING and DESIGN. By DAVID ALLAN LOW (Whitworth Scholar). With 65 Illustrations and Diagrams. Crown 8vo. 2s.

TEXT-BOOK on PRACTICAL, SOLID, or DESCRIPTIVE GEOMETRY. By DAVID ALLAN LOW (Whitworth Scholar). Part I. crown 8vo. 2s. Part II. crown 8vo. 3s.

ELEMENTARY PHYSIOGRAPHY. By J. THORNTON, M.A. With 10 Maps and 150 Illustrations. Crown 8vo. 2s. 6d.

A MANUAL of MECHANICS: an Elementary Text-Book for Students of Applied Mechanics. With 138 Illustrations and Diagrams, and 188 Examples taken from the Science Department Examination Papers, with Answers. By T. M. GOODEVE, M.A. Fcp. 8vo. 2s. 6d.

INORGANIC CHEMISTRY, THEORETICAL and PRACTICAL; with an Introduction to the Principles of Chemical Analysis. By WILLIAM JAGO, F.C.S. F.I.C. With 49 Woodcuts and numerous Questions and Exercises. Fcp. 8vo. 2s. 6d.

An INTRODUCTION to PRACTICAL INORGANIC CHEMISTRY. By WILLIAM JAGO, F.C.S. F.I.C. Head Master of the Brighton School of Science and Art. Crown 8vo. 1s. 6d.

PRACTICAL CHEMISTRY: the Principles of Qualitative Analysis. By WILLIAM A. TILDEN, D.Sc. Fcp. 8vo. 1s. 6d.

ELEMENTARY INORGANIC CHEMISTRY. Alternative Course. By W. FURNEAUX, F.R.G.S. Lecturer on Chemistry, London School Board. 2s. 6d.

ELEMENTARY BOTANY, THEORETICAL and PRACTICAL. By HENRY EDMONDS, B.Sc. London. With 312 Diagrams and Woodcuts. Fcp. 8vo. 2s. 6d.

An ELEMENTARY COURSE of MATHEMATICS. Specially adapted to the requirements of the Science and Art Department. Crown 8vo. 2s. 6d.

BUILDING CONSTRUCTION. By EDWARD J. BURRELL, Teacher of Building Construction at the Technical School of the People's Palace, Mile End. Fully Illustrated with Working Drawings. Crown 8vo. 2s. 6d.

THEORETICAL MECHANICS. By J. EDWARD TAYLOR, M.A. Lond. Head Master of the Central Higher Grade and Science Schools, Sheffield. With 175 Illustrations and numerous Examples and Answers. Crown 8vo. 2s. 6d.

ANIMAL PHYSIOLOGY. By WILLIAM S. FURNEAUX, Special Science Teacher, London School Board. With 218 Illustrations. Crown 8vo. 2s. 6d.

STEAM. By Professor W. RIPPER, the Technical School, Sheffield. *[In preparation.]*

London : LONGMANS, GREEN, & CO.

TEXT-BOOKS OF SCIENCE,

MECHANICAL AND PHYSICAL.

Adapted for the Use of Students in Public and Science Schools.

ABNEY'S PHOTOGRAPHY. 105 Woodcuts	3s. 6d.
ANDERSON'S The STRENGTH of MATERIALS and STRUCTURES. 66 Woodcuts.....	3s. 6d.
ARMSTRONG'S ORGANIC CHEMISTRY. 8 Woodcuts.....	3s. 6d.
BALL'S ELEMENTS of ASTRONOMY. 136 Woodcuts...	6s.
BARRY'S RAILWAY APPLIANCES. 207 Woodcuts...	3s. 6d.
BAUERMAN'S SYSTEMATIC MINERALOGY. 373 Woodcuts	6s.
BAUERMAN'S DESCRIPTIVE MINERALOGY. 236 Woodcuts	6s.
BLOXAM & HUNTINGTON'S METALS : their PROPERTIES and TREATMENT. 130 Woodcuts.....	5s.
GLAZEBROOK & SHAW'S PRACTICAL PHYSICS. 80 Woodcuts.....	6s.
GLAZEBROOK'S PHYSICAL OPTICS. 183 Woodcuts...	6s.
GORE'S ART of ELECTRO-METALLURGY. 56 Woodcuts.	6s.
GRIFFIN'S ALGEBRA and TRIGONOMETRY.....	3s. 6d.
HOLMES'S The STEAM ENGINE. 212 Woodcuts.....	6s.
JENKIN'S ELECTRICITY and MAGNETISM. 177 Woodcuts.....	3s. 6d.
MAXWELL'S THEORY of HEAT. 41 Woodcuts.....	3s. 6d.
MERRIFIELD'S ARITHMETIC and MENSURATION.	3s. 6d.—KEY, 3s. 6d.
MILLER'S INORGANIC CHEMISTRY. 72 Woodcuts.	3s. 6d.
PREECE & SIVEWRIGHT'S TELEGRAPHY. 160 Woodcuts	5s.
RUTLEY'S The STUDY of ROCKS. 6 Plates and 88 Woodcuts.....	4s. 6d.
SHELLEY'S WORKSHOP APPLIANCES. 291 Woodcuts.....	4s. 6d.
THOMÉ & BENNETT'S BOTANY. 600 Woodcuts.....	6s.
THORPE'S QUANTITATIVE CHEMICAL ANALYSIS. 88 Woodcuts	4s. 6d.
THORPE & MUIR'S QUALITATIVE CHEMICAL ANALYSIS. 67 Woodcuts.....	4s. 6d.
TILDEN'S CHEMICAL PHILOSOPHY. 5 Woodcuts.	With or without Answers to Problems, 4s. 6d.
UNWIN'S MACHINE DESIGN. 325 Woodcuts.....	6s.
WATSON'S PLANE and SOLID GEOMETRY	3s. 6d.

London : LONGMANS, GREEN, & CO.