ELEMENTARY BOTANY

BY

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PREFACE

In writing the present volume, I have endeavoured to place the subject before elementary students in such a way as to exercise to the full their powers of observation, and to enable them to make accurate deductions for themselves from the facts which they observe. To attempt the study of Botany without the practical examination of plants is futile. Students of plant-life *must* look at plants, and this book is specially designed for use during the process. Considerable experience as examiner in Botany as taught in schools has convinced me that comparatively few learners have the advantage of seeing specimens with the aid of a compound microscope, although the treatises usually employed should involve the frequent use of such an instrument. Under these circumstances, I have in the following pages assumed that a compound microscope is not employed, and for their proper understanding such an instrument is quite unnecessary. An ordinary inexpensive lens should be used to aid the naked eye; but, on the other hand, in commencing the study of Botany a compound microscope is absolutely needless, and, in the case of young beginners, does more harm than good. The section on Physiology has been so written that no knowledge of the histology of plants is assumed—a feature which is, I believe, here introduced for the first time. Though by no means a "cram-book" for elementary examinations, a thorough knowledge of the contents of this book will enable a candidate to pass with distinction.

In order to lay more emphasis on the observation of facts, and with a view to simplify the whole matter, I have inserted no unnecessary technical terms, but, for the convenience of students who afterward use "Floras," I have added an appendix for use as a dictionary, but not for the purpose of elementary study.

Some words of explanation may be required in reference to the definitions of *flowers* and *fruits*. In more advanced works we are told that a flower is a collection of sporophylls inserted on a simple axis. This definition seems to me imperfect. That the young carpels and stamens are homologous with leaves, and particularly with sporophylls, is proved beyond a doubt. But the mature carpel with the ripe ovules is no longer homologous with a sporophyll; it is a sporophyll containing parasitic and symbiotic gametophytes. The symbiosis of the gametophytes and the sporophylls before, during, and subsequent to fertilisation constitutes a phenomenon which is unique in the vegetable kingdom. Consequently, it appears that, when judged by the facts of the case and on historical grounds, it is at least incomplete and inexpedient to employ to the cone of *Equisetum* the same term as to the flower of a Buttercup. A single flower of a Buttercup is no more a mere collection of sporophylls than a frog is a fish because it passes through the tadpole stage. In reference to the definition of a fruit, I have followed that given in the "Lehrbuch der Botanik" written by Professors Strasburger, Noll, Schenck, and Schimper. The definition of a fruit is thus brought closer to the popular usage of the term, while we are extricated from any dilemma in reference to distinguishing between an inferior and a false fruit.

In conclusion, it should be stated that for the most part the illustrations have, after careful consideration, been specially executed by my friend Mr A. H. Church of Jesus College, Oxford, to whose skill and care I am much indebted. To him, also, I owe a careful revision of the proofs of this book. Further assistance in the matter of illustrations has been rendered by Mr A. Robinson of the University Museum, Oxford. Students who desire a simple introduction to the study of Microscopical Botany are recommended to procure Dr D. H. Scott's "Structural Botany"; while those who wish for a comprehensive work, dealing with the science as a whole, will find all they require in "The Student's Text-book of Botany," by Professor S. H. Vines. Finally, such students as desire to identify wild British plants, and to do field-work, will find Hayward's "Botanist's Pocket Book" an excellent little work which contains all the necessary information.

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PART I

GENERAL MORPHOLOGY

ELEMENTARY BOTANY

CHAPTER I

INTRODUCTION

Plants, like animals, are living beings, and may be regarded from two standpoints. In the first place, a plant may be considered as a living machine designed to execute certain work and consisting of definite parts or *organs*, to each of which there is allotted a particular office or *function*. After this definition we naturally inquire how a plant lives, feeds, grows, and multiplies. We then ask precisely what work is performed by the various organs, such as the leaves, stems, and roots. This aspect of botany is termed **Physiology**. Again, we may look at a plant simply as a machine consisting of various parts or *members*, which are arranged in a particular order and have certain shapes. In fact, we learn the exact form of the plant without taking notice of the work it does. This department of botany is termed **Morphology.** Studied from this point of view, we find that plants exhibit resemblances to, and differences from, one another. For instance, a Fern seems very unlike a Mushroom, and yet both are alike in so far as neither of them possesses flowers. On the other hand, a tuft of Grass and a Buttercup are widely different in appearance, but at the same time they resemble each other insomuch as they both produce true seeds from flowers. These points of likeness and unlikeness among plants lead us to arrange the latter into groups. This grouping is described as **Classification,** and constitutes **Systematic Botany.** For our present purpose, let us be content to divide plants into two great classes—namely, *Flowering Plants* and *Non-Flowering Plants.* In the first group are included all plants which bear seed-producing flowers, whether they have showy blossoms such as those of the Buttercup, Wallflower, and Dandelion, or blossoms which we hardly notice, such as those of Grasses, Oaks, and Hazels. *Non-Flowering Plants* bear no seed-producing flowers: amongst them are the Ferns, Mosses, Seaweeds, and Fungi. In this book we treat only of flowering plants, so far as they can be studied with the naked eye aided by a simple lens.

Method of using this book.—This book is divided into three Parts:—Part I. relating to General Morphology (and including a special chapter on the Scotch Pine); Part II. referring to the Classification of Angiosperms; and Part III. relating to the Physiology of plants.

Beginners should first read chapters ii. to v. in Part I., and should practically examine the roots, stems, and leaves described. They may then pass on to the study of Physiology contained in Part III. (chapters xv. to xxii.); or they may read the remaining chapters of Part I. (omitting that which relates to the Scotch Pine), at the same time studying the families specially marked at the commencement of Part II. (chapter xiv.). In this book the characters of each family are denoted by a description of one or more representatives which are *types* of that family. While a student is reading the description of one of these types, he *must* have before him a specimen of the plant described, so that he can constantly examine and refer to it. Should any point in the description be beyond the comprehension of the learner, reference should be made to the teacher or, by means of the index, to the explanations given in Part I. The families should not be studied in the exact order in which they are placed in the book: the season of the year and other considerations will determine the order in which the types are to be examined. As examples of flowers appropriate for beginners we may mention the Buttercup, Poppy, Wallflower, Pea, Rose, Primrose, Dead Nettle, Hyacinth, and Daffodil. In beginning the study of the types for the first time, students should entirely ignore, and omit to read, the characters given at the commencement of the description of each family.

If the beginner has studied the systematic portion of the book thus outlined before working at the Physiology, he should then pass on to Part III.

Finally, when the student has acted as previously advised, the whole of Part I. should be read over again: and the remaining types and families in Part II. might also be dealt with.

CHAPTER II

THE DISTINCTION OF A FLOWERING PLANT INTO ROOT AND SHOOT

EVERYONE is familiar with the fact that ordinary flowering plants possess roots, stems, leaves, and flowers. The roots of a plant constitute its **root-system**, and are usually concealed in the soil; whereas the stems, leaves, and flowers of the plant together compose the **shoot-system**, and are generally visible and above ground. But stems and leaves are occasionally embedded in the soil; whilst roots may be found raised above the ground on sub-aerial parts of the plant. Hence we cannot define a root as being the subterranean part of the plant, nor the shoot as being the sub-aerial portion. It will, therefore, be well to consider first what we mean by the terms "root" and "shoot." For this purpose the seedling of a bean may be examined. The seedling consists of a main axis, which bears certain structures—the lateral members—on its sides. The ascending portion of this axis is the **stem**, which possesses the flattened **leaves** as its lateral members. At the tip of the stem the leaves are crowded together to form a bud. The main stem may also produce lateral stems—the branches—which are like itself. The descending part of the main axis of the seedling is the main **root**, which has no leaves, and therefore does not terminate in a bud.* The root does, however, bear branches similar to itself which are called the lateral roots.

Even inside the seed of the Bean, the young plant, or embryo, displays this distinction into root and shoot. The bean-seed (fig. 1) is externally clothed by a shell-like seed-coat termed the *testa* (*ts*). The testa has a minute pore (*m*) at one end of the scar (*hi*) on its side. The whole of the space enclosed within

* The tip of the root is covered by a little cap termed the *root-cap*, which can only be properly seen by the aid of a compound microscope.

the testa is occupied by the embryo. The embryo (fig. 2) has a small rod-like main axis, which is composed of the primary or main root, the *radicle* (*r*); the primary or main stem (*pl*); and a part of the axis, the *hypocotyl* (*hp*), which connects the root and stem. The tip of the young root lies close within the pore of the testa. No lateral roots occur on the radicle at this stage. The main body of the embryo is constituted of the two large fleshy leaves—the *cotyledons* (*cot*), which are attached to that

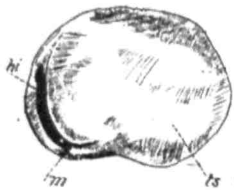


Fig. 1.—Seed of Bean.

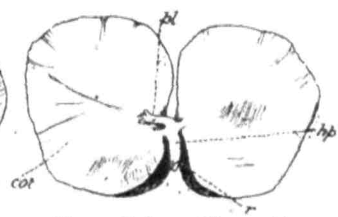


Fig. 2.—Embryo of Bean, with Cotyledons separated.

portion of the axis which is termed the hypocotyl. Lying hidden between the two cotyledons is the minute main stem, which terminates in a small bud. Thus, beginning at the root, the axis has no lateral members on its root-portion: above succeeds the hypocotyl* with two lateral cotyledons: still higher the axis represents the young main stem, and bears a few lateral commencements of leaves.

When the seed germinates, the various parts of the embryo emerge. The radicle elongates and becomes the primary root: it grows downwards and produces lateral roots which may branch in their turn. The little stem grows upwards and sends out from its sides, leaves, branches, and flowers; its branches may in turn bear, not only leaves, but also branches of their own. We thus see that the development of this flowering plant from its embryo consists in the elongation of its primary axis, and the production of lateral members on that axis. The parts possessed by a mature flowering plant, whether it be a large tree or a small herb, are all to be traced back to the primary axis.

* It is impossible to define exactly the limits of the hypocotyl unless the compound microscope be employed.

We can now define a root and a shoot. *A stem is an axis which bears lateral members—the leaves—dissimilar to itself. A stem together with its leaves constitutes a shoot.* A shoot terminates in a bud, and is usually the ascending portion of the plant: at least, parts of it are generally green. Lastly, the shoot bears the flowers. *A root is an axis which cannot produce leaves as lateral members of itself: consequently it does not terminate in a bud.** A root can only produce as lateral members branches like itself: as a rule it is a descending axis, and has no green colouring-matter.

THE ROOT.

If we fix a germinating bean (or pea) in a bottle containing air which is saturated with moisture, in the manner shown in fig. 3, when once the root has commenced to grow straight, we can follow the method of growth. To accomplish this, we make a number of transverse marks in Indian ink at equal and short distances along the root. After twenty-four hours' growth it will be found that the distance between the consecutive marks remains the same, excepting near the tip of the root, where the marks have become separated by longer intervals. This shows that the *root increases in length by elongation which only takes place in the region of its apex*: consequently, the youngest part of a root is that which is nearest its apex, whereas the oldest is that nearest its base.

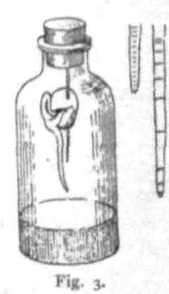


Fig. 3.

A short distance behind its apex (fig. 4 *rx*) the root has a broad encircling band of fine silky hairs—**root-hairs** (*rh*). As the root grows at its apex new root-hairs form constantly behind the tip, which, of course, has been carried forward, so that the youngest root-hairs are those nearest the tip. These hairs live for a short time only, for they soon shrivel and peel off, and therefore they are found solely on the young and more terminal portions of a root.

A root may bear branches structurally similar to itself. These arise on the main root at points nearer to the root-

* It has a root-cap, which is not possessed by a stem.

apex than the last-formed lateral roots; so that the youngest and smallest of them are seen to be nearest to the tip of the main root (fig. 4). *The lateral roots* are therefore said to *arise in acropetal succession.* They do not appear at indifferent points; on the contrary, they emerge only on certain determined sides of the main root, so as to form regular ranks or rows along the length of the latter. For

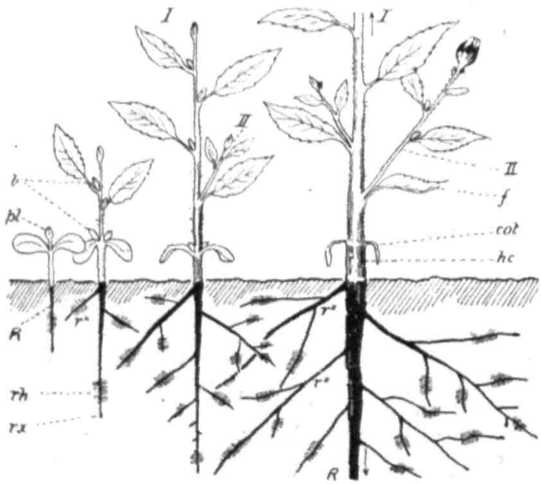


Fig. 4.—Development of a typical Dicotyledon.

example, the branches of a Wallflower-root form two rows, while those of the Creeping Buttercup-root are ranged in four rows.*

Adventitious Roots.—Lateral roots frequently arise on stems—for instance, on the creeping stems of the Strawberry (fig. 54), Creeping Buttercup, and Grasses; or on the underground parts of the stem of the Primrose or on "Cuttings." Inasmuch as these roots do not arise in the normal method—

* One important character concerning the origin of lateral roots is that they arise as internal growths, which push their way through the rind of the mother-root, and eventually reach the soil. They are said to be *endogenous* (arising within) in origin.

that is, as acropetal branches of another root — they are said to be *adventitious*. The difference between adventitious and normal lateral roots is well illustrated by considering the root-system of *Dicotyledons* and *Monocotyledons*. One of the general characteristics of a Dicotyledon is that its embryo in the seed has two cotyledons (*e.g.* Bean, Hazel, Oak). Frequently the root-system of Dicotyledons is formed after the manner described as occurring in the Bean, and well illustrated by fig. 4. The embryo of a Monocotyledon, on

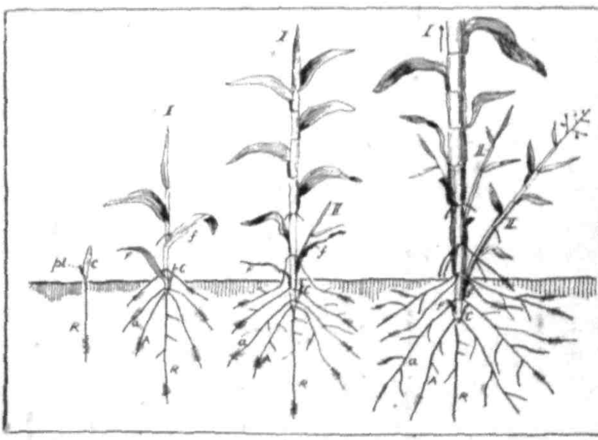


Fig. 5.—Development of a typical Monocotyledon.

the other hand, possesses only one cotyledon (*e.g.* Grasses, Lilies). Nearly always the root-system of a Monocotyledon develops in a manner entirely different from that pursued by the Bean. The young primary root (R) of the embryo grows for a short time only and produces at the most few lateral roots, eventually shrivelling up; but, sooner or later, lateral roots arise successively higher up the stem, first on the hypocotyl (A), then on the stem (*a*)—as is denoted in fig. 5. Consequently, in full-grown Monocotyledons practically the whole root-system is adventitious, and there is no main-root with branches. [In fig. 5 the roots have pulled the base of the shoot down into the soil.]

Shapes of Roots.—The roots may be thin and *fibrous*, or they may present various forms between this and a swollen or *tuberous* condition. The main root of the Carrot and Turnip, thickens and forms the swollen part which we eat. The Dahlia-plant produces a number of adventitious tuberous roots, which grow out from the base of the stem. As will be shown later on, these thick fleshy roots serve as reservoirs in which food is stored for future consumption by the plant.

Aerial Roots.—Some plants, like the Ivy, climb by means of adventitious roots which, in place of dipping down into the soil, adhere to the surface of a tree, wall, or rock. Roots above the surface of the soil are described as being *aerial* roots.

CHAPTER III

VEGETATIVE SHOOT—LEAVES

A SHOOT, in addition to possessing stems and leaves, may bear flowers. If we exclude the flowers, the remainder of the shoot may be spoken of as constituting the *vegetative shoot*. For the present, flowers will not be considered.

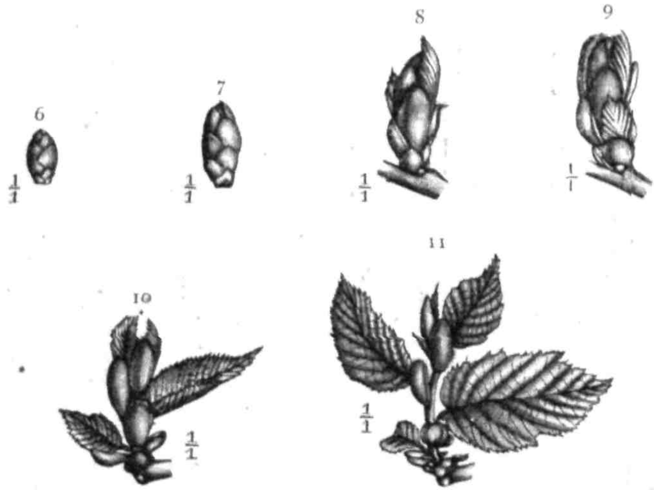
By making marks in Indian ink at equal distances along the stem, it is easily shown that a *stem grows in length only near its tip*. We can see this apical growth even more simply by observing the leaves constituting a growing bud. At first they are packed close together, but as the terminal part of the stem elongates they become separated by distinct intervals along the latter (figs. 6-11). Thus the youngest part of a single stem is nearest its tip, and the oldest part is that portion which is nearest its base.

If we pull the leaves from an actively growing bud of a Wallflower or Sunflower, we see that the external leaves of the bud are inserted lower down the stem than the internal leaves, and are larger than the latter; and the inmost leaves are the smallest, and are inserted nearest the actual end of the stem. Thus *leaves arise** *only in the region of the apex of a stem and appear in acropetal succession*—that is, the youngest leaf is the one which is nearest the end of the stem. As the tip of the stem elongates, the leaves are, so to speak, left behind, and continue to grow till they attain their full size.

The leaves are attached laterally to the stem at certain points, which are termed **nodes**. These points of attachment are separated by portions of the stem—the **internodes**—which are devoid of leaves but connect the successive nodes (see figs. 4, 5).

* The leaves arise as external lumps on the side of the stem, and are thus *exogenous* in origin.

If the young part of a shoot be examined, it will be found that in the angle between the upper face of each leaf and the stem there is a bud (fig. 4 *b*). This angle is described as the *axil of the leaf*. Thus we may say that a *lateral bud* arises on a stem in the axil of every leaf*. These buds are the beginnings of the lateral shoots or branches, and can develop into shoots (fig. 4 ii.). We see, therefore, that lateral shoots arise in the axils of leaves—in other words, the *branching of the*



Figs. 6-11.—Development of bud of Hazel. (After Dennert.)

shoot is axillary. A shoot possessing an unbranched stem is described as *simple* (figs. 3, 4, the two left-hand drawings), but when the stem is branched, the shoot is said to be *compound* (figs. 3, 4, the right-hand drawing).

Normal buds, then, are terminal or axillary. A bud does not necessarily develop at once into a branch. It may remain in a resting or dormant condition, and is then described as a *resting-bud*, to distinguish it from an active bud.

* The bud appears as an external outgrowth of the stem; it is *exogenous*.

Adventitious Shoots.—Lateral shoots may arise on some flowering plants in places other than the axils of leaves. Such shoots are said to be *adventitious*. For instance, adventitious shoots may burst out from the roots of Poplars, Rose-trees, Hazels, and raise themselves above the surface of the soil. Again, adventitious shoots may spring from cut fragments of Dandelion-roots, or from Begonia-leaves pegged down to produce cuttings. When young branches shoot out from older parts of tree-trunks they are often axillary branches, and their appearance is merely due to the sudden activity of resting-buds which were formed years before. But in the case of Willow-trees from which the upper shoots have been lopped, many entirely new lateral buds arise on the upper part of the trunk. These grow out to form branches which are adventitious, because they are not due to the development of resting axillary buds. In all these cases of adventitious branching the shoots produced have stems and leaves, and therefore are shoots.

ARRANGEMENT OF THE LEAVES.

The leaves are attached to the nodes of the stem. On the stems of some plants (*e.g.* Buttercup, Wallflower) no two leaves are inserted at the same level on a simple stem—that is, there is only one leaf at each node. This leaf-arrangement is described as alternate or, better still, as *spiral* (*acyclic*). On other stems two or more leaves are attached at the same level and at the same node of a stem. The leaf-arrangement is then described as *whorled* (*cyclic*), and the collection of leaves at each node constitutes a *whorl*.

Whorled (Cyclic) Leaves.—In this leaf-arrangement the leaves at a single node are disposed in a very regular manner. They are inserted in such a way that the angular distance between each two adjacent leaves is the same. Thus, if there be two leaves at the node, they are inserted on the opposite sides of the stem (say the north and south sides), as in the Chickweed (fig. 43) and Dead Nettle; if there be four leaves, they are ranged like the four points of a compass (say N. S. E. W.); if there be three leaves at a node, each is separated from its neighbour by one-third of the circumference. The relative disposition of the leaves at the different nodes is equally regular. In some cases the leaves at the successive nodes are exactly above one another *(superposed)*, so that there are just as many rows of leaves along the stem (longitudinal rows) as there are leaves at each node — for instance, there will be two longitudinal rows of leaves if there are two leaves at each node. But on other stems with whorled leaves, the leaves at one node stand above the gaps midway between the leaves of the next lower or next higher node; thus the leaves at the successive nodes exactly alternate with one another. Consequently, the leaves of every second node will stand above one another. In this case there will be exactly twice as many longitudinal rows of leaves as there are leaves at a single node. For example, the Dead Nettle, the Chickweed (fig. 43), have two leaves at each node, but those at the successive nodes alternate so that there are four rows along the stems.

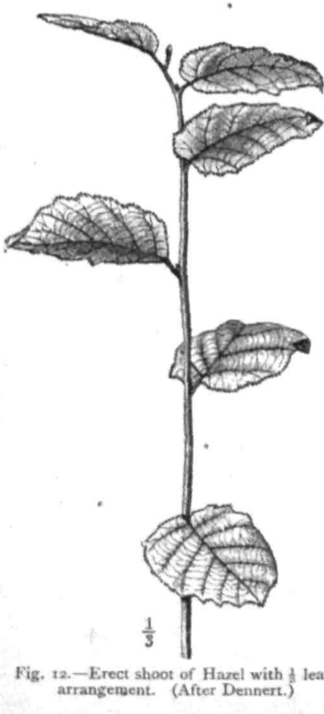


Fig. 12.—Erect shoot of Hazel with $\frac{1}{3}$ leaf-arrangement. (After Dennert.)

Alternate or Spiral (Acyclic) Leaves.—When only one leaf stands at each node (fig. 12), the leaves are arranged in spirals, and not in circles or whorls. They form rows, and are ranged one above the other along the stem, as is the case with whorled leaves. Each leaf is separated from the one at the next node, either below or above it, not only by a variable distance along the stem, but also by a certain invariable angular distance round the stem. For example, on Grass-stems and most Hazel-stems there is one leaf at each node, and each leaf is inserted on the side exactly opposite to that on which the leaf at the next node is attached; consequently we have to travel half-way round the stem (as well as go higher up) in order to reach the single leaf at the next higher node: the divergence, or angular distance, is described as being $\frac{1}{2}$. Again, in some Hazel-shoots (fig. 12) we have to travel one-third of the way round the stem in passing from one leaf to its predecessor or successor, and the divergence is said to be $\frac{1}{3}$. On the stems of the Oak, Red Currant, Pear, Poplar, Musk Rose, the divergence is $\frac{2}{5}$. The consequence of this constancy of the divergence between the leaves of the successive nodes of a stem is that the above-mentioned longitudinal rows of leaves are formed. In the Grasses and most Hazel-shoots with $\frac{1}{2}$ divergence, the leaves are ranged in two rows; in the Hazel-shoots with $\frac{1}{3}$ divergence, in three rows; on Pear-trees, etc., with $\frac{2}{5}$ divergence, in five rows. Thus in each case the numerator of the fraction denotes the number of longitudinal rows of leaves. And the numerator of the fraction represents the number of times it is necessary to travel round the stem in passing from one leaf on a stem to the next one vertically above it, at the same time touching all the leaves on the way thither. This gives us an easy method for determining the exact leaf-arrangement of a shoot. The commonest series are represented by the fractions $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$. This series can be remembered with ease if we note that—

$$\frac{1+1}{2+3}=\frac{2}{5}, \quad \frac{1+2}{3+5}=\frac{3}{8}, \quad \frac{2+3}{5+8}=\frac{5}{13}.$$

Possibly the most simple way to understand the spiral method of arrangement of leaves is to look at the cone of a Pine-tree, or to remember that the leaves are distributed like the steps of a spiral staircase.

Diagrams to represent the leaf-arrangement.—We can denote the method of arrangement of the leaves on a stem by a plan or map, representing a side view of the surface of the stem unrolled into one plane, much as we show the surface of the spherical earth with its two hemispheres extended on a single flat map. Or, on the other hand, we can for a moment imagine that a shoot is like a large bud, and that we are looking down complicated in form. The root-system consists of a short primary root (*r*), with a peculiar sheath, and several small lateral roots. The axis (*pl*) above the primary root bears a number of alternate sheathing-leaves. But one characteristic feature of the embryo of this and other grasses is that, attached to the hypocotyl, is a shield-like outgrowth—the *scutellum* (*sc*)—which separates the rest of the embryo from the endosperm. Botanists are not agreed as to which portion of the embryo represents the cotyledon. There are the three following views:—(1) The scutellum is the cotyledon. (2) The first sheathing-leaf and the scutellum together constitute the cotyledon. (3) The scutellum is merely a "subsidiary outgrowth" (emergence) of the hypocotyl: and the first sheathing-leaf represents the cotyledon.

Comparison between a Wheat-grain and a Bean-seed and their Germination.

GRAIN OF WHEAT.	BEAN-SEED.
1. Is a fruit which contains one seed. The wall is composed of the fruit-wall (pericarp), together with a very thin testa, which can be distinguished only with the help of a compound microscope.*	1. Is a seed. Its wall is formed by the thick testa only.
2. The space within the testa is occupied by endosperm and an embryo. The seed is consequently described as *endospermic*.	2. The space within the testa is occupied by an embryo only. There is no endosperm. The seed is said to be *non-endospermic*.
3. Embryo has one cotyledon.	3. Embryo has two cotyledons.
4. In germination.	4. In germination.
(*a*) The endosperm shrivels as the seedling develops: it is the food-supply of the embryo. The scutellum is the sucking-organ which absorbs nutriment for the benefit of the young plant.	(*a*) The cotyledons shrivel as the seedling develops. They contain the food-supply of the embryo.
(*b*) The main root forces its way through a peculiar root-sheath.	(*b*) The root has no peculiar root-sheath.
(*c*) The main root soon ceases to grow, and adventitious roots arise on the stem.	(*c*) The main root continues to develop and produces acropetal lateral roots.

* Recent investigations tend to show that, in reality, the testa is entirely destroyed before the grain is ripe.

PROPHYLLS OR PROPHYLLA.

In many Dicotyledons the first two, therefore the lowest two, leaves borne on each branch are small and scale-like. These two simple leaves—the *prophylls*—are inserted on opposite faces, the right and left sides of the branch. In Monocotyledons, on the other hand, there is only one of these simple leaves at the base of the branch, and it is inserted alone on the upper face of the branch—that is, on the face which is directed towards the main axis. We can easily remember these facts if we recollect that in Dicotyledons and Monocotyledons the leaves first formed on any stem are usually simplified. The first leaves of the primary stem are cotyledons; those of a lateral stem are prophylls. In Dicotyledons the primary axis has two cotyledons, the branch two prophylls; in Monocotyledons the primary axis possesses one cotyledon, the branch one prophyll.

BRACTS.

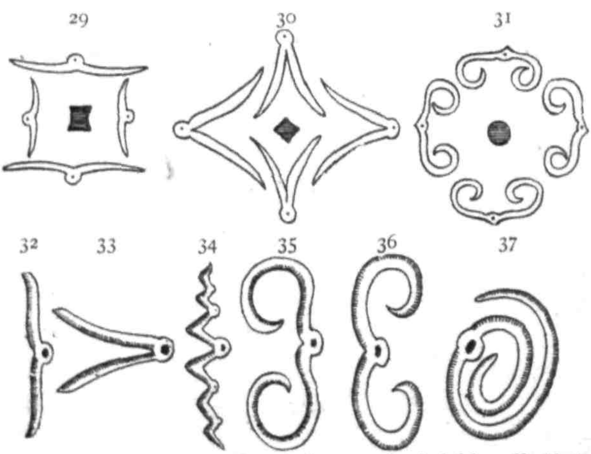
Often the leaves situated on that region of the stem which bears the flowers are simpler, and usually smaller, than the foliage-leaves of the same plant. These simplified leaves borne in the region of the flowering part of the shoot are termed bracts—*e.g.* Daisy, Bluebell, Hyacinth. In the majority of cases, bracts are small, without stalks, and attached by broad bases; their margins tend to be entire. Bracts may assume the form of small scales, as, for example, in the case of the *glumes* of grasses (fig. 231), the chaffy bracts of the Sunflower (fig. 208). Exceptionally large sheathing bracts, which enclose the whole inflorescence, occur in the *Arum*, also in the Snowdrop, and are termed *Spathes* (fig. 226).

CONSIDERATIONS WITH REGARD TO SCALES, PROPHYLLS, COTYLEDONS, AND BRACTS.

The remarks in the few preceding paragraphs render it obvious that scales are defined by their form, and are not confined to any particular regions of the shoot; but the other three varieties of simplified leaves occupy certain definite positions on the plant, and are defined as well by their position as by their simple forms. That they all represent true leaves is proved by the following considerations:—(i.) They are lateral appendages of the stem arranged like foliage-leaves, and have buds in their axils. Often it is an easy matter to cause these axillary buds to develop into branches; for instance, if we nip off the stem of a Scarlet Runner just above the points of insertion of the cotyledons, the buds in the axils of the latter will shoot out and become branches. (ii.) In many plants transitions from foliage-leaves to bracts (*e.g.* Rose, Christmas Rose), or to scales (*e.g.* buds of the Horse-chestnuts), or even to cotyledons, occur. (iii.) It is possible to cause foliage-leaves to appear in place of scales; for example, some stems (*e.g.* Potato-tubers), which are normally subterranean, when caused to develop above ground, produce foliage-leaves instead of small scales.

BUDS.

Æstivation is the term applied to denote the arrangement of the different leaves of a bud with reference to one another. In the bud the leaves forming a single whorl or spiral may not be in contact, in which case the æstivation is said to be



Figs. 29-37.—Diagrams of Vernation. In figs. 32-37 the shaded face of leaf is the upper face. The leaves are transversely cut.

open. When their edges just touch, without overlapping, the æstivation is *valvate*. Finally, when the leaves overlap the æstivation is *imbricate*.

Vernation is the term applied to denote the manner in which each single leaf is packed in the bud. Each leaf may be flat or *plane* (figs. 29, 32). In some cases the leaf is *folded* in various ways along the courses of the chief veins. The two halves of the lamina may be simply *folded* together along the mid-rib, like two pages of a book (figs. 30, 33); or there may be a number of folds (fig. 34) along several of the large veins, especially in leaves with parallel venation (*e.g.* many grasses) and with palmate venation, so that the young leaf reminds us of a closed fan or a pleated garment. In other instances the leaf is *rolled* from side to side. Each half of the lamina may be rolled towards the middle line of the upper face of the leaf, as in the Pear (figs. 31, 35, 38), or towards the middle line of the lower face (fig. 36). Occasionally the whole lamina is rolled sideways in one direction (fig. 37). Finally, the leaf may be *coiled* from the apex of the leaf towards the base, like a watch-spring.

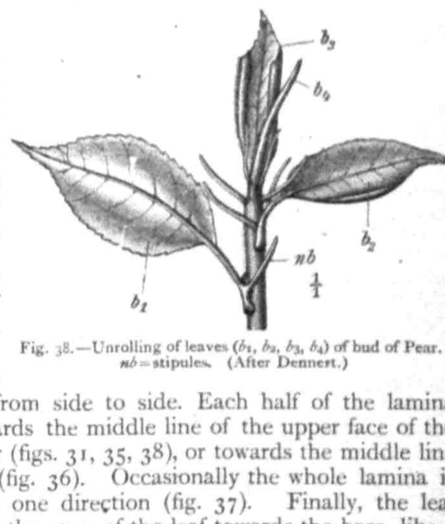


Fig. 38.—Unrolling of leaves (b_1, b_2, b_3, b_4) of bud of Pear. nb = stipules. (After Dennert.)

CHAPTER IV

STEM AND SHOOT

DEFINITE AND INDEFINITE GROWTH IN LENGTH.

An ordinary stem of a flowering plant elongates solely by means of growth at its apex. The apex may continue to grow for a long period, so that the stem will bear many leaves and lateral buds; such a stem is said to be unlimited or *indefinite* in its growth. On the other hand, the apex may soon cease to grow, so that the stem attains only a limited or *definite* length. The Scotch Pine (fig. 62) has shoots which exhibit both these methods of growth. The main trunk and conspicuous branches are of indefinite growth, and bear leaves only in the form of scales; they constitute the so-called *long-shoots*. In the axils of most of the scales on the long-shoots there arise lateral *dwarf-shoots* (fig. 39). Each dwarf-shoot consists of a short definite stem, bearing just below its apex two needle-like green foliage-leaves (*f*), and below these a number of scale-leaves (*s*): the apex (*a*) of the stem lies between the two needles (fig. 40).

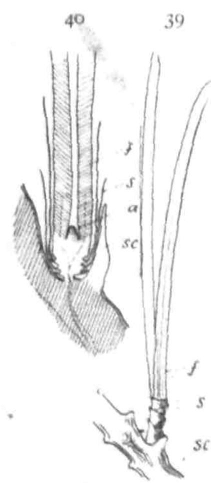


Fig. 39.—A dwarf-shoot of Pine, in axil of scale (*sc*).
Fig. 40.—Vertical section of ditto.

Stem or axes of different orders (fig. 41).—A stem is an axis bearing leaves. This definition gives us no means of stating simply whether the stem be a main stem or a lateral one: hence it is advisable to adopt some terms by which we can explain to which stem we are alluding. The main stem (I.) is described as an *axis* (stem) *of the first order*, or as the *primary axis*. A lateral axis (II.)

arising on the primary stem is termed an *axis of the second order*, or a *secondary axis*. A lateral axis (III.) arising on a secondary axis is an *axis of the third order*, or a tertiary axis; and so on.

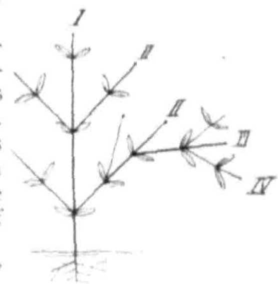


Fig. 41.

Formation of false-stems or sympodia.—A simple stem being unbranched obviously must be an axis of the first, second, or third, etc. order. Frequently, branched stems are formed which, at first sight, seem to be simple; this is particularly the case in plants possessing stems of definite growth.

The formation of such a falsely simple stem—a *sympodium*—may be illustrated by considering the growth of a grass which lives for several years and possesses a subterranean shoot-system. Following out the development of a horizontal under-ground stem of a grass, it will be seen that the end of the stem eventually bends out of the soil, becomes erect, and terminates in an inflorescence. But the base of the erect portion of this stem produces a bud which grows for a certain distance in the soil and presents the false appearance of being a continuation of the original stem. This lateral axis in turn bends out of the soil and produces flowers as did the first stem. A third axis arises on the second lateral axis and behaves in exactly the same manner as its predecessors. Fig. 42 is a diagram of a grass which is supposed to be flowering at the present time (in summer). A year ago, axis I. bore flowers (which are now invisible), and it also possessed a leafy branch (II.), the

Fig. 42.—Method of growth of a perennial Grass.

termination of which had emerged from the soil. This year, axis II. is flowering, and its branch (axis III.) has just emerged from the soil with its foliage-leaves, and will next year terminate in an inflorescence. Axis III. has a branch of its own, (axis IV.), which next year will push above the soil and assume the present condition of axis III., and in the second year after will flower. It will thus be seen that the creeping subterranean axis is not a true axis, but is composed of the subterranean portions of axes I., II., III., IV., apparently strung together end to end. Each true axis is roughly L-shaped, and the sympodium is made up of the bases of successive Ls.

Some of our trees, especially Willows, Elms, Limes, Beeches, have sympodial branches, which are produced in a slightly different manner. In these trees the terminal buds of the branches often die in autumn, and in the following year the highest axillary bud on each shoot grows out and behaves as if it were the true terminal bud. Again, in the Hazel occasionally an axillary inflorescence arises close to the apex of a shoot, and as it develops it causes the terminal bud to die and drop off (see fig. 131).

ARRANGEMENT OF BRANCHES.

So far as we have considered a flowering plant, we have found that every leaf has a bud in its axil. An axillary bud is simply a small lateral shoot which may develop into a branch. If all the axillary buds of a plant were to grow out, the branches would be arranged on exactly the same plan as the leaves (*i.e.* in whorls or in spirals). But many leaves have no branches in their axils; this is due to the fact that, though the buds are present they remain inactive. Thus we may range buds under two heads: those which are active or *growing*, and those which are inactive or *resting*. The disposition of branches on a stem depends, therefore, not only on the arrangement of the leaves, but also upon the behaviour of the axillary buds.

Racemose branching.—When a stem grows strongly and produces a considerable number of branches which remain smaller than itself, the branching is said to be *racemose* (fig. 4).

Cymose branching.—When a stem grows only for a limited time and produces only a few branches which subsequently develop more vigorously than the stem which bears them, the branching is said to be *cymose* (fig. 43).

HERBACEOUS AND WOODY STEMS.

There is considerable variety in the toughness, consistence, and longevity of stems. A stem may be soft and relatively short-lived: in which case it is said to be herbaceous. A plant, the above-ground stems of which are invariably herbaceous, is described as a *herb*. With the exception of our herbaceous climbers (*e.g.* *Convolvulus*) nearly all British herbs are plants of low stature, like the Buttercup and Primrose. Opposed to herbs are trees and shrubs whose stems are hard and woody, and capable of existing for considerable periods. A *tree* is distinguishable from a shrub by its possession of a distinct main-trunk which bears branches. A *shrub* is usually smaller than a tree, and, in place of having a main-trunk, possesses several woody branches which spring from a common point: *e.g.* Blackberry.

SECONDARY INCREASE IN THICKNESS OF STEMS.

The old part of the stem of a grass, a palm, or almost any Monocotyledon, is no thicker than the young part near the apex. The stem of the Mono-

Fig. 43.—Cymose branching of Chickweed (*Stellaria media*). The main stem (axis I.) ends in a flower I., which is bent down in the figure. On the main stem there arise two branches (axes II.), each ending in a flower II. (which is bent down in the illustration), and having two branches (axes III.), which terminate in flowers III.; and so on.

cotyledon cannot increase in thickness when it has once ceased to elongate. But the reverse is the case with Dicotyledonous trees. An old part of an Oak stem is much thicker than a young part near the apex: the older the stem the thicker it is. After the stem of a Dicotyledon has ceased to elongate it may be able to grow in thickness. If we examine the trunk of an oak-tree which has been cross-cut, we note the bark lying outside the wood. In the centre of the trunk there is a dark patch of *heart-wood*, which is surrounded

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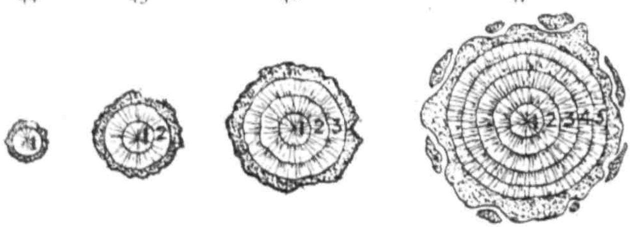


Figs. 44-47.—Cross-sections of stems showing annual thickening rings of wood. Fig. 44 is one year old. Fig. 45 is two years old. Fig. 46 is three years old. Fig. 47 is five years old, and shows the bark peeling off. 1 denotes wood formed in the first year; 2, the wood formed in the second year; and so on.

by the lighter-coloured *splint-wood.* Still looking at the cross-section of the trunk, we note that there are a number of ring-like markings ranged round the centre. We find that in a two-year-old stem there are two rings, in a three-year-old stem three rings; in fact, that the number of rings corresponds with the number of years of growth of that portion of the stem. For this reason the rings are termed *annual rings.* Each ring denotes one year's growth in the thickness of the stem. There are also numberless radial lines which are the *medullary rays.* The knots met with on cutting across timber are the remains of portions of branches, which have been buried in the wood as the stem thickened.

SUBTERRANEAN SHOOTS.

A stem may protrude into the air and be *sub-aerial*; or live under water and be *submerged*; or lie buried in the soil and be *subterranean.*

In the case of many plants only a part of the shoot is raised out of the soil, the remaining portion being underground. The subterranean stems are distinguishable from roots (i.) by their possession of leaves and buds; (ii.) by reason of their continuity with axes which bear foliage-leaves, or by their aris-

Fig. 48.—Base of Potato-plant, showing tubers. (After Baillon.)

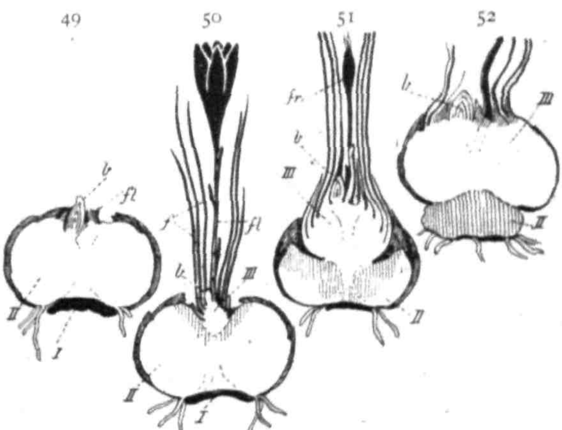
ing in the axils of leaves. There are four common types of subterranean shoots—*rhizomes*, *tubers*, *corms*, and *bulbs*.

A **rhizome** is a more or less elongated subterranean shoot which frequently extends in a horizontal direction in the soil. Its stem often bears scales which are membranous, and it usually gives off adventitious roots. Nearly all rhizomes are sympodia, as, for instance, in Grasses, in *Iris*, and in the Dandelion, their subterranean portions being formed of the persistent bases of successive lateral axes, whose sub-aerial portions produce flowers and then die. The development of the rhizome of a grass as given on page 25 illustrates the mode of formation of the underground sympodia. The Woodsorrel (*Oxalis acetosella*) affords an exception to this rule; the axis of its rhizome is a single true axis which does not emerge from the soil; the shoots (flowering axes) which protrude into the air are axillary branches of this horizontal subterranean stem, which bears scale-leaves and compound foliage-leaves.

A **tuber** is a subterranean shoot, which consists of a short swollen stem bearing small membranous scales. The tuber gives off adventitious roots. The Potato-tuber is a tuberous stem; its "eyes" are buds which arise in the axils of minute scale-leaves. The difference between these tubers and tuberous roots is well brought out by a comparison between the Dahlia and the Potato-plant. The subterranean tuberous bodies of the Dahlia arise on the base of the stem, in positions which bear no relation to the leaves on that stem; they possess no leaves. (They arise endogenously, and their tips are clothed with root-caps.) In fact, they are adventitious roots. The tubers of the Potato-plant are thickened portions of lateral stems which definitely arise in the axils of leaves (fig. 48) at the base of the main stem of the plant; furthermore, they bear scales, and when caused to develop above the soil they produce foliage-leaves. (They are exogenous in origin.)

A **corm** is a subterranean shoot which consists of a short thickened stem more or less invested by membranous scales. The corm has relatively larger scales than a tuber.

Life-History of the Garden-Crocus (*Crocus vernus*) (figs. 49-52).—Each corm of this plant is the swollen basal part of an axis which terminates in a flower; but the corm does not develop on that axis until after the latter has blossomed. Examining a plant in spring (fig. 50), shortly after the flower has withered (or even whilst it is flowering), we note that there is a yellowish wrinkled corm, on the upper face of which is either the stump or the scar of the flowering axis of the preceding year. This is encased in brown scales, and represents an axis which we will term "axis II." On its upper face there is also inserted the axis which terminates in the recently withered flower (*fl*). This is really a lateral branch of "axis II.," and may be termed "axis III." The flowering stem—axis III.—has below its terminal flower several bracts, beneath which are a limited number of long, narrow foliage-leaves (*f*) with broad basal sheaths; and still lower down the stem a few sheathing scales succeed. Already the base of this flowering axis III. is swelling, above the insertion of its lowest scales, to form a new corm, so that one slender internode intervenes between the



Figs. 49-52.—Yearly history of Garden Crocus. Fig. 49.—Plant resting in winter. Fig. 50.—Plant flowering. Fig. 51.—Plant fruiting. Fig. 52.—Plant preparing for winter-rest after fruiting.

older corm and the younger one. The new corm is growing at the expense of the food manufactured by the foliage-leaves, and also the nutriment which is being supplied by the mother-corm (axis II.). The latter is gradually shrivelling up and parting with its contents. In the axil of the uppermost foliage-leaf of the flowering stem (axis III.) is a bud (*b*), which will next year develop into a flowering axis (axis IV.) and will produce a new basal corm. Thus each year a new corm arises above the preceding one, and represents the uppermost axillary branch of its predecessor, by which it is fed. Therefore, axis II. is a branch of the shrivelled axis I., which is to be seen in the resting corm during winter (fig. 49). Occasionally several axillary buds develop on an axis, and each produces a seen outside the daughter-bulb. The Hyacinth-bulb (fig. 53) has scales of both sorts; there are true scale-leaves (*fs*), as well as scales (*fb*) which are the persistent basal parts of green leaves (*f*). In all these bulbs each new one (*b*) arises as an axillary bud on the bulb of the previous year. The older bulb-scales shrivel and give their contents to the younger parts. The lower surface of the stem of the bulb gives off adventitious roots.

SUB-AERIAL STEMS—DIRECTION OF GROWTH.

Occasionally the foliage-bearing part of a stem which is above ground is so short that the leaves form a tuft, apparently

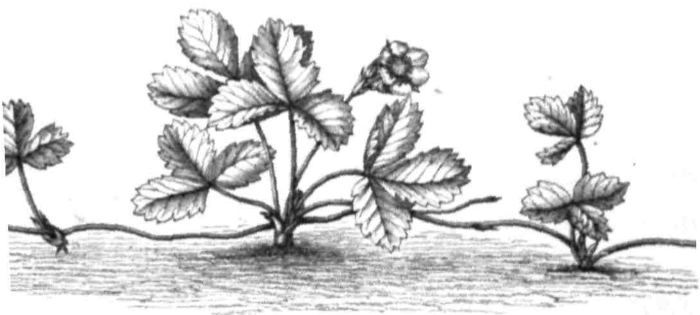


Fig. 54.—Strawberry plant, showing runners. (From Dennert.)

springing from the ground—*e.g.* Dandelion and Daisy. The leaves are then said to be *radical* in position.

Fig. 55.—Plant of *Convolvulus arvensis*, which is prostrate because it has met with no support up which it can climb. (After Dennert.)

corm, so that when the mother-corm shrivels up, the several new corms become separate and form distinct individuals. The adventitious roots are given off from the old corm, and serve to supply water and nutriment to the flowering axis and to the developing corm.

A **bulb** is a subterranean shoot which consists of a short bun-like stem with fleshy scales. The main mass of the bulb is made up of leaf-structures. In the case of the bulb of the Tulip the scales are complete scale-leaves, and the plant has foliage-leaves in addition. But the scales of some bulbs are not complete leaves, they are merely the persistent basal portions of green leaves, the blades of which have decayed. For instance, the single stem of a Snowdrop, which terminates in an inflorescence, bears two long, narrow foliage-leaves, which are attached to its base. As the season advances, the green upper portions of these two leaves decay and their bases thicken to form two fleshy scales. The bulb of a Snowdrop consequently consists mainly of two thick scales borne on a short axis. In the axil of one of the scales is a bud which, in the following year, will develop to form a new flowering axis. As the latter grows, the two scales will shrivel as they pass their contents on to the growing stem. This new flowering shoot will subsequently behave just like its predecessor, and the brown shrivelled remains of the two old scales will be

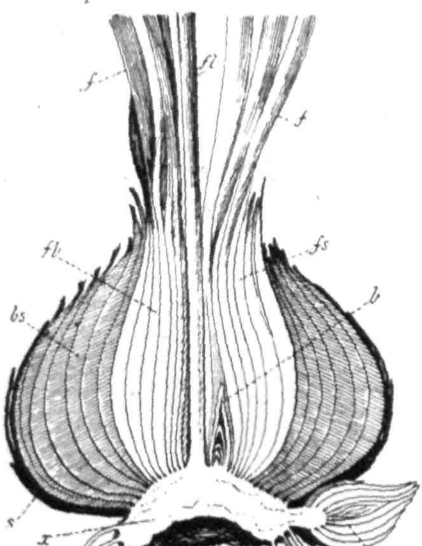


Fig. 53. — Vertical section of bulb of Hyacinth: *x* is the flattened axis; *fl* is the inflorescence axis; *lb* is an additional lateral bud forming a small bulb.

seen outside the daughter-bulb. The Hyacinth-bulb (fig. 53) has scales of both sorts; there are true scale-leaves (*fs*), as well as scales (*fb*) which are the persistent basal parts of green leaves (*f*). In all these bulbs each new one (*b*) arises as an axillary bud on the bulb of the previous year. The older bulb-scales shrivel and give their contents to the younger parts. The lower surface of the stem of the bulb gives off adventitious roots.

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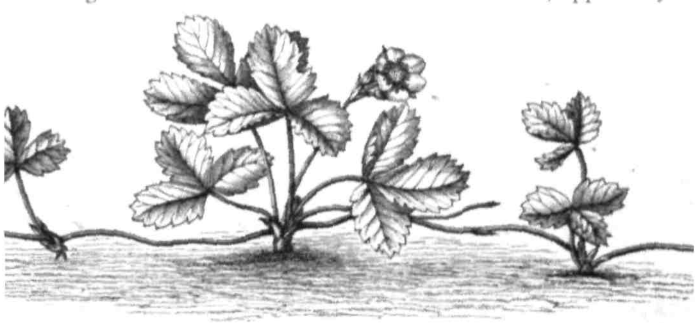

Fig. 54.—Strawberry plant, showing runners. (From Dennert.)

springing from the ground—*e.g.* Dandelion and Daisy. The leaves are then said to be *radical* in position.

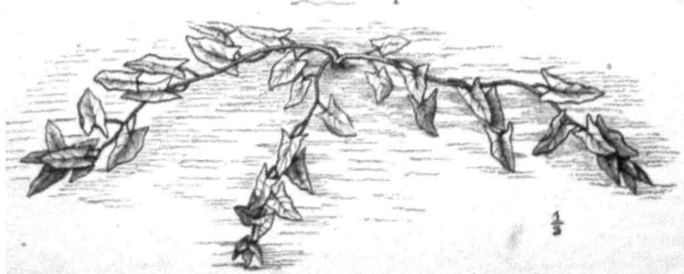

Fig. 55.—Plant of *Convolvulus arvensis*, which is prostrate because it has met with no support up which it can climb. (After Dennert.)

that twining plants can only twine round supports which are erect or nearly so.

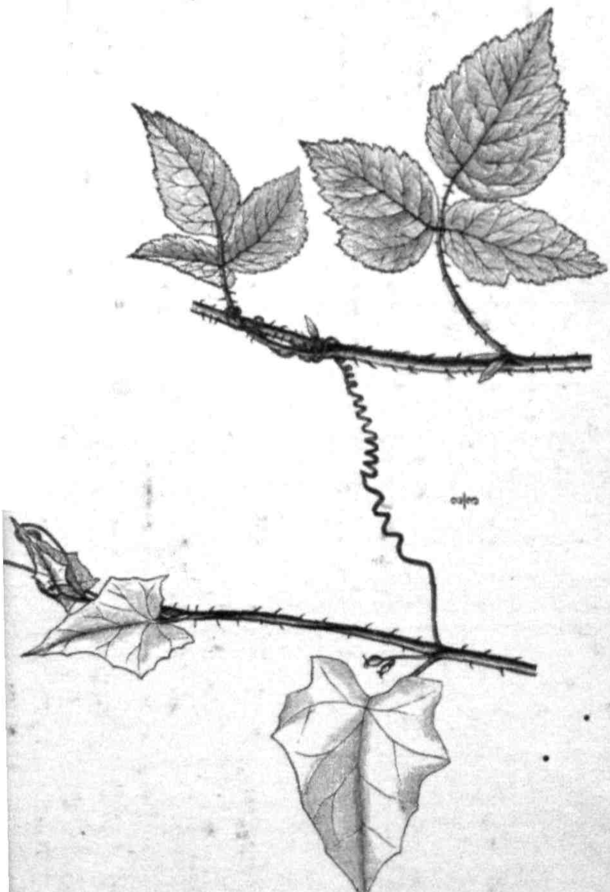

Fig. 57.—*Bryonia dioica* (left side of figure) climbing up a Bramble (right side of figure) by means of a tendril. (After Dennert.)

(iii.) **Tendril-Climbers** and **Irritable Climbers.**—Some plants (*e.g.* Pea and Vine) possess peculiar slender climbing organs

As a rule the sub-aerial foliaged axis is of appreciable length. It may be *erect*, as in the Sunflower, or it may be extended horizontally over the surface of the soil (fig. 55). The "runners" of the Strawberry are creeping stems which have long internodes and produce tuft-like shoots and adventitious roots at the nodes (fig. 54). Between erect and prostrate stems various transitional stages occur.

Fig. 56. Twining *Convolvulus arvensis*. (After Dennert.)

CLIMBING PLANTS.

A prostrate trailing plant usually has long, slender stems which call in the assistance of the soil to bear the weight of the branches and leaves. Another group of plants—climbers—also require external support; they rise above the soil and lean against, or fix themselves to, other plants, rocks, walls, etc. Like the majority of prostrate plants, climbers have slender stems, usually with long internodes—in fact, a climbing plant may become prostrate if it finds no external object up which it can climb (fig. 55). Climbing plants may be ranged for the present under four heads: root-climbers, twiners, irritable-climbers, scramblers.

(i.) **Root-Climbers.** — The Ivy ascends by means of numerous aerial adventitious roots, which are given off by the stem and serve to fix it to the supporting object.

(ii.) **Twining Plants** are those possessing stems which twist round the supporting objects. In most cases the twining stem twines in a definite direction; for example, the Bindweed (*Convolvulus*) climbs in a left-handed spiral, as is shown in fig. 56; whereas the stems of the Hop and Honeysuckle ascend in a right-handed spiral. The differences between these twiners and the following class of climbing plants are not easy to explain in this elementary work, but it may be generally stated that twining plants can only twine round supports which are erect or nearly so.

Fig. 37.—*Bryonia dioica* (left side of figure) climbing up a Bramble (right side of figure) by means of a tendril. (After Dennert.)

(iii.) **Tendril-Climbers** and **Irritable Climbers.**—Some plants (*e.g.* Pea and Vine) possess peculiar slender climbing organs termed *tendrils* (figs. 57, 59). A tendril is a simple or branched string-like irritable* structure which is capable of coiling round, or fixing itself to, suitable objects. Tendrils and other irritable climbing organs can embrace slender supports which are horizontal in position. The leaf-stalks of the garden *Tropæolum* and of *Clematis*, also the finely-divided leaves of the Fumitory, act like tendrils and coil round slender stems.

(iv.) **Scramblers** do not adopt any of the methods above mentioned; they merely lean against or scramble over other plants. Some clamber up by the aid of hooks or prickles, as in the case of *Galium* (Cleavers) and *Rubus* (Brambles).

SUBSIDIARY OUTGROWTHS (Hairs, etc.).

So far we have mentioned roots, stems, and leaves, but have given no account or explanation of the hairs, hooks, and prickles scattered over various parts of plants. We have learnt that roots, stems, and leaves all arise, and are arranged, in accordance with certain definite laws. Furthermore, they are recognisable by their structure. The hairs, prickles, etc., which are irregularly arranged over the plant, cannot be regarded as being roots, stems, or leaves, because they do not occupy the definite positions assigned to these members. In particular, hairs are found on roots, stems, and leaves: prickles occur on leaves and stems; these structures are not axillary in position, nor do they have buds in their axils. We therefore require a term to include all outgrowths which are neither roots, stems, nor leaves, but are, more or less, irregularly disposed on those members. We may term these structures "*subsidiary outgrowths.*" [In the majority of text-books "subsidiary outgrowths" are referred to under the heading of "hairs and emergences"; but it is impossible to give the complete definition of a hair or an emergence without assuming a knowledge of microscopical botany.]

METAMORPHOSED SHOOTS.

Stems and leaves assume many different forms, and they may present appearances so changed, or metamorphosed, as to

* See the section on Physiology.

render it a matter of difficulty to recognise them as such. For instance, stems may assume the appearance of leaves; stems, leaves, or parts of them, may appear in the form of spines or of tendrils. It is mainly by the study of their arrangement that we can recognise as such these metamorphosed stems and leaves, and can distinguish them from "subsidiary outgrowths."

SPINES, THORNS, AND PRICKLES.

Many plants are armed with sharp-pointed woody structures, which may represent stems, leaves, or subsidiary outgrowths.

(i.) **Stem-spines.**—The spines of the Hawthorn (fig. 58) occupy the position of branches, for they stand in the axils of leaves; they bear small leaves, which soon fall off. These spines, therefore, represent stems of definite growth, whose growing points become hard and woody. Certain branches of the Pear-tree often end in spines, which, therefore, are metamorphosed stems.

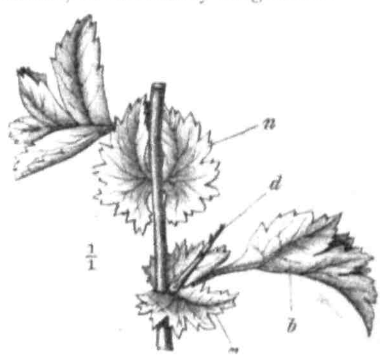

Fig. 58.—Shoot of Hawthorn with a stem-spine (*d*) in the axil of a leaf. *n* represents stipules; *b* denotes the lamina. (After Dennert.)

(ii.) **Leaf-spines.**—The leaves of Thistles and of the Holly have spinose outgrowths, which are obviously portions of the lamina. The Barberry-plant has branched spines, in whose axils branches arise: hence they are metamorphosed leaves. This view is confirmed by the fact that on a stem of the Barberry it is often possible to see all the transition stages between the green leaves and the branched spines. Each foliage-leaf of many Acacias has two spines occupying the position of the two stipules: therefore the spines are metamorphosed stipules.

The Common Furze or Gorse (*Ulex europæa*) has thorns, some of which possess axillary buds, and others of which terminate stems. Thus in this plant both leaves and stems have changed to form spines.

(iii.) **Spines, Prickles** which are **subsidiary outgrowths.**—The leaves and stems of Brambles (fig. 57) and of many Roses have prickles, woody hooks, or long spines scattered over them in indefinite positions. These structures, therefore, represent "subsidiary outgrowths."

TENDRILS.

(i.) **Leaf-tendrils.**—The leaves of the Pea (fig. 59) are pinnately-compound, and have large green stipules. The positions which should be occupied by the terminal leaflet and the two or more pairs of uppermost leaflets are taken by a single terminal tendril and two or more pairs of lateral ones. The tendrils of the Pea, therefore, represent metamorphosed leaflets.

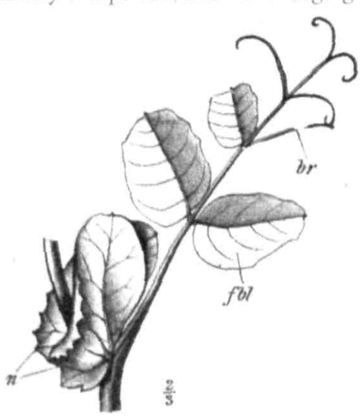

Fig. 59.—Compound leaf of Garden Pea. *n* = stipules ; *fbl* = leaflets ; *br* = leaflets converted into tendrils. In this leaf the terminal tendril is wanting. (After Dennert.)

(ii.) **Stem-tendrils.**—The tendrils of the Passion-flower arise in the axils of leaves, and are therefore modified branches.

The tendrils of *Bryonia dioica* (fig. 57) are not so easily understood. They probably represent metamorphosed shoots, the leaves of which are absent.

LEAF-LIKE STEMS (*CLADODES*).

The green feathery part of an Asparagus-shoot consists of numerous green stems arising in the axils of minute colourless scales. The Butcher's Broom (*Ruscus aculeatus*) has short, flattened, leaf-like branches, each terminating in a sharp point. That these leaf-like members are lateral stems is evident from the fact that they bear leaves and flowers, and arise in the axils of the true leaves, which are inconspicuous scales.

CHAPTER V

THE LIFE-HISTORY OF FLOWERING PLANTS

WHILST flowering plants display a considerable uniformity in their general conduct, they vary amongst themselves in regard to details, such as the duration of their existence, and their precise behaviour during life. Even a single individual does not acquit itself in a constant and uniform manner throughout life. Its variations in conduct are largely associated with corresponding changes of season. For example, flowering plants in Britain, for the most part, grow actively during summer, but at the onset of winter they tend to enter into a passive or resting condition, during which growth is practically at a standstill. We can therefore regard the life of a plant as made up of actively vegetating or growing periods and resting periods. Though the British flowering plants commence and conclude their phases of active growth at different times of the year, yet for the vast majority of them the period from spring to autumn is the vegetative season, whilst winter is the resting season.

FREQUENCY OF FLOWERING AND DURATION OF LIFE.

Some plants blossom only once in their lives, and die as soon as their seeds have ripened; they are described as being *monocarpic*. Opposed to these are others which flower repeatedly and produce crops of flowers year after year: these are termed *polycarpic* plants.

Monocarpic plants may be further sub-divided into three groups, according to the age at which they produce their single crop of flowers. A plant which germinates, produces its flowers and fruits, and then dies, all in one vegetative season, is termed an *annual—e.g.* Wheat and Field Poppy. Some annuals complete this cycle of life within a few weeks, so that in one vegetative season several generations of individuals may be derived from one plant: these are small herbs, and are distinguished by the name of *ephemerals*—*e.g.* Chickweed and Shepherd's Purse. Annuals proper can produce only one generation in a single vegetative season, because their life extends over several months. A plant which germinates and vegetates in its first active season, and blossoms and dies in its second year, is described as a *biennial*—*e.g.* Turnip. Finally, a plant which is capable of existing for several years is termed a *perennial*; and if it can blossom only once it is described as a *monocarpic perennial*—*e.g.* some Palms.

Polycarpic plants are all perennials. They vegetate and produce flowers and seeds season after season—*e.g.* Dandelion, British trees and shrubs.

It is more important to lay stress upon the number of times a plant can flower than to consider whether the plant be annual, biennial, or perennial: for the distinctions amongst these latter are largely arbitrary. For instance, many plants which are described as annuals can germinate in autumn, rest during the winter, and flower in the following spring—in fact, they act as biennials. Again, if by artificial or natural means the formation of fruits or flowers on an annual be prevented, the annual may live for years—in fact, it becomes a perennial: *e.g.* Mignonette and Annual Meadow-Grass. The Daisy, which is perennial in England, is annual at St Petersburg.

METHODS OF RESTING.

Ephemerals and annuals rest during the winter in the form of seeds. In most cases their vegetative organs are dead. But some annuals, when sown in autumn, can pass the winter in the form of young green plants.

Biennials and perennials retain only certain portions of their vegetative organs at the resting season. There are certain broad distinctions between the modes of resting of herbs and of woody plants belonging to these classes.

Resting condition of perennial herbs.—A number of perennial herbs retain their sub-aerial stems and green leaves during the winter; amongst these are many Grasses, and Wallflowers in gardens. But in the majority of perennial herbs the parts of the shoot which are above the soil die down, and only subterranean portions of the plant continue to exist at the resting season. Herbaceous perennials may rest in the form of subterranean shoots:—rhizomes (*e.g.* Dandelion), tubers (*e.g.* Potato), bulbs (*e.g.* Hyacinth), corms (*e.g.* Crocus)—or in the form of roots. In the following vegetative season these underground parts send up shoots which force their way out of the soil and bear foliage-leaves and flowers.

Resting Condition of Trees and Shrubs.—In perennial woody plants a considerable part of the sub-aerial shoot persists during winter. The woody stems and the buds, usually covered with scales, represent the resting tree or shrub. Some of these woody plants shed their foliage-leaves before winter sets in—*e.g.* Hazel and Larch—and are described as *deciduous*. Others retain their green leaves during that season, and are termed *evergreens*—*e.g.* Pines, Firs, Yew, Ivy, Box, and Heaths. But even the evergreens do not retain the whole of their leaves for an indefinite period: each year the oldest leaves drop off, so that a green leaf lives only for a few years.

METHODS OF VEGETATIVE MULTIPLICATION.

Many flowering plants are able to increase in number without the intervention of seed-production. Portions of the plant become separated from the mother-plant by the decay of parts which connect them with the latter. These disconnected younger sections, having produced roots of their own, become distinct individuals. For example, the long internodes of the Strawberry-runners may decay and the tufted shoots at the nodes consequently become separate plants. Again, the decay of those parts of the stem which connect the tubers of a Potato with the mother-plant has the same result, for each tuber can produce a new Potato-plant. Frequently in bulbous plants young bulbs arise in the axils of several scales, or a number of little bulbs may appear side by side in the axil of one scale; in either case, the death of the old bulb leads to separation of the daughter-bulbs. The horizontal lateral roots of the Hazel, Poplar, and Rose, give off erect adventitious shoots—the so-called *suckers*—which force their way out of the soil and assume the appearance of ordinary shoots. The suckers may become separate individuals by the decay of the connecting root and the production of adventitious roots at the bases of their own stems. "Cuttings," as taken by gardeners, also illustrate the vegetative multiplication of plants.

ORDER OF SUCCESSION OF EVENTS.

After germination, a plant at first confines itself to vegetative growth and finally bears flowers and fruits. Even in each vegetative season a shoot tends to adopt the same course of action—first its vegetative buds flush, the foliage-leaves unfold, and the stems elongate, and eventually the flowers open. In some plants this order of succession in one single vegetative season is changed: the flowers may appear before the leaves unfold, as is the case with the Hazel, Almond, and some Cherries.

CHAPTER VI

THE FLOWER

FLOWER OF A BUTTERCUP (FIGURES 60, 61).

IF we examine the flower of a Buttercup, we note that it consists of four kinds of members inserted laterally upon a central axis. This is seen with particular clearness if we cut the flower down the centre (fig. 61).

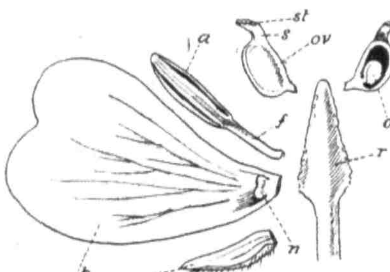

Fig. 60.—Dissected flower of Buttercup.

The portion of the axis which bears these lateral members is termed the **receptacle** (*r*).

The outermost series of lateral members is formed by a whorl of five small, green, leaf-like *sepals* (*sp. cal*).

Standing immediately within the gaps between the five sepals, and thus alternating with them, are five yellow, leaf-like **petals** (*p. cor.*).

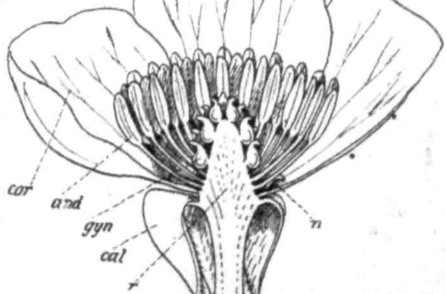

Fig. 61.—Vertical section of flower of Buttercup.

Again, within these succeed numerous yellow **stamens** (*and*). Each stamen consists of a stalk—the *filament* (*f*)—and a head — the *anther* (*a*). The young anther has four closed little chambers — the *pollen-sacs*—which contain innumerable microscopic rounded bodies

—the *pollen-grains*. When the anther is fully ripe, the pollen-sacs open down their sides and allow the pollen to escape in the form of fine yellow dust.

The centre of the flower is occupied by many small green **carpels** (*gyn*) situated laterally on the terminal portion of the axis. Each carpel, at its summit, terminates in a minute glistening tip — the *stigma* (*st*), which is connected by a scarcely appreciable short stalk — the *style* (*s*) — with the swollen basal portion—the *ovary* (*ov*). The ovary is inserted directly on the receptacle. The ovary forms a closed chamber which contains a minute egg-shaped body—the *ovule* (*o*)—attached to its floor.

FLOWERS OF THE SCOTCH PINE (FIGURES 63-67).

The flowers of the Scotch Pine are very different in appearance and in structure. This plant has two kinds of flowers (fig. 62)—those which possess stamens (*m*), and those which bear carpels (*c*, *cP*).

The stamen-bearing flowers are yellow cones clustered together (fig. 62 *m*). Each cone (fig. 63) is a single flower with a short stalk, and stands in the axil of a scale (*sc*). The simple axis of the cone has a basal portion which bears simple bract-scales (*s*). Above these, on the axis, are inserted lateral scales (fig. 63 *po*, fig. 64), each of which has two pollen-sacs attached to its lower face. These latter scales are stamens, for they possess pollen-sacs. The flower thus consists of a simple axis—the receptacle—with spirally arranged lateral stamens. At its base the receptacle is continuous with a short portion of the axis—the flower-stalk—to which bracts are attached.

The carpel-bearing flowers (fig. 62 *c*, *cP*) are also cones, and present the appearance of erect reddish buds. Each cone (fig. 65) arises in the axil of a scale: its simple axis is continuous with a short stalk which bears a few bracts (*sc*). Above these bracts the simple receptacle has scale-like members of somewhat complicated form, each member consisting of a small scale (*cp*), from the upper face of which a larger scale (*ps*) protrudes: again attached to the upper surface of each larger scale are two ovules (fig. 66 *ov*). These peculiar double-scales are carpels, for they bear ovules. The flower thus consists of a simple axis with spirally-arranged carpels; it has a short stalk, which is continuous with the receptacle.

DEFINITION OF A FLOWER.

Widely different as they are, the flowers of the Scotch Pine and Buttercup agree in that each consists of a simple axis bearing lateral members unlike itself. Thus the flower agrees with a simple shoot as regards its component parts, and there are reasons for regarding the flower as actually equivalent to a shoot—(i.) a flower always occupies the position of a shoot: it either terminates a shoot (*e.g.* Tulip, Bulbous Buttercup), or is in the axil of a foliage-leaf (*e.g.* Poor-man's Weather-glass), or of a bract (*e.g.* Scotch Pine, Hyacinth). Thus the receptacle of a flower is a simple stem, because it is continuous with a stem which bears leaves, or is axillary in position. (ii.) The lateral floral members—sepals, petals, stamens, and carpels—are leaves, as is proved by the following considerations:—

(*a*) Like leaves, they are arranged laterally on stems in whorls (*e.g.* petals of the Buttercup), or in spirals (*e.g.* stamens and carpels of the Buttercup and Scotch Pine).

(*b*) They are often distinctly leaf-like in form (*e.g.* sepals and petals of the Buttercup, stamens and carpels of the Scotch Pine).

(*c*) Frequently plants possess lateral members, which are arranged like leaves and assume forms intermediate between bracts, sepals, petals, or stamens. Thus in the Christmas Rose there are all stages of transition between the foliage-leaves, bracts, and sepals. In the White Water-lily there are numerous lateral floral members which in form are intermediate between petals and stamens.

(*d*) The flowers of a plant may assume peculiar abnormal forms in which the lateral floral members are strangely modified; such flowers are described as being ***monstrous***. In "Double Buttercups" some of the stamens are replaced by petals; in green roses green leaves appear in place of carpels.

(*e*) Lateral floral members differ from ordinary leaves in that they have no buds in their axils; but in some monstrous flowers buds do appear in their axils.

Thus the position of a flower and the arrangement of its various parts prove that it is equivalent to a simple shoot. Further, we are familiar with the fact that seeds form in connection with flowers, but on no other part of the plant. We may, therefore, give the following definition of a flower:—*A flower is a simple shoot, or part of a simple shoot, which is set apart for the purpose of effecting reproduction by means of seeds.* The lateral members—sepals, petals, stamens, and carpels—represent leaves, and may be described as *floral leaves.*

Comparing the flowers of the Scotch Pine and Buttercup, it is apparent that there is a great difference between their carpels. They are types of the two great natural classes into which we divide flowering plants. (i.) **Gymnosperms,** which include Pines, Firs, Cedars, etc., have their ovules freely exposed on open carpels. (ii.) **Angiosperms,** which include the majority of familiar flowering plants—Buttercups, the Wallflower, the Hazel, Grasses, and Lilies, for instance—have closed carpels, so that the ovules are concealed inside an ovary. Further, a carpel of an Angiosperm has several differentiated parts—an ovary, a stigma, and usually a style.

CHAPTER VII *

GYMNOSPERMÆ

CONIFERÆ (PINE FAMILY)

TREES or shrubs with simple leaves and inconspicuous naked diclinous Flowers. The ovules are borne on open carpels.

TYPE: SCOTCH PINE (*PINUS SYLVESTRIS*).

Vegetative Characters.—A tall evergreen, resinous tree. (Consult fig. 62 for an explanation of the following descrip-

Fig. 62.—Diagram of branching of *Pinus sylvestris*, also showing the position of flowers.

tion.) The obvious branches (lateral long-shoots) are arranged in false whorls. The vegetative shoots and leaves are of two

* Beginners should omit this chapter.

kinds (see p. 24). At the end of each active vegetative season the terminal bud (*bs*) of the main stem (or of a lateral long-shoot (*l*,'*l*)) enters into a resting condition, and close beneath it the axillary buds form a whorl-like collection of scaly resting buds. These terminal buds, and the lateral ones (excepting such as develop into cones), grow out in the following year to form long-shoots. Consequently, the number of false whorls of long-shoots denotes the number of years of growth of the stem which bears them; it is, however, necessary to add three to the number thus obtained if we wish to calculate the age of a tree, because no false whorls are formed till the end of the third year of the life of the main stem. In fig. 62 the part of the stem above the top whorl of branches, and opposite I. is a one-year-old stem; that part (II.) between the uppermost whorl and the second whorl is a two-year-old stem, and so on.

63

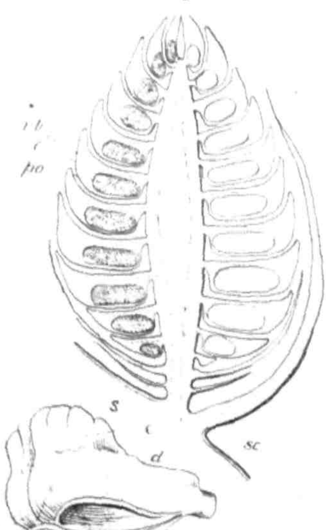

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Fig. 63.—Vertical section of staminate flower of Scotch Pine.
Fig. 64.—Stamen of ditto.

Inflorescence and Flowers.—The staminate and carpellary flowers have been described on page 44. They arise in the axils of scale-leaves on the long-shoots. (Consult fig. 62.) The open flowers are found only on the young shoots of the current year. The carpellary flowers (*c*, *cP*) are small, erect lateral cones, often two or three together, immediately behind the terminal bud of the long-shoot. They occupy positions similar to the lateral buds which would grow out to form long-shoots. But the staminate flowers (*m*) are inserted laterally on the more basal parts of the long-shoots of the current year—that is, they are just above the uppermost false whorl of branches, and occupy positions taken by dwarf-shoots on vegetative branches. Above the spike-like inflorescence of staminate flowers, a few foliaged dwarf-branches are seen. On older shoots, two to three years old, the spurs (*n*) or scars of the fallen staminate flowers denote the points at which the latter were attached. Thus a carpellary flower takes the place of a lateral long-shoot; whereas a staminate flower replaces a vegetative dwarf-shoot.

Pollination and ts consequences.—The flowers are polinated by the agency f the wind. When eady for pollination 1 May, the carpelary cone stands rect (*c*, *cP*). Its xis (receptacle) ongates, and thus uses the carpels separate to a ght extent. The llen-grains which blown against the

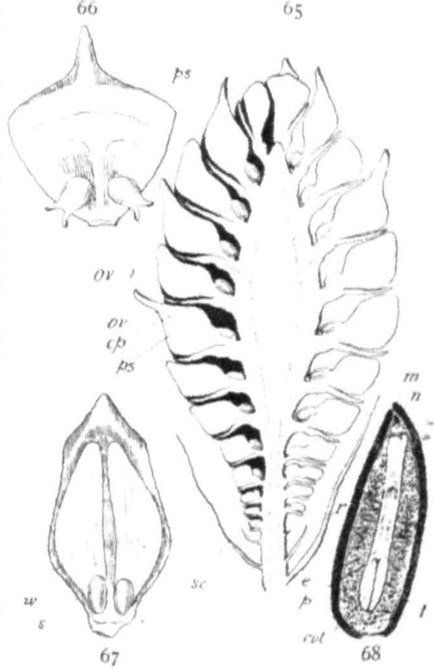


Fig. 65.—Vertical section of carpellary flower of Scotch Pine.
Fig. 66.—Carpel of ditto.
Fig. 67.—Carpel of fruit of ditto, with two seeds (*s*) having wings (*w*) in contact with them.
Fig. 68.—Vertical section of seed of ditto: *e*=endosperm; *cot*=cotyledons; *p*=plumule; *r*=radicle; *m*=micropyle.

nes naturally reach the crevices between the carpels. They then l down the prominent rib of the placental scales, and thus meet h the integuments of the ovules. The integuments curl up htly, and carry the pollen towards the top of the nucellus hat is, towards the bottom of the micropyle-passage. In Pine, the pollen-grain itself reaches the micropyle, whereas in Angiosperms it is conveyed only as far as the stigma. After pollination the carpels again close together, and the placental scales become hard, green, and woody. Each cone gradually bends over till it finally points downwards (*cF*), and its closely-set scales become brown in colour. Finally, the hard brown scales separate at their tips, and allow the seeds to be set free. The escape of the seeds does not take place till more than a year after pollination; a few seeds may escape in the October of the year following pollination, but the majority (*cD*) remain on the tree till about two years subsequent to pollination, when the woody carpels gape apart as they dry. The **fruit** of the Pine is a cone of woody carpels. The ovule develops into a hard endospermic **seed** (fig. 68), containing an embryo which possesses a whorl of cotyledons (*cot*). Attached to the seed is a separable wing (fig. 67 *w*), which is not really a part of the seed, because it is formed by a layer of the scale. The wings act as sails, through the aid of which the seeds are scattered by the wind; the wind blows the seed, causes it to spin, and so delays its journey to the soil. In addition, the cones drop off and are blown along the ground, shedding at the same time any seeds they may contain.

As **other members** of the Coniferæ we may quote the Larch (which is deciduous), the Yew (the seed of which has a red fleshy aril), and the various Cypresses, Cedars, and Monkey-puzzles cultivated in gardens.

CHAPTER VIII

ANGIOSPERMÆ

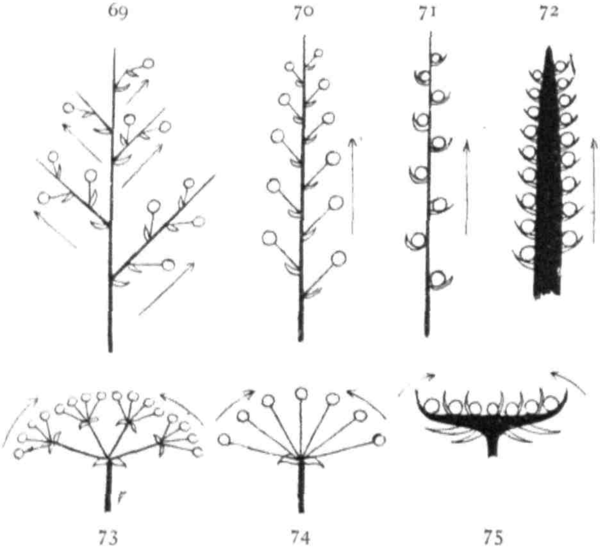
INFLORESCENCE

EACH flower of a plant may be *solitary*, either in a terminal position, as in the Tulip, or in the axil of a foliage-leaf, as in the Poor-man's Weather-glass. On the other hand, a plant may have its flowers grouped together and subtended by simplified leaves in place of foliage-leaves. Such a group of flowers is described as an *inflorescence*. The distinction between a flower and an inflorescence lies in the circumstance that the axis of a flower is unbranched, whereas the axis of an inflorescence is branched. The axis of a flower bears floral leaves; whereas the axis of an inflorescence bears lateral shoots in the axils of bracts. We may therefore define an inflorescence as a branched shoot set apart for the purpose of accomplishing reproduction by means of seeds. Like a vegetative stem, the main axis of an inflorescence may be continuous with the axis of a foliaged shoot, in which case it is said to be *terminal*—*e.g.* Foxglove and Wallflower; or the inflorescence may arise in the axil of a leaf, when it is described as *axillary*—*e.g.* Pea and Hazel.

Just as a vegetative stem may branch in a racemose or a cymose manner, so may a reproductive axis. Remembering that a flower represents a simple shoot, and occupies the position of bud, it is easy to define racemose and cymose inflorescences (compare page 26).

A. RACEMOSE INFLORESCENCES.

In this type of inflorescence the main axis grows more strongly than its lateral axes, and bears a considerable number of branches. These branches may themselves be flowers, as in the Hyacinth, in which case the inflorescence is said to be of the *simple racemose* type. Or the main inflorescence-axis may bear lateral inflorescences in place of flowers, as in the



Figs. 69-75.—Diagrams of Racemose inflorescences. The arrows denote the general order of succession in the opening of the flowers.

Parsley, and the inflorescence is described as being *compound racemose*.

I. *Simple Racemose Inflorescences.*—The main axis of the inflorescence directly bears a number of flowers.

(*a*) The flowers are separated by distinct internodes, so that the axis is elongated.

(α) The flowers are stalked (fig. 70) = **Raceme**
Examples—Hyacinth, Foxglove.

(β) The flowers are not stalked.

(i.) The main axis is not fleshy (fig. 71) = **Spike.**
Example—Spikelet of Grasses.

(ii.) The main axis is fleshy (fig. 72) = **Spadix**
Example—*Arum.*

(iii.) A *catkin* (fig. 131, ♂) is an inflorescence of inconspicuous sessile, staminate or carpellary, flowers: after flowering it usually drops off as a whole. It is racemose in type, but in the axils of the bracts cymes may occur in place of single flowers, in which case the catkin is a compound inflorescence.

(*b*) The flowers are set close together on a shortened main axis.

(α) The flowers are stalked = **Umbel.**

The umbel exhibits a considerable number of flowers springing from the shortened terminal part of the axis. Usually there is a terminal flower in the inflorescence. An umbel is essentially a condensed simple raceme (fig. 74).

Example—Ivy.

(β) The flowers are not stalked (fig. 75) = **Capitulum.**

The shortened terminal part of the main axis bears a number of closely-clustered stalkless flowers, forming a capitulum or head.

Examples — Sunflower (fig. 208), Dandelion (fig. 253), Daisy.

II. *Compound Racemose Inflorescences.*—The main axis of the inflorescence does not itself bear flowers, but has lateral branches which are inflorescences. The main type of branching of the inflorescence is termed the main or primary inflorescence, and the lateral inflorescences are styled the secondary inflorescences, etc.

(*a*) The main axis is elongated, so that its branches are separated by distinct internodes.

(α) The main axis bears lateral racemose inflorescences with stalked flowers (fig. 69) = **Panicle.**

(β) The main axis bears somewhat shortened lateral inflorescences which are spikes (fig. 231) = **Compound Spike.**

Example—Wheat.

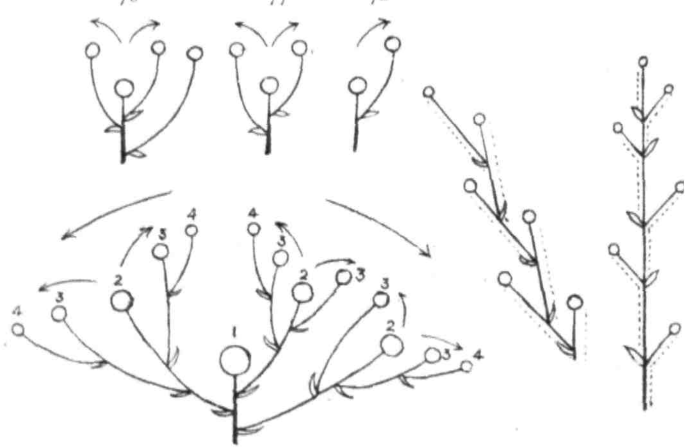
(*b*) The main axis has its lateral inflorescences set closely together to form an umbel, and the lateral inflorescences are in turn umbels (fig. 73)
= **Compound Umbel.**

Examples—Parsley, Carrot.

B. CYMOSE INFLORESCENCES.

In this type of inflorescence every axis grows only for a limited, *definite* period, and terminates in a flower; each axis possesses only a very few (usually one or two) branches, and

76 77 78



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Figs. 76-81.—Diagrams of Cymose inflorescences. The arrows denote the general order of succession in the opening of the flowers. Fig. 81 also shows a sympode formed from fig. 80 by the successive displacement of each terminal flower: each dotted line denotes a single axis.

these latter grow more strongly than the inflorescence-axis which bears them. Usually the flowers at the apex of a cymose inflorescence open before those on the branches, so that they do not open in acropetal succession.

There are three main types of cymes—

(1) Several-branched. The main inflorescence-axis has more than two branches (figs. 76, 79).
Example—Some Spurges.

(2) Two-branched. The main inflorescence-axis has only two branches (figs. 77, 43), and is termed a forked-cyme = **Dichasium.**
Example—Many members of the Pink-family.

(3) One-branched. The main inflorescence-axis has only one branch (figs. 78, 80, 81) = **Monochasium.**
Example—Some Geraniums.

The so-called *scorpioid cyme* of the Borage-family is most properly regarded as a monochasium; its axis is a sympodium (compare figs. 80 and 81).*

In cymose inflorescences often the main (primary) inflorescence and lateral (secondary, etc.) inflorescences are of different types. The main inflorescence, for example, may be a several-branched cyme, and its branches may be dichasia, and their branches ultimately bear monochasia (as in the Petty Spurge). Frequently the main inflorescence is a dichasium and the lateral inflorescences are monochasia (as often in the Dead Nettle family).

BRACTS.

These are usually small and simple (see page 21). In the Wallflower-family the inflorescence is frequently devoid of bracts. In capitula the individual flowers may be without subtending bracts, as in the Dandelion. The opposite extreme is reached in the Arum, where a large bract—the *spathe*—encloses the inflorescence. Capitula and umbels usually have closely-set collections of bracts, termed involucres; even single flowers may have similar involucres beneath them, as in the Mallow.

Prophylls.—On page 21 it has already been mentioned that the first leaf of a branch in Monocotyledons, and the first two leaves in Dicotyledons, are often small and simple, and occupy definite positions with reference to the main axis. These

* Some modern botanists, laying undue stress on the development of this inflorescence, conclude that it is racemose in type, and that the axis is a true axis. This view is undoubtedly incorrect.

leaves are termed the prophylls. The same holds good for the branches of inflorescences. Thus the stalk of each lateral flower of a Monocotyledon often has a prophyll on that face (posterior face), which is towards the axis bearing it. In Dicotyledons, the stalk of a lateral flower often has two prophylls on its sides, as is shown in fig. 98 *pr*, and is clearly seen in the Violet (fig. 158, *3*). These prophylls are therefore bracts occupying definite positions in the inflorescence. Occasionally no prophylls occur on the flower-stalk: examples, Wallflower, *Arum maculatum*.

CHAPTER IX

THE FLORAL LEAVES

PERIANTH

Of the floral leaves which, together with the receptacle, constitute a flower, those which are inserted outside the stamens and carpels compose the *perianth*. The perianth may be clearly differentiated into sepals and petals, or all its leaves may be alike.

CALYX.

The whole collection of sepals belonging to a single flower constitutes the *calyx*. In its simplest condition the calyx consists of a whorl or spiral of separate, simple sepals (*e.g.* Buttercup, Poppy), which are attached to the receptacle usually by relatively broad bases. The calyx is then said to be *polysepalous*. Often, however, the sepals are combined to form a more or less cup-like calyx (*e.g.* Pea, White Dead Nettle), and are then described as being *gamosepalous*. Even when the calyx is gamosepalous it is usually possible to ascertain the number of sepals which comprise it, because from the rim of the cup a corresponding number of free portions, lobes or teeth, protrude. For example, the gamosepalous calyx of the Dead Nettle has five long teeth, and consists of five sepals.

The sepals may form a single whorl of two (*e.g.* Poppy) or more (*e.g.* five in the Buttercup) members. Less frequently the flower has more than one whorl of sepals, as in the Wallflower, in which the sepals form two whorls of two each. On the other hand, the sepals may be arranged in a spiral manner.

In the case of the flowers of many plants the calyx merely serves to protect the inner parts of the flower whilst the latter is in the bud-condition. When this protective function is no longer called for, because the flower has opened, the sepals may fold back, as in some Buttercups, or fall off, as in the

Poppy (fig. 153 *sep*). When the younger flowers are crowded together and do not require protection on the part of the calyx, the latter is frequently small or even absent, as in the Daisy-family. As a rule the sepals are green, but in some flowers the sepals are brightly coloured—*e.g.* *Clematis* and *Anemone*—and are said to be *petaloid*; in this case they perform the functions of petals in serving to attract the notice of insects. In the Wallflower-family two of the sepals tend to be sac-like at their bases, and serve as receptacles for honey. Sometimes the calyx persists even when the fruit is formed; an interesting example of this occurs in the Dandelion (fig. 129), the flower of which possesses a circle of many fine silky hairs, forming the *pappus*, in place of the calyx. The pappus aids in the dispersal of the fruit by the agency of the wind.

Epicalyx.—Outside the calyx of a flower there sometimes stands a whorl, or whorl-like collection, of members apparently forming an outer calyx, which is known as the epicalyx. The epicalyx of the Mallow (fig. 163 *bc*) is in reality not a part of the flower, but is an involucre of bracts. The epicalyx (fig. 82 *ep*) of the Strawberry-flower consists of a whorl of five small green members, which alternate with the five sepals and represent the stipules of the latter: in this instance the epicalyx is truly a part of the flower, as it is a portion of the calyx.

Fig. 82. — Calyx and epicalyx of Strawberry.

COROLLA.

The whole collection of petals of a single flower constitutes the *corolla*. In its simplest condition the corolla is *polypetalous*,—that is, it consists of a number of separate petals, as in the Buttercup, Wallflower, and Poppy. Each petal (fig. 83) is typically bright-coloured, flattened and inserted by a relatively narrow base; often it is distinguishable into two parts, a lower narrow portion (*cl*)—the *claw*—and an upper broad part (*la*)—the *blade*. In many flowers, however, the petals composing a single whorl are combined to form a shorter or longer tube, and the corolla is said to be *gamopetalous*—*e.g.* Primrose, Dead Nettle, and Potato (fig. 84 *co*).

The petals form a single whorl (*e.g.* Buttercup, Primrose) or two (*e.g.* Poppy) or more whorls. In some flowers the petals are spirally arranged—*e.g.* "Double Buttercups."

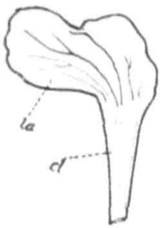

Fig. 83.—Petal of Wallflower.

When the perianth of a flower does not consist of sepals and petals clearly distinguishable from one another, but is composed of a single whorl—*e.g.* Clematis—or a continuous spiral of floral leaves, we assume that the corolla is absent, and describe the flower as *apetalous*; in fact, we regard the single whorl or spiral of the perianth as representing a calyx. To this rule there are exceptions, as examples of which plants belonging to the Daisy-family and Parsley-family may be cited. Each flower of the Parsley (compare fig. 183) has a calyx (*ca*) in the form of a small green ring with five minute teeth; its corolla consists of five white petals alternating with the calyx-teeth. But the flowers of some other representatives of the same family, though they possess five white floral leaves occupying the same position with reference to the stamens and carpels as in the Parsley, yet have no appreciable ring of teeth to correspond with the calyx of this plant. It is clear that in this case the single perianth-whorl of five white floral leaves represents the corolla, and the calyx is absent. Similarly, in the Daisy-family, the calyx is frequently small or absent (fig. 209).

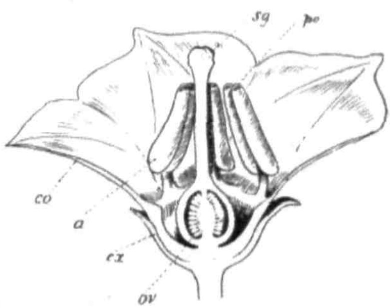

Fig. 84.—Vertical section of flower of Potato: *cx*=calyx; *co*=corolla; *a*=anther; *po*=pores of anther; *ov*=ovary; *sg*=stigma.

The chief function of the corolla is to render the flower conspicuous so as to attract the notice of insects (see page 80). When the flower does not profit by insect-visits the corolla is small and inconspicuous, as in certain flowers of the Violet, or absent, as in the Hazel. Even in cases in which the visits of insects to a flower benefit the plant, the petals are absent when the notice of the insects is sufficiently secured by the attractive nature of conspicuous sepals (*e.g.* Clematis), stamens, or bright-coloured bracts. Occasionally the petals further allure insects by manufacturing honey—for example, the little pockets at the base of the Buttercup-petals are honey-manufacturing organs—*nectaries*—(figs. 60, 61 *n*). Finally the petals may serve as a receptacle and hiding-place for the honey poured out by the nectaries—*e.g.* spur of the Violet. In other words, the corolla is concerned in securing insect visits: accordingly, when the seeds begin to form in the flower, the corolla is no longer required, and it speedily withers.

PERIANTH.

When the perianth consists of two or more whorls of members which are all alike, the latter are termed perianth-leaves. For instance, Tulips and Hyacinths have perianths composed of two whorls of floral leaves which are all similar, and cannot be differentiated into three sepals and three petals. The perianth may be brightly coloured (*petaloid*), as in Tulips, Lilies, and Hyacinths; or it may be green (*sepaloid*). If the perianth-leaves be separate, they are said to be *polyphyllous*—*e.g.* Tulip; if they form a coherent tube the perianth is *gamophyllous*—*e.g.* Hyacinth (fig. 213).

Naked flowers (figs. 132, 148).—Flowers may be devoid of sepals—*e.g.* some Compositæ; or without petals—*e.g.* *Clematis*; finally, they may possess no perianth whatever, in which case they are said to be *naked*—*e.g.* the stamen-bearing flowers of the Hazel and the Petty Spurge, and the flowers of *Arum maculatum*. Such flowers consist solely of one or more stamens or carpels, or both of these, inserted upon a receptacle.

ANDRŒCIUM.

The whole collection of stamens of a flower constitutes the *andrœcium*.

A stamen usually consists of two parts, the filament and the anther. Occasionally the filament is absent, and the anther is consequently sessile. More rarely the anther is absent, and the sterile stamen thus formed is termed a *staminode*. The anther generally consists of two halves or *lobes*, and each half has two pollen-sacs in which the pollen-grains are lodged (fig. 85). Occasionally an anther represents half a complete anther and possesses only two pollen-sacs—*e.g.* Mallow and Hazel. The two lobes of the anther are connected by a continuation of the filament, which is termed the *connective* (*co*). The connective may be a narrow, almost imperceptible, continuation of the filament, so that the two halves of the anther are close together; or it may be wider, and thus cause the anther-lobes to be clearly separated. Occasionally the connective is continued beyond and above the rest of the anther to form a flap-like process—*e.g.* Violet (fig. 158, *5*, *c*), and some Compositæ.

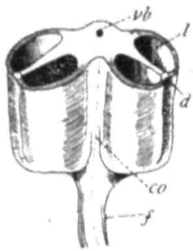

Fig. 85.—Part of a stamen with the top of the anther cut off.

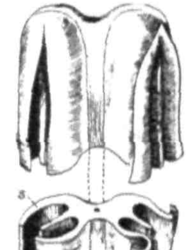

Fig. 86. — Longitudinal dehiscence of anther, showing the escaping pollen (*p*).

The stamens may be separated from one another, or they may be united by their filaments or anthers. In the Mallow (fig. 161) and some of the members of the Pea-family, the filaments of all the stamens in a flower are united for a certain distance so as to form one bundle; in some other members of the Pea-family (fig. 87) nine of the ten stamens are similarly united (*an. t*) by their filaments, but the tenth is separate (*p. a*). In the Daisy-family the filaments of the stamens are separate, but their anthers cohere (fig. 202).

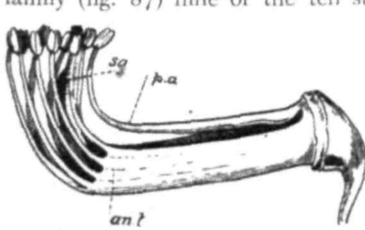

Fig. 87.—Flower of Garden Pea, with calyx and corolla removed.

Like the sepals and petals, the stamens may form one whorl—*e.g.* Violet; or several whorls (two whorls in the Wallflower, *Geranium*, and Hyacinth; many whorls in the Poppy). Or the stamens may be arranged spirally on the receptacle—*e.g.* Buttercup.

Usually all the stamens of a flower are similar in form and size. In the Wallflower-family (fig. 88), however, the andrœcium consists of six stamens, of which two have shorter filaments (*at*) than the remaining four (*am*). Many members of the Foxglove—and Dead Nettle-family (figs. 191, 193) have flowers with four stamens, two of which have shorter filaments. Again, in some members of the Geranium-family, the flower may possess five stamens with anthers, and five without.

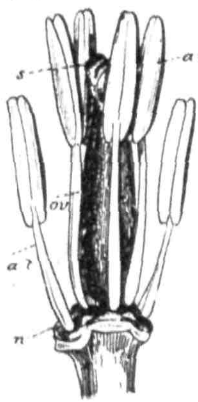

Fig. 88. — Flower of Wallflower, with calyx and corolla removed; *n* = nectary; *at*, *am* = stamens; *ov* = ovary; *s* = stigma-lobe.

Dehiscence and insertion of the anther.—When the anther is ripe, the pollen-sacs open in such a manner as to permit the escape of the pollen. Usually each anther-lobe opens by one split down the line which denotes the junction of the pair of pollen-sacs (figs. 85 *d*, 86): its dehiscence is *longitudinal*. Occasionally the anther opens by small circular holes—*e.g.* Potato (fig. 84 *po*): this dehiscence is *porous*. Or, finally, the anther may open by small doors or valves—*e.g.* Barberry: this dehiscence is *valvular*. When an anther opens on the face towards the centre of the flower, its dehiscence is *introrse*—*e.g.* Violet and Daisy-family; but when it opens towards the periphery of the flower, dehiscence is *extrorse*; finally, when the anther dehisces neither in an inward nor an outward direction, but opens along the edges, the dehiscence is *marginal*. Unfortunately the terms extrorse and introrse are also employed in another sense. An anther which is inserted in such a manner that its lobes and pollen-sacs appear to face the centre of the flower is described as *introrse*: when the pollen-sacs appear to face the periphery of the flower the anther is *extrorse*; finally, there remains a third class of anthers, in which two pollen-sacs face the centre of the flower, and two face the periphery. Frequently the direction of dehiscence corresponds with the mode of insertion of the anther, but this is not invariably the case; for example, though an anther with introrse dehiscence is often found to be introrse in insertion, it is not always the case.

GYNÆCIUM.

The whole collection of carpels of a single flower constitutes the gynæcium.

APOCARPOUS GYNÆCIUM.

The simplest type of carpel met with amongst Angiosperms is that of the Pea or Bean (fig. 91). Its summit is formed by the *stigma*, which is connected by the stalk-like *style* with the pod-shaped *ovary*. The ovary forms a closed vessel with a single cavity, in which are a number of ovules. That precise part of the ovary upon which the ovules are immediately inserted is described as the *placenta*; in this case the placenta assumes the form of a protruding line running straight up the one side of the ovary, and bearing a double row of ovules. The carpel of the Pea looks much like a small leaf, the two halves of which have folded along the mid-rib and joined at the margins, the ovules being attached to the incurved margins. And we assume that the carpel is a leaf which has thus become coherent at its margins. Figs. 89, 90, 91, show the successive stages by which such a carpel could have been built from a leaf with marginal ovules. A Gymnosperm—*Cycas*—has an open carpel, very like that shown in figure 89. When their ovaries have become fruits, the carpels of the Christmas Rose and the Winter Aconite are half-opened, as shown in fig. 90. In a simple closed carpel like that of the Pea, the line which corresponds to the fused margins of the leaf is termed the *ventral suture* (fig. 119 *vs*), whilst the line which corresponds to the mid-rib is the *dorsal suture* (*ds*).

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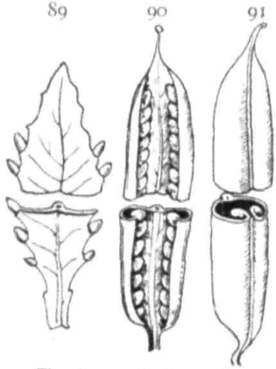


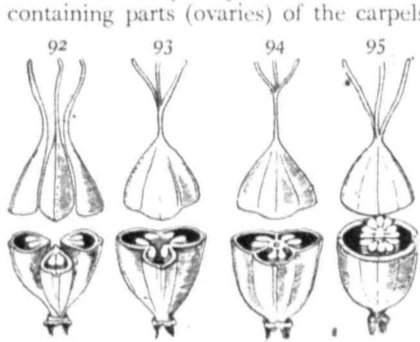
Figs. 89-91.—Single carpels.

Each carpel of the Buttercup (fig. 60) is essentially like that of the Pea, excepting that it contains only one ovule (*o*), which is attached to the floor of the ovary-chamber.

The flower of the Pea contains only one carpel: that of the Buttercup has many carpels; but in both cases the gynæcium is said to be *apocarpous*, because it is not made up of several carpels joined together. Fig. 92 shows an apocarpous gynæcium composed of three carpels.

SYNCARPOUS GYNÆCIUM.

When a flower possesses more than one carpel, and its carpels cohere together to form a single body, the gynæcium is said to be *syncarpous*. In such a gynæcium the ovule-containing parts (ovaries) of the carpels are joined together to form a single ovary, which is also described as being syncarpous (figs. 93, 94, 95). But the styles may remain separate along their whole lengths (fig. 95); or along part of their lengths (fig. 95). Again, not only may the ovaries be completely fused, but also the styles, so that only the stigmas remain distinct in the form of stigma-lobes (*e.g.* Wallflower); or finally, the ovaries, styles, and stigmas of the constituent carpels are completely joined together —*e.g.* Primrose. The syncarpous ovary, representing as it does parts of several carpels, may have several chambers, each corresponding to one carpel.* Thus the Hyacinth has three carpels joined to form a single ovary, which is three-chambered; or the syncarpous ovary may have one general chamber, the wall of which is formed by several carpels joined together (*e.g.* Violet).



Figs. 92-95.—A gynæcium composed of three carpels. Fig. 92 is an apocarpous gynæcium; the other three figures represent syncarpous gynæcia.

PLACENTATION.

The mode of arrangement of the ovule-bearing portions—the placentæ—of the ovary is referred to under the head of

* Rarely these chambers of the ovary are further sub-divided by additional partitions, so that the chambers of the ovary are more numerous than the carpels composing it—*e.g.* Labiatæ, Boraginaceæ.

placentation. When the ovules are attached to the walls of the ovary the placentation is *parietal* (fig. 93, *e.g.* Violet, Poppy, Wallflower, Pea): an ovary with parietal placentas is usually one-chambered, but in the Wallflower-family the ovary has two parietal placentas, and yet is two-chambered. When the ovary is syncarpous and has several chambers, and the ovules are attached to the central axis of the ovary (where the carpels meet), the placentation is *axile* (fig. 94, *e.g.* Hyacinth). If a chamber of an ovary contains only one ovule which is attached to its floor, the placentation is *basal* (*e.g.* Buttercup). Finally, when the ovary is one-chambered, and possesses a number of ovules attached to a swelling springing from the floor of the ovary, the placentation is *central* (*e.g.* Chickweed) or *free-central* (fig. 95, *e.g.* Primrose).

Methods of ascertaining the number of carpels which compose a syncarpous gynæcium.—By definition a syncarpous gynæcium consists of several carpels joined together. The following rules enable us to learn how many carpels enter into the composition of an ovary:—

(i.) When an ovary has several chambers, each chamber represents one carpel.*

(ii.) If the ovary be one-chambered and the placentation parietal, the placentas correspond with the joined ventral sutures (margins) of the carpels, and consequently denote the number of carpels.

(iii.) If there be several styles, style-branches, or stigma-lobes, their number corresponds with the number of the carpels. Occasionally, however, the styles or stigmas branch so that this rule does not hold.

(iv.) When the fruit is ripe, the wall of the ovary frequently opens along as many lines as there are carpels.

(v. and vi.) Development, and comparison with closely-related plants, often aid us in determining the number of carpels (see next chapter).

As examples of the application of these methods, we may select the two cases. The Pea has a one-chambered ovary, with one style, one stigma, and one parietal placenta down one side. The gynæcium, therefore, consists of one carpel and is apocarpous, in spite of the fact that in the fruit-condition

* Exceptions to this rule occur in the Labiatæ and Boraginaceæ.

it opens along two lines. In the Wallflower the gynæcium consists of a two-chambered ovary with two parietal placentas, and one style with two stigmas: in the fruit-condition the ovary opens along two lines; therefore the gynæcium consists of two carpels which are joined together (syncarpous).

THE ABSENCE OF STAMENS OR CARPELS.

The majority of familiar flowers possess both stamens and carpels, and are said to be *monoclinous* (*e.g.* Buttercup, Wallflower, Pea, Hyacinth). But the stamens and carpels of some plants do not occur in the same flowers, which are then described as being *diclinous* (*e.g.* Hazel, Scotch Pine). A plant having diclinous flowers naturally will possess two kinds of flowers: *staminate* flowers, which have stamens but are without carpels; and *carpellary* flowers, endowed with carpels but devoid of stamens.

CHAPTER X

ARRANGEMENT OF THE FLORAL LEAVES

LIKE the leaves on the vegetative part of a stem, the floral leaves are arranged in whorls or in spirals. When all its floral leaves are arranged in whorls, a flower is said to be *cyclic* (*e.g.* Wallflower, *Geranium*, Hyacinth); but when they are inserted in spirals, the flower is *acyclic*. Finally, if some of its floral leaves are in spirals and others in whorls, the flower is *hemi-cyclic* (*e.g.* most species of Buttercups).

CYCLIC FLOWERS.

In the case of a cyclic flower which may be described as a model or a typical flower the following rules hold good:— (i.) The number of floral leaves in each and every whorl of the flower is the same. (ii.) The successive whorls alternate. (iii.) The floral leaves in each whorl are all alike. To take an example: suppose that a flower possesses five sepals, in each other whorl of the flower there should be five floral leaves; so there might be five sepals, five petals, ten stamens, and five carpels. The five petals will alternate with the five sepals, and will be succeeded by an alternating whorl of five outer stamens (which are therefore opposite to the sepals); the five other stamens will form an inner whorl, and will alternate with the five outer stamens (and therefore be opposite to the petals); finally, the five carpels will alternate with the five inner stamens. Comparatively few cyclic flowers conform with all the three rules laid down; they exhibit variations.

(i.) **Obdiplostemony.**— Some flowers have two alternating whorls of stamens, there being in each whorl the same number of stamens as there are petals in a whorl; but the outer whorl of stamens are opposite to the petals in place of alternating with them. In addition, it is frequently the case that when the number of carpels is the same as that of the petals, the carpels alternate with the inner whorl of stamens, so that they are opposite to the petals in place of being opposite to the sepals (fig. 166). Such flowers are said to be *obdiplostemonous* (*e.g. Geranium, Oxalis*).

(ii.) **Unequal Growth.**—In many flowers the floral leaves which form a single whorl are not all alike in size and shape.

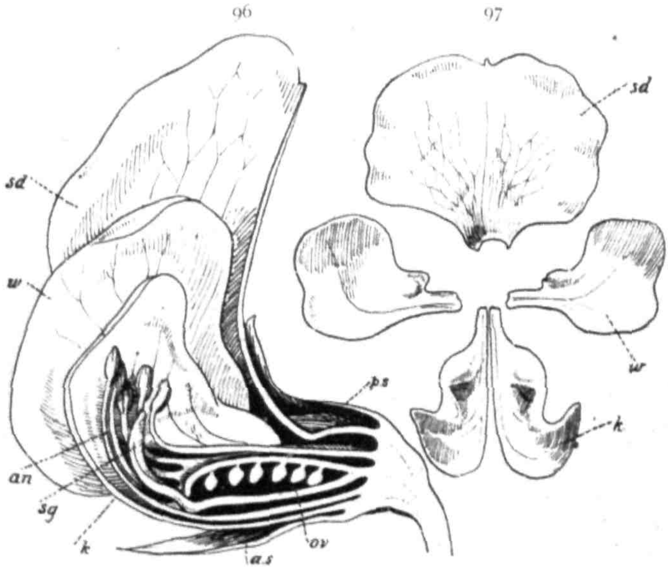


Fig. 96.—Vertical section of flower of Garden Pea. Fig. 97.—Separated petals of ditto.

The flower as a whole, or the whorl itself, is then said to be *irregular*. The corollas of the Pansy, Pea (figs. 96, 97), and Dead Nettle are irregular. In the Dead Nettle (fig. 191) two stamens with short, and two with long, filaments form one whorl. On the other hand, the andrœcium of the Wallflower (fig. 88) consists of two stamens with shorter, and four with longer, filaments; but the two short stamens form one whorl, and the four long ones comprise another, so that the andrœcium is not irregular. When all the floral leaves of each separate whorl of the flower are alike, the flower is *regular* (*e.g.* Wallflower, Poppy, *Geranium*, Hyacinth).

(iii.) **Atrophy and Suppression.**—By the word *atrophy* we mean the dwarfed development of a structure: atrophy, therefore, is a special example of unequal growth. Staminodes are examples of atrophy: they are stamens which have not produced their anthers. Comparing various flowers of the Umbelliferæ or Compositæ: in some we find the calyx represented by five minute teeth (fig. 183 *cx*), it has undergone atrophy; in still others no calyx is represented, it is entirely missing, and we then speak of the *suppression* of the calyx. In the Foxglove and the Dead Nettle, though there are five sepals and five petals represented in each flower, only four stamens occur. In each case one stamen which should alternate with two of the petals is missing. In the Primrose and the Iris a whole whorl of stamens is suppressed: in the former flower, the outer whorl is absent (see p. 149), so that the five stamens are opposite to the five petals; in the latter flower the three inner stamens are wanting (see p. 173), so that the three carpels are opposite to the three stamens.

(iv.) **Fusion or Cohesion.**—It has already been noted that the sepals, petals, stamens, or carpels may be combined in place of being separate. Occasionally some of the floral leaves forming a whorl are so intimately joined together that there seems to be a smaller number than is really the case. Thus, in flowers the corolla of which is two-lipped and consists of five petals, two of the petals forming one lip may be so closely fused that the double nature of the lip is not distinguishable. In this case we know that the lip represents two petals either because it is opposite to one sepal or to one stamen: if it represented a single petal it should alternate with two sepals or two stamens (see p. 154).

(v.) **Branching or Doubling.**—The floral leaves may be branched or doubled so that a whorl appears to represent more members than is really the case. For instance, the four stamens of the staminate Hazel-flower are almost completely divided down the middle, so that a careless observer might imagine that eight stamens were present (fig. 132).

In all these instances of deviations from the typical cyclic flower it is possible to understand the real structure of the flower, by considering the rules already given. In particular, there should be an equal number of floral leaves in each whorl, and the successive whorls should alternate. Often we are assisted in comprehending the apparent exceptions to these rules by observing the structure of flowers belonging to plants closely related, and therefore included in the same family (see Foxglove-family, page 157). And again we know that a foliage-leaf commences as a single little lump on the surface of the stem. A separate floral leaf arises in the same manner. If, therefore, we see five lumps grow out to form the commencement of the andrœcium of a flower, and they alternate with five outgrowths which are the beginnings of the petals, we can assume that the andrœcium is constituted of five stamens, however the stamens may cohere or branch subsequently.

Symmetry of Cyclic Flowers.—If we compare the flower of a *Geranium* or Hyacinth with that of a Pea (figs. 96, 97)

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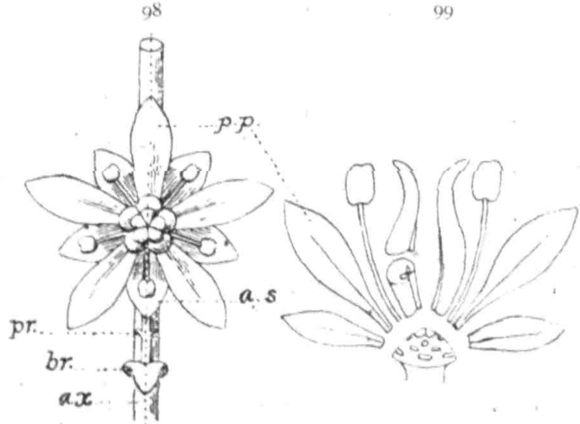


Fig. 98.—A regular actinomorphic cyclic flower on an axis (*a.x*) in the axil of a bract (*br*): *pr*=lateral prophylls; *a.s*=anterior sepal; *p*=posterior petal. The dotted line down the axis and over the flower is median.

Fig. 99.—The same flower showing the various floral leaves.

or Clover, we note that, in the case of the first two plants all the parts are regular, and are arranged in such a manner that the flower can be divided down the centre into two equa and similar halves by vertical cuts made in several different planes (directions); whereas in the other two plants named the parts are not regular, and the flower can be equally halved by a cut made only in one direction—*i.e.* passing through the middle of the standard and between the two keel-petals. All these flowers mentioned are said to be *symmetrical*, because it is possible to divide them into two similar halves. The *Geranium* and Hyacinth flowers are symmetrical in several planes (directions), or *actinomorphic*: the Pea and Clover flowers are symmetrical in one plane (direction) only, or *zygomorphic*. The zygomorphy of flowers is caused by the irregular growth, by suppression, by fusion, or by doubling of their parts.* When a cyclic flower cannot be divided into two equal halves, it is said to be *asymmetrical* (*e.g.* some members of the Pink-family). It is convenient to have some method of describing the relative positions occupied by the parts of a flower and the stem on which the latter is inserted. The half of the flower which faces the bract, or leaf, in the axil of which the flower stands, is said to be the *anterior* half; whilst the half of the flower which faces the inflorescence-axis is the *posterior* half. The plane dividing the flower vertically into its posterior and anterior halves is the *transverse* plane. Whereas

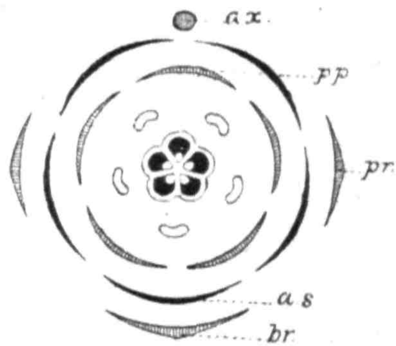


Fig. 100.—Floral diagram of same flower.

* In the majority of books a flower is not said to be zygomorphic when its solitary deviation from an actinomorphic flower is the suppression of some of its carpels. For example, many regular flowers possess five sepals, five petals, but only two carpels. If we assume that each floral leaf cut must be exactly halved, these flowers are, strictly speaking, symmetrical only in one plane: nevertheless, they are usually described as actinomorphic.

the vertical plane at right angles to the transverse plane, and, therefore, passing through the middle of the bract and the inflorescence-axis, is described as *median*. These definitions will be understood more easily if a Pea-flower (fig. 96) be examined. The standard is posterior (nearest the inflorescence-axis), the two keel-petals are anterior (nearest the bracts): furthermore, the standard is median in position, as it is inserted in a vertical plane passing through the middle of the bract and the inflorescence-axis: whereas the wings and the two keel-petals, being on each side of the median line, are lateral in position. Thus the standard is median-posterior, the wings are lateral, and the keel-petals are anterior-lateral (see also fig. 98).

ACYCLIC AND HEMICYCLIC FLOWERS.

Many of the remarks made in reference to cyclic flowers are also true of acyclic and hemicyclic flowers. But the definitions with regard to the symmetry of cyclic flowers usually do not hold good for hemicyclic and acyclic flowers, because the divergences of the various floral leaves are not constant throughout the whole flower. For instance, the sepals may be two-fifths, the petals three-eighths, and the stamens five-thirteenths. This renders it impossible to divide the flower with mathematical accuracy into two equal halves. Nevertheless, acyclic and hemicyclic flowers which present the appearance of actinomorphic flowers are usually described as actinomorphic (*e.g.* Buttercup), and those which resemble zygomorphic flowers are described as zygomorphic (*e.g.* Monkshood).

FLORAL DIAGRAMS.

In order to represent graphically the relative arrangement of the parts of a flower, we construct maps or ground-plans, which are known as *floral diagrams*. The simplest method of gaining an idea of a floral diagram is to cut across a flower-bud through the sepals, petals, stamens, and ovaries, and then to look down upon the cut surface exposed. The floral leaves will be seen to form successive circles or spirals. Figs 100 and 101 show floral diagrams. The sepals naturally stand at the outside, and the carpels in the centre (compare pages 13, 14). It is also well to include in the diagrams the inflorescence-axis, and the bract or leaf in the axil of which the flower stands: we at once see which is the anterior and which the posterior part of the flower. The diagram will show where suppressions, etc., have taken place (see figs. 192, 194, 219).

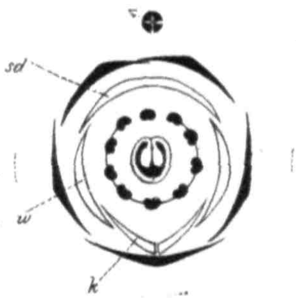
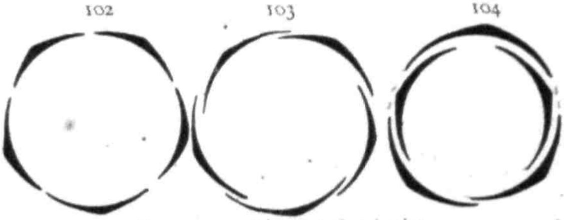


Fig. 101.—Floral diagram of Garden Pea.

Æstivation. — A cut made across a flower-bud further reveals the nature of the æstivation of the calyx and corolla. The sepals and petals, like leaves of vegetative buds, may be arranged in an *open*, a *valvate* (fig. 102), or an *imbricate* (figs. 103, 104) manner (see p. 128); especially frequent is the two - fifths æstivation of the calyx (fig. 104). The corolla is often *contorted* (fig. 103; fig. 166)—that is, one edge of each petal overlaps the edge of one adjoining petal, whilst its other margin is overlapped by the margin of the petal on its other side. The

102 103 104



Figs. 102-104.—Diagrams of æstivation.

æstivation of the corolla of the Pansy (fig. 158) and Pea (fig. 101) is characteristic, and is described as *descending-imbricate.* In the bud, the posterior petals (or petal) enfold with their edges the lateral petals, and these in turn overlap the anterior petal (or petals). When the æstivation of the corolla is precisely the reverse, it is ascending-imbricate.*

* In a complete floral-diagram the æstivation of the calyx and corolla, the insertion of the anthers, as well as the position of main axis and bract, should be denoted; but young beginners might omit these details.

Floral formulæ and symbols.—Certain symbols and formulæ may be employed to denote briefly the morphology of a flower. The signs $\oplus$ and $\downarrow$ denote actinomorphic and zygomorphic flowers respectively; the direction of the arrow serves also to show the plane of symmetry. A vertical arrow $\downarrow$ corresponds with a median-zygomorphic, and a horizontal arrow $\rightarrow$ with a transverse-zygomorphic, flower. The signs ♂, ♀, ☿, denote respectively staminate, carpellary, and monoclinous flowers. The capital letters K C (P), A and G represent the calyx, corolla (perianth), andrœcium, and gynæcium. The number placed *immediately after each capital letter shows the number* of leaves in that particular whorl or spiral. If the gynæcium be syncarpous, its number is enclosed in brackets, otherwise the number is not in brackets; if the ovary be inferior, a horizontal line is drawn above its number, if it be superior the line is placed below the number. The sign ∞ denotes that more than twelve floral leaves are present, it therefore means numerous.

Floral formula of the ☿ flower of the Buttercup,

$$\oplus \ K5 \ C5 \ A\infty \ G\underline{\infty}$$

Floral formula of the ☿ flower of the Pea,

$$\downarrow K5 \ C5 \ A5+5 \ G\underline{1}$$

Floral formula of the ♂ flower of the Hazel,

$$\oplus \ P0 \ A4^2 \ G0$$

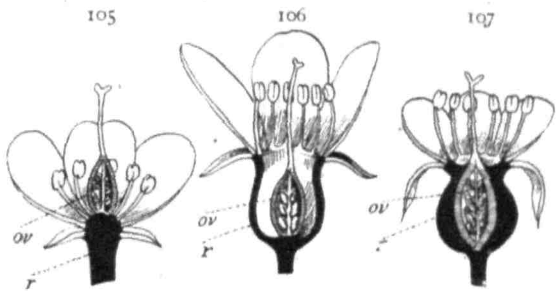
Floral formula of the ♀ flower of the Hazel,

$$\oplus \ P0 \ (?) \ A0 \ G \ (\overline{2})$$

SHAPE OF THE RECEPTACLE.

Hypogynous flowers (fig. 105).—In some simple flowers the portion of the stem which bears the floral leaves—that is, the receptacle—is distinctly elongated (*e.g.* Scotch Pine, figs. 63, 65; Buttercup, fig. 61). More frequently the internodes of the receptacle are much shorter, though the flower-stalk terminates in a rounded convex end (*e.g.* Wallflower, fig. 156; Poppy, fig. 153; Violet, fig. 158; Primrose, fig. 187). In such flowers the carpels occupy not only the most central, but also the highest, position; and petals and sepals are inserted at successively lower levels. The flower is then said to be *hypogynous*, and the gynæcium is *superior*.

Perigynous flowers (fig. 106).—The end of the flower-stalk of some other flowers is hollowed out to form a basin-like or deep urn-like concave receptacle. The carpels are attached to the



Figs. 105-107.—Vertical sections of flowers, showing the shape of the receptacle (*r*) which is shaded black: *ov* = ovary.

base (*e.g.* Cherry, fig. 177), to an outgrowth from the base (*e.g.* Blackberry, fig. 173), or to the sides and base (*e.g.* Rose, fig. 168), of the concavity, whilst the sepals and petals are inserted on its rim. The flower is then *perigynous*; the gynæcium is still described as *superior*.

Epigynous flowers (fig. 107).—Finally, there are flowers possessing a receptacle which is hollowed, as in the perigynous flowers, and the carpels are not only concealed in the concavity thus formed, but they are actually fused with and coherent to its sides. It thus becomes impossible to separate the wall of the ovary (or ovaries) from the receptacle, and the sepals and petals appear as if they were inserted upon the ovary (or ovaries). The flower is then described as *epigynous*. The gynæcium is, in this case, said to be *inferior* (*e.g. Heracleum*, fig. 183; Daisy-family, figs. 202, 209, 211; Honeysuckle, fig. 199; Daffodil, fig. 215). It will be seen that the wall of an inferior ovary really consists of portions of the carpels and of the receptacle.

Other peculiarities of insertion.—In hypogynous, perigynous, and epigynous flowers, frequently the stamens are attached to the petals (*e.g.* Primrose, Dead Nettle, Daisy-family); they are then said to be *epipetalous*. When the stamens are inserted on the perianth-leaves they are described as being *epiphyllous* (fig. 213). In the Orchids the stamens and style combine to form a central column.

Disk. Frequently the receptacle of a flower has upon it certain subsidiary outgrowths, which collectively form the *disk*. The disk may take the form of a whorl of two or more little swellings (*e.g.* *Geranium*, Chickweed) or scales; or it may be in the form of a single horse-shoe-like or ring-like outgrowth at the base of the style or stamens (*e.g.* Daisy-family), or may be a lining to the concave receptacle (*e.g.* Rose). Very frequently the disk secretes honey: in which case it is a nectary or a collection of nectaries.

CHAPTER XI

NECTARIES—POLLINATION

NECTARIES.

At the base of each petal of the Buttercup there is a small pit, the lining of which pours out sugar, and is termed a *nectary* or honey-gland. The petals of the Winter Aconite and Christmas Rose assume the form of tubes, which likewise excrete sugar, and are thus nectaries. The flower of the Monkshood (figs. 151, 152) has only two nectaries, which are attached by long stalks and represent portions of two posterior petals (*pp*), which are concealed beneath the large blue cowl-like posterior sepal. The two anterior stamens of the Violet or Pansy (fig. 158) send narrow band-like processes (*ap*) into the spur of the anterior petal; on each of these processes is a spot which denotes the location of the honey-gland. Thus, in the Pansy or Violet, we can distinguish between the nectaries which are portions of the stamens and make the honey, and the *nectar-receptacle* which is the spur of the anterior petal and receives the sugar manufactured by the nectaries. In the Marsh Marigold, and in *Arum*, parts of the gynæcium act as honey-glands; whilst in the Mallow the five nectaries are on the five sepals (fig. 161 *n*). In fact, sepals, petals, stamens, or carpels may be partially or wholly modified to excrete sugar. In other cases, however, the nectaries do not represent portions of the floral leaves, but are parts of the receptacle. For instance, in the flower of the Wallflower (figs. 88, 156 *n*) there are two honey-glands, each being in the form of a green ring-shaped outgrowth round the base of one of the short stamens; the two lateral saccate sepals act as honey-receptacles to receive the sugar overflowing from the two nectaries which lie above them.

POLLINATION.

Under certain circumstances the ovules of a plant change into seeds; in fact, seeds cannot be formed excepting from ovules

Consequently, flowers which possess stamens, but have no carpels, do not bear seeds. Whereas flowers devoid of stamens, but endowed with carpels, may produce seed. Experiment has shown that the ovules do not change into seeds unless pollen grains have previously been conveyed on to the stigma (or, in Gymnosperms, into the micropyle of the ovule). The pollen in some way exerts a fertilising influence on the ovule. The transference of pollen from an anther to the receptive part of the carpel of a flower is referred to under the term *pollination*.

Cross - Pollination and Self - Pollination.—The simplest method of pollination is the transference of the pollen from the anther to the stigma of the same flower; this is described as *self-pollination*, and the flower is said to be *self-pollinated*. When, on the other hand, the stigma of a flower receives pollen from the flower of another individual-plant of the same kind, it is, said to be *cross-pollinated*. Lastly, pollen may be transferred from one flower on to the stigma of another flower of the same individual-plant; this is obviously a stage between cross-pollination and self-pollination, but there is no simple word or term in use by which to distinguish it.

CROSS-POLLINATION.

It has been proved that in many species of plants cross-pollination leads either to larger crops of seeds, or to the production of seeds which are better in quality than is the case when the same plants are self-pollinated. Accordingly, many arrangements exist in flowers which are calculated to hinder self-pollination and facilitate the more invigorating cross-pollination.

Arrangements for hindering Self-pollination:—

(i.) Sometimes *the stamens and carpels do not occur in the same flowers*, consequently the pollen must be conveyed from one flower to another. The stamen-bearing (staminate) and carpel-bearing (carpellary) flowers may occur on the same individual-plant, as in the Hazel, Oak, and Pine. Or the two kinds of flowers may be on different individual-plants, as in the Willows, in which case the stamens are borne on one tree and the carpels on another tree.

(ii.) Sometimes *the stamens and carpels in one flower ripen at different times*; the consequence is that, though the flower possesses both stamens and carpels, the pollen and the stigmas are not ready for pollination at the same time. When the stamens shed their pollen before the stigma is ready to receive it, the flower is said to be *proterandrous* (*e.g.* Daisy-family, Mallow). But when the stigma is ripe before the anthers are able to dehisce, the flower is described as *proterogynous*.

(iii.) Sometimes *the pollen has no fertilising effect on the ovules of the same flower*, so that when the stigma receives pollen from the same flower no seeds result (*e.g.* some Orchids).

(iv.) *The relative arrangement of the parts of the flower*, in some cases, prevents the pollen reaching the stigma of the same flower (see Pansy, on page 129; also see the long-styled form of Primrose, on page 150).

Cross-pollination by the aid of the wind—Wind-pollinated flowers.—In the case of ordinary flowering plants with flowers raised above ground or above the water, it is necessary for pollen to be transported through the air if the flowers are to be cross-pollinated. The pollen has no power to move unaided, only rarely does the plant itself assist by throwing the pollen violently (as in the Stinging Nettle); so that the pollen is necessarily conveyed from one plant to another by the aid of the wind or by the agency of animals. Flowers which are cross-pollinated by the aid of the wind are described as *wind-pollinated flowers*. Flowers which are cross-pollinated by the agency of animals are *animal-pollinated*: in Britain the only animals which are of importance in effecting the cross-pollination of flowers are insects: hence we speak of *insect-pollinated* flowers.

As examples of wind-pollinated flowers, we may mention Hazels, Poplars, and Grasses (see pages 109-112, 182-184). In regard to these wind-pollinated flowers, it will be noted that:

(i.) They are small, inconspicuous, and unscented.

(ii.) They have no nectaries.

(iii.) Their pollen is powdery, and not sticky.

(iv.) The anthers are attached to long filaments, and hang freely out of the flowers, or are arranged in easily movable inflorescences, so that the pollen is readily shaken out by a gentle breeze.

(v.) The stigmas are well-developed, and often feathery or thread-like, so that a large surface is exposed to receive any pollen blown thither by the wind.

(vi.) Usually a large amount of pollen is produced.

These characters serve to illustrate the general peculiarities of wind-pollinated flowers. The wind-pollinated flowers of the Pine differ in that the pollen is blown on to the open carpels, but here the open crevices of the carpellary cone must be regarded as exposing the large surface to receive the pollen.

Cross-pollination by the agency of insects—Insect-pollinated flowers.—The Buttercup, Wallflower, Poppy, Pea, and Hyacinth all possess flowers which are cross-pollinated by the agency of insects. They serve to illustrate the general features of insect-pollinated flowers.

(i.) They are brightly coloured or scented.

(ii.) They usually possess nectaries, for the sake of whose honey insects visit them; occasionally (*e.g.* Poppy, Potato) insect-pollinated flowers do not manufacture honey, but supply their insect-visitors with food in the form of pollen.

(iii.) The pollen-grains, in place of being powdery, are usually sticky, so that they adhere to the bodies of insects.

(iv.) There is a certain correspondence between the positions of the anthers and the stigmas of the flowers.

(v.) The stigma is not feathery or pencil-like, but, as a rule, is relatively small.

These general statements are liable to exceptions; some insect-pollinated flowers are inconspicuous, and, so far as we can smell, are also scentless (*e.g.* Virginia Creeper). Insect-pollinated flowers have one advantage over wind-pollinated flowers; they are pollinated by agents which move in definite directions—namely, from flower to flower. Wind-pollinated flowers are pollinated by the wind, which blows the pollen in any direction; so that for every pollen-grain which reaches the flower of another individual-plant of the same kind, millions of other pollen-grains fall to the ground and are wasted. The insect-pollinated flower can afford to manufacture less pollen, and is more economical than a flower pollinated by the aid of the wind. The various colours and scents of flowers not only serve to attract insects, but they assist the insect in identifying the flower it wishes to visit. For example, we often see a bee confining its visits to one kind of plant—say a Poppy—during the whole of a morning. The fact that honey is sipped by insects visiting the flowers, together with the fact that wind-pollinated flowers have no nectaries, denotes that the nectaries serve to entice insects.

The insects which visit flowers in order to obtain honey or pollen, belong to the families of the Beetles, Flies, Bees (including Wasps and Humble-bees), and Butterflies (with Moths). The majority of Flies and Beetles have very short tongues, and are not intelligent, so that they can only obtain such honey as is easily accessible; the hover-flies form an exception to this rule, for they possess long tongues. The Bee-family provides the most important pollinating insect-agents; the simplest members have only short tongues; but many species of bees and wasps are clever, and possess long tongues, consequently they are able to discover and obtain honey which is carefully concealed and deeply placed. Finally, many Butterflies and Moths, with tongues even longer than those of humble-bees, can reach honey which is so deeply placed at the bottom of long tubes as to be inaccessible to the latter insects.

We find that flowers of different shapes and tints do not receive equal attention from all these families of insects. Flowers like those of the Parsley-family, with freely-exposed honey (fig. 183), or the Buttercup, with honey scarcely concealed (fig. 61), receive relatively more visits from the short-tongued insects—flies and beetles—than do flowers with deeply-concealed honey (*e.g. Geranium*, fig. 165). Opposed to these flowers which are suited to the requirements of many kinds of insect-visitors are others which are specially adapted to receive certain particular classes of insects. The flowers of the Pea, Vetch, Clover, and Violet have their honey so well concealed that only clever insects with tolerably long tongues can reach the nectaries (figs. 96, 158); they are pollinated by the agency of bees, and are specially adapted to receive their visits, and may therefore be termed "Bee-flowers." The Monkshood (fig. 151) and Foxglove (fig. 193) are similarly "Humble-bee flowers" (see pages 120, 157). Finally, Pinks and the Honeysuckle are adapted to receive Butterflies and Moths respectively: their honey is not fully accessible to bees.

Comparing the actinomorphic flowers of the Buttercup with the zygomorphic "Bee-flowers" mentioned, it will be noted that the buttercup-flower may be entered from any side, and the visiting insect may crawl about in the flower and receive pollen on various parts of its body. On the contrary, the "Bee-flower" is so constructed that its honey cannot be obtained unless the insect visits in a certain special manner; the consequence is that the visiting insect receives pollen on a certain definite region of its body, and may unerringly convey that pollen to the stigma of the flower next visited. For instance, in the pea-flower it is the under-surface of the bee's body which comes into contact with the pollen and stigma; in the Foxglove, it is the back of the humble-bee which is pollen-dusted and meets with the stigma. This arrangement in these "Bee-flowers," therefore, not only allows the flower to economise in pollen, but it also places the pollen and honey in a position of greater safety in regard to the injurious action of rain and the inroads of marauding insects. For further illustrations, refer to Ranunculaceæ (p. 121), Papilionaceæ (p. 138), Labiatæ (p. 155), Scrophulariaceæ (p. 157), Caprifoliaceæ (p. 160), Araceæ (p. 180).

SELF-POLLINATION.

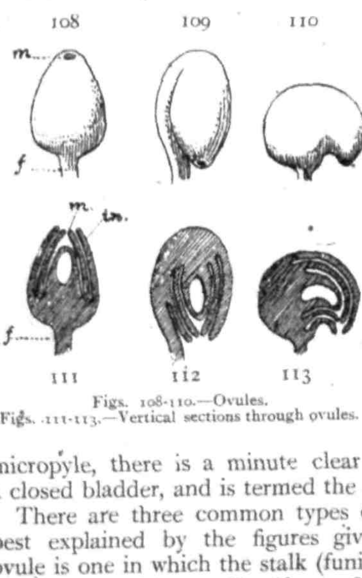
Although in the case of many plants cross-pollination leads to the production of better seeds, or more seeds, than self-pollination, yet some plants produce quite as many seeds, and those of as good quality, by self-pollination as by cross-pollination. Cross-pollination has this advantage over self-pollination, that it frequently affords a better crop of seeds. But self-pollination is superior in one respect, it is easily secured and rendered certain: the pollen simply has to come into contact with a stigma which is ready and close at hand. The self-pollinated plant is not dependent on the presence of another individual-plant of the same kind in the immediate neighbourhood: furthermore, it neither demands the attendance of special insects nor the influence of wind in a certain direction to carry the pollen to another individual. Many flowers are self-pollinated, either spontaneously or by the agency of insects. Insects wandering over the Buttercup-flower frequently effect self-pollination. In *Malva rotundifolia* (see page 134), and in some members of the Daisy-family, the stigmas curl down until they reach the pollen-laden anthers, so that the flower spontaneously pollinates itself. The flower of the Poor-man's Weather-glass (*Anagallis*), if it be not cross-pollinated within the first three days, remains permanently closed, and its anthers, coming into contact with the stigma, effect self-pollination. The Pansy (see page 129) has two kinds of flowers, the large variegated ones, which are cross-pollinated, and smaller ones, similar in shape, which remain closed and pollinate themselves. Finally, the Violet and the Woodsorrel, in addition to possessing their familiar conspicuous flowers, which are cross-pollinated, also have minute green and bud-like flowers of quite different form. These latter never open: they are peculiar self-pollinating or *cleistogamic* flowers.

CHAPTER XII

OVULE—FERTILISATION—SEED—FRUIT

OVULE.

AN ovule (figs. 108, 111) is a more or less egg-shaped body attached to the placenta by means of a stalk—the *funicle* (*f*). The main body of the ovule consists of a central egg-shaped mass — the *nucellus* — which is surrounded by one or two coats — the *integuments* (*in*). Each integument is attached by its base to the nucellus, but elsewhere it surrounds the nucellus like a narrow-mouthed bag, which is open at the top. The opening at the top of the integument or integuments is the *micropyle* (*m*); it allows free communication between the nucellus and the chamber of the ovary. In the nucellus itself, near the micropyle, there is a minute clear space. This is in reality a closed bladder, and is termed the *embryo-sac.*



Figs. 108-110.—Ovules.
Figs. 111-113.—Vertical sections through ovules.

There are three common types of ovules, whose forms are best explained by the figures given. (1) An *orthotropous* ovule is one in which the stalk (funicle) is in the same straight line as the straight nucellus (figs. 108, 111). (2) An *anatropous* ovule is one in which the nucellus itself is straight, but is inverted, and consequently appears to be attached by its side to the funicle (figs. 109, 112). (3) A *campylotropous* ovule is one in which the nucellus is itself curved; often it is kidney-shaped (figs. 110, 113).

FERTILISATION AND CHANGES IN THE OVULE.

When a healthy pollen-grain reaches a suitable stigma (fig. 114 *sg*) it germinates by sending a slender tube (*pt*) down the style. The end of this pollen-tube eventually enters the micropyle (*m*), and comes into contact with the nucellus close to the top of the embryo-sac (*es*).*

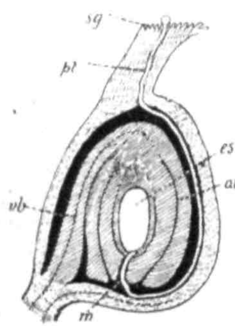


Fig. 114.—Vertical section through a carpel and an anatropous ovule, showing the pollen-tube entering the micropyle.

The consequence of fertilisation is that the *ovule grows and becomes a seed* (compare figs. 114 and 115). The most important change in the ovule is that a minute new plant—the embryo—develops inside the embryo-sac. The embryo-sac grows and becomes, wholly or partially, filled with endosperm, which surrounds the embryo. This endosperm may be present still in the seed, and the seed is said to be *endospermic*—*e.g.* Grass and Violet (figs. 118, 158). Or the endosperm formed in the ovule may be gradually absorbed by the growing embryo, so that in the ripe seed there remains no trace of it: the seed is then said to be *non-endospermic*—*e.g.* Bean and Wallflower (fig. 116). In most flowering plants, whilst the embryo-sac, the contained endosperm, and the embryo are grow-

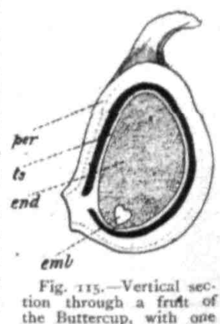
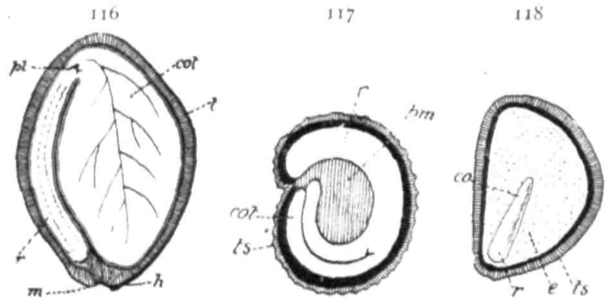


Fig. 115.—Vertical section through a fruit of the Buttercup, with one anatropous seed: *per* = pericarp; *ts* = testa; *end* = endosperm; *emb* = embryo.

* This process can only be followed properly by the aid of a compound microscope. In a few Angiosperms the pollen-tube does not enter by the micropyle, but pushes its way through the substance of the ovule till it reaches the embryo-sac. In the Pine and Gymnosperms the pollen-grain itself reaches the micropyle and then sends out a tube.

ing, the nucellus is being absorbed by them, and no trace of it remains in the mature seed. In such cases the whole of the seed within the testa represents the embryo-sac and its contents. In some plants the nucellus is not entirely absorbed, but persists and forms an endosperm-like layer within the



Figs. 116-118.—Vertical sections of seeds: *h* = scar on seed; *m* = micropyle; *t*, *ts* = testa; *e* = endosperm; *pm* = perisperm; *co*, *cot* = cotyledon; *pl* = plumule; *r* = radicle. Fig. 116.—Wallflower. Fig. 117.—*Stellaria*. Fig. 118.—*Iris*.

testa: this is termed the *perisperm*—*e.g. Stellaria* (fig. 117). The testa is formed by the growth and hardening of the integument or integuments, and the micropyle of the seed represents the micropyle of the ovule. The funicle or stalk of the seed is identical with the funicle of the ovule. The subjoined table represents the corresponding parts in the ovule and seed:—

Ovule		Seed
(*a*) The contents of the embryo-sac	=	Embryo and Endosperm.
(*b*) Nucellus	=	Perisperm.
(*c*) Integuments	=	Testa.
(*d*) Micropyle . . .	=	Micropyle.
(*e*) Funicle	=	Funicle.

As examples of different types of seeds, the following may be cited as occurring in both Monocotyledons and Dicotyledons.

(i.) *No endosperm, no perisperm*: Pea, Bean, Wallflower, Mustard, Pear, Apple, Hazel, Oak, and Chestnut (figs. 1, 116).

(ii.) *Endosperm, but no perisperm*: Buttercup, Violet, Mallow, Castor Oil plant, and Grasses (fig. 118).

(iii.) *Perisperm with scarcely a trace of endosperm*: *Stellaria* (fig. 117).

Outgrowths on Seeds.—The Violet and the Spurge have each a little lump near the micropyle (fig. 158). Many outgrowths are concerned with the scattering of the seed: for instance, the long silky hairs or the seeds of Poplars, Willows, and Willow-herbs, facilitate the dispersal of the seeds by the wind.

FRUIT.

The consequences of fertilisation are not confined to the ovules; the carpels, and frequently other parts, of the flower are stimulated into vigorous growth, whereas the remaining parts

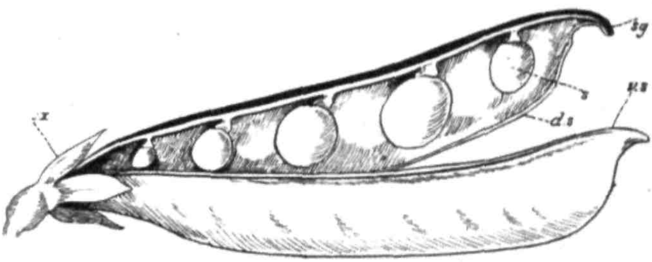


Fig. 119.—Fruit (legume) of Garden Pea.

wither and fall off more speedily than they would have done had fertilisation not taken place. *That portion of a single flower which persists after fertilisation until the seeds are ripe is termed the* **fruit**. There is one part of the flower which invariably persists—the ovary (or ovaries)—this remains to form a protective case round the ripening seeds. Obviously the receptacle, or a portion of it, also remains. The corolla and stamens almost always wither soon and fall, consequently they play no part in the formation of the fruit; whereas the calyx not infrequently persists.

The Pea (or Bean, or Clover) may be selected as having one of the simplest of fruits. Its ovary, composed of one carpel, enlarges and becomes the familiar pea-pod (fig. 119), and constitutes the fruit inside which are the seeds. The

Wallflower is slightly more complicated, in that the ovary is syncarpous, being composed of two carpels; but in this flower, as in the Pea, it is the single ovary alone which, by its growth, gives rise to the single fruit (fig. 120). The Buttercup differs from the two preceding examples in that every flower has a number of separate ovaries, each representing one carpel. Each ovary enlarges and eventually encloses one seed (fig. 115). This flower thus gives place to a number of apocarpous seed-containing vessels, each similar to the pea-pod in so far as it consists of a single ripened carpel. We can, therefore, divide fruits into two groups: (i.) **Simple fruits**, produced by a single ovary which is composed of one (*e.g.* Pea) or more carpels (*e.g.* Wallflower). (ii.) **Compound fruits**, produced by a number of apocarpous carpels in one flower (*e.g.* Buttercup). Thus the fruit of a Buttercup is a compound fruit and consists of a number of simple fruits.

The external wall of the chamber, or chambers, of a simple fruit is termed the **pericarp**. In the case of the simple fruits already mentioned, the pericarp is derived solely from the carpels; it is the original wall of the ovary, which has grown. But if we consider a simple fruit derived from a single inferior ovary (*e.g.* Honeysuckle, Parsley, Yellow Flag, Orchid), the wall of the fruit represents part of the receptacle as well as portions of the carpels (see p. 75).

Again, if we examine a ripened (fertilised) Dandelion-head (fig. 129), we shall see that it consists of a number of simple fruits. Every one of these is formed by the growth of a single inferior ovary, each of which belongs to a separate flower. This Dandelion-head is formed as a result of the fertilisation of a number of flowers. A fruit is formed from one flower, consequently the Dandelion-head is not a fruit, not even a compound fruit: it is a collection of fruits, or an *infructescence*.

Comparing the behaviour of the pericarp of the simple fruits of the Pea, Wallflower, Buttercup, and Dandelion, we see that the pericarp of the first two gapes open, or *dehisces*, when it is ripe, so that the carpels are freely open; whereas, on the contrary, the fruits of the last two do not open of their own accord. If we now examine the fruit of a Parsley-plant (or any Umbellifer), we note that it is formed by a single inferior, two-chambered ovary, composed of two carpels. When the fruit is ripe the two carpels separate, but do not open. We may, therefore, divide simple fruits into three groups:— (1) **Dehiscent** fruits, the carpels of which open spontaneously. (2) **Indehiscent** fruits, the carpels of which remain closed, and, if syncarpous, do not separate. (3) **Separating** fruits, which are always syncarpous, and the carpels of which separate without opening.

Again, comparing the fruits of the Pea, Wallflower, and Buttercup with those of the Honeysuckle, Gooseberry, and Currant, the first three have a thin, *dry*, hard or brittle pericarp; whereas the second three possess a fresh, more or less *fleshy* or *succulent* pericarp. We may, therefore, further classify fruits into (1) **dry** fruits; (2) **fleshy** or **succulent** fruits.

CLASSIFICATION OF SIMPLE FRUITS

DEHISCENT FRUITS (Carpels opening)

A. DRY (DEHISCENT).

(i.) *One-carpellary* (composed of one carpel).

(*a*) Opening down the ventral suture only, containing one or more seeds (*e.g.* Pæony, Winter-Aconite) = **Follicle.**

(*b*) Opening down the two sutures, dorsal and ventral, and containing one or more seeds (*e.g.* Pea, Bean, Clover) = **Legume.**

(ii.) *Two-carpellary* (composed of two carpels).

(*a*) The two carpels separate as two valves, commencing from below upwards, and leave the seeds attached to a persistent frame-like parietal placenta which is termed the *replum*. The chamber of the fruit may (*e.g. Cruciferæ*) be divided into two chambers by a thin septum which spans the space between the two parietal placentæ and persists in the fruit (fig. 120); or there may be no such septum, so that the ovary is one-chambered as is the fruit—*e.g. Chelidonium* (fig. 121). A number of seeds are present in the fruit = **Siliqua.**

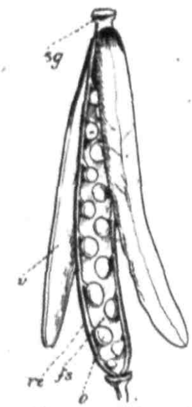


Fig. 120.—Siliqua of Wallflower: *re* = replum; *fs* = false septum; *o* = seed; *v* = valve; *sg* = stigma.

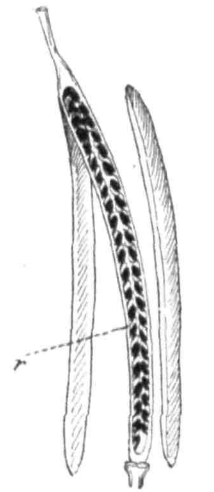


Fig. 121.—Siliqua of *Chelidonium*: *r* = replum.

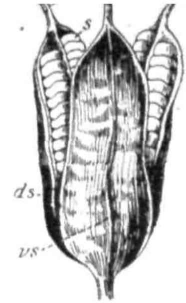


Fig. 122.—Capsule of *Iris* dehiscing along three dorsal sutures (*ds*): *vs* = ventral suture; *s* = seed.

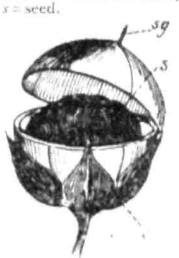


Fig. 125. — Capsule of *Anagallis* dehiscing transversely: *c* = calyx; *s* = seeds; *sg* = style.

Fig. 123. — Capsule of Foxglove dehiscing along two ventral sutures, and leaving the seeds attached to the axile placenta (*pl*); *sy* = style; *cx* = calyx.

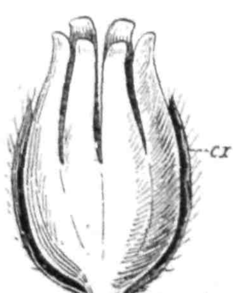


Fig. 124. — Capsule of *Stellaria media* dehiscing for a certain distance along three dorsal sutures and three ventral sutures; *cx* = calyx.

Fig. 126. — Capsule of Poppy dehiscing by pores (*w*).

The siliqua is typically pod-like in shape, but a short broad form is often distinguished as a *Silicula* (*e.g.* Shepherd's Purse).

(iii.) *Two or more carpels* = **Capsule.**

(*a*) Usually a dry dehiscent fruit formed by more than two combined carpels, dehisces *longitudinally*, and causes the pericarp to split into a number of valves. The splits may descend from the apex to the base of the fruit, or they may be merely confined to the upper part, in which case the separate valves are tooth-like (*e.g.* *Cerastium*, Primrose). Longitudinally dehiscing capsules are of four kinds.

(α) Splitting along the ventral sutures.

(β) Splitting along the dorsal sutures (*e.g.* Violet, fig. 158; *Iris*, fig. 122).

(γ) Splitting along the ventral sutures, and separating from the partition walls of the capsule so as to leave the seeds attached to a middle axial column (*e.g.* Foxglove, fig. 123).

(δ) Splitting for a certain distance along both dorsal and ventral sutures, so that there are twice as many valves as there are carpels (especially in capsules with tooth-like dehiscence) (*e.g.* *Stellaria media*, fig. 124).

(*b*) Capsule with *transverse* dehiscence. The top of the capsule separates like a lid (*e.g.* Poor-man's Weather-glass, fig. 125).

(*c*) Capsule opening by a number of little holes or *pores* in the pericarp (*e.g.* Poppy, fig. 126).

(*d*) Capsule opening *irregularly*.

B. FLESHY (DEHISCENT).

Some *follicles* are soft and green when they dehisce. The green succulent *capsules* of the Balsam open violently, and fling their seeds to some distance. The capsule of the Woodsorrel has a soft pericarp, which splits open and allows the seeds to be violently ejected. The Horse-Chestnut capsules are succulent. The Walnut-fruit is not a nut: it is a stone-fruit, the outer fleshy layer of which bursts irregularly; its so-called nut is therefore a "stone."

INDEHISCENT FRUITS

Fig. 127.—Achene of Sunflower.

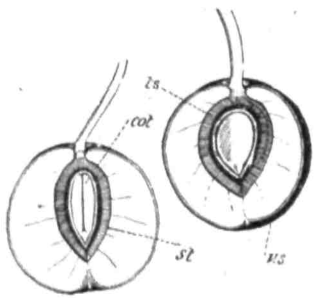


Fig. 128.—Vertical sections of the drupe of Cherry: in the right-hand figure the fruit is cut vertically through the ventral suture (*vs*) and dorsal suture: in the left-hand figure the fruit is vertically cut in a plane at right angles to the preceding one: *st* = stony layer of pericarp; *ts* = testa of seed; *cot* = cotyledon.

A. DRY (INDEHISCENT).

One-Seeded.

(1) Pericarp stone-like (*e.g.* Hazel, fig. 138). = **Nut.**

(2) Pericarp leathery, or hard skin-like.

(α) Pericarp not adhering to the testa (*e.g.* Buttercup, fig. 115; Daisy-family, figs. 127, 212). = **Achene.**

(β) Pericarp adhering closely to the testa, or the testa absent (*e.g.* Grains of Grasses, Wheat, fig. 28). = **Caryopsis.**

B. FLESHY (INDEHISCENT).

(1) The inmost layer of the pericarp is stone-like = **Drupe.**

(*a*) The outer layer of the pericarp of a drupe is like a thin "skin," the middle layer is usually soft and juicy, and the inmost layer is very hard and stone-like. The simplest drupes are composed of one carpel, with one stone enclosing one seed (*e.g.* Cherry, fig. 128, Plum, Apricot). The most complicated drupes are syncarpous, and have several stones, *because the walls of each of the ovary-chambers has become separately changed into a stone with one seed inside it.* It must be noted that the stones (*e.g.* Hawthorn) of stone-fruits are not seeds. A seed is produced from an ovule only, whereas the hard stone of a drupe is formed by a layer of the ovary-wall.

(*b*) The pericarp is *soft and fleshy throughout* (*e.g.* Grape, Gooseberry, Currant, Orange, Cucumber) = **Berry**.

(*c*) The fruit of the pear and apple is quite peculiar, and is termed a **Pome**. The component five carpels are fused with the hollow receptacle by their outer faces, hence the gynæcium is inferior (fig. 178). The carpels are also combined with one another by their sides, but may be free towards their centres (ventral sutures), thus the *gynæcium is only incompletely syncarpous* (fig. 179). In the fruit a parchment-like membrane forms round each chamber, just as stones may form round the several chambers of a *stone-fruit*, whilst the rest of the pericarp grows vigorously and remains fleshy (figs. 180, 181). The seeds are contained in the five parchment-walled chambers (fig. 182). The pome is intermediate between a berry and a stone-fruit, also between a compound and a simple fruit.

SEPARATING FRUITS (SCHIZOCARPS)

These all possess more than one carpel. The constituent carpels separate as closed one-seeded chambers.

(*a*) The fruit separates into as many closed one-seeded one-chambered parts as there are carpels. Each part represents a closed carpel, and is termed a **mericarp** (*e.g.* two-carpellary fruits of the Parsley-family, fig. 185, and Sycamore) or a **coccus** (if the ovary consists of more than two carpels, *e.g.* Mallow, fig. 164) = **Schizocarp.**

(*b*) The two-carpellary fruit is divided into four one-chambered one-seeded parts which separate as little "nuts." Each "nut" therefore represents half a carpel (*e.g.* fruits of the *Labiatæ*, and many *Boraginaceæ*).

COMPOUND FRUITS.

The compound fruit may possess a number of follicles (*e.g.* Pæony, Winter Aconite), of achenes (*e.g.* Buttercup, Rose, fig. 170, Strawberry, fig. 172), of drupes (*e.g.* Blackberry, fig. 175, Raspberry), inserted on a receptacle. But obviously it cannot possess a number of siliquæ or capsules, because these are always syncarpous fruits.

DESCRIPTIONS OF COMPLETE FRUITS.

The classification of fruits so far given refers only to the nature and behaviour of the pericarp. A few examples will illustrate the application of this classification to complete fruits.

(1) Pea: the fruit is simple (legume) and is the ripened carpel.

(2) Honeysuckle: the fruit is simple (berry), is the ripened inferior ovary, and therefore includes the receptacle.

(3) Dandelion: the fruit is simple (achene), and consists of the ripened inferior ovary (carpels and receptacle) and pappus.

(4) Raspberry: the fruit is compound; the simple fruits are drupes (= carpels) inserted on a receptacle, which also bears a persistent calyx.

(5) Strawberry: the fruit is compound, and consists of many achenes (= carpels), and a large fleshy receptacle bearing a calyx with an epicalyx.

(6) Rose: the fruit is compound, consisting of many achenes (= carpels) attached to and concealed in a hollow receptacle which bears a persistent calyx.

CHAPTER XIII

THE DISPERSAL OF SEEDS, AND A SUMMARY WITH REGARD TO THE FLOWERS

In one season a single plant, say a Foxglove, may produce thousands of seeds. If every one of these seeds is to be afforded an opportunity of developing into a mature plant, means must be provided to enable the seeds to reach suitable spots at some distance from the mother-plant. The seeds of flowering plants are conveyed through the air in the same manner as the pollen, in so far that they are either violently ejected (*e.g.* Balsam, *Oxalis*), or are carried by the wind (*e.g.* Dandelion), or borne by animals (*e.g.* Rose, Cherry, *Galium*).

Explosive fruits are not common. The capsule of the Violet opens into three boat-shaped valves, each containing a double row of smoothly-polished seeds. The sides of the boat-shaped valves contract as they dry, and fling out the seeds. To understand this mechanism, we have only to remember the manner in which an orange-pip springs out when squeezed between two fingers.

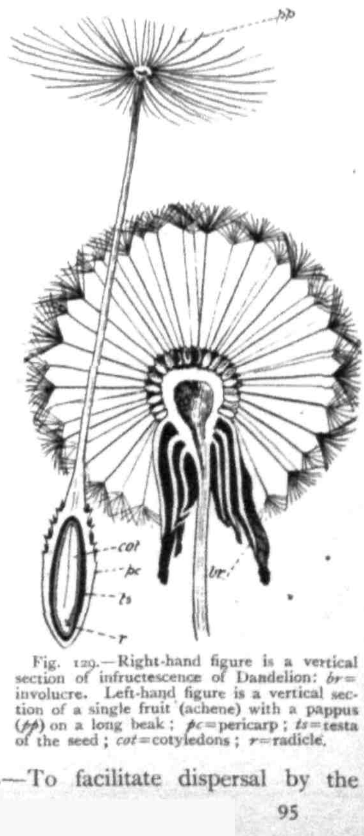


Fig. 129.—Right-hand figure is a vertical section of infructescence of Dandelion: *br*=involucre. Left-hand figure is a vertical section of a single fruit (achene) with a pappus (*pp*) on a long beak; *pc*=pericarp; *ts*=testa of the seed; *cot*=cotyledons; *r*=radicle.

Dispersal by the wind.—To facilitate dispersal by the agency of the wind, the fruits or seeds are very small; or they oppose a large surface to the wind. The large surface may be merely due to the flattened form of the fruit or seed, or it may be caused by the possession of wings or tufts of hair. It is to be noted that when fruits (or their carpels in the case of schizocarps) are closed and indehiscent, they (or the mericarps) are the *parts scattered*, and adapted to aid dispersal; the seeds in this case are passively borne inside the fruits. But if the fruit dehisces, or is open (*e.g.* Gymnosperms), the seeds are the parts scattered, and, as a rule, it is they and not the fruits which are adapted for transference to distant spots. The following table shows the corresponding mechanisms, or forms, in fruits and seeds to aid dispersal by the wind:—

Fig. 130.—Samara of Elm.

Mechanism or Form.	SEEDS DISPERSED (Fruits dehiscent or open).	FRUITS DISPERSED (Fruits indehiscent or separating).
1. Minute size.	Orchid (Fruit = capsule).	Nutlets of Labiatæ.
2. Flattened form.	Wallflower (Fruit = *siliqua*).	Mericarps of many *Umbelliferae* (fig. 185).
3. Wings.	Scotch Pine (is a *Gymnosperm*), fig. 67.	Samaræ (fig. 130) of Elm, Birch, and Sycamore.
4. Tufts of hair.	Willow, Poplar, Willow-herbs (Fruits are capsules).	The achenes of many Compositæ (Dandelion, etc.) with a *pappus* (fig. 129). Achene of *Clematis* with a hairy style.

Dispersal by clinging to Animals.—Many fruits possess hooks, or rough or sticky surfaces, which cause them to adhere to animals which happen to brush against them. It is usually the fruit, not the seed, which possesses hooks, etc. As examples may be cited, the "burrs" of the infructescences of many Compositæ (Daisy-family), the hooked achenes of *Geum*, and the fruits of *Galium* (Goose-grass).

Seeds dispersed by being transported inside Animals.—It is to be noted that when the seeds or fruits are scattered by the wind, or by clinging to animals, the fruits are dry, whereas seeds or fruits which are dispersed by being carried inside animals are usually possessed of conspicuous and fleshy coats, which invite animals to notice and eat them. The fruits being eaten, the seeds are protected by an indigestible stone (in drupes) or testa (in berries and Gymnospermous fruits), and pass through the body of the animal uninjured. When the fruit is indehiscent it is usually the pericarp which is succulent and invites the animals which effect the dispersal of the fruit. When, on the other hand, the carpels are open, as in Gymnosperms and dehiscent fruits, the seed is often brightly coloured, and may have a succulent inviting outgrowth (the *aril*).

SEEDS DISPERSED.	FRUITS DISPERSED.
(*a*) *Fleshy aril*— Seeds of Yew (Gymnosperm) with bright-red fleshy "aril," distributed by birds.	(*a*) *Fleshy pericarp*— Drupes of Cherry, Blackberry, Raspberry, distributed by birds. Larger drupes of plums, etc., distributed by larger animals (Mammals). Berries of Mistletoe, Currants, distributed by birds. (*b*) *Fleshy or coloured receptacle*— Rose-hip, Strawberry, both distributed by the agency of birds.

Protection of the embryo in the seed.—The embryo and food-substance inside the testa require protection against climatic influences which would hasten their disorganisation and decay, and against attacks on the part of animals and fungi. The embryo and food-substance are therefore protected by a firm hard coat. When the fruit is dehiscent and the seeds travel naked, the testa is thick and strong (*e.g.* Wallflower, Bean). When the fruit is dry, indehiscent or separating, the seed is protected by the pericarp, and there is no necessity for the testa to be so thick—in fact, it may be quite imperceptible or absent (*e.g.* Grasses). Finally, in fleshy indehiscent fruits the stony layer of the pericarp of drupes protects the embryo, and the testa is thin, whereas in berries there is no stony layer, so that the testa of the seed must be well developed in order to withstand the action of the digestive juice of animals which eat the fruits.

SUMMARY OF THE FUNCTIONS OF PARTS OF FLOWERS, FRUITS, AND SEEDS.

1. The **calyx** usually protects the young flower bud (*e.g.* Poppy). It may also serve as a means of attracting insects by its colour (*e.g.* Clematis), or act as a factory (*e.g.* Mallow), or as a receptacle for honey (*e.g.* Wallflower). Sometimes the calyx aids in the dispersal of the seeds by the agency of the wind (*e.g.* pappus of Compositæ).

2. The **corolla** serves to attract insects which will effect cross-pollination. It may further bear nectaries (*e.g.* Buttercup).

3. The **andrœcium**.—The pollen pollinates the flower, and is indispensable for the production of seed. The anther manufactures the pollen. The filaments bring the anthers into the position which will lead to cross-pollination by wind or insects, or to self-pollination. As good examples, illustrating the fact that the length of the filaments is to be explained in accordance with the method of pollination, we have but to compare and contrast the flowers of the Primrose, of Grasses, and the cleistogamic flowers of the Violet. The time and direction of dehiscence also are related to the method of pollination; we note, for instance, the introrse dehiscence of the Violet and of Composites, the extrorse dehiscence in the Buttercup when the flower opens.

4. The **gynæcium**.—The embryo-sac in each ovule is the region in which the embryo and its food (endosperm) arise. The ovary protects the ovules. The stigma receives the pollen-grains. The style raises the stigma to the proper height so as to bring about cross-pollination or self-pollination. The size, shape, and time of ripening of the stigma and style bear relation to the method of pollination (see Grasses, Compositæ, Violet).

5. **Sugar**.—Sugar is excreted in flowers in order to attract insects which will effect cross-pollination. Sugar is manufactured in many fruits, and is responsible for their sweetness of flavour, in order to allure animals (mainly birds in this country) which will disperse the seeds.

6. **Pericarp**.—The pericarp protects the seeds and often facilitates their dispersal. Often it is brightly coloured so as to attract the notice of animals. It may or may not dehisce.

7. The **testa** serves to protect the embryo and food-substance of the seeds. Consequently it is thin and delicate when the seeds are adequately protected by the pericarp.

8. *Wings, hooks,* and *hairs on seeds or fruits* serve to facilitate the dispersal of the seeds. Sometimes the hooks or spines may also aid in protecting the fruits against animals which would eat them and destroy the seeds.

PART II

CLASSIFICATION OF ANGIOSPERMS

CHAPTER XIV

CLASSIFICATION

WHEN a number of plants are so closely alike that they obviously may be the offspring of one original parent, they are said to be a number of *individuals* all belonging to one *species*. But if two or more plants are very similar, yet exhibit certain constant slight distinctions, they are described as being different species of one *genus*. For example, in English meadows there are to be found three common kinds of Buttercups—the Bulbous Buttercup, the Creeping Buttercup, and the Meadow Buttercup. As they possess so many characteristics in common, they are included in one genus, *Ranunculus*; but as they each display certain characteristics peculiar to themselves, they receive distinct species-names, and are known as *Ranunculus bulbosus*, *R. repens*, and *R. acris* respectively. When the divergences between two or more plants are more considerable, they are referred to different genera. For example, the Clovers are included in the genus *Trifolium*. Comparing the various genera thus constituted, they exhibit amongst themselves both resemblances and dissimilarities. Those genera which are sufficiently alike are grouped together to form a *family* or *order*; so that all genera are included in certain orders. Thus the Buttercups (*Ranunculus*) and the Marsh Mallow (*Caltha*) are included in one order, the Ranunculaceæ; whilst the Clovers (*Trifolium*) and Vetches (*Vicia*) belong to another order, the Leguminosæ. In like manner the families may be grouped together to form cohorts, then series, then sub-classes, and finally classes; but this statement will be more easily understood after glancing through the following scheme of classification of some of the Angiosperms:—

ANGIOSPERMS.

CLASS I.: **Dicotyledons.**—Seedling has two cotyledons. Leaves net-veined. Floral leaves in fours and fives.

CLASS II.: **Monocotyledons.**—Seedling has one cotyledon. Leaves parallel-veined. Floral leaves in threes.

CLASS I.: DICOTYLEDONS

SUB-CLASS I.: APETALÆ. Petals absent.

1. *Cupuliferæ.* Flowers epigynous diclinous. ♂ flowers in catkins. Fruit indehiscent one-seeded. Trees or shrubs.
2. *Salicaceæ.* Flowers hypogynous diclinous. ♂ flowers in catkins. Fruit dehiscent with many seeds. Trees or shrubs.

[3. *Euphorbiaceæ.** Flowers diclinous. In the fruit the three (sometimes two) carpels separate and open; one or two seeds in each chamber.]

SUB-CLASS II.: POLYPETALÆ. Corolla polypetalous.

I. **Thalamifloræ.**—Flowers hypogynous without a well-developed disk.

(a) *Gynæcium apocarpous.*

4. *Ranunculaceæ.* Stamens indefinite.

(b) *Ovary syncarpous with parietal placentation.*

5. *Papaveraceæ.* Flowers actinomorphic. Sepals and petals in twos or threes. Stamens indefinite.
6. *Fumariaceæ.* Flowers zygomorphic. Sepals and petals in twos.
7. *Cruciferæ.* Flowers actinomorphic. Sepals and petals four each. Stamens two short and four long.
8. *Violaceæ.* Flowers zygomorphic. $K5\ C5\ A5\ G\ (\underline{3})$.

(c) *Ovary syncarpous. Placentation free-central.*

9. *Caryophyllaceæ.* Flowers actinomorphic. Stamens ten or fewer.

* This is not the correct systematic position of the **Euphorbiaceæ**; but the family is placed here because it is easier for beginners to identify plants belonging to it when it is classed amongst the Apetalæ.

(d) *Ovary syncarpous. Placentation axile.*

10. *Malvaceæ.* Flowers actinomorphic. Stamens indefinite, filaments united and adhering at the base to the corolla. Anthers one-lobed.

II. **Discifloræ.** Flowers hypogynous with a distinct disk.

11. *Geraniaceæ*. Flowers actinomorphic. Stamens 5 + 5 (obdiplostemonous) or five only. Fruit beaked with five chambers, each with one seed.
12. *Oxalidaceæ.* Flowers actinomorphic. Stamens 5 + 5 obdiplostemonous. Fruit five-chambered, with a number of seeds in each chamber.

III. **Calycifloræ.** Flowers perigynous or epigynous.

(a) *Perigynous usually. Gynæcium apocarpous.*

13. *Papilionaceæ*. Flowers zygomorphic, papilionaceous, weakly perigynous. Stamens ten, with the filaments all combined, or one separate from the other nine. Carpel one.
14. *Rosaceæ*. Flower actinomorphic. Stamens usually indefinite (rarely epigynous).

(b) *Epigynous. Gynæcium syncarpous.*

15. *Umbelliferæ*. Flowers actinomorphic in umbellate inflorescences. K5 or 0 C5 A5 $G\ (\overline{2})$. Fruit a schizocarp.

SUB-CLASS III.: GAMOPETALÆ. Corolla gamopetalous.

(a) FLOWERS HYPOGYNOUS. Gynæcium syncarpous.

(1) *Flowers actinomorphic* (stamens equal in number to the petals; corolla regular.)

16. *Primulaceæ*. Placentation free-central. Stamens equal in number to the petals opposite to them.
17. *Convolvulaceæ.* Ovary two- (three-) chambered, with two ovules in each chamber; sometimes each chamber subdivided by a false partition into two halves, each containing one ovule. Twining herbs.
18. *Solanaceæ.* Ovary two-chambered, with several ovules in each chamber.

19. *Boraginaceæ*. Ovary four-lobed, four-chambered, with one ovule in each chamber. Fruit four nutlets.

(2) *Flowers zygomorphic* (stamens fewer than the petals; corolla irregular).

20. *Labiatæ*°. Ovary four-lobed, four-chambered, with one ovule in each chamber.
21. *Scrophulariaceæ*. Ovary two-chambered, with several ovules in each chamber.

(b) Flowers Epigynous. Gynæcium syncarpous.

22. *Caprifoliaceæ*. Ovary two- (three-) chambered. Leaves opposite.
23. *Compositæ*°. Inflorescence a capitulum. Anthers united. Ovary one-chambered, with one ovule.

Class II.: MONOCOTYLEDONS

I. Perianth Petaloid. Ovary syncarpous.

(a) *Flower actinomorphic* (perianth regular, ovary inferior).

24. *Liliaceæ*°. Stamens six.

(b) *Flower actinomorphic*. Ovary inferior.

25. *Amaryllidaceæ*. Stamens six.
26. *Iridaceæ*. Stamens three.

(c) *Flower zygomorphic*. Ovary inferior.

27. *Orchidaceæ*. Perianth irregular. Usually only one anther present; it is gynandrous.

II. Perianth small or absent.

(a) Flowers ♀ ♂ on a spadix usually in a spathe.

28. *Araceæ*.

(b) Flowers usually ☿ in spikelets invested by chaffy bract-scales.

29. *Gramineæ*.

[It will be well for young beginners to confine their attention to those families which are specially marked with the sign ° in the above list.]

DICOTYLEDONS.

CUPULIFERÆ (Oak Family).

Trees or shrubs. Leaves simple. Monœcious. Staminate inflorescence usually a catkin. Flowers small, inconspicuous, apetalous. Perianth small, green, or absent. Carpels two or three (rarely four or six), syncarpous, inferior, usually with a two or three-chambered ovary; one or two ovules in each chamber. Fruit one-seeded, indehiscent, often a nut. Seeds without endosperm.

TYPE: HAZEL (*Corylus avellana*).

Vegetative Characters.—Shrub: the main stem breaks up into several larger branches a short distance above the ground. The main root present in the seedling grows only for a short time; it gives off several lateral roots which run horizontally close beneath the surface of the soil. These horizontal roots (or the base of the stem) frequently produce slender adventitious shoots—*suckers*—which grow vertically upwards. These shoots, in turn, can produce adventitious roots of their own at their bases, and subsequently may become disconnected from the mother-plant by reason of the decay of the connecting parts. Thus the Hazel may multiply by suckers (compare Raspberry canes and Rose trees).

Leaves alternate, arranged in two rows, or on vigorous suckers often in three rows, with small stipules which soon fall; the margin is twice-serrate. It will be noted that in the bud-condition the two halves of each leaf are folded together along the mid-rib: the one half of the leaf is slightly larger than the other and overlaps the latter in the bud.

On the approach of winter the stem ceases to elongate, and produces a terminal resting-bud. This resting-bud is clothed externally by leaves whose stipules are developed into scales, but which possess no lamina. Inasmuch as the leaves are ranked into two rows, their stipules naturally are arranged into two double rows. Consequently these bud-scales are arranged in pairs on opposite sides of the stem, and each pair of scales represents the two stipules of one leaf. The lateral (vegetative) resting-buds are similar, but they have in addition two scale-like prophylls inserted below the remainder of the scales. Within the scales are hidden the young foliage-leaves. In February or March the plant blossoms before its vegetative buds unfold; when the latter become active their scales drop off after being forced apart by the growing stem and by the emerging foliage-leaves (figs. 6-11). Inasmuch as these scales were set close together, after they have fallen their scars form small groups; whereas the fallen foliage-leaves, having been separated by longer internodes, are represented by scars which are widely separated along the stem. Consequently, on parts of the stem which are from one to three years old, it is easy to recognise which portions bore scales. Each such group of scale-scars represents one winter. We can, therefore, tell the age of a tolerably young stem by counting the number of its groups of scale-scars. Thus, if we commence at the apex of a resting vegetative shoot, the portion of the stem which connects it with the first group of scale-scars represents one year's growth. Again, travelling farther down, that part of the stem which connects this first group of scars with the next lower group represents another (previous) year's growth, and hence it is two years old, and so on.

Inflorescences.—The stamens and carpels do not occur together in the same flowers. The staminate flowers are arranged in pendulous spike-like inflorescences — catkins. The carpellary flowers are grouped together in small bud-like inflorescences, which can be recognised by the tufts of red stigmas which protrude from their tips. Both kinds of inflorescences are borne upon certain axillary dwarf-branches. In order to understand the arrangement of these dwarf-branches, we will follow the growth of a vegetative bud which commences to sprout in spring. The bud opens, the stem emerges and grows during the summer, and bears foliage-leaves. In the axils of these leaves three varieties of buds arise—vegetative buds, buds enclosing the young carpellary flowers, and buds destined to grow out into branches bearing the staminate inflorescences. The first two forms of buds are externally similar; they are resting-buds, and remain dormant during the following winter. But the third type of bud grows out at once and develops into a dwarf-branch. This branch has no foliage-leaves, but it bears on its basal parts a number of scales, whilst its terminal portion is a staminate inflorescence (catkin). In addition, lateral catkins may arise in the axils of one or two of the higher scales of this dwarf-branch. The scales soon drop off. Thus, when we examine the Hazel-trees flowering in February (see fig. 131); we find the staminate catkins (♂) are arranged, usually several together, on short branches of the previous year's stem: the catkins rest naked through the winter. The buds (♀) enclosing the carpellary flowers now show that they are not vegetative resting-buds, a tuft of red stigmas protrudes from their tips. These buds also stand laterally on a part of the stem which was formed in the previous year; also occasionally in the axils of the basal scales of the dwarf-branch which bears the catkins.

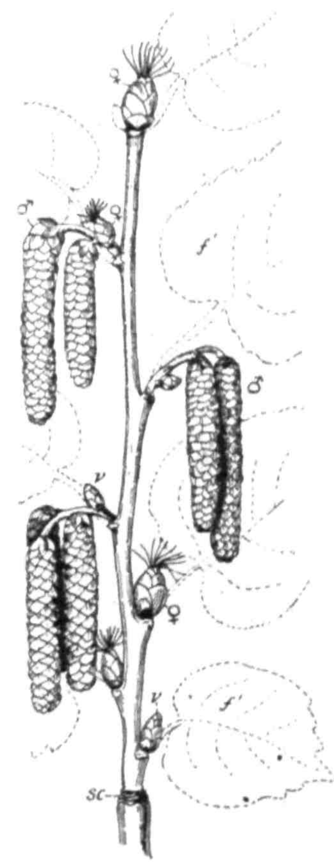


Fig. 131.—Shoot of Hazel bearing inflorescences. The stem from the scale-scars (*sc*) was produced in the previous year. The dotted leaves have fallen off; *v* = vegetative buds.

Staminate Inflorescence (fig. 131 ♂).—The inflorescence consists essentially of a number of bracts and axillary flowers, which are spirally arranged on a long axis. There is one flower in connection with each bract. Two prophylls (fig. 132, *pr*), representing the first two leaves on the flower-stalk, are present, but are fused with the bract (*br*), for no flower-stalk occurs. The **staminate flower** (fig. 132) consists solely of four stamens, which are attached to the bract in place of being on a flower-stalk in the axil of that bract. Each stamen is halved almost to the base of its filament, so that at first sight there appear to be eight stamens, each of which possesses only half a complete anther. The anther is crowned by a tuft of hairs.

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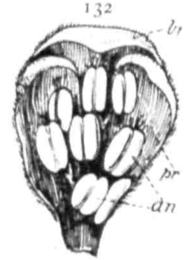


133

Fig. 132.—Staminate flower of Hazel inserted on bract (*br*), with which two prophylls (*pr*) are fused.
Fig. 133.—Diagram of ditto.

The bud of the dwarf branch (fig. 134) which produces the carpellary inflorescence is often loosely described as being the inflorescence. The bud is really the commencement of a foliaged branch which terminates in an inflorescence; but the foliage-leaves do not unfold till after the flowering is over. On the axis of this bud the most external and lowest leaves are two prophylls; then succeed three to four pairs of scale-like stipules (*sc*), and within these two to four foliage-leaves. Thus so far the bud is like a vegetative bud; but above these foliage-leaves follows the true inflorescence. The **carpellary inflorescence** consists of four to eight spirally-placed bracts (*br*) with axillary flowers, which are borne on a shortened axis. In the axil of each bract (fig. 135) there stand the buds of two carpellary flowers, so that the whole inflorescence possesses eight to sixteen flower-buds. But only a few of the flower-buds develop into mature flowers. Each **carpellary flower** has a minute, indistinctly lobed, green perianth (*pe*), which is inserted on the

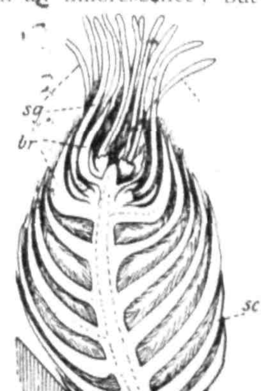


Fig. 134.—Vertical section of bud of Hazel terminating in a carpellary inflorescence.

ovary. The flower is therefore epigynous. The inferior ovary is two-chambered, and is surmounted by two long purplish-red thread-like stigmas (*sg*): thus the gynæcium consists of two

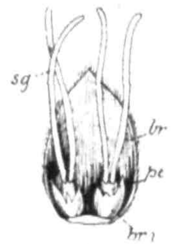


Fig. 135.—Two carpellary flowers of Hazel in the axil of a bract (*br*).

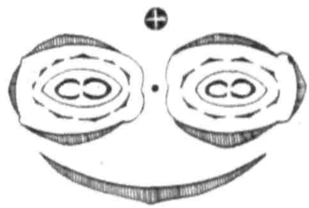


Fig. 136.—Diagram of ditto.

carpels, and is syncarpous. The ovules do not develop until after the pollination of the stigma (fig. 137); consequently it is useless to look for ovules before pollination. Each chamber of the ovary (*ov*) then contains one ovule (*o*). At the base of each flower (*i.e.* below the insertion of the ovary) there is a little cup-like envelope (*br.i*)—an involucre. It is well to note that this is not a calyx or a perianth; it is a collection of bracts.*

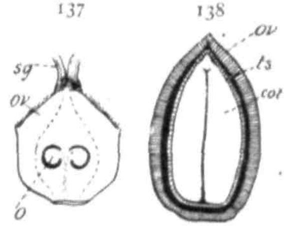


Fig. 137.—Vertical section of recently pollinated gynæcium of Hazel.
Fig. 138.—Vertical section of nut of Hazel.

Fruit. — After pollination the ovules are produced, but, as a rule, only one ovule in an ovary develops fully so as to form a seed. The fruit (fig. 138) is a nut containing the one seed. The involucre originally investing the base of the ovary grows vigorously and forms the green cup (fig. 139, *cp*) round the fruit. **Seed.**—The kernel of the nut is the seed; it has a thin papery testa (*ts*), but possesses no endosperm. The main mass of the seed is

* It is impossible to explain in this book the exact method in which this involucre is formed; but in reality it represents three joined bracts which are also prophylls. The diagram 136 explains the nature of the cupule and the inflorescence in the axil of each bract.

constituted of the two large fleshy cotyledons (*cot*) of the embryo. **Dissemination.**—The fruits merely fall to the ground, or may be carried away by animals (especially squirrels) for future use.

Pollination.—The flowers are wind-pollinated. When the staminate catkins have matured they bend down, and, as their bracts separate, the anthers dehisce and drop pollen on to the bracts below them. The pendulous catkins are easily shaken by the wind, and the pollen may reach the tufts of stigmas.

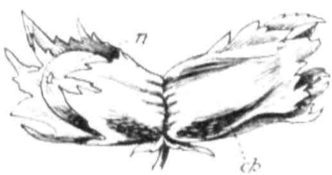


Fig. 139.—Two nuts of Hazel invested with cupules (*cp*).

(i.) Note the inconspicuousness of the flowers which are not visited to any appreciable extent by insects.

(ii.) That a large amount of dry pollen is produced, and easily shaken from the flowers.

(iii.) The large filamentous stigmas.

(iv.) The absence of nectaries.

All these are common features of wind-pollinated flowers.

TABLE ILLUSTRATING THE FLORAL CHARACTERS OF OTHER CUPULIFERÆ.

	BIRCH (*Betula*).	OAK (*Quercus*).	BEECH (*Fagus*).
♂ INFLORESCENCE.	Catkin: 3 flowers in the axil of each bract. Note two prophylls lying within the bract.	Catkin, pendulous: 1 flower in the axil of each bract. No prophylls.	Head-like cluster pendulous.
♂ FLOWER.	Perianth 2—1-phyllous. Stamens 2, halved, therefore apparently 4 ½-anthers.	Perianth 6-7-lobed. Stamens 6-12.	Perianth 4-7-segmented. Stamens 4-12.
♀ INFLORESCENCE.	Catkin: 3 flowers in the axil of each bract. Note that the bract is fused with two prophylls.	Erect head-like spike: 1 flower in the axil of each bract. Usually no prophylls visible, but a basin-like cupule occurs.	Head-like cluster, 2-flowered, erect.
♀ FLOWER.	Perianth absent. Ovary 2-chambered, each chamber 1-ovulate: styles 2.	Perianth 3 + 3. Ovary 3-chambered, each chamber 2-ovulate: style 1, stigma 1.	Perianth 3 + 3. Ovary 3-chambered, each chamber 1-ovulate: styles 3.
FRUIT.	1-seeded winged achene (samara) No cupule.	Acorn = a nut with a woody cupule. Note that of the six ovules in an ovary, only one develops into a seed.	The 4-valved cupule encloses the infructescence of two fruits. Fruit (from one ovary) is a 3-angled, 1-seeded nut.

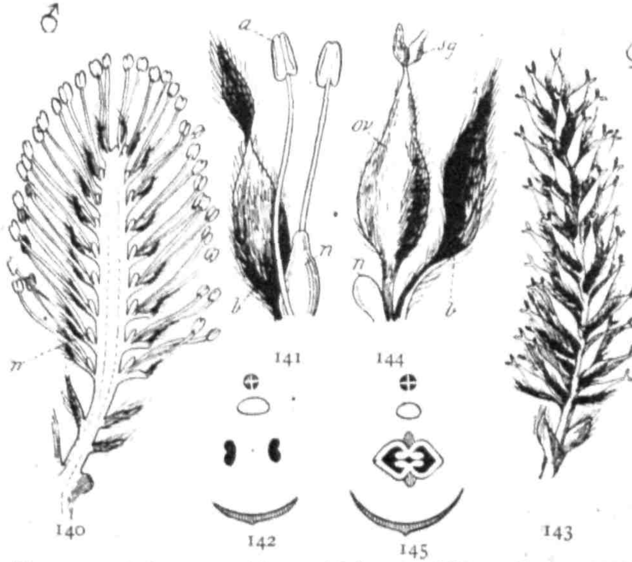
For the remaining characters of these three trees, see the characters of the family.

SALICACEÆ (Willow Family)

Trees or shrubs. Leaves alternate stipulate. Diœcious. The inflorescences are catkins. The staminate flower consists of two or more stamens and a disk. The carpellary flower consists of a hypogynous disk, and a syncarpous superior gynæcium composed of two carpels: ovary, two-chambered, with many ovules on two parietal placentæ: stigmas, two.

TYPE I.: COMMON SALLOW OR WILLOW (*Salix caprea*).

Vegetative characters.—A tree or shrub, with alternate, stipulate leaves. Each resting-bud is completely encased in



Figs. 140-145.—Inflorescence and flowers of *Salix caprea* (Willow). Fig. 140.—Vertical section of staminate inflorescence. Fig. 141.—Staminate flower inserted on a bract. Fig. 142.—Diagram of ditto. Fig. 143.—Carpellary inflorescence. Fig. 144.—A carpellary flower inserted on a bract. Fig. 145.—Diagram of ditto.

two bud-scales. Many of the terminal buds of the branches die in late autumn and drop off during the winter, and in the following year the highest axillary bud of these branches shoots out, and thus continues the growth of the branch. Thus the Willow-branches are sympodia. **Inflorescences**: the stamens and carpels do not occur on the same individual, the plant is diœcious. The flowers are arranged in catkins which are erect, not pendulous. Each catkin arises, in July, in the axil of a foliage leaf, on a part of the stem formed during that year. The foliage-leaves fall off in autumn. Consequently, when the catkins burst out in the following year (from March to May), they are seen to be in the axils of fallen leaves on a part of the stem which was produced during the previous year. The inflorescences (figs. 140, 143) open before the foliage-leaves emerge from their buds. The axis of the inflorescence bears at its base a few scales, and higher up a number of scale-like bracts and axillary flowers. One flower stands in the axil of each bract. The **staminate** (♂) **flower** (fig. 141) consists of two stamens (*a*) and a greenish nectary (*n*) situated on the base of a bract (*b*). The stamens have long filaments, extrorse anthers, and sticky pollen. The **carpellary** (♀) **flower** (fig. 144) is also inserted on a bract (*b*); it consists of a nectary (*n*) and a syncarpous gynæcium composed of two carpels. The ovary (*ov*) is stalked, and has one chamber which contains many ovules attached to two parietal placentæ. The single short style forks above into a two-armed stigma (*sg*). The nectary is regarded as part of the flower, and, being inserted below the ovary, the flower is described as hypogynous. **Fruit and dissemination.**—The fruit is a two-valved capsule which allows the escape of the numerous minute seeds. The seeds are scattered by the wind, and each seed is possessed of a tuft of silky hairs, which forms the sailing mechanism.

TYPE II.: POPLARS (*Populus*).

Poplar-trees differ from the Willows in having pendulous catkins, staminate flowers with from four to an indefinite number of stamens [some Willow flowers have as many as five stamens], and dry pollen. Moreover, the flowers have no nectaries, though they possess a hypogynous basin-like outgrowth, which is regarded as either a disk or as a perianth.

Pollination of the Willow and Poplar.—The Willow is insect-pollinated, whereas the Poplar is wind-pollinated. In accord ance with these facts we note that the catkins of the Willow are erect, its flowers produce honey, and its pollen is sticky. But the catkins of the Poplar hang loosely and are easily shaken by the wind; the flowers produce no honey; the pollen is dry; and finally the stigma, being lobed to a greater extent than in the Willow, it offers a larger surface for the reception of the pollen.

EUPHORBIACEÆ (Spurge Family)

Plants sometimes having a milky juice. Flowers usually apetalous, diclinous, hypogynous. Perianth small or absent. Gynæcium, syncarpous, with a lobed three- (rarely two-) chambered ovary, having one-two ovules in each chamber. Fruit a capsule. Seeds endospermic.

TYPE: PETTY SPURGE (*Euphorbia peplus*).

Vegetative characters.—An annual herb containing a white milky juice and with simple leaves. **Inflorescence**: the stem, which is simple or has two large branches, terminates in a compound inflorescence, which is an umbel-like cyme of three

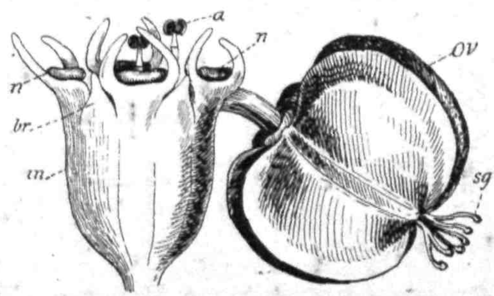


Fig. 146.—Cyathium of *Euphorbia peplus.*

branches. Each of the latter is in turn a two-branched cyme (dichasium), the branches of which may again be forked cymes (dichasia). But throughout the whole inflorescence the actual termination of each shoot is formed by a peculiar inflorescence termed a *Cyathium*, which looks like a simple flower (figs. 146, 147).—The cyathium has a cup-like involucre (*in*) formed by the union of five bracts (*br*) which collectively surround a number of flowers. At the points of junction of four of these bracts are four crescent-shaped *nectaries* (*n*), often described as *glands*. Within the involucre a

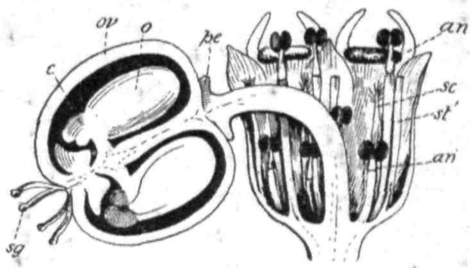


Fig. 147.—Vertical section of cyathium of *Euphorbia peplus*.

number of stamens (*a*, *an*, *an'*) and small scales (*sc*) appear to be ranged round a long-stalked three-lobed ovary (*ov*). **Staminate flower** (fig. 148): each apparent stamen is really a naked staminate flower consisting of only one stamen situated on a flower-stalk. A joint in the stalk of the stamen represents the point at which the filament is inserted on the flower-stalk. The part below the joint is the flower-stalk (*st*), and the portion above is the stamen with a filament (*f*). [In a plant which is closely related to *Euphorbia* there is a little perianth at the joint.] The floral formula is K0 C0 A1 G0. These stamen-like flowers are arranged in five lines opposite the five bracts* (figs. 149, 150). Each of these radial lines of staminate flowers represents an inflorescence standing in the axil of a bract (diagram 149). **Carpellary flower** (figs. 146, 147): the single central gynæcium with its long stalk represents a simple naked flower composed of three carpels. In some spurges there is a distinct hypogynous perianth, consisting of three or six perianth-leaves: even in the Petty Spurge there is a trace of this perianth (*pe*). The ovary (*ov*) is three-lobed and three-chambered, with one

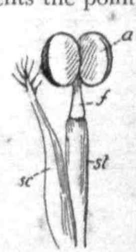


Fig. 148.—A staminate flower of *Euphorbia peplus*, and an adjoining scale (*sc*).

* This is more clearly seen in a large cyathium like that of *Euphorbia lathyris*.

ovule (*o*) in each chamber. There are three forked styles with stigmas (*sg*) on the summit of the ovary. The floral formula is K0 (minute) C0 A0 G $\underline{(3)}$. **Fruit.**—The three-lobed ovary forms a three-valved capsule. **Seed.**—Endospermic.

We see therefore that the cyathium (figs. 149, 150) is a cymose inflorescence consisting of one terminal carpellary

Fig. 149.—Diagram of cyathium of *Euphorbia*. 1, 2, 3, 4, 5 are bracts.

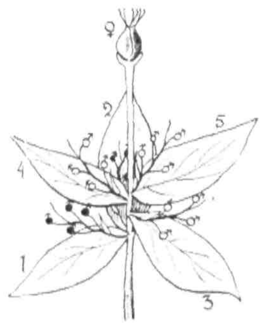


Fig. 150.—Scheme of cyathium of *Euphorbia*. 1, 2, 3, 4, 5 are bracts.

flower and lateral staminate inflorescences arising in the axils of five bracts which form the involucre.

RANUNCULACEÆ (Buttercup Family)

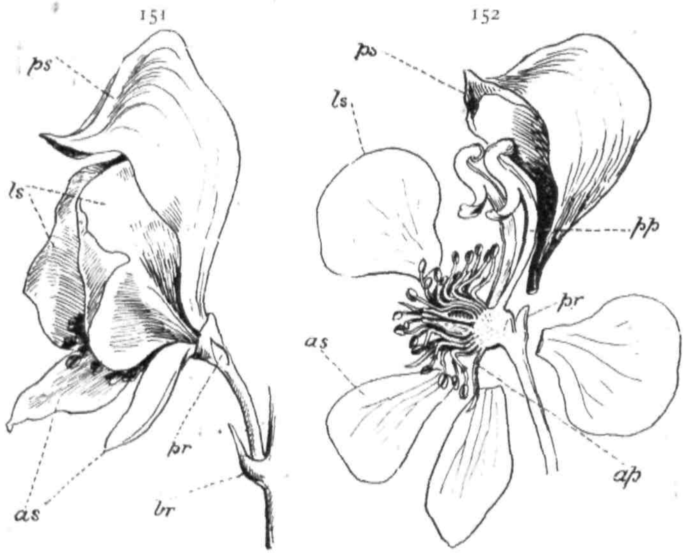
Usually herbs. Leaves alternate (except *Clematis*). Flowers, usually showy, acyclic or hemicyclic, regular (except Monkshood and Larkspur), hypogynous. Sepals polysepalous, often petaloid. Petals polypetalous or absent. Stamens numerous. Carpels usually more than one, apocarpous, superior. Seed endospermic.

TYPE I.: BUTTERCUPS (*Ranunculus acris*, *R. bulbosus*, *R. repens*).

Vegetative characters.—Perennial herbs. Leaves alternate, simple, deeply divided. Stipules are absent, but there is a leaf-sheath at the foot of the petiole. In the first two species the stem is erect, and in *R. bulbosus* it is swollen at the base. In *R. repens* the stem is not erect, but forms creeping runners, which are fixed to the soil by adventitious roots given off from the nodes. **Inflorescence**:—cymose; the axis ends in a flower. When present, the lateral inflorescences are two-branched (dichasia) or one-branched (monochasia). Note the two small prophylls on each lateral axis of the inflorescence, and that in the region of the flowers the leaves are simplified; they are bracts. **Flower** (figs. 60, 61).—The flowers of these three species of buttercup are so alike that one general description will suffice. The flowers are hemicyclic, monoclinous (☿), regular, and hypogynous. *Sepals* (*cal*, *sp*) five, separate, green. *Petals* (*cor*, *p*) five, alternating with the sepals, separate. Note that there is a little pocket—the *nectary* (*n*)—at the base of the inner face of each petal. *Stamens* (*and*) numerous (∞), hypogynous, spirally arranged, separate. *Carpels* (*gyn*) numerous (∞), apocarpous, superior, spirally arranged on a conical *receptacle* (*r*). Each carpel contains one basal ovule (*o*) in its one-chambered ovary; style, very short; stigma, knob-like. **Fruit**:—compound, consisting of numerous achenes (fig. 115) upon a common receptacle. (Each achene is derived from one carpel.) **Seed** endospermic (*end*) with a minute embryo (*emb*). **Pollination**.—The outermost stamens ripen before the inner ones and before the carpels. Their anthers dehisce towards the petals. At this early stage the flower is practically staminate, for the stigmas cannot be pollinated because they are not ripe, but are covered by the closed anthers of the inner stamens. Gradually the rest of the stamens ripen and dehisce, but the stigmas are ready for pollination before the innermost stamens have dehisced. Thus, when it first opens, the flower cannot be pollinated, subsequently it can be either cross-pollinated or self-pollinated. Many kinds of insects (beetles, flies, bees, and butterflies) visit the flowers for the sake of the scarcely-concealed honey or for the pollen, and act as pollinating agents.

TYPE II.: MONKSHOOD (*Aconitum napellus*).

The Monkshood differs from the Buttercups in the following points:—*Inflorescence*, a terminal raceme. *Calyx* (*ps*, *as*, *ls*) blue, petaloid; of the five sepals the posterior one (*ps*) is hood-like; irregular. *Petals* eight; the two posterior (*pp*) petals are long-clawed nectaries concealed under the large posterior sepal; the other petals (*ap*) are small or absent. There are three separate *carpels*, each with many parietal ovules in the ovary. The *fruit* consists of three follicles. The flower is irregular, and is zygomorphic in a median plane. **Pollination.**—The flower is proterandrous;



Figs. 151, 152.—Flower of Monkshood: *br* = bract; *pr* = prophylls.

pollination by its own pollen appears to be thus rendered impossible. Cross-pollination is accomplished exclusively by the aid of humble-bees. As the humble-bee alights on the flower, it uses the two lateral sepals as a platform, and the consequence is that the lower surface of the bee's body comes into contact with the anthers and stigmas. In freshly-opened flowers it is the anthers against which the insect strikes. But in older flowers the stamens have bent back, and the stigmas, which are now ripe, touch the lower surface of the body of the bee at precisely the same spot as do the anthers in a younger flower. This arrangement favours cross-pollination. The insect, when visiting the inflorescence, commences at the lowest flowers, and travels up the inflorescence. In this manner pollination by the pollen even of the same plant is averted. The long-stalked nectaries are completely concealed from outside view, nor can their honey be reached excepting with great difficulty by any insects other than humble-bees. The Monkshood-flower is a flower especially adapted for pollination by the agency of these particular insects, consequently it is absent from those regions of the earth which are without humble-bees.

Comparison between the pollination and flowers of the Buttercup and of the Monkshood.—The yellow Buttercup-flower is actinomorphic, and is directed upwards. Inasmuch as its nectaries are feebly concealed and easily accessible, insects with quite short tongues can discover and reach the honey. The flower is therefore visited by many (more than sixty) kinds of insects. These alight on the petals or on the carpels, and may cause cross-pollination or self-pollination. The blue Monkshood-flower is zygomorphic, and is inclined to the horizon. Its honey is carefully concealed and protected, so that only specialised insects can discover and reach it. The flower is pollinated exclusively by one group of insects—humble-bees—which visit in one particular way, and necessarily effect cross-pollination as they go from plant to plant. Self-pollination is impossible in the Monkshood-flower. The Monkshood- and Buttercup-flowers thus illustrate the fact that the colours and shapes of flowers are associated with the varieties of insects which visit and pollinate those flowers. We also see that the irregular zygomorphy is a means employed to cause the visiting insect to deal with the flower in a particular manner so as to ensure cross-pollination. Finally, we note that the zygomorphic flowers are associated with certain classes of insects, not, as is the Buttercup, with many varieties of flower-visiting insects.

TABLE SHOWING THE CHARACTERS OF OTHER RANUNCULACEÆ.

NAME.	SYMMETRY.	SEPALS.	PETALS.	FRUIT, a collection of	NOTES.
Clematis.	⊕	Petaloid.	Absent.	Achenes.	Climbing by means of the stalks of the opposite leaves. Achene blown by the wind, and possessing a persistent feathery style.
Anemone.	⊕	Petaloid.	Absent.	Achenes.	Involucre.
Marsh Marigold (*Caltha palustris*).	⊕	Yellow, petaloid.	Absent.	Follicles.	Honey excreted by the bases of the carpels.
Christmas Rose (*Helleborus*).	⊕	Large, persistent, sometimes petaloid.	About 13, spirally arranged, tubular nectaries.	Follicles.	Transition from foliage-leaves to bracts and sepals.
Winter Aconite (*Eranthis hiemalis*).	⊕	6, petaloid.	6, tubular nectaries.	Follicles.	Involucre.
Larkspur (*Delphinium ajacis*).	↓	5, blue, petaloid; irregular; posterior is spurred.	1, posterior blue spur, which possibly may represent two joined petals.	1, follicle.	

PAPAVERACEÆ (Poppy Family)

Herbs with milky juice. Leaves exstipulate. Flowers usually showy, regular, hypogynous. Sepals, two (three), polysepalous. Petals, 2 + 2, polypetalous. Stamens numerous. Carpels, from 2 to ∞, syncarpous: ovary one-chambered, with many ovules on parietal placentæ. Fruit dehiscent. Seeds endospermic.

Type I: FIELD-POPPY (*Papaver rhœas*).*

Vegetative characters.—Annual herbaceous plant, with milky juice (latex) and bristly hairs. Leaves alternate, stalked,

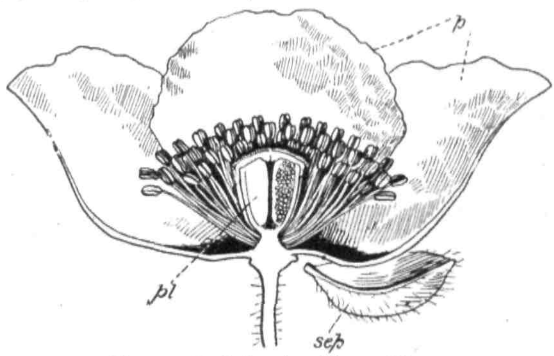


Fig. 153.—Vertical section of flower of Poppy.

without stipules, simple, pinnately cleft. **Flower** (fig. 153) solitary, terminal, actinomorphic, hypogynous. *Sepals* (*sep*) two, separate, falling off as the flower opens. *Petals* (*p*), 2 + 2, separate, arranged in two alternating whorls of two each; the outer two also alternate with the two sepals. The petals are crumpled in the bud; each petal may have a black spot at the base of its inner face. *Stamens* numerous (∞), hypogynous. *Carpels* from eight to twelve, syncarpous, superior. Ovary (*ov*) one-chambered, with from eight to twelve parietal placentæ (*pl*) protruding inwards from the wall, and having many ovules on their faces (also fig. 155). Stigmas (fig. 154 *s*) from eight to twelve, sessile, forming velvety bands radiating

* The flowers of almost any sort of Poppy may be examined in place of the one here described.

from the centre of the roof of the ovary. We should expect the stigmas to lie above the gaps between the placentæ, because a stigma usually stands above the dorsal suture (mid-rib) of the carpel to which it belongs. But in the

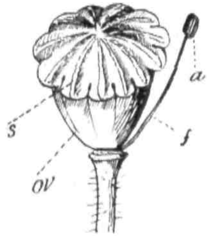


Fig. 154.—Gynæcium and one stamen of Poppy.

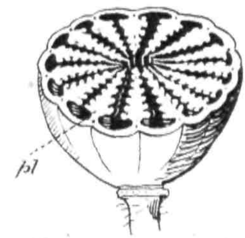


Fig. 155.—Cross-section of ovary of Poppy.

Poppy the stigmas stand directly above the placentæ, instead of alternating with them. When stigmas are thus superposed on the placentæ they are said to be *commissural*. **Fruit** (fig. 126) a capsule, opening by lateral pores which alternate with the stigmas. **Seeds** minute, and easily transported by the wind. **Pollination**: the flower has no nectaries, but is visited by insects desiring its pollen.

TYPE II.: COMMON CELANDINE (*Chelidonium majus*).

Herb with yellow juice and yellow flowers. Its flowers differ from those of the Poppy in that the gynæcium consists of two combined carpels, with two commissural stigmas surmounting a one-chambered ovary possessed of two parietal placentæ. The fruit (fig. 121) is a *siliqua*, which has no septum; consequently the persistent placenta (*r*) (*replum*) forms an empty frame which bears the ovules.

Uses, Peculiarities, etc. of Papaveraceæ.—The latex of *Papaver somniferum* is the source of opium. *Eschscholtzia* is a familiar garden plant, with flowers tending to become perigynous.

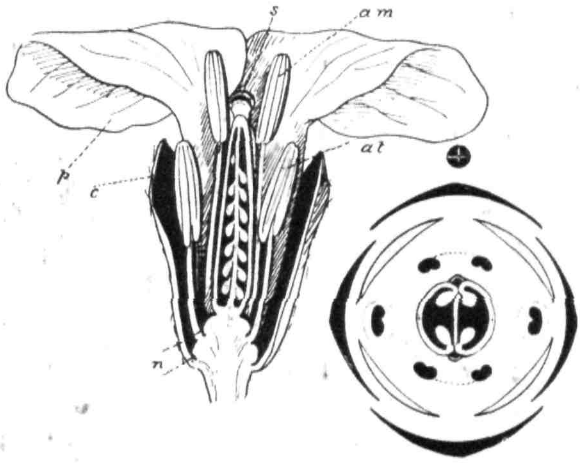
CRUCIFERÆ (Wallflower Family)

Herbs. Leaves alternate, exstipulate. Inflorescence, racemose, usually without bracts. Flower, regular, hypogynous.

Sepals, 2 + 2, polysepalous. Petals, 4, polypetalous. Stamens, 2 + 4, two short and four long. Carpels, 2, syncarpous: ovary, divided by a false septum connecting two parietal placentæ; ovules numerous. Fruit usually a siliqua. Seed, no endosperm.

TYPE I.: WALLFLOWER (*Cheiranthus cheiri*).*

Vegetative characters.—A perennial herb, slightly woody at the base. Leaves alternate, exstipulate, simple. **Inflorescence**: a raceme without bracts. *Note the absence of prophylls from the flower-stalks.* **Flower** (*fig.* 156) *actino-*



156 157

Fig. 156.—Vertical section of flower of Wallflower.
Fig. 157.—Floral diagram of ditto.

morphic, hypogynous, brown or yellow, sweet-scented. *Sepals* 2 + 2, separate. The four sepals are arranged in two alternating *whorls of two each. The two lateral sepals (c) form the inner* whorl, and are inserted higher on the receptacle than the two outer median sepals. The lateral sepals are slightly enlarged

* Almost any Crucifer will serve in place of the Wallflower, so uniform is the structure of the flowers, excepting as regards the nectaries.

and pouched at their bases: the little pouches act as receptacles to hold the honey poured out by the nectaries. *Petals* (*p*) four, separate, arranged in one whorl alternating with the four sepals. Note the blade (*la*) and claw (*cl*) of each petal (fig. 83). *Stamens* (figs. 156, 88) 2 + 4, hypogynous, separate. There are two short stamens (*at*) and four long ones (*am*). The two shorter stamens are opposite the inner (lateral) sepals, and are inserted at a lower level than the four long stamens. Therefore the two shorter stamens form an outer whorl, and the four long ones constitute an inner whorl of stamens. *Nectaries* (figs. 156, 88): a green nectary (*n*) is situated at the base of each of the two shorter stamens. *Carpels* (figs. 156, 88) two syncarpous, superior. Ovary (*ov*): the two parietal placentæ, bearing numerous ovules, are connected by a delicate partition (septum) which divides the cavity of the ovary into two chambers. When an ovary is divided into several chambers, and contains numerous ovules, the placentation is usually axile; but in the Cruciferæ the ovules are attached to the walls, and not to the axial partition. It is for this reason that the partition is regarded as not originally a true part of the carpels, and is therefore termed a *false septum* (fig. 156). The short style is surmounted by two commissural stigma-lobes (*s*). **Fruit** (fig. 120) a pod-like siliqua. It is necessary to distinguish between the persistent placentæ forming the replum (*re*) and the false septum (*fs*). **Seed** (fig. 116) contains no endosperm, the embryo is bent. The seeds are compressed, and are easily carried about by the wind, and are thus able to reach the tops of walls, on which the plants frequently grow.

TYPE II.: SHEPHERD'S PURSE (*Capsella bursa pastoris*).

This plant is an annual little weed, in reality an ephemeral, flowering at nearly all seasons of the year. The inflorescence and flowers are constructed on the same plan as those of the Wallflower. The length of the four long stamens is such as to occasion regular self-pollination. The fruit is of peculiar shape, and is a shortened siliqua.

Uses, peculiarities, etc., of Cruciferæ.—Though they appear so different, Cabbages, Cauliflowers and Broccolis, Brussels-sprouts, Turnips, Rape, and Mustard are plants all belonging to the same genus—*Brassica.* They are placed in one single genus, because the flowers, fruits, and seeds are closely alike. The Cabbage (*Brassica oleracea*) is cultivated for the sake of its large leaves. The Brussels-sprouts is merely a variety of cabbage producing many large green axillary buds which form the edible portions. The Cauliflower and Broccoli are other varieties of the cabbage, cultivated for the sake of their much-branched inflorescences, the stems of which are fleshy and colourless, the flowers being reduced to minute buds. The "heart" of a Cauliflower or Broccoli is a branched terminal inflorescence. The Turnip (*Brassica campestris*) is a biennial possessing a tuberous main root, which we eat as a vegetable. The Swede is a variety of the Turnip, also cultivated for the sake of its swollen tap-root. The Rape is still another variety of *B. campestris*, and from its seeds colza-oil is obtained. The seeds of the Black Mustard (*Brassica nigra*) are the source of the condiment mustard. We use the young plants of the White Mustard (*Brassica alba*) in the composition of salads; this is the Mustard cultivated with Cress to form "mustard and cress." Cress (*Lepidium sativum*) is also one of the Cruciferæ. The edible part of the Horse-Radish (*Cochlearia armoracia*) is the rhizome (not the root): the leaves of the Horse-radish are stipulate. The swollen red tubers of the Radish (*Raphanus sativus*) are formed mainly by the hypocotyl. Water-cress (*Nasturtium officinale*) also belongs to this family. A few Cruciferæ are cultivated in gardens for the sake of their flowers: such are the Stocks, Candytuft (with zygomorphic flowers).

VIOLACEÆ (Violet Family)

Herbs. Leaves alternate, stipulate. Flowers often showy, irregular, hypogynous. Sepals five, polysepalous. Petals five, polypetalous. Stamens five. Carpels three, syncarpous; ovary one-chambered, with three parietal placentæ bearing many ovules. Fruit, a three-valved capsule.

TYPE: PANSY (*Viola tricolor*).

Vegetative characters.—Herb. Stem branched, with or without a rhizome. Leaves alternate, stalked; stipules large, leaf-like. Leaves rolled towards their upper faces in the bud. **Inflorescence.**—The flower is solitary, axillary. Note the two prophylls (fig. 158-3, *pr*) inserted at a considerable distance up the flower-stalk. **Flower** median-zygomorphic, hypogynous. *Sepals* five, separate. Note the prolongation of the sepals below their points of attachment. *Petals* five, separate, irregular. The anterior petal is produced into a long spur

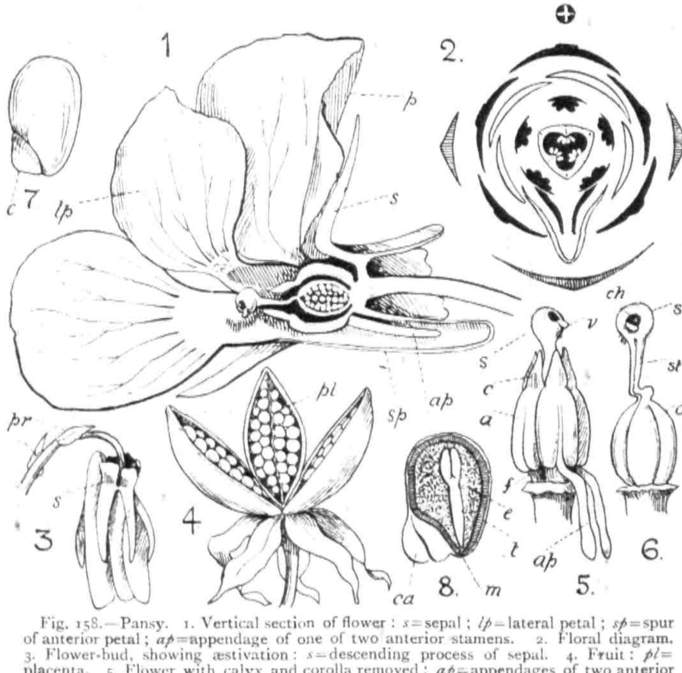


Fig. 158.—Pansy. 1. Vertical section of flower: *s*=sepal; *lp*=lateral petal; *sp*=spur of anterior petal; *ap*=appendage of one of two anterior stamens. 2. Floral diagram. 3. Flower-bud, showing æstivation: *s*=descending process of sepal. 4. Fruit: *pl*=placenta. 5. Flower with calyx and corolla removed: *ap*=appendages of two anterior stamens; *f*=filament; *a*=anther; *c*=continuation of connective; *s*=swollen end of style; *v*=shutter of stigma-cup. 6. Gynæcium: *ov*=ovary. 7. Seed with lump (*c*). 8. Vertical section of seed: *ca*=lump: *m*=micropyle; *t*=testa; *e*=endosperm. (1-6 based on Kny's figures of Pansy.)

(fig. 158-1, *sp*) which conceals the two nectaries and acts as a honey receptacle. The petals are arranged in the bud condition in the manner known as *descending*-imbricate. *Stamens* (fig. 158-5) five, hypogynous. Anthers (*a*) introrse, arranged close together round the single gynæcium. The connectives are continued above the anthers, and form little flaps (*c*). The filaments (*f*) are very short. The filament of each of the two anterior stamens sends a slender elongated process or appendage (*ap*) into the spur of the anterior petal. The green spots at the ends of these two appendages secrete honey, and are the *nectaries*. *Carpels* (fig. 158-6) three, superior, combined. Ovary (*ov*) one-chambered, with three parietal placentæ which bear many ovules. Style (*st*) one, club-like, with a stigma in a pit (*ch*) on the anterior surface of its summit (*s*). **Fruit** (fig. 158-4) a capsule splitting down the dorsal sutures. The three valves contract and jerk out the smooth seeds. **Seed** (figs. 158-7-8) endospermic, with a lump (*c*, *ca*) near the micropyle. **Pollination.**—The anthers dehisce towards the gynæcium at the same time as the stigma ripens. At first sight it appears that self-pollination is inevitable; and, indeed, self-pollination does take place in the whitish-yellow small-flowered variety of the Pansy (*V. tricolor* var. *arvensis*). But in the large-flowered variety of Pansy, which possesses variegated flowers, self-pollination is hindered by a very neat mechanism. The stigma-cup has a little shutter or flap (fig. 158-5, *v*) hinged on to its lower edge. A bee visiting the flower alights on the anterior petal, and, in order to sip the honey, it must push its tongue into the spur of the petal. In so doing, the tongue necessarily passes along the hairy groove between the stigma and the anterior petal. The pollen collects in this groove. Consequently, when the bee alights, its tongue first rubs against the stigma and drags open the "shutter," so that any pollen previously present on the bee's tongue is rubbed into the stigma-cup. As the tongue is pushed farther towards the honey it comes now for the first time into contact with the pollen belonging to the flower itself; and in this way the tongue becomes coated with the flower's own pollen. When the bee has obtained some honey and proceeds to withdraw its tongue, the backward movement of the latter closes the shutter of the stigma-cup, and thus prevents the pollen of that flower from being rubbed into the stigma-cup. In the large blue or variegated flowers of the large-flowered variety of Pansy, the honey is so deeply placed (because the spur is long) that it can be reached only by insects with long tongues: these flowers are pollinated chiefly by bees and humble-bees. On the other hand, in the small yellow or yellowish-white flowers of the other variety of Pansy the honey is more easily accessible: consequently these flowers are visited by insects with shorter tongues (beetles and flies) as well as by bees. It is well to note that the yellow-flowered form has more accessible honey and a wider circle of visitors than the blue-flowered form, which is a "bee-flower"; and to compare this with the case of the yellow Buttercup and the blue Monkshood. Some of the flowers of the small-flowered variety do not open, but pollinate themselves.

The Violets belong to the same genus (*Viola*) as the Pansy, and have their flowers constructed on the same general plan; but the structure of the stigma varies in different species. Many violets have two different kinds of flowers. In the springtime they produce the familiar white or blue flowers; but later in the year they bear a second crop of flowers which are minute and bud-like, and incapable of opening. These closed flowers pollinate themselves and are hence said to be *cleistogamic*.

CARYOPHYLLACEÆ (Pink Family)

Herbs. Leaves opposite. Inflorescence cymose. Flowers regular, cyclic, hypogynous. Sepals four or five. Petals four, five (or none), polypetalous. Stamens usually eight or ten, often obdiplostemonous, usually hypogynous. Carpels from two to five, syncarpous, superior; ovary one-chambered: ovules many, on a central placenta; styles from two to five. Seed perispermic, embryo curved.

TYPE I.: CHICKWEED (*Stellaria media*).

Vegetative Characters.—Annual herb, much branched in a cymose manner (fig. 43). Note the line of hairs on one side of each internode, continuous with a fringe of hairs on the bases of the leaves. Leaves opposite, exstipulate, simple, entire; lower leaves stalked, upper leaves sessile. **Inflorescence** axillary, commences as a two-branched cyme (dichasium). **Flower** (fig. 159) ☿ regular, cyclic; small, white. The flowers vary considerably, but a complete typical flower will be described first, and then the variations will be noted. *Sepals* (*cx*) five, separate. *Petals* (*co*) five, separate. Note the deep division of each petal. *Stamens* $5+5$, hypogynous. The stamens composing the outer whorl (*ap*) are opposite to the petals: whilst the five inner stamens (*as*) alternate with them. The flower is therefore obdiplostemonous. Anthers introrse. *Nectaries* (*n*) five, very small knobs standing outside the five inner stamens and, therefore, opposite the sepals.

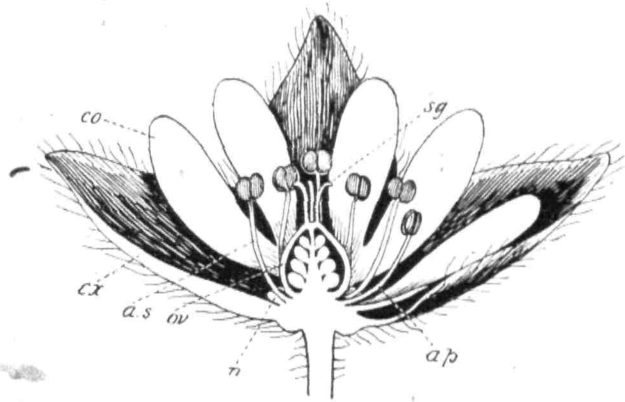


Fig. 159.—Vertical section of flower of *Stellaria media*.

Carpels three, syncarpous, superior: styles three: ovary (*ov*) one-chambered, with many ovules on a central placenta. **Fruit** (fig. 124) a capsule, opening by six valves. **Seed** (fig. 117) small, kidney-shaped, with perisperm. **Variations in the flower.**—The sepals and carpels remain constant in number (excepting that very rarely the sepals may be six in number). In some flowers the five stamens which should be opposite the petals are wanting: in others there are only three stamens, which are opposite three sepals: in still other flowers no stamens are present, so that the flower is carpellary. Again, in some cases the petals are wanting. **Pollination.**—The plants are found in flower throughout the year. The honey is accessible to short-tongued insects, and the flowers are cross-pollinated

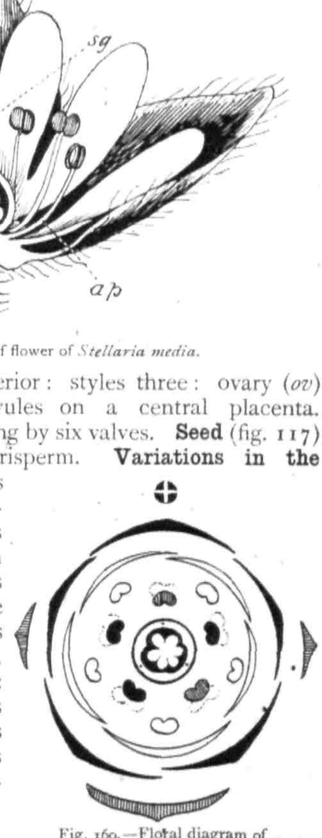


Fig. 160.—Floral diagram of *Stellaria media*.

by the agency of many kinds of insects (bees, beetles, flies, etc.). Self-pollination often takes place in open flowers, because the stigmas come in contact with the anthers; but it also occurs in flowers which remain closed. These closed self-pollinating flowers are merely ordinary flowers which fail to open; they are not reduced and altered as are the cleistogamic flowers of the Violet.

OTHER TYPES: PINK (*Dianthus*): CATCHFLY (*Silene*): CAMPION (*Lychnis*).

The flowers of these plants differ from those of the Chickweed more particularly in having a tubular gamosepalous calyx and long-clawed petals. Their honey is consequently concealed at the bottom of a long tube, and cannot be reached by short-tongued insects. These flowers are exclusively pollinated by insects with long tongues—*i.e.* mainly by butterflies and moths. The comparison between these flowers and those of *Stellaria* gives us additional evidence for the view that the shapes of insect-pollinated flowers bear relation to the sorts of insects which pollinate them (see pages 81, 82 and 119-121). It is important to note that Pinks are pollinated by butterflies flying during the daytime, and that they often have a pink colour and delicious scent. Contrast this with the white colour of the flowers of *Lychnis vespertina*, which open at dusk, give out their strongest scent at that time, and are pollinated by night-flying moths. The white colour renders flowers more conspicuous at night.

MALVACEÆ (Mallow Family)

Herbs or shrubs. Leaves alternate, stipulate. Flowers regular, hypogynous, often showy. Sepals five, gamosepalous, valvate. Petals five, nearly polypetalous, joined to the stamens at the base. Stamens numerous, filaments united. Anthers with only two pollen-sacs each. Carpels from three to ∞, syncarpous (or apocarpous). Ovary with from three to many chambers.

TYPE: MALLOWS (*Malva sylvestris* and *M. rotundifolia*).

These two species may be treated together, as they are very similar.

Vegetative characters.—Herbs with hairs. Leaves alternate, stipulate, simple, palmately-veined, lobed, margins scalloped. The leaves are folded in the bud. **Inflorescence,** axillary tufts

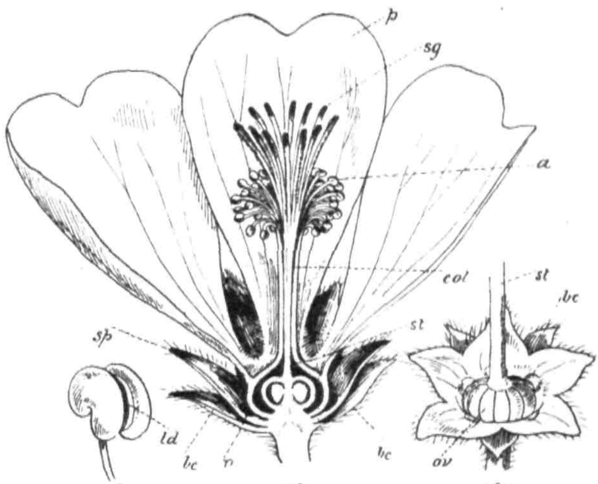


Fig. 161.—Vertical section of flower of *Malva sylvestris*.
Fig. 162.—Upper part of stamen of ditto, showing dehiscence of anther.
Fig. 163.—Portion of flower of ditto, showing calyx, epicalyx (*bc*), and part of style : the stamens and petals are removed.

too complicated for description here. Three bracts close beneath the calyx form an involucre, which is known as the epicalyx (*bc*). **Flower** (fig. 161) actinomorphic ☿, cyclic, showy. *Sepals* (*sp*) five, combined, valvate in the bud. *Nectaries* five pits on the bases of the five sepals, protected by hairs on the margins of the bases of the petals. *Petals* five, contorted in the bud. The petals are united to one another and to the stamens by their bases. *Stamens* numerous, united by their filaments to form a tube (*col*), epipetalous. The numerous stamens are in reality produced by a branching of five stamens placed opposite the five petals. Each anther has only two pollen-sacs, and represents only half a complete anther; it is kidney-shaped (fig. 162). *Carpels* (figs. 161, 163) several, syncarpous, superior. Ovary (*ov*) with several chambers, each representing one carpel and containing one ovule attached to the axile placenta. Style (*st*) one, which divides above into as many branches as there are carpels and ovary-chambers: each branch of the style is stigmatic on its inner and upper surface. **Fruit** (fig. 164) a schizocarp splitting into one-seeded cocci (*cc*). **Pollination.**—In both these species of Mallows the stamens ripen before the carpels, and their opened anthers form a group round the closed erect style-branches. As the stigmas ripen and commence to separate, the filaments gradually bend backwards and outwards. In *M. sylvestris* the anthers are carried completely out of reach of the stigmas, so that the flower cannot pollinate itself. But in *M. rotundifolia* the anthers are not borne so far backwards, whilst the style-branches gradually curl over and bring the stigmas into contact with the open anthers: thus the flower can regularly pollinate itself. The flowers of *M. sylvestris* are more showy, and are visited more frequently by insects which cause cross-pollination. Thus we see that of these two flowers which are so much alike, the more conspicuous is more frequently visited by insects, and consequently more extensively cross-pollinated. This tends to prove that conspicuousness of flowers aids in attracting insects. On the other hand, the less conspicuous flower of *M. rotundifolia* is more often self-pollinated. This fact goes to show that the more perfectly cross-pollination by insects is ensured, the more precautions are taken to avert self-pollination; and that, on the other hand, when cross-pollination is not adequately secured, the flower makes provision for the formation of seeds by self-pollination. Putting both results together, we see that flowers are conspicuous in order to attract insects which shall effect cross-pollination.

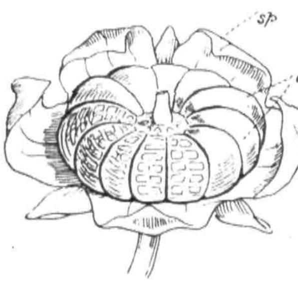


Fig. 164.—Fruit of *Malva sylvestris*: *sp*=sepals; *cc*=cocci.

GERANIACEÆ (Geranium Family)

Herbs with stipulate leaves. Flowers usually regular, hypogynous. Sepals five. Petals five, polypetalous. Stamens 5 + 5, obdiplostemonous, or only five; filaments slightly united at their bases. Carpels five, syncarpous; ovary, five-chambered. Fruit possessing a "beak."

TYPE: HERB ROBERT (*Geranium robertianum*).

Vegetative characters.—Herb, strongly scented, erect or spreading. Leaves alternate, stipulate, simple, deeply divided. The leaf is in the first place incompletely divided into three

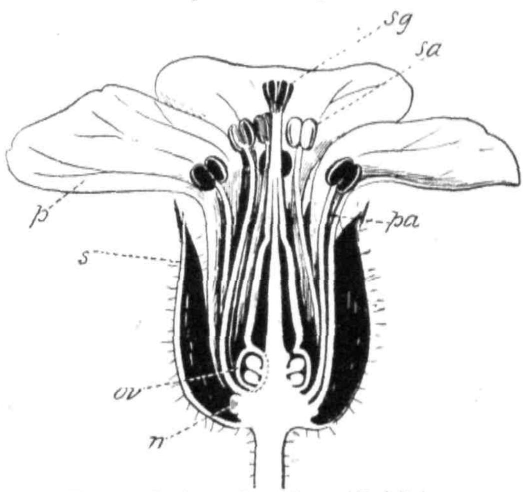


Fig. 165.—Vertical section of flower of Herb Robert.

primary divisions, thus showing that the venation is essentially palmate, though the finer nerves are pinnate. **Branching and Inflorescence.**—The branching at the summit of the stem is cymose: the primary method of branching is forked (dichasium), but the subsequent branches are monochasia. The flowers are ultimately arranged in pairs. Each pair represents a monochasium with a terminal flower and a lateral flower which arises in the axil of the larger of the two prophylls of that axis. **Flower** (fig. 165) actinomorphic, ☿, cyclic: purplish-red.

Sepals (*s*) five, imbricate. *Petals* (*p*) five, separate. *Stamens* 5 + 5, with their filaments slightly combined at their bases.

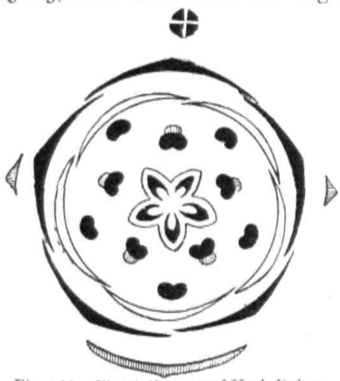


Fig. 166.—Floral diagram of Herb Robert.

The stamens (*pa*) forming the outer whorl are opposite the petals (obdiplostemonous) and are shorter than those (*sa*) opposite the sepals; anthers, introrse. *Nectaries* (*n*) five lumps opposite the sepals, and lying between them and the five inner stamens. *Carpels* five, syncarpous, superior. Ovary (*ov*) five-lobed, five-chambered: each chamber contains two ovules attached to the axile placenta. Style single, but dividing above into five branches with stigmas (*sg*). It is important to note that the ovary-chambers and five style-branches are opposite to the petals. Thus the five carpels are opposite to the petals instead of being opposite to the sepals: this is an additional peculiarity of many obdiplostemonous flowers.

Fruit (fig. 167).—The main single part of the style elongates, and becomes a strong "beak." Only one ovule in each chamber forms a seed. When the fruit is ripe, as it dries, the five carpels separate, one by one or simultaneously, from below upwards in such a manner that the five seed-containing chambers (cocci) are carried up by elastically curling strips of the "beak," and are thrown off. The fruit is a peculiar schizocarp, because the carpels do not open whilst still attached to the mother-plant. In some of the British species of *Geranium* the

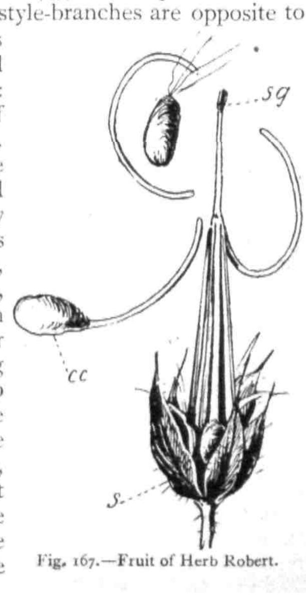


Fig. 167.—Fruit of Herb Robert.

carpels open, and the seeds are violently thrown out as the strips of the beak contract, so that their fruits are explosive capsules.

OXALIDACEÆ (Woodsorrel Family)

This family is often included in the Geraniaceæ. The typical floral formula is the same in both families K5 C5 A5 + 5 G(5). The Oxalidaceæ differ from *Geranium* in the following respects:—(i.) The leaves are compound. (ii.) Often there are more than two ovules in each of the five chambers of the ovary. (iii.) There are five styles. (iv.) The capsular fruit has no "beak."

TYPE: WOODSORREL (*Oxalis acetosella*).

Herb with a rhizome, which is a true axis and not a sympode. The leaves are compound, digitate, with three leaflets. Note their day- and night- movements (figs. 249, 250). Inflorescence is cymose. Flowers ⊕ white. (i.) The petals are contorted in the bud. (ii.) The five nectaries are opposite the petals, and lie between them and the five outer stamens. (iii.) The plant produces small cleistogamic flowers in addition to ordinary white ones. (iv.) The fruit is a capsule dehiscing along the dorsal sutures: the seeds are ejected violently from it by the elastic contraction of a white fleshy coat which envelops each seed separately like an outer testa.

PAPILIONACEÆ (Pea Family).

Herbs or shrubs. Leaves alternate, stipulate, usually compound. Flowers irregular, cyclic, weakly perigynous. Sepals five, gamosepalous. Petals five, polypetalous, consisting of a standard, two wings, and a keel. Stamens ten, weakly perigynous; filaments of all, or of all but one, combined. Carpel one, superior. Fruit usually a legume. Seed non-endospermic.

TYPES: GARDEN PEA (*Pisum sativum*): WHITE CLOVER (*Trifolium repens*).

Vegetative characters.—Herbs, with alternate compound stipulate leaves. The Clover is a creeping perennial, its leaves (figs. 251, 252) having three leaflets and two small stipules each. The pea is a climbing annual with pinnate leaves (fig. 59) and large green persistent stipules (*n*); some of the leaflets are converted into tendrils (*br*). **Inflorescences** axillary: capitulum in the clover; peculiar, two-flowered in the pea. **Flowers** (figs. 96, 97) median-zygomorphic, irregular, ☿, cyclic, perigynous. *Sepals* five, combined to form a five-toothed cup. *Petals* five, polypetalous, irregular. The posterior petal (*sd*) is the largest, and is termed the standard (*vexillum*); the two lateral petals (*w*) are termed the wings (*alæ*); whilst the two anterior petals (*k*), which have separate claws, cohere by their blades, and form the boat-shaped keel (*carina*). The æstivation (fig. 101) is *descending-imbricate* (see page 73). *Stamens* (fig. 87) ten, weakly perigynous. The single posterior stamen (*pa*) is separate, but the filaments of the nine others cohere to form a tube (*an. t*), which is open only along its posterior face (as well as at the summit). Though the ten stamens represent two whorls of five each, all ten are inserted at the same level on the receptacle. The stamens lie hidden inside the keel, and they in turn conceal the single ovary. The base of the inner face of the staminal tube acts as a *nectary*. *Carpel* one, superior; ovary (*ov*) one-chambered, bearing a double line of ovules on the parietal placenta; style one; stigma (*sg*) simple. **Fruit** (fig. 119), a legume. *Seeds* non-endospermic. **Pollination**.—Like the flowers of all the Papilionaceæ, these flowers are specially constructed for pollination by means of bees. The bee alights on the flower in such a way as to use the alæ as a platform. This depresses the alæ, which in turn drag the keel (carina) down. In this manner the upwardly directed stigma and the pollen inevitably come into contact with the under-surface of the bee's body. The bee thrusts its tongue into the slit on the upper (posterior) face of the staminal tube and sips the honey which accumulates between the base of the ovary and the base of the staminal tube. When the bee flies away, the two alæ and the keel rise up again and assume their former positions. The bee, visiting flower after flower, may thus effect cross-pollination. The flowers may self-pollinate themselves. In these flowers we may note: (i.) How completely the alæ and carina protect the honey and pollen from rain and marauding insects. (ii.) The honey can only be reached from above (from the posterior face of the staminal column). (iii.) The alæ, when forced down, drag the carina with them, because they are inter-locked with (*e.g.* Pea), or actually joined to (*e.g.* Clover), the sides of the carina. [Try and see what causes the wings and keel to return to their places when the pressure of the bee is removed.]

OTHER TYPES OF PAPILIONACEÆ.

In the flower of the Broom and some other Papilionaceæ the filaments of all ten stamens are joined together, but there still remains a small window-like opening on each side of the base of the posterior stamen. These two openings render the honey accessible to bees. The White Clover has a creeping stem; the Broad Bean (*Vicia faba*) is an erect plant; the Pea, Vetches, and others climb by tendrils, which are modified leaflets; whilst the Scarlet Runner (*Phaseolus*) has a twining (left-handed) stem by which it climbs erect slender supports. The Papilionaceæ have on their roots peculiar swellings or tubercles, which are caused by microscopic fungi. The compound leaves of many types display day- and night- movements.

ROSACEAE (Rose Family)

Herbs or shrubs. Leaves usually alternate, stipulate. Flowers regular, usually perigynous. Sepals usually 4 or 5. Petals usually 4 or 5, polypetalous. Stamens usually numerous, bent inwards in the bud. Carpels, from 1 to ∞, usually apocarpous, usually superior; styles more or less separate; often 1 or 2 ovules in each carpel. Fruit various. Seeds with very little or no endosperm.

TYPE I.: DOG ROSE (*Rosa canina*).*

Vegetative characters.—Shrub, with numerous prickles, which are "subsidiary outgrowths." Leaves alternate, with persistent stipules, pinnately compound with a terminal leaflet; margins of the leaf saw-like (serrate). **Inflorescence** terminal; the flower terminates a branch; in addition, one or two subjacent bracts may have a flower in the axil of each. [Look for the transitions between the foliage-leaves and bracts.] **Flower** (fig. 168) actinomorphic, ☿, cyclic; coloured and scented. *Sepals* (*cal*) five. The sepals are imbricate in the bud. The two external sepals have "beards" on both lateral

* Any Rose, save a double variety, may be selected for examination.

margins; a third sepal has one exposed margin which is

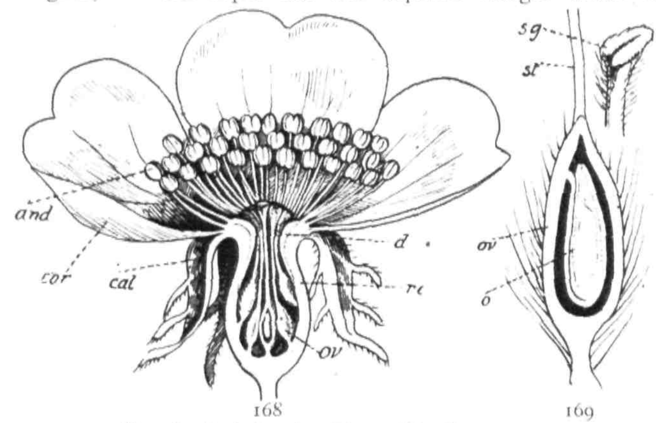


Fig. 168.—Vertical section of flower of Dog Rose.
Fig. 169.—A carpel of ditto, with the ovary cut down the centre.

bearded, and the other margin concealed and not bearded (entire); finally, the fourth and fifth sepals are completely overlapped by the others, and have both margins even. *Petals* (*cor*) five, separate. *Stamens* (*and*) numerous, perigynous, curved inwards in the flower-bud. *Receptacle* (*rc*) [often termed the *calyx-tube*] deeply hollowed, so as to be urn-shaped, with its opening narrowed above. The sepals, petals, and stamens are inserted round the margin of the opening; they are all perigynous. A *disk* (*d*) clothes the lips and coats the lining of the receptacle-tube above the insertion of the carpels. The disk has not been seen to pour out honey. *Carpels* numerous, apocarpous; the many separate ovaries (*ov*) are concealed inside tube of the receptacle, and are inserted on its base and sides. They are superior, because they are not indistinguishably fused with

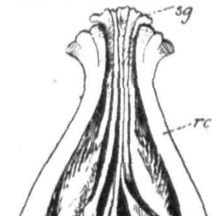


Fig. 170.—Vertical section of compound fruit of Dog Rose: *ov* = pericarp of a simple fruit; *ts* = testa of seed; *e* = embryo *rc* = concave receptacle.

the receptacle. Each one-chambered ovary (fig. 169, *ov*) contains one ovule (*o*), and is surmounted by a single style (*st*), which emerges through the mouth of the receptacular tube and bears a simple stigma (*sg*). **Fruit** (fig. 170) compound, consisting of numerous achenes concealed in the red hollowed receptacle, which bears a persistent calyx. (Each achene is, of course, developed from one of the separate carpels.) **Seeds** having no endosperm. **Dissemination.**—The achenes are scattered by the agency of birds, which peck at the red receptacle and incidentally dislodge the achenes. The red colour serves to render the fruit easily visible to birds.

TYPE II.: STRAWBERRY (*Fragaria vesca*).

The floral formula is the same as for the Rose, K5 C5 A ∞ G ∞. Beneath the calyx, and alternating with the sepals, is a whorl of sepal-like members which forms an epicalyx (fig. 82). The epicalyx represents, in this case, the stipules of the sepals, which have joined together in pairs. The shape of the receptacle is curious (compare fig. 173, representing the Blackberry flower), it is like a shallow saucer (*rc*) with a large lump (*rp*) rising from its centre. The sepals, petals, and stamens are attached to the rim of the saucer, and are therefore perigynous. Numerous apocarpous carpels are inserted on the central outgrowth. The *disk* (*d*) is like a ring, and lines the space between the rim of the saucer and the place of attachment of the central swelling; it excretes honey, and is a nectary. Each carpel (fig. 171) has its style (*sy*) attached to the side of the ovary (*ov*). The ovary contains one ovule (*o*). **Fruit** (fig. 172).—After pollination, the central mass of the receptacle (*rc*) enlarges greatly, becomes first white in colour, and finally changes into the red, sweet, juicy "strawberry" which we eat. Each carpel remains small and forms an achene (*ac*) with one seed (*s*) inside it. The complete **fruit** of the Strawberry is compound, and consists of many achenes

Fig. 171.—A carpel of Strawberry, showing the ovary cut down the middle.

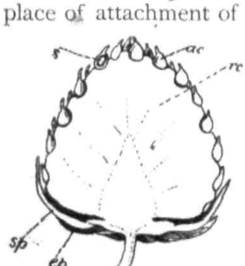


Fig. 172.—Vertical section of compound fruit of Strawberry.

inserted upon an enlarged fleshy receptacle, to which the calyx (*sp*) and epicalyx (*cp*) still adhere. **Dissemination.**—The fruits are dispersed by birds, which eat the juicy receptacle and incidentally swallow the little dry achenes. These achenes have indigestible hard pericarps, and consequently pass uninjured through the bird's body. **Vegetative characters** (fig. 54).—Note the "runners," also the stipulate leaves with three leaflets.

TYPES III.: BLACKBERRY (*Rubus fruticosus*) AND RASPBERRY (*Rubus idæus*).

The flowers (fig. 173) are structurally very like those of the Strawberry, the only important distinctions being that there is

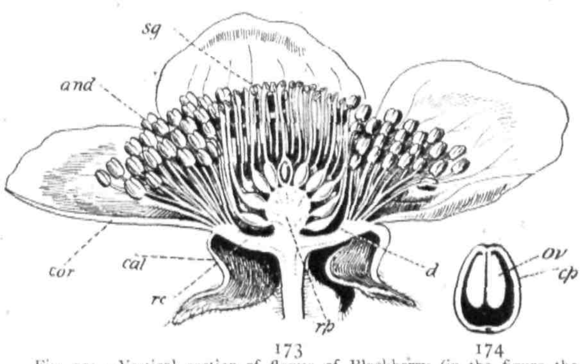


Fig. 173.—Vertical section of flower of Blackberry (in the figure, the terminal part of the receptacle (*rp*) is drawn more spherical than it is in reality).
Fig. 174.—Cross-section of a single ovary of ditto.

no epicalyx, and the carpels contain two ovules each (fig. 174). After pollination the behaviour is different, however. The central outgrowth (*rp*) of the receptacle which bears the carpels does not develop into a large fleshy mass; it remains relatively small. But the carpels enlarge considerably and become one-seeded stone-fruits (drupes), which conceal the receptacular lump in their midst. Thus the fruit (fig. 175) of the Blackberry or Raspberry is compound: it consists of a collection of small stone-fruits (*d*) inserted upon a receptacle which bears also a persistent calyx (*sp*). **Dissemination.**—The fruits are distributed by birds in the same manner as in the

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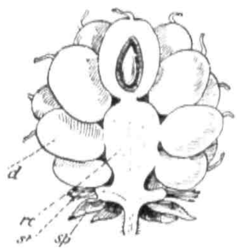

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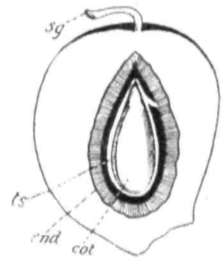


Fig. 175.—Vertical section of compound fruit of Blackberry: *sp*=sepals; *st*=shrivelled stamens; *d*=drupes.

Fig. 176.—Vertical section of a single drupe of ditto: *end* =stony layer of pericarp; *ts*=testa of the seed; *cot*=cotyledons.

Strawberry, but the stony endocarps (fig. 176, *end*) protect the seeds.

Types IV.: CHERRY, PLUM, and APRICOT (*Prunus*).

Prunus (including the Cherry, Plums, and Apricot) has flowers (fig. 177) constructed on the same plan as those of the Rose; but there is only one carpel, containing two ovules, at the bottom of the deep receptacular tube (*rc*) of each flower. After pollination great differences in the behaviour of *Prunus* and of the Rose set in. The receptacle-tube of *Prunus* drops off, and the single carpel grows greatly and becomes a one-seeded stone-fruit

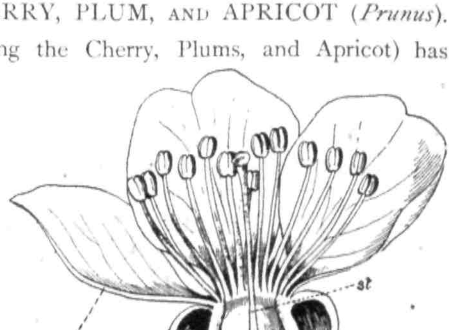


Fig. 177.—Vertical section of flower of Cherry.

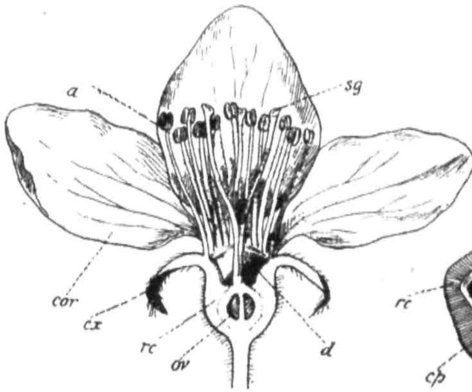
(drupe) (fig. 128). Thus the fruit is simple, and consists of one drupe. The stipules of *Prunus* are not persistent, but drop off.

TABLE SHOWING SOME DISTINCTIONS BETWEEN DIFFERENT SPECIES OF *Prunus*.

I. Leaves rolled (convolute) in the bud.	(*a*) Fruit smooth, with "bloom."	Plums (*Prunus domestica*).
	(*b*) Fruit velvety, yellow.—Apricot (*Prunus armeníaca*).	
II. Leaves folded (conduplicate) in the bud.	(*a*) Fruit black, red, or yellow, smooth, without "bloom."	Cherry (*Prunus cerasus*).
	(*b*) Fruit more or less greenish, usually velvety.	Peach (*Prunus persica*). (A smooth variety of the Peach is known as the Nectarine.)

TYPES V.: APPLE AND PEAR (*Pyrus*): VI.: HAWTHORN (*Cratægus*).

The genus *Pyrus* includes both Apples and Pears. The **flower** (fig. 178) of *Pyrus* possesses five sepals (*cx*), five petals (*cor*), numerous stamens (*a*), and usually five carpels (fig. 179 *cp*). Not only is the receptacle (*rc*) hollowed to form a cup (as in the Rose), but the outer faces of the carpels are fused with the lining of the receptacle-tube. Thus the flower is markedly epigynous. The five carpels are also united to one another by their sides, and, at the most, are only free from each other along their ventral sutures and styles; consequently, a five-chambered inferior ovary is produced. In the flower of the Pear the five styles are separate, but in the Apple the styles are united at their bases. Each of the five ovary-chambers contains not more than two ovules. As the **fruit** (figs. 180, 181, 182) ripens, the lining of each chamber of the ovary becomes a parchment-like endocarp (*cp*). The portion (*rc*) lying outside this core of five endocarps enlarges greatly, and is responsible for the production of the large, fleshy part of the Apple or Pear fruit. The fruit is a peculiar inferior fruit known as a pome. **Dissemination.**—The fruits are adapted



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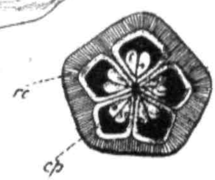

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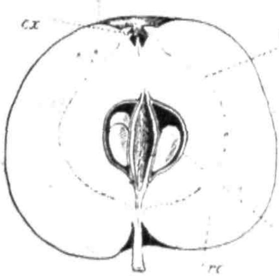

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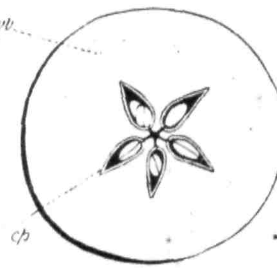

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Figs. 178-181.—Apple. Fig. 178.—Vertical section of flower. Fig. 180.—Ditto of fruit. Fig. 179.—Cross-section of ovary. Fig. 181.—Ditto of fruit.

to invite the visits of fruit-eating beasts, which inadvertently swallow the seeds as they eat the fleshy parts of the fruit.

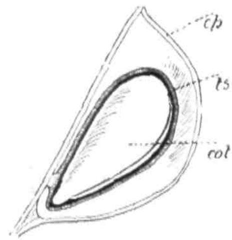


Fig. 182.—A parchment-like chamber removed from fruit of apple, containing a seed: *ts* = testa of seed; *cot* = cotyledons.

The Hawthorn (*Cratægus oxyacantha*) has flowers very similar in plan to those of the Apple and Pear; but the ovary consists of two carpels only, and has two chambers. In the fruit the endocarp around each chamber becomes hard and stony (not parchment-like), so that the fruit is a stone-fruit with two stones. Birds are responsible for the distribution of these red fruits, which are commonly called "haws" or Hawthorn-berries (though they are really stone-fruits). The leaves (fig. 58) have large stipules (*n*), and in the axils of some leaves protective thorn-branches (*d*) arise.

UMBELLIFERÆ (Parsley Family)

Herbs. Leaves alternate. Inflorescence simple or compound umbel. Flower usually regular, cyclic, epigynous, small. Sepals five or none, small. Petals five, polypetalous. Stamens five. Carpels two, syncarpous; ovary inferior, two-chambered, with one ovule in each chamber; styles two. Disk, epigynous. Fruit a schizocarp.

There is such a uniformity in the general habit of the Umbelliferæ, and in the structure of their flowers and fruits, that it is unnecessary to select any particular type. The CARROT (*Daucus carota*), the COW-PARSNIP (*Heracleum sphondylium*) may be mentioned as easily obtainable and recognisable.

Vegetative characters.—The stems are hollow. The leaves are alternate, deeply divided, with broad large sheaths. **Inflorescence** a compound umbel. There is usually a general involucre at the base of the whole inflorescence (main umbel), and also small involucres at the bases of the secondary (partial) umbels. In some plants the axis of an umbel ends in a flower which differs in colour from the rest of the flowers. In the Carrot this central flower is red, whereas the other flowers are white. **Flower.**—Usually ☿, usually actinomorphic, cyclic, usually white or yellow. Floral formula is K5 C5 A5 $G(\overline{2})$. In the Cow-parsnip, and to a less degree in the Carrot, the flowers (fig. 183) at the margin of the inflorescence are zygomorphic by

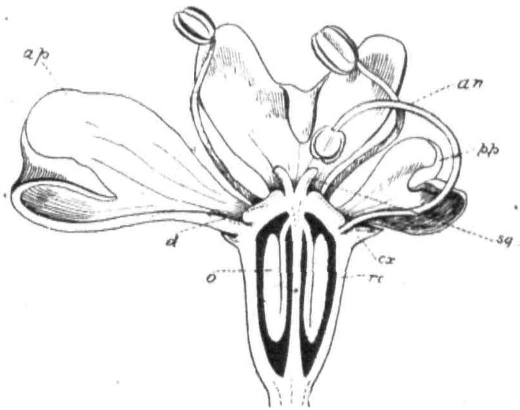


Fig. 183.—Vertical section of a marginal zygomorphic flower of *Heracleum sphondylium.*

reason of the special enlargement of the anterior petals (*ap*), which are directed outwards. *Sepals* (*cx*) five or none; when present the calyx is small, and is only represented by five teeth; in some Umbelliferæ the calyx is absent. *Petals* (*ap*, *pp*), five, separate, often bent inwards at their tips. *Stamens* (*an*) five, epigynous, separate, alternate with the petals, bent inwards in the bud. *Carpels* two, syncarpous, inferior; ovary two-chambered, with one ovule in each chamber; styles two, short. *Disk.*—The fleshy disk (*d*) lies on the roof of the ovary chamber, and the styles appear to emerge from this disk. The disk is a nectary. **Fruit.**—The fruit (figs. 185, 186) is a schizocarp splitting into two one-seeded closed mericarps, which remain for a time attached to the persistent thin portion of the axis (*ch*) (*carpophore*) of the fruit. The

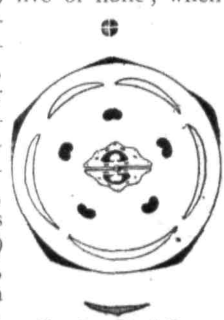


Fig. 184.—Floral diagram of zygomorphic flower of *Heracleum sphondylium.*

fruits have oil canals (v) in their walls which are ribbed. The oil-canals of the mericarps of the Cow-parsnip are of a characteristic club-shape (v). **Seed** (sd) endospermic. **Pollination.**—The flowers are small, and therefore not conspicuous, but they are crowded together in order to form a showy mass of bloom which shall serve to attract the notice of insects. In the Cow-parsnip this showiness is further enhanced by the enlargement of the petals at the margin of the inflorescence.

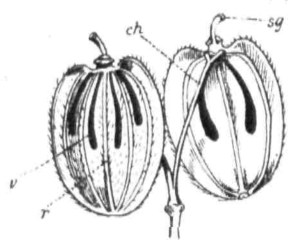


Fig. 185.—Fruit (schizocarp) of *Heracleum sphondylium*: r = ribs; v = oil-canals; sg = stigma; ch = carpophore.

The flowers are for the most part regular, with honey so freely exposed that insects possessing even the shortest tongues can sip at the honey. The consequence is that these flowers are largely visited and cross-pollinated by short-tongued insects, especially by flies, beetles, and wasps; but are largely neglected by long-tongued insects, such as moths and butterflies.

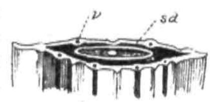


Fig. 186.—Part of mericarp of *Heracleum sphondylium* cut across: sd = seed.

USES, PECULIARITIES, ETC., OF UMBELLIFERÆ.

The Carrot and Parsnip (*Pastinaca*) are cultivated for the sake of their large tap-roots; Parsley (*Petroselinum*) for its green leaves; Celery (*Apium graveolens*) for its partially etiolated leaf-stalks and stem-base. The Hemlock (*Conium*) and some other Umbelliferæ are poisonous.

PRIMULACEÆ (Primrose Family)

Herbs. Flowers regular, hypogynous, often showy. Sepals five, gamosepalous. Petals usually five, gamopetalous. Stamens usually five, opposite the petals, epipetalous. Carpels superior, syncarpous; ovary one-chambered, with many ovules on a free-central placenta; style one; stigma simple. Fruit a capsule.

TYPE I.: PRIMROSE (*Primula vulgaris*).

Vegetative characters.—Perennial herb with a stout vertical rhizome. Leaves radical, exstipulate, simple. **Inflorescence**

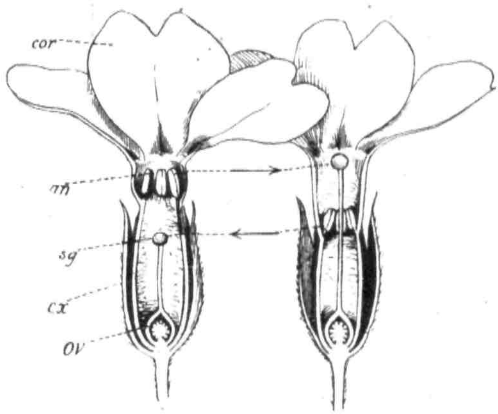


Fig. 187.—Vertical sections of the two forms of flowers of Primrose, showing *the corresponding positions of anthers and stigmas.*

an umbel at the summit of a bare inflorescence-axis. Bracts are present, but there are no prophylls on the flower-stalks. **Flower** (fig. 187) actinomorphic, ☿, cyclic, hypogynous. Two different forms of flowers occur on different individuals. *Sepals* (*cx*) five, combined. *Petals* (*cor*) five, combined to form a corolla with a long tube. Stamens five, inserted on the corolla. The five stamens are opposite (not alternate with) the five petals. Anthers with introrse dehiscence. *Carpels* five, syncarpous, superior. Ovary (*ov*) one-chambered, with many campylotropous ovules on a free-central placenta. Style one. Stigma knob-like. As there is only one style, a simple stigma, and the ovary is one-chambered with a central placenta, it be-

Fig. 188.—Floral diagram of Primrose.

comes a matter of difficulty to prove that there are five carpels. The facts that the capsule opens by five double-teeth, and that in "monstrous" flowers five leaves often replace the single gynæcium, suggest that the gynæcium represents five carpels. **Fruit** (fig. 189) a capsule dehiscing by five double-teeth. **Seeds** shield-like in shape, endospermic. **Pollination.**—The flowers of some Primrose plants have stamens inserted in the throat of the corolla, so that the five anthers form a circle just within the mouth of the corolla-tube; in these flowers the style is short, the stigma is hidden deep down in the corolla-tube: this is the *short-styled form* of flower (fig. 187, left-hand figure). In other plants the relative positions of the anthers and stigma are just reversed, and a long style raises the stigma to the mouth of the corolla-tube, whilst the shortness of the filaments and their insertion lower down the corolla-tube cause the anthers to be hidden inside the tube: this is the *long-styled form* of flower (fig. 187, right-hand figure). Comparing the two forms of flowers, we see that the anthers of one form stand at just the same level up the corolla-tube as does the stigma of the other form (see fig. 187). Honey is excreted by the base of the ovary. An insect with a sufficiently long tongue, when it goes from one form of flower to the other, will accurately transfer the pollen from the anthers of the one on to the stigma of the other in each case, because the pollen is deposited on a particular part of the insect's tongue. Spontaneous self-pollination is possible in the short-styled form.

Fig. 189.—Fruit of Primrose.

TYPE II.: POOR-MAN'S WEATHER-GLASS

(*Anagallis arvensis*).

A small annual herb with red flowers. [There are very few British plants with red flowers.] Flowers solitary in the leaf-axils. The flowers are constructed on the same plan as in the Primrose, but with a shortened tube: K5 C5 A5 G(5). There is only one form of flower however. The fruit (fig. 125) is a capsule with transverse dehiscence. **Pollination.**—The flower closes in dull weather; it also opens by day and shuts in the evening. It has no honey, but is visited for the sake of its pollen. If it has not been cross-pollinated after opening regularly for three days, the flower finally closes, and the stigma is brought into contact with anthers which are coated with pollen. Thus self-pollination is inevitable in the absence of cross-pollination.

CONVOLVULACEÆ (Convolvulus Family)

Twining herbs with alternate, simple, exstipulate leaves. Flower regular, hypogynous. Sepals five. Petals five, gamopetalous. Stamens five, epipetalous. Carpels two, syncarpous, superior; ovary usually two-chambered, with two ovules in each chamber; style two-branched; stigmas two. Fruit a capsule.

Type I.: BINDWEEDS (Convolvulus).

In addition to the family characters given above, the following are worthy of note:—*Convolvulus* twines in a left-handed direction (fig. 56). **Flower.**—*Sepals* five, separate. *Petals* five, combined, plaited and contorted in the bud. *Stamens* five, with anthers shaped like arrow-heads. *Ovary* two-chambered, with two ovules attached to the base of each chamber. *Disk* ring-like with angles, and surrounding the base of the ovary: it secretes honey. The flowers close in the evening.

SOLANACEÆ (Potato Family)

Herbs. Leaves alternate or paired, exstipulate. Flower usually regular, cyclic, hypogynous. Sepals five. Petals five, gamopetalous. Stamens five, epipetalous. Carpels two, syncarpous, superior; ovary two-chambered, with many ovules on an axile placenta.

TYPE: NIGHTSHADE (*Solanum nigrum*).

Vegetative characters.—Annual herb. Leaves exstipulate, alternate, but near the flowering portion of the stem the leaves are seemingly arranged in pairs of one large leaf and one smaller one at a node. The branching is really cymose, and each inflorescence appears to spring from the side of the stem, yet not to arise in the axil of a leaf.* **Inflorescence** cymose; note that no prophylls are visible on the flower-stalks. **Flower** (fig. 84) actinomorphic, ☿, cyclic, hypogynous. *Sepals* (*cx*) five combined. *Petals* (*co*) five, combined. *Stamens* (*a*) five, alternating with the five petals and inserted on the corolla-tube; the anthers are close together in the centre of the flower, each opening by two pores at its summit. *Carpels* two, syncarpous, superior. Ovary (*ov*) two-chambered, with many ovules on a thick axile placenta. Style one. Stigma (*sg*) one. [Try and see that the two carpels are not median or transverse in position, but are oblique.] **Pollination.**—The flower has no nectary, but is visited for the sake of its pollen. **Fruit** a berry. **Seeds** kidney-shaped. **Dissemination.**—In spite of their being poisonous, the berries are eaten by birds, which consequently are responsible for the dispersal of the seeds.

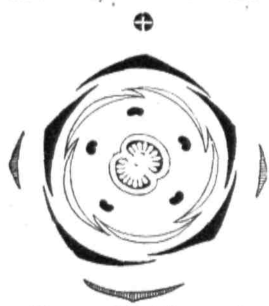


Fig. 190.—Floral diagram of *Solanum*.

The Potato-plant (*Solanum tuberosum*) has flowers so similar to those of the Nightshade that they may be selected for examination in place of the latter. The plant is a perennial with subterranean tuberous shoots. The unequal size of the leaflets composing a leaf is specially worthy of note (fig. 48).

USES, PECULIARITIES, ETC. OF SOLANACEÆ.

Many Solanaceæ contain powerful poisons, some of which are used as medicines. Belladonna is obtained from *Atropa*

* This characteristic method of branching, and the peculiar paired arrangement of the leaves, cannot be explained in this book.

belladonna. The Tobacco-plant (*Nicotiana*) contains a poisonous alkaloid, nicotin. The Tomato (*Lycopersicum*) is cultivated for the sake of its fruits (berries). Cayenne pepper is obtained from the red fruits of *Capsicum*. Some Solanaceæ are ornamental plants grown in gardens—*e.g.* *Petunia*, *Datura* (with prickly capsules), *Nicotiana*.

BORAGINACEÆ (Forget-me-not Family)

Herbs, often with stiff hairs. Leaves alternate, entire, exstipulate. Inflorescence, a scorpioid cyme. Flowers regular, cyclic, hypogynous. Sepals five, gamosepalous. Petals five, gamopetalous. Stamens five, epipetalous. Carpels two, syncarpous, superior; ovary four-lobed, divided into four chambers each containing one ovule; style one, inserted between the four lobes of the ovary. Fruit a schizocarp separating into four nutlets.

TYPE: SCORPION GRASS, FORGET-ME-NOT (*Myosotis*).

The flowers exhibit the characters given above. In addition, we observe that the scorpioid cyme is a curved cyme looking like a raceme: the best method of regarding this inflorescence is to consider the axis as a sympode (see figs. 80, 81) made up of a number of monochasia (one-branched cymes). In each flower we note—(i.) Five little scales attached to the corolla and roofing over its mouth. These form the *corona* which protects the pollen and honey. (ii.) The five stamens are hidden in the corolla-tube, and have introrse anthers. (iii.) The honey is excreted by the fleshy base of the ovary and collects at the bottom of the corolla-tube.

The Heliotrope (*Heliotropium*), commonly cultivated in hot-houses, differs in having an ovary which is not lobed.

LABIATÆ (Dead Nettle Family)

Herbs or shrubs with four-sided stems. Leaves opposite, exstipulate. Inflorescences opposite, axillary, cymose clusters. Flower irregular, cyclic, hypogynous. Sepals five, gamosepalous. Petals five, gamopetalous, usually two-lipped. Stamens two or four, epipetalous; if there be four, two are longer and two shorter. Carpels two, syncarpous; ovary four-lobed and divided into four chambers, each containing one ovule; style attached between the bases of the four lobes of the ovary. Fruit a schizocarp of from one to four nutlets.

TYPE: WHITE DEAD NETTLE (*Lamium album*).

Vegetative characters.—Perennial herb with a four-sided stem. Leaves opposite, exstipulate, with scalloped or saw-like margins. **Inflorescence.**—Each infloresence which stands in the axil of a leaf is a dichasium with a terminal flower and two lateral one-branched cymes (monochasia). **Flower** (fig. 191) median-zygomorphic, ☿, cyclic, hypogynous. *Sepals* (*cx*) five, combined. *Petals* (*pp*, *lp*, *ap*) five, combined to form a two-lipped corolla. In order to understand that there are five petals represented in the corolla, it is necessary first to remember that the petals alternate with the sepals. It will then be seen that the three-lobed lower lip represents one anterior petal (*ap*) and two lateral petals (*lp*) alternating with two anterior sepals. In like manner the upper lip of the corolla represents two posterior petals (*pp*), one on each side of the median posterior sepal (see diagram fig. 192). The slight notch in the apex of the upper lip also denotes that the latter represents two closely joined petals. A ring of hairs (*h*) lines a zone of the corolla-tube. *Stamens* four, the two anterior stamens having longer filaments than the other pair, inserted on the corolla. In order to understand the andrœcium we must again remember that the stamens should alternate with the petals. There should, therefore, be a median posterior stamen, but no such stamen is present. We therefore conclude that the median posterior stamen has been suppressed:

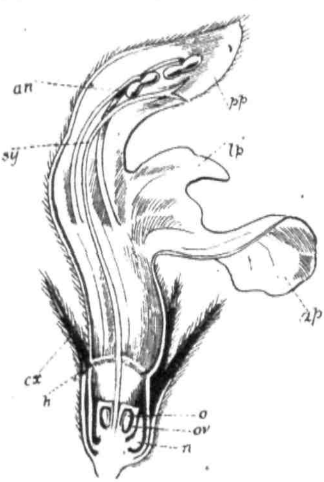


Fig. 191.—Vertical section of flower of Dead Nettle.

and the other four stamens alternate with the petals (see diagram). The anthers are in pairs close together under the arching upper lip of the corolla: they have peculiar diverging anther-lobes. *Carpels* two, syncarpous, superior. The ovary (*ov*) is four-lobed and divided into four chambers, each with one ovule (*o*). The style is attached to the ovary at the base of the junctions of the four lobes: it (*sy*) is single, but forks above and is capped by two stigmas. The two stigmas indicate that only two carpels are represented in the gynæcium. Thus the ovary should be two-chambered, but each chamber is further divided into two halves by a false septum. The two stigmas are median in position, thus indicating the two carpels are median. *Nectary* (*n*) a fleshy hypogynous outgrowth of the receptacle lying at the anterior face of the ovary. **Fruit.** — Each chamber of the ovary becomes a one-seeded indehiscent nut-like body (nutlet). The fruit may be described as a peculiar schizocarp. **Pollination.**—We note—(i.) The flowers are not erect but point obliquely upwards, and are median-zygomorphic. (ii.) The upper lip protects the pollen and honey from rain. (iii.) The honey is deeply placed and concealed; it collects at the bottom of the corolla-tube. A ring of hairs in the latter acts as a rampart to protect the honey from marauding insects which would not effect cross-pollination. (iv.) The flower is specially adapted for cross-pollination by the agency of humble-bees. The humble-bee alights on the middle lobe of the lower lip, pushes its head down the tube in order to reach the honey which is at the anterior face of the ovary. The back of the bee thus comes into contact, first with the anterior stigma, and immediately afterwards with the anthers. The consequence is, that pollen lodged on the bee's back by a previously visited flower is conveyed to the stigma of a flower before the pollen of this latter is touched by the humble-bee; and cross-pollination results. We note how perfectly the humble-bee fits into

Fig. 192.—Floral diagram of Dead Nettle.

the flower. This flower is a good example of one which is pollinated by pollen conveyed on the back of a bee. In the Pea-family, on the other hand, the pollen is transferred from flower to flower on the under surface of the bee's body. In accordance with this we observe that in the Dead Nettle the honey is accessible on the lower (anterior) face of the ovary, and the bee has, so to speak, to crouch down to obtain the honey; whereas in the Pea the honey can only be reached on the upper (posterior) face of the ovary. In both the Pea and the Dead Nettle the anterior part of the corolla acts as a platform on which the bee alights. The Purple Dead Nettle has a corolla with a shorter tube, and may be pollinated by ordinary bees, as well as by humble-bees.

USES, ETC. OF LABIATÆ.

Many Labiatæ contain odorous ethereal oils which are used for various purposes. Ethereal oils of Peppermint and Thyme are familiar. Thyme (*Thymus*), Mint (*Mentha*), Sage (*Salvia*) are used for culinary purposes, and their aroma is due to the ethereal oils which they possess.

SCROPHULARIACEÆ (Foxglove Family)

Herbs. Flowers irregular, cyclic, hypogynous. Sepals five, gamosepalous. Petals five, gamopetalous, often two-lipped. Stamens usually four, often two shorter, two longer (sometimes two or five), epipetalous. Carpels two, syncarpous, superior; ovary, two-chambered, with many ovules on an axile placenta; style one. Fruit usually a capsule.

TYPE I.: FOXGLOVE (*Digitalis purpurea*).

Vegetative characters.—Tall herb. Leaves: lower ones radical, crowded and stalked; upper ones alternate, sessile. **Inflorescence** a terminal raceme. **Flower** (fig. 193) median-zygomorphic, ☿, cyclic, hypogynous. *Sepals* (*ps*, *cx*) five, combined. *Petals* (*cor*) five, combined to form a large tube with five short, broad, free lobes; the anterior part of the corolla (lower lip) is longer than the posterior portion (upper lip). The corolla is spotted. *Stamens* (*an*) four, attached to the corolla, two stamens with longer filaments than the other two; the medium posterior stamen is absent (see Labiatæ for method of proof); anthers inclined together in pairs, and with divergent lobes. *Disk* (*n*) forms a ring round the base of the ovary; it is a nectary. *Carpels* two, syncarpous, superior. Ovary (*ov*) two-chambered, with numerous ovules on an axile placenta. Style (*sy*) one. Stigma two-lobed. The

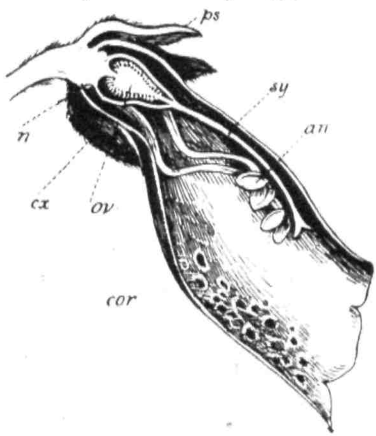


Fig. 193.—Vertical section of flower of Foxglove.

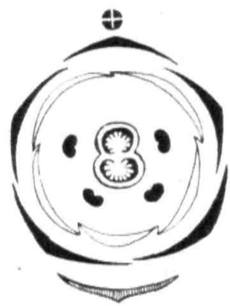


Fig. 194.—Floral diagram of Foxglove.

carpels are median in position. **Fruit** (fig. 123) a two-valved capsule, leaving the numerous seeds attached to the thick axile placenta (*pl*). **Pollination.**—The stamens dehisce before the gynæcium is ripe: that is, the flower is *proterandrous.* The flowers are cross-pollinated by the agency of humble-bees only. The humble-bee creeps bodily into the flower (we notice that it just fits the flower), and its back comes into contact with the stigma-lobes and anthers. Thus, as in the Dead Nettle, the pollen is conveyed from flower to flower on the back of the bee.

THE SUPPRESSION OF STAMENS IN THE SCROPHULARIACEÆ.

The andrœcium of different Scrophulariaceæ is interesting in showing the gradual suppression of special stamens. The Mullein (*Verbascum*) has a nearly regular flower with five stamens, which alternate with the five petals (fig. 195). The Snapdragon

(*Antirrhinum*) and the Toadflax (*Linaria*), with irregular flowers, have four stamens, alternating with petals, and in addition they may have a fifth stamen, which is smaller, and is median posterior in position (fig. 196); in the Figwort (*Scrophularia*) the same arrangement is found, but the median posterior stamen exists in the form of a scale-like staminode. In the Foxglove and many other types the posterior stamen has completely disappeared, so that only four stamens are present (fig. 197). Finally, in the Speedwell (*Veronica*) the two anterior stamens have also vanished, so that the flower possesses only two lateral stamens (fig. 198). The flower of the Speedwell is not two-lipped; it has a very short corolla-tube, and the two posterior petals are so closely united as to look like a single petal.

195 196 197 198

Figs. 195-198.—Diagrams of the andrœcium of Scrophulariaceæ.

THE SHAPES OF SCROPHULARIACEOUS FLOWERS AND THE INSECTS POLLINATING THEM.

In the Scrophulariaceæ we can see that the varied forms of flowers pollinated by insects are to be explained by observing the insects which pollinate them. The Speedwell (*Veronica chamædrys*), with open small flowers, having a very short corolla-tube and easily accessible honey, is especially cross-pollinated by certain flies—hover-flies: it is a *Hover-fly-flower.* The Figwort (*Scrophularia*), with short, wide chocolate-coloured flowers, and easily visible honey, is particularly cross-pollinated by wasps: it is a *Wasp-flower.* The Foxglove, Snapdragon, and Toadflax possess flowers with long corolla-tubes and deeply-placed honey; the visiting insect creeps bodily into the tube, and its body must fit the flower if cross-pollination is to be ensured; thus large-bodied bees are the sole cross-pollinating agents: they are *Bee-flowers*, especially Large-bee-flowers. The Snapdragon-flower is closed, so that only a strong insect can push its way in and reach the honey; the pollen and honey are consequently well protected against rain and marauding insects.

CAPRIFOLIACEÆ (Honeysuckle Family)

Shrubs or herbs. Leaves opposite, exstipulate, or with minute stipules. Flowers regular or irregular, cyclic, epigynous. Sepals five, small, gamosepalous (with three to five lobes). Petals five, gamopetalous. Stamens five, epipetalous. Carpels usually three (three to five), syncarpous, inferior; ovary with one or several chambers, containing one or more ovules. Seeds endospermic.

TYPE I.: HONEYSUCKLE (*Lonicera periclymemum*).

Vegetative characters.—Woody climber with opposite exstipulate leaves. **Inflorescence.**—Head-like cymes terminate a number of the upper branches; small bracts are present. **Flower** (fig. 199) median-zygomorphic, two-lipped, ☿, cyclic, epigynous. *Sepals* five, combined to form a five-toothed calyx (*cx*). *Petals* five, combined to form a corolla with a very long

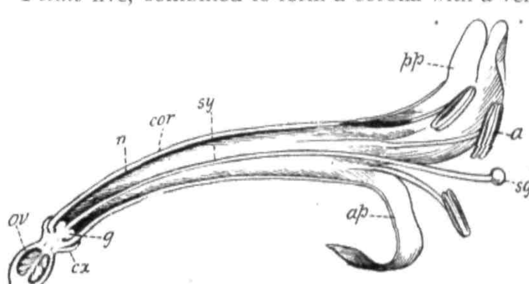


Fig. 199.—Median vertical section of flower of Honeysuckle: *g*=disk.

tube (*cor*), and two lips; the upper lip has four teeth, and therefore represents four petals (*pp*); the lower lip is not toothed, and represents the single anterior petal (*ap*). *Stamens* (*a*) five, inserted on the corolla-tube, alternating with the petals. *Carpels* three, syncarpous, inferior. Ovary (*ov*) three-chambered, with several ovules in each chamber on an axile placenta. Style one. The style (*sy*) is very long, and brings the stigma far beyond the mouth of the corolla-tube. Stigma (*sg*) knob-like. **Fruit**, a red berry, containing a few seeds. Note that the head of flowers forms a cluster of fruits (infructescence, fig. 201). **Pollination.**—The honey is secreted along the posterior middle line of the corolla (*n*) by the fleshy part of the base of the tube, and collects there. As the corolla-tube is long, the honey can be fully reached only

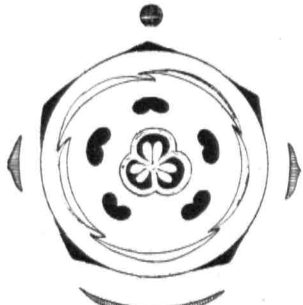


Fig. 200.—Floral diagram of Honeysuckle.

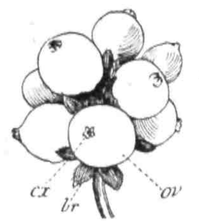


Fig. 201.—Infructescence of Honeysuckle: *br*=bracts; *cx* = calyx of each fruit (*ov*).

by insects with very long tongues—that is, solely by butterflies and moths. The flower is cross-pollinated chiefly by the night-flying hawk-moths. The light colour and sweet scent, especially strong at night time, serve to attract the notice of moths. The position of the stigma obviously renders self-pollination by the flower itself well-nigh impossible. [Endeavour to follow out the dehiscence and movements of the stamens.]

Types II. and III.: The ELDER (*Sambucus nigra*) and GUELDER-ROSE (*Viburnum opulus*).

Although the flowers of these two plants are constructed on the same general plan (K5 C5 A5 $\overline{G(3)}$) as those of the Honeysuckle, they differ from the latter very widely as regards their shapes. Their flowers are erect and regular, and their corolla-tubes are very short. Accordingly, we find that their insect-visitors are widely different from those of the Honeysuckle. The honey is freely exposed in the Guelder-Rose, whilst the Elder flowers, though they secrete no honey, are highly-scented, and are visited by insects desiring their pollen. Thus, in both these plants, the insect-food is very easily accessible; and the chief pollinating agents are short-tongued beetles and flies.

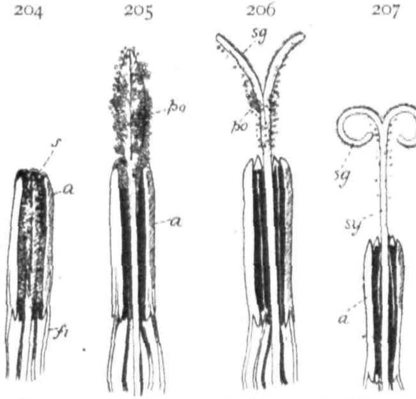
The seed-producing flowers of both plants are small and relatively inconspicuous; yet, being grouped together, they form showy masses of bloom. The inflorescence of the Guelder-Rose consists of two kinds of flowers: (i.) Those in the centre, which are normal in structure, each being endowed with perfect stamens and carpels, and a small regular corolla; (ii.) others ranged round the margins of the inflorescence, having their stamens and carpels so reduced as to be useless, yet each possessing a large and conspicuous corolla. The marginal flowers are incapable of taking any direct share in the production of seeds; their sole office is to attract insects to the central blossoms, which alone make seeds. The "Snowball Tree" is an artificial variety of the Guelder-Rose: all its flowers are changed into the non-productive marginal flowers with showy corollas.

COMPOSITÆ (Daisy Family)

Herbs, rarely shrubs. Leaves exstipulate. Inflorescence a capitulum with an involucre. Flowers small, regular or irregular, cyclic, epigynous. Sepals small or absent, sometimes replaced by a pappus. Petals five (or four), gamopetalous, valvate in the bud. Stamens five (or four), epipetalous; anthers united. Carpels two, syncarpous, inferior; ovary one-chambered, with one basal ovule. Seeds non-endospermic.

TYPE I.: DANDELION (*Taraxacum officinale*).

Vegetative characters.—A perennial herb containing a milky juice, with simple radical leaves, and a bare inflorescence-axis terminating in a capitulum. The Dandelion has a tap-root surmounted by a short erect rhizome. The rhizome is a sympode. Each year the visible axis, which bears the radical leaves at its base and terminates in an inflorescence, dies down nearly to its base. A bud in the axil of one of the radical leaves on this persistent basal part grows out the following year, and produces a similar radical tuft of leaves and a terminal inflorescence. This in turn dies down to near its base, and an axillary bud on it grows up in the next year to produce a new flowering axis. Thus the rhizome is made up of the persistent bases of all these successive branches strung together to form a false axis or sympode. The rhizome is pulled (fig. 129, right-hand): this collection is an infructescence (not a compound fruit), because it is formed by a number of flowers (not by one flower only). **Dissemination.**—The fruits are dispersed by the wind, and the pappus forms a parachute. **Pollination.** — The flowers are proterandrous. The anthers dehisce around the style before the latter has attained its full length, and whilst the two terminal arms of the style are still applied to each other (fig. 204). The style then elongates and the hairs on its sides brush the pollen out of the tube formed by the ring of anthers (fig. 205). Inasmuch as these hairs serve to hold and carry up the pollen, they are termed "collecting-hairs." The style thus acts like a brush employed in sweeping a chimney. Insects now visiting the flower to sip at the nectar touch the pollen thus carried up on the style. Soon the arms of the style separate and the stigmas on their upper faces are ready for the reception of pollen (fig. 206). An insect dusted with pollen, and visiting flowers at this later stage, will transfer pollen on to the stigma, and thus may effect cross-pollination. But if the stigmas are not pollinated, the branches of the style continue to curl downwards, and even execute complete curves at their ends, so that eventually they touch the collecting hairs (fig. 207), and are self-pollinated.



Figs. 204-207.—Diagrammatic figures of the behaviour of the anthers, style, and stigmas of Dandelion.

TYPES II., III., IV.: DAISY (*Bellis perennis*): SUNFLOWER (*Helianthus annuus*): OX-EYE DAISY (*Chrysanthemum leucanthemum*).

These three plants also have capitula of flowers (fig. 208), which differ from the Dandelion-heads in that they possess two sorts of flowers. In the two Daisies the numerous central flowers—termed the *disk-flowers*—are yellow; whereas the marginal flowers—termed the *ray-flowers*—form a single white series immediately within the involucre. In the Sunflower the conspicuous ray-flowers are yellow, and form a single series

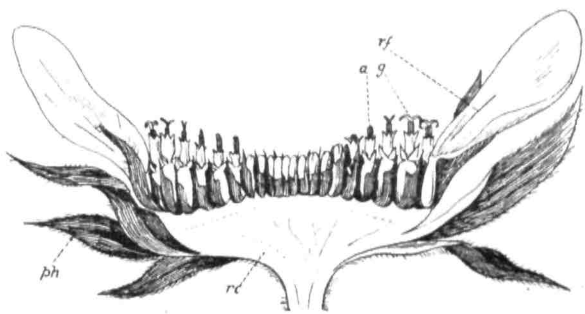
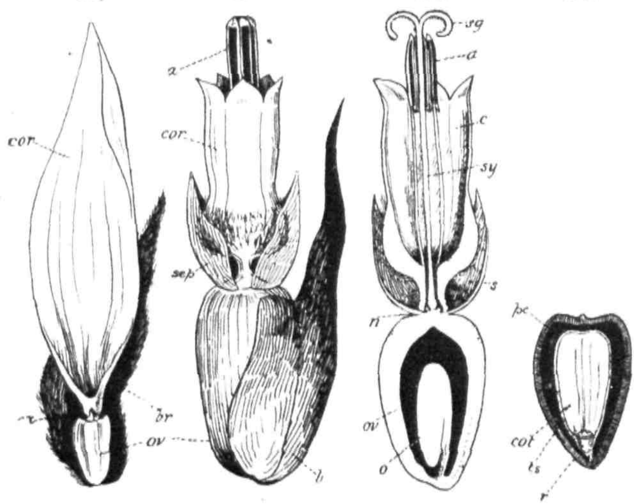


Fig. 208.—Vertical section of capitulum of Sunflower: *rc*=receptacle of inflorescence: *ph*=green bracts; *g*=disk flower with style, arms already protruding: *a*=younger disk flower, with anthers visible.

surrounding the central brown mass composed of innumerable little disk-flowers.

The **disk-flowers** (figs. 210, 211).—Each flower is regular, and has a tubular five-toothed corolla (*cor*), within which succeed five epipetalous stamens with united anthers (*a*); in the centre is a gynæcium (*ov*, *sy*, *sg*) like that of the Dandelion-flowers. There is no pappus in the two Daisies, but the calyx is represented by epigynous scales (*sep*, *s*) in the Sunflower. Thus in their general structure these flowers agree with those of the Dandelion, but they differ from the latter in being actinomorphic.

The **ray-flowers** (figs. 208 *rf*, 209), though superficially more like the flowers of the Dandelion, are in reality constructed on a different plan. Their calyx is absent in the case of the two kinds of Daisies, but in varieties of the Sunflower there are from one to five minute scales (*cx*). The corolla is tubular at the base, and represents at this point five petals (judging by comparisons with the other flowers); but above the tubular part, the three more anterior petals grow out to form a long strap. That the strap thus represents three petals is feebly denoted by its terminal teeth in the Ox-eye Daisy, but is much more distinctly seen in some other species of *Chrysanthemum*, the straps of which have three terminal teeth. The straps of the Sunflower and Daisy are not toothed at their ends. Thus



Figs. 209-212.—Sunflower. Fig. 209.—Ray-flower. Fig. 210.—Disk-flower. Fig. 211. —Vertical section of Disk-flower. Fig. 212.—Vertical section of achene: *pc*=pericarp; *ts*=testa; *cot*=cotyledons; *r*=radicle.

the strap of the Dandelion represents five joined petals, and the flower may be described as a *true ligulate* (strap-like) *flower*; whereas the strap of the corolla belonging to the ray-flowers of the three other types represents only a part of the corolla (three petals), and may be referred to as a *false ligulate flower*. The ray-flowers of all three types possess no stamens; in the two Daisies they have a gynæcium, and are therefore carpellary flowers: but in the Sunflower they have no style and stigma, though an empty ovary-tube is present.

We note each disk-flower of the Sunflower arises in the axil of a scale-like bract (figs. 208, 210 *b*); whereas the inflorescence-receptacle of the two Daisies, like that of the Dandelion, only has those bracts which form the involucre.

Pollination.—Cross-pollination is accomplished much as in the Dandelion. The flowers are proterandrous, and the pollen is carried out of the corolla-tube of the disk-flowers by collecting-hairs on the unopened style. The hairs, however, are limited to the outer surfaces of the style-branches: and so long as these latter are not separated, the collecting-hairs form a tuft somewhat like a paint-brush. This terminal brush sweeps the pollen upwards. These collecting-hairs are absent from the style of the carpellary ray-flowers, because they are obviously useless to a flower which produces no pollen. The ray-flowers serve to make the inflorescences more conspicuous; in the Sunflower this is the only service they render to the plant (compare the Guelder-Rose).

TYPE V.: CORN-FLOWER (*Centaurea cyanus*).

The Corn-flower has no strap-like flowers. Its capitulum is composed solely of tubular flowers. The central flowers, though blue in colour, are very like the disk-flowers of the Daisy, but with a pappus of hairs. The marginal flowers are large, somewhat irregular, and are devoid of stamens, style, stigma, and ovules. **Pollination.**—The collecting-hairs are arranged on a globular swelling of the style just beneath the point at which the latter forks. In freshly-opened flowers the filaments of the stamens rapidly contract when the anthers are touched for the first time, and consequently the pollen is suddenly exposed on the collecting hairs.

GENERAL REMARKS ON THE COMPOSITÆ.

In examining the Compositæ the chief points to note are—(i.) The inflorescence-receptacle; its form; the presence or absence of scale-like bracts amongst the flowers. (ii.) The opening and closing movements of the capitulum. (iii.) The calyx and pappus. (iv.) The form of the corolla. (v.) The presence or absence of stamens and carpels in the flowers. (vi.) The occurrence or non-occurrence of an outgrowth of the connective, and of appendages of the anthers. (vii.) The arrangement of the stigma-lines on the arms of the style and the disposition of the collecting-hairs. (viii.) The presence or absence and the form of the pappus on the fruit.

Cultivated plants—Uses, etc.—The root of the Chicory (*Cichorium*) which has capitula of blue ligulate flowers, is the source of the substance "chicory," which is used in the adulteration of Coffee. The Lettuce (*Lactuca*) has yellow ligulate flowers. The tubers of the Jerusalem Artichoke (*Helianthus tuberosus*) are subterranean stems which are consumed as vegetables. But the "tubers" of the *Dahlia* are very thick adventitious roots. The Artichoke (*Cynara*) possesses fleshy capitula which are edible. The Marigold (*Calendula*) has carpellary disk-flowers, and staminate ray-flowers: it often produces several kinds of fruits in the same inflorescence. The so-called double varieties of *Dahlia*, and the cultivated varieties of *Chrysanthemum*, are plants whose disk-flowers have been artificially converted into false ligulate flowers. Other familiar garden plants are *Cineraria*, *Gaillardia*, *Calliopsis*, *Pyrethrum*, Everlasting Flowers (*Helichrysum*).

MONOCOTYLEDONS

LILIACEÆ (Lily Family)

Perennial herbs with bulbs or rhizomes. Flowers usually regular, hypogynous. Perianth 3 + 3, petaloid. Stamens 3 + 3. Carpels three, syncarpous, superior; ovary three-chambered; style usually single. Fruit, a capsule or berry.

TYPE: GARDEN HYACINTH (*Hyacinthus orientalis*).

Vegetative characters.—Perennial herb with a coated bulb (for description, see page 33, also fig. 53). Foliage-leaves radical, long, narrow, with sheathing bases, parallel-veined.

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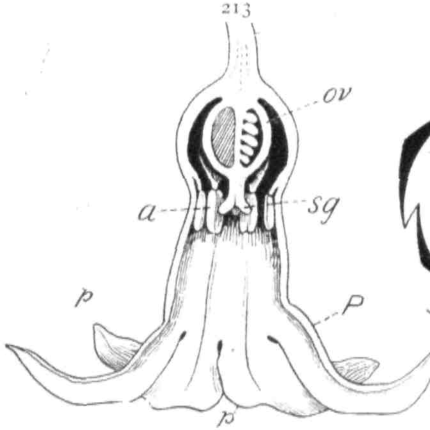

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Fig. 213.—Vertical section of flower of garden Hyacinth.
Fig. 214.—Floral diagram of ditto.

Inflorescence.—A bare inflorescence-axis terminates in a raceme of pendulous flowers, which stand in the axils of small narrow bracts. **Flower** (fig. 213) actinomorphic, ☿, cyclic, hypogynous. *Perianth* (*P*, *p*) 3 + 3, brightly coloured, combined to form a single tube with six free segments. *Stamens* (*a*) 3 + 3, inserted on the perianth-tube; anthers introrse. *Carpels* three, syncarpous, superior; ovary (*ov*) three-chambered, placenta axile, with a number of ovules in each chamber; style, one; stigma, three-lobed. **Pollination.**—The flower-buds are directed upwards, but they bend downwards as they open. This pendulous position of the flowers serves to protect the pollen. Apparently no honey is excreted; probably long-tongued insects stab the fleshy parts of the perianth and suck the juice. The stamens and carpels ripen simultaneously. **Fruit** a three-valved capsule dehiscing along the dorsal sutures. Seeds numerous, endospermic. **Dissemination.**—After pollination, as the fruit ripens, each flower-stalk once more bends upwards and straightens. The ripe capsules consequently become erect, and the seeds do not drop down immediately round the parent plants (as they would if the capsule were pendulous), but are wafted away by the wind.

OTHER TYPES, USES, ETC. OF LILIACEÆ.

The Asparagus has certain slender green stems and definite green branches, which might be mistaken for leaves. The leaves assume the form of minute pale scales, in whose axils the green branches arise. The edible parts of the Asparagus are the succulent basal shoots which just protrude above the soil. The Asparagus has small flowers, which are frequently diclinous; its fruits are berries. The Lily-of-the-Valley (*Convallaria*) possesses a sympodial rhizome and a raceme of pendulous white flowers, which, in their main features, agree with those of the Hyacinth. Onions and Garlic are cultivated for the sake of their bulbs. The Bluebell, Tulip, Lilies, Fritillaries, Meadow Saffron are familiar plants belonging to this family.

AMARYLLIDACEÆ (Daffodil Family)

The characters are practically the same as those of the Lily-family, except that the flowers are epigynous: P3 + 3 A3 + 3 G $(\overline{3})$.

In the DAFFODIL (*Narcissus pseudo-narcissus*) (fig. 215) and in the Narcissus we note—(i.) The spathe; (ii.) the petaloid

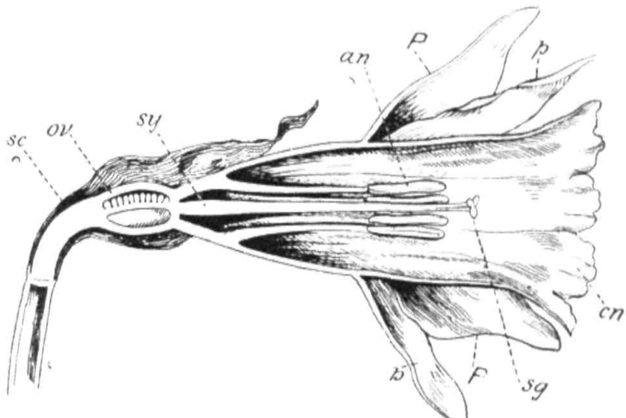


Fig. 215.—Vertical section of flower of Daffodil.

tubular perianth (*P*, *p*), on which is inserted a yellow outgrowth—the corona (*cn*).

In the SNOWDROP (*Galanthus nivalis*), the bulb consists of the swollen bases of the two foliage-leaves of the previous year inserted on a short axis. The plant has only two foliage-leaves each year. The inflorescence-axis bears a spathe and a single pendulous flower. The two whorls of the perianth are composed of separate perianth-leaves; the outer whorl differs in appearance from the inner whorl, so that we may speak definitely of three sepals and three petals. The stamens are not inserted on the perianth, they are epigynous. Each anther opens by two terminal pores. (See also page 32.)

IRIDACEÆ (Crocus Family)

Perennial herbs with rhizomes or corms. Flowers usually regular, cyclic, epigynous, conspicuous. Perianth 3 + 3, petaloid. Stamens three, with extrorse anthers. Carpels three, syncarpous; ovary three-chambered, with many ovules on axile placentæ; stigmas three. Fruit a capsule.

TYPE I.: YELLOW FLAG (*Iris pseudacorus*).*

Vegetative characters.—A perennial herb with a creeping sympodial rhizome. The leaves are mostly radical, sword-like, and overlap in an *equitant* manner. **Inflorescence.**—The main type of branching is cymose. **Flower** (figs. 216, 217) actinomorphic, ☿, cyclic, epigynous. *Perianth* 3 + 3, united to form a long tube, petaloid, yellow. The free parts of the three perianth-leaves, which represent the outer whorl (*P*), are bent downwards, and each has a narrow band of hairs along its middle line. The free portions of the inner perianth-leaves (*p*) are smaller and incline upwards. *Stamens* (*a*) 3 + 0, inserted *on the perianth opposite to the outer whorl of perianth-leaves*; anthers extrorse. *Carpels* three, syncarpous, inferior; the ovary (*ov*) three-chambered, with many ovules on an axile placenta. The style (*sy*) is single below, but above it divides into three broad flattened petaloid branches, which are opposite to, and arch over, the three stamens (see also fig. 218). On the surface of each band-like branch of the style there is a small thin shelf (*sg*), whose upper face is the stigma. The three chambers of the ovary and the three branches of the style are opposite to the three stamens. This fact convinces us that the three carpels do not alternate with the three stamens. Why are the carpels thus opposite to, or superposed on, the stamens? If we look at a floral-diagram of a Liliaceous plant, and compare it with that of the Yellow Flag, we note that the

Fig. 216.—Flower of Yellow Flag.

* The flowers of other species of *Iris* grown in gardens are sufficiently like the one here described, to be examined in place of the latter.

two are alike, except that the inner whorl of stamens is missing from the latter. If we now add these three missing stamens to the Iris-diagram, all the successive whorls of the flower alternate in the usual manner. We therefore suppose that in the Yellow Flag (and other Iridaceæ) the inner whorl of stamens is suppressed; and, consequently, in a floral diagram (fig. 219) we put dots to represent the missing whorl, and write down the andrœcium as 3 + 0 (not as three). **Fruit** (fig. 122) a capsule splitting along the dorsal sutures. The numerous flat endospermic **seeds** are dispersed by the wind.

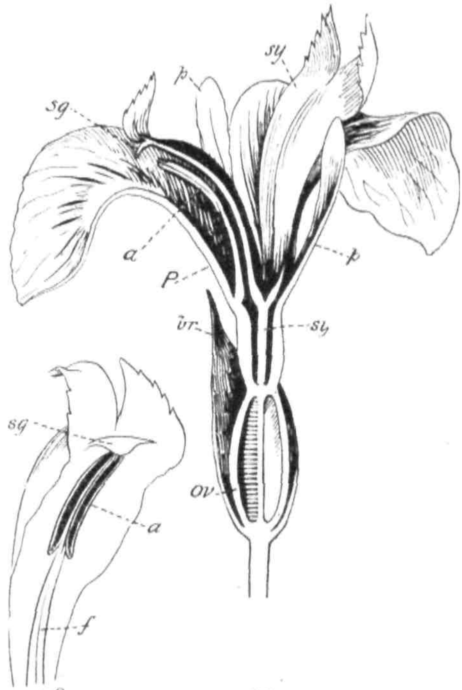


Fig. 217.—Vertical section of flower of Yellow Flag.
Fig. 218.—Stamen with the overhanging arm of style and stigma (*sg*) of ditto.

Pollination.—[In order to understand the method of pollination, a careful examination of the flowers themselves is absolutely essential.] The honey is excreted by the inner face of the base of the perianth-tube, and collects round the base of the style. If an insect is to obtain honey, it must therefore be able, in some way, to reach down nearly to the bottom of the long perianth-tube. Consequently, only insects with long tongues can sip the honey. The Yellow Flag has two varieties of flowers. The one variety is especially suited for pollination by humble-bees; and has the three branches of its style quite a noticeable distance above the free parts of the three outer perianth-leaves, so that a humble-bee can creep under the arms of the style. The other variety of flower is adapted to a long-tongued hover-fly (*Rhingia rostrata*); and its style-arms stand so close above the outer perianth-segments that a humble-bee cannot crawl under them. Either insect visiting the flower suited to it alights on the reflexed portions of the outer perianth-leaves; and as it crawls under one of the arms of the style, it touches with its back, first the stigma, and secondly an anther. It then pushes its tongue down the perianth-tube, sucks the honey, and finally backs out of the flower. The stigma is not touched by the retreating insect, because it is situated on the upper face of the ledge which is pushed upwards and backwards as the insect withdraws. In this manner cross-pollination is ensured and self-pollination averted. The flowers of the Yellow Flag again illustrate the principle that the shapes of insect-pollinated flowers are to be associated with the kinds of insects which pollinate them. Flowers of different shapes are adapted to different circles of insect-visitors. The Yellow Flag, in particular, has both "Bee-flowers" and "Rhingia-flowers."

Fig. 219.—Floral diagram of *Iris*.

TYPE II.: CROCUS (*Crocus*).

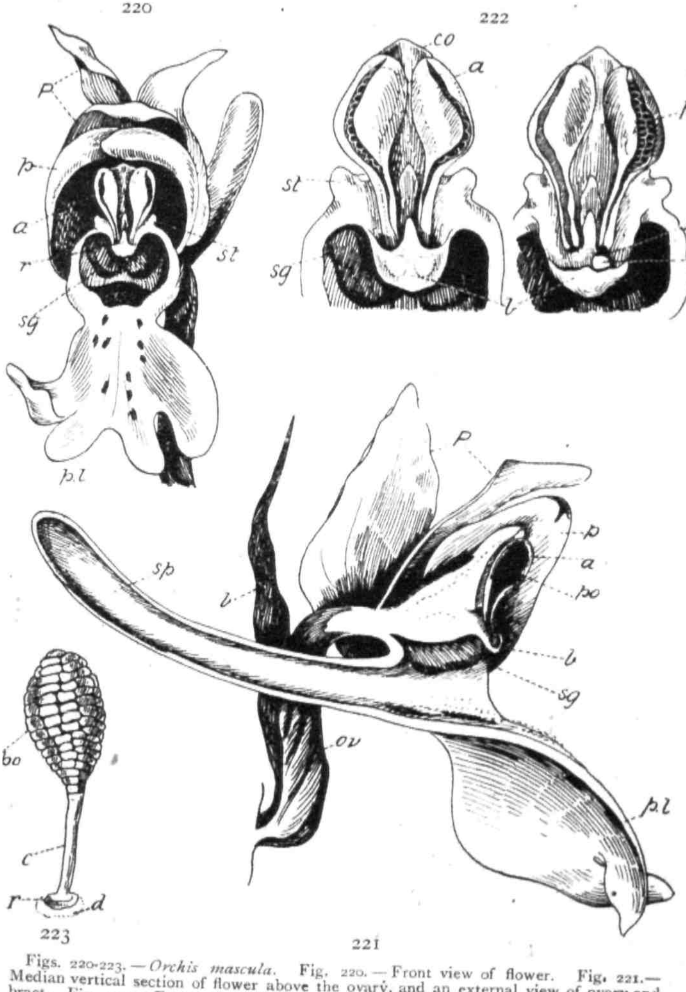
The underground shoot is a corm (figs. 49-52). [Dig up Crocuses at different seasons of the year, and observe the method of development of the new corms on the old ones.] The leaves are not equitant. The flowers are constructed on the same general plan as those of the Yellow Flag: $P3+3$ $A3+0$ $G(\overline{3})$. The flower-stalk is short, whereas the perianth-tube is extremely long. The branches of the style are not so conspicuous as those of the Yellow Flag: they are band-like, but are coiled to form tubes.

ORCHIDACEÆ (Orchid Family)

Perennial herbs. Flowers very irregular, epigynous. Perianth 3 + 3, petaloid. Usually only one fertile stamen present; gynandrous. Carpels three, syncarpous; ovary one-chambered, with three parietal placentæ bearing many ovules. Fruit a capsule containing innumerable minute seeds.

TYPE: EARLY ORCHIS (*Orchis mascula*).

Vegetative characters.—A perennial herb with oval subterranean tubers. There are two tubers visible: one is darker in tint, softer, and terminates above in the flowering axis. It is the older tuber at the apex of which there originally occurred a bud which has now developed into the flowering axis. At the base of the latter are inserted spirally-arranged leaves with sheathing bases: the lowest of the leaves are mere sheathing scales. The second tuber, originally developed in the axil of the lowest scale, is lighter in colour and firmer in texture than the mother-tuber. When the inflorescence-axis decays, the older tuber shrivels up, and in the following year the younger tuber will in turn produce another stem bearing foliage-leaves and flowers, as well as an axillary tuber destined to flower in the third year. Each tuber thus lives for two vegetative seasons only. Although a tuber arises as an axillary bud on its predecessor, it is not wholly constituted of shoot: its basal portion is made up of several fleshy adventitious roots which are closely combined. An Orchid-tuber, therefore, consists of root and shoot. The foliage-leaves are parallel-veined and often spotted. **Inflorescence**: a spike with small bracts. **Flower** (figs. 220, 221, 222) median-zygomorphic, ☿, two-lipped, epigynous: colour varying from pinkish-purple to white. *Perianth* (*P*, *p*, *p. l*) 3 + 3. The six perianth-leaves are combined only at their bases. The free portions of five of them [three outer (*P*) and two inner (*p*)] form an upper lip, whilst the sixth (a median inner one) forms a lower lip—the *labellum* (*p. l*). The labellum has a long spur (*sp*). *Stamens* and *carpels*.—The centre of the flower is occupied by a short, thick mass—the *column*—which is formed by the cohesion of the filaments with the style. The column is inserted directly upon the inferior ovary. Looking at the centre of the flower we see, immediately over the entrance to the spur and attached to the column, two lateral stigma-lobes (*sg*), and just above these a median beaked structure—the *rostellum* (*r*)—which is supposed to represent a third stigma-lobe, though it is incapable of acting as a receptive stigma. Above and behind the rostellum is a single median stamen, consisting of two lobes (*a*) separated by a somewhat broad connective (*co*). In addition to this fertile stamen there occur two lateral stamens without anthers—staminodes (*st*)—attached as appendages to the column, behind the two lateral stigma-lobes. The single anther stands erect, and dehisces towards the rostellum. Each anther-lobe is one-chambered, and contains many pollen-grains adhering together to form a pear-shaped mass—the *pollinium* (*po*, fig. 223)—which possesses a short stalk—the *caudicle* (*c*). The rostellum is shaped like a little bowl (*b*), and contains a gummy mass. The caudicles are attached by their bases to two small balls (*d*) of this gummy substance. The *ovary* is one-chambered, with many ovules (forming after pollination) on three parietal placentæ. **Pollination.**—There is no free honey in the flower; insects pierce the internal lining of the spur and suck the juice from the wound. The flower is visited by bees and flies. The labellum acts as a platform on which the insect alights. A bee pushing its tongue into the spur must of necessity touch the rostellum; the consequence is that one or both pollinia are transferred to its head, where they adhere by means of the adhesive bases of their caudicles. At first the pollinia stand erect on the head of the bee, but they subsequently bend slowly forward, though remaining fixed at their bases. As a result of this movement, the pollinia will inevitably be pushed against the stigma-lobes of a subsequently visited orchid-flower. Did the pollinia remain erect they would, in all probability, be rubbed against the rostellum of a flower visited later: so that no pollination would take place. [The action of the bee in pollinating Orchis-flowers may be imitated by thrusting a sharp-pointed lead pencil into the entrance of the spur; the separation of the pollinia and their subsequent movements will then also be seen.] **True morphology of the flower.**—Hitherto no reference has been made to a peculiarity in the Orchis-flower. The wall of its inferior ovary in its growth causes the flower to execute half a revolution — in fact, 220 222



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Figs. 220-223.—*Orchis mascula.* Fig. 220.—Front view of flower. Fig. 221.—Median vertical section of flower above the ovary, and an external view of ovary and bract. Fig. 222.—Front view of the stamens and stigmas: left-hand figure, before removal of one pollinium; right-hand figure, after removal of one pollinium, also showing the ruptured rostellum. Fig. 223.—One pollinium and caudicle. (In fig. 221, unfortunately, the letter *b* is used to denote the bract, as well as the bowl-like part of the rostellum.)

to twist so that the true anterior part of the flower occupies a posterior position. Thus the labellum is in reality a median posterior perianth-leaf, and all the other floral-leaves have their true positions reversed in the same manner. The flower consists thus of six perianth-leaves, the median posterior being the labellum; three gynandrous stamens, only one (median anterior) of which is complete; a gynæcium composed of three carpels, syncarpous, with three stigma-lobes, the anterior median lobe of which no longer functions as a stigma, but is the rostellum (see fig. 224 for further details). The floral formula is P3 + 3 A1 + 2 G($\overline{3}$). **Fruit** (fig. 225) a capsule dehiscing along the dorsal sutures, and allowing the innumerable minute **seeds** to be dispersed by the wind.

Fig. 224.—Floral diagram of *Orchis*.

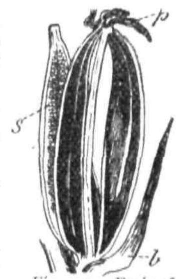

Fig. 225.—Fruit of *Orchis mascula*: *b* = subtending bract; *s* = seeds.

[In place of *Orchis mascula*, other British species of *Orchis* may be selected for examination, and the various points described above will be easily seen.]

ARACEÆ (Arum Family)

Smooth herbs with leaves which are often broad and net-veined. Inflorescence a spadix with a spathe; no bracts subtending the separate flowers; no prophylls in the inflorescence. Flowers small, inconspicuous. Perianth small or absent. Fruit, a berry.

TYPE: THE CUCKOO PINT (*Arum maculatum*).

Vegetative characters.—Herb with a corm. The leaves are radical, each possessing a basal sheath, a petiole, and a net-veined spotted lamina shaped almost like an arrow-head. **Inflorescence** (fig. 226).—A large sheathing bract—the *spathe*

—encloses the part of the flowering axis which bears the flowers. The flowering axis above the point of insertion of the spathe bears—(i.) At its base, a zone of many sessile ovaries (*ov*); (ii.) higher up, an encircling band of incomplete or rudimentary ovaries (*sf*); (iii.) still higher, a belt of numerous sessile anthers (*a*); (iv.) above these again, a zone of hairy structures (*sf'*), the hairs of which span the space between the floral axis and the narrowed portion of the spathe-sheath. Finally, the purple-tinted terminal part of the axis (*sx*) is thickened, but devoid of any lateral structures. This axis, with its stamens and ovaries, does not represent a single flower, for the ovaries are inserted below the stamens on the convex axis. It is an inflorescence consisting of many carpellary and staminate flowers borne on a fleshy axis. This view is shown to be correct by the circumstance that in some other Araceæ each of the numerous little flowers of the spadix possesses a small perianth of its own. The **carpellary flower** (fig. 228) consists solely of one single carpel. The ovary (*ov*) is one-chambered, and contains several ovules (*o*) attached to its wall. The stigma (*sg*) is sessile. Above these fertile

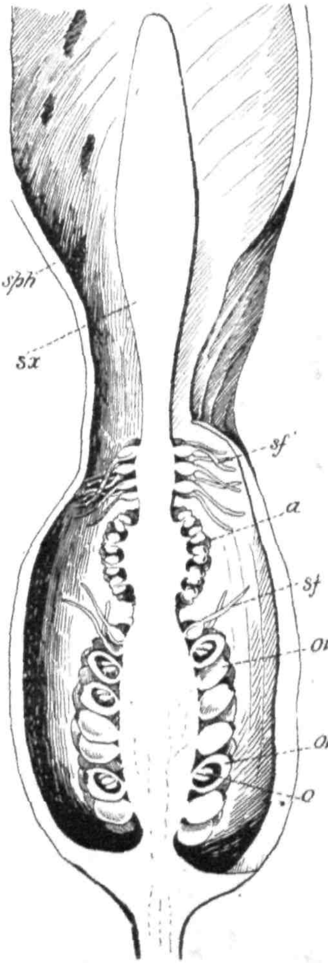

Fig. 226.—Vertical section of spadix and part of spathe of *Arum maculatum*.

carpellary flowers are a number of **sterile carpellary flowers** (*sf*) without ovules. The **staminate flower** consists of a small group of three or four stamens (or at the very base of the staminate region each flower may have only one or two stamens). The anthers are sessile (fig. 227). Above the staminate flowers the band of hairy structures represents a belt of **sterile flowers** (*sf'*). **Fruit**.—After pollination, each ovary gives rise to a single red berry (fig. 229). Thus the carpellary inflorescence produces a cluster of berries (fig. 230), which is an infructescence, because it is formed by several flowers, and not by one. **Pollination**.—In spite of their inconspicuousness, the flowers are insect-pollinated; the inflorescence emits a peculiar odour, and the purple tip of the spadix aids in alluring the small flies which effect cross-pollination. The whole inflorescence forms a trap to catch these minute flies, which creep down the spathe into the chamber formed by the tube of the latter. The ovaries mature before the stamens, and at this stage of flowering the palisade of hairs spanning the mouth of the spathe-tube does not prevent the entrance of the midges, though it hinders their departure. If the flies have come from another spathe, they bear pollen and pollinate the stigmas of the ovaries which are now ready. After a

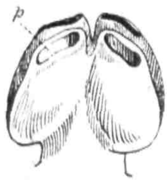

Fig. 227.—A stamen of *Arum maculatum*.

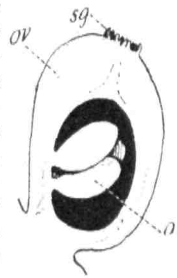

Fig. 228.—Carpellary flower of *Arum maculatum*.

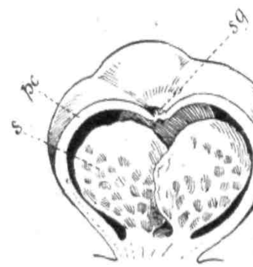

Fig. 229.—A berry of *Arum maculatum* cut open.

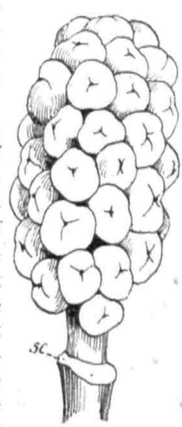

Fig. 230.—Infructescence of *Arum maculatum*.

time, the stigmas wither and secrete honey which is sipped by the imprisoned midges. Only then do the anthers ripen and pour out their pollen, with which the captive-insects become sprinkled. Finally the bars of the prison are loosed, for the hairs forming the palisade wither and allow the flies to escape dusted with pollen. The whole inflorescence is therefore specially constructed so as to accomplish the cross-pollination of the flowers by the agency of small flies.

GRAMINACEÆ (Grass Family)

Herbs. Stems cylindrical, hollow except at the nodes. Leaves alternate, ligulate, with sheaths usually split down to the base. Flowers ranged in spikelets with chaffy bracts. Flowers regular, inconspicuous, hypogynous. Perianth absent (or perhaps represented by two minute scales). Stamens usually three, with dangling anthers; ovary one-chambered, with one ovule; stigmas usually two, feathery or brush-like.

TYPES: WHEAT, COUCH-GRASS, MEADOW-GRASSES, FOXTAIL, COCKSFOOT.

Our British Grasses are *herbs* with cylindrical stems which are hollow except at the nodes.

The *leaves* are alternate, and ranged in two rows along the stem. They are long, narrow, parallel-veined, and usually have prominent ribs. The base of the leaf surrounds the stem in the form of a sheath which is, in most cases, split down one side. At their regions of insertion the sheaths are thickened, and thus cause the nodes to appear swollen. Each leaf has a *ligule* (see page 15). In the bud the leaves are often rolled; but the Meadow-Grass and Cocksfoot have their young leaves folded.

Branches which bear foliage-leaves arise only in the axils of radical leaves. In some Grasses these axillary branches burst through the enveloping sheaths, and, running horizontally underground for some distance, lead to the formation of sympodial rhizomes with scale-leaves, as described on page 25. On the other hand, the branches which arise in the axils of the radical leaves may at once ascend, after either bursting through the surrounding sheaths or pushing their way between the latter and the stem. Even in one and the same Grass-plant both horizontal and ascending branches may occur together. It is the method of branching, together with the direction of growth of the lateral shoots, which determines whether the particular Grass will form a simple tuft, a series of tufts, or a mat-like layer.

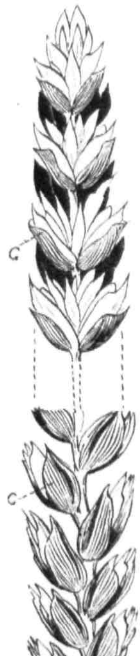

Fig. 231.—Inflorescence of Wheat.

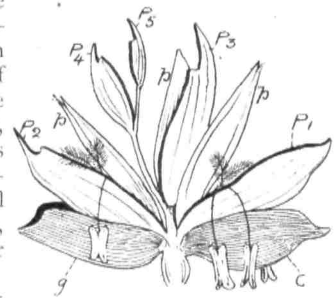

Fig. 232.—A spikelet of Wheat.

Some Grasses are annual (*e.g.* Wheat), others are perennial (*e.g.* Couch-Grass). Some annual Grasses, when sown in autumn, become biennial in that they rest during the winter and do not flower until the following spring.

Inflorescence.—The flowers are arranged in small spikes which are termed *spikelets.* A head of wheat (fig. 231), for instance, at first sight looks like a spike with two rows of sessile flowers: whereas, in reality, it is a spike of spikelets. A spikelet (figs. 232, 233) consists of a stem bearing a few alternating bracts arranged in two rows, and a small number of sessile flowers with prophylls. The lowest two bracts (*G*, *g*) on the spikelet axis are termed *glumes*; one of them, the *lower glume* (*G*), is inserted nearly opposite to, but at a slightly lower level than, the other, which is the *upper glume* (*g*). These two glumes have

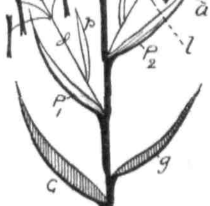

Fig. 233.—A scheme of a spikelet of a Grass.

no flowers in their axils; they constitute, in fact, a small involucre. Above them, on the spikelet axis, are bracts which form two rows, have single flowers in their axils, and are termed *flowering glumes* or *lower pales* or *paleæ* (P_1, P_2, P_3, P_4, P_5). These latter alternate as do the glumes, so that the first or lowest of them (P_1) stands above the lower glume (G): the second (P_2) is inserted on the opposite side of the axis and is above the upper glume (g). The flowering glumes, and less frequently the barren glumes, may have their mid-ribs continued into a tail-like "awn."

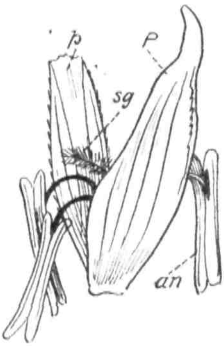

Fig. 234. — A flower of Wheat enclosed in its two paleæ.

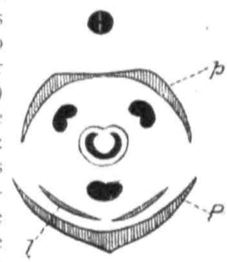

Fig. 235.—Diagram of flower of Wheat.

There are from three to five flowering glumes and flowers in a spikelet of the wheat. The *flower-stalk* is scarcely perceptible, but, as is usual amongst Monocotyledons, it bears a single *prophyll* (p) which is typically on the face (posterior) towards the inflorescence-axis. This prophyll is scale-like, and is termed the *upper pale* or *upper palea.* Each flower (fig. 234) lies partially hidden between its prophyll (the upper pale) and its subtending bract (the flowering glume). It is important to note that each flowering glume is on the axis of the spikelet, and is usually one-ribbed:

Fig. 236.—Dissected parts of flower of Wheat with the lodicules, and two investing paleæ. The ovary (*ov*) is cut vertically, and shows one ovule (*o*).

whereas the upper pale is on the almost imperceptible flower-stalk, and is often two-ribbed. In many Grasses, on each flower-stalk, higher up than the upper pale, are inserted two minute scales—the *lodicules* (figs. 233, 236 *l*). Some botanists regard these latter as representing a simple perianth; others are of opinion that they represent a small divided bract, in which case they are not a portion of the flower proper. The **Flower** consists of three (rarely two) stamens inserted below the ovary, and possessing dangling anthers; together with a one-chambered ovary containing one parietal ovule, and surmounted by two brush-like or feathery stigmas. It is usually supposed that the gynæcium represents one carpel, the style of which has branched. If this view be correct, it must be described as being apocarpous.

Different types of Grasses.—The spikelets may be arranged in panicles or in spikes. In each spikelet there may be one or more flowers. The lodicules may be present or absent. The accompanying table (see opposite) illustrates the general details in some common types of Grasses. (In all these the gynæcium is the same throughout as regards its general constitution.)

Pollination of Grasses.—In some grasses (*e.g.* *Poa* and others) the upper and lower paleæ enveloping a flower separate considerably; the anthers emerge and dehisce quickly, and the stigmas separate. It is the lodicules which cause the opening; they swell and force back the lower paleæ. After a time the lodicules shrivel up, and consequently the paleæ close. In other grasses the paleæ scarcely open, and the stigmas are brush-like (not feathery). As the lodicules are not called upon to force the paleæ apart, they are absent (*e.g.* Timothy-grass) or very minute (*e.g.* Foxtail-grass). The grasses are cross-pollinated by the agency of the wind; the long filaments, with their dangling anthers, are easily shaken by even light breezes, and the large brush-like or feathery stigmas display a large surface to receive the wafted pollen. Many grasses are regularly self-pollinated (*e.g.* Wheat, Barley, Oats).

Fruit.—After fertilisation the one-ovuled ovary gives place to a dry one-seeded indehiscent fruit very like an achene; but the seed is so closely adherent to the pericarp (original wall of the ovary), and the testa so thin, that it is impossible to distinguish the testa and pericarp without the aid of a compound microscope, or, more frequently, the testa is completely destroyed before the fruit is ripe. This fruit is distinguished under the name of *caryopsis*. A grain of wheat (fig. 28), or a so-called grass-seed, is in reality a fruit, because the ovary takes part in its formation. Often the paleæ persist and continue to envelop the ripe fruit. Usually the fruit is grooved along one side (ventral side). **Seed.** — This has already been described (page 19); it is endospermic, with an embryo of peculiar structure.

	On the main Inflorescence axis.	On the axis of the Spikelet.		On the axis of the Flower (gynæcium omitted).		
Name and Vegetative Characters.	Arrangement of the Spikelets.	Glumes.	Flowering Glumes (lower paleæ).	Upper Paleæ.	Lodicules.	Stamens.
Sweet-scented Vernal Grass (*Anthoxanthum odoratum*). A tufted grass; perennial.	Spike-like panicle.	4	1	1	0	2
Meadow Foxtail (*Alopecurus pratensis*). With long scale-bearing rhizomes; perennial.	Spike-like panicle.	2	1	0	2 minute.	3
Wheat (*Triticum vulgare*). Annual.	Spike.	2	3-5	1	2	3
Couch-grass (*Agropyrum repens*). Perennial, with elongated scaly rhizomes.	Spike.	2	3-9	1	2	3
Annual Meadow Grass (*Poa annua*). Tufted annual.	Panicle.	2	3-7	1	2	3
Smooth Meadow Grass (*Poa pratensis*).	Panicle.	2	3-5	1	2	3

PART III

PHYSIOLOGY

CHAPTER XV

THE NUTRITION OF THE PLANT

1. **A Plant absorbs** (feeds itself).—If healthy seeds be sown under suitable conditions, they germinate, and finally give rise to plants much larger than themselves. A small acorn develops into a huge oak-tree: a tiny turnip-seed produces a large turnip-plant. The plants obviously weigh more than the seeds from which they have developed, and they must therefore contain more matter or substance than was originally possessed by the seeds. This substance gained by the plant during its growth has not been created out of nothing; it must have been derived from matter previously present outside the plant. Thus it is certain that the plant takes in, or absorbs, substance from the outside world—that is, takes food from the soil or from the atmosphere, or from both.

2. **What does a Plant absorb?** A seed, or a whole plant, is composed of solid substance and water; in addition it contains gases, which we will not discuss for the present. If we dry a seed, or a plant, at a temperature slightly higher than the boiling-point of water (100° Centigrade), the water will be driven off in the form of steam, and only solid substance will remain. An ordinary seed, though it appears to be quite dry, contains at least one-tenth of its whole weight of water, whilst there is still more water in growing plants; for instance, nine-tenths of the weight of a turnip-plant is due to the water. If we weigh separately a plant and one of its seeds, both before and after drying them, we find that there is more water and more solid substance in the plant than in the seed. We thus see that as a plant grows it absorbs not only water but also other substances.

3. **Chemical Composition of a Plant.**—In order to learn what substances, in addition to water, are taken into the plant, we must find out what simple chemical substances (*elements*) are present in the plant. If we still further heat a completely dried seed or plant there will be an additional loss in its weight, because some of the substances composing the plant

are decomposed, and some combine with the oxygen in the air, and pass off in the form of gases (carbonic acid, ammonia, water, etc.). There remains behind only a little mass of solid called the *ash*. Examining the gases which pass off and the ash which remains, we learn that the following elements are always present in plants:—**Carbon** (C), **Hydrogen** (H), **Oxygen** (O), **Nitrogen** (N), **Sulphur** (S), **Phosphorus** (P), **Potassium** (K), **Magnesium** (Mg), **Calcium** (Ca), **Iron** (Fe). [Sodium (Na), and Chlorine (Cl).] Occasionally other elements also occur. These elements are combined to form the various chemical compounds of which the plant is composed. The grown-up plant contains a larger quantity of each of these elements than did the seed from which it developed. The growing plant, therefore, must have absorbed these elements from the soil or from the atmosphere.

4. **Composition of the Air and of the Soil.**—The atmospheric *air* consists mainly of free nitrogen (N)* and free oxygen (O), very little carbonic acid (CO_2), traces of ammonia, (NH_3), and water vapour (H_2O).

The *soil* is mainly made up of small particles or grains, amongst which there are little spaces occupied by air and water. The grains of soil contain salts which are soluble in water: thus the water in the soil is not pure, it is a solution of certain salts. These soluble salts contain all the elements required by the plant. In addition, the soil contains the decaying remains of dead plants and animals, or *humus*. The accompanying table shows which are the commonest inorganic salts dissolved in the water of the soil. We particularly note the absence of carbon from this list—

NAME.	SYMBOL.	ELEMENTS PRESENT.
Common table salt	Na Cl	Sodium and chlorine.
Gypsum	Ca SO_4	Calcium, sulphur, and oxygen.
Glauber's salts	Na SO_4	Sodium, ,, ,,
Epsom salts	Mg SO_4	Magnesium, ,, ,,
Traces of chlorides, nitrates, and phosphates of calcium, magnesium, and potassium		Chlorine, nitrogen, oxygen, phosphorus, calcium, magnesium, and potassium.

* The element *Argon* is included under the head of Nitrogen, because we do not know its relation to plant life.

5. Cultivation of Plants in Artificial Soils or Solutions.—The soil contains all the chemical elements required by a plant, but the atmospheric air contains only four* elements (N, O, C, H). Those chemical elements present only in the soil are obviously absorbed from that source. But with regard to the four elements present in the soil as well as in the air, experiment alone can decide whence the plant obtains them. In order to decide this question, and to ascertain which elements are absolutely essential to the existence of plants, we cultivate plants with their roots dipping in water containing only certain definite salts dissolved in it (fig. 237); or we may make a simple artificial soil by pouring this nutritive solution on pure insoluble sand.

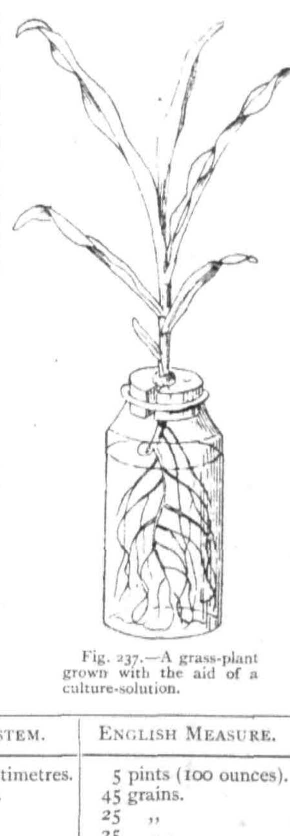

Fig. 237.—A grass-plant grown with the aid of a culture-solution.

A good nutritive solution (termed a "culture solution") can be made up as follows:—

	METRIC SYSTEM.	ENGLISH MEASURE.
Water	1000 cub. centimetres.	5 pints (100 ounces).
Potassic nitrate	1 gramme.	45 grains.
Calcic sulphate	$\frac{1}{2}$,,	25 ,,
Magnesic sulphate	$\frac{1}{2}$,,	25 ,,
Calcic phosphate	$\frac{1}{2}$,,	25 ,,
†Sodic chloride	$\frac{1}{2}$,,	25 ,,
Sulphate of iron	A trace.	Trace.

* Five with Argon. Occasionally, too, the air has impurities such as common salt.

† The sodic chloride is not absolutely necessary, but serves to keep the plant healthy.

A seed provided with this nutritive solution, under suitable conditions (see after), can produce a seedling, which in turn may develop into a plant with flowers and fruit. The plant therefore has every chemical element it requires.

6. **A green plant can manufacture complex organic (carbon-) compounds from simple inorganic food.**—The solid matter of a seed, or of the plant derived from it, consists mainly of organic compounds—that is, it consists chiefly of compounds *of carbon which readily combine with oxygen.* Comparing the seed and the plant, apart from the great increase in the amount of water in the plant, the most marked difference in the composition of the two is the immense addition to the quantity of the organic carbon compounds. Cultivated with the "culture-solution" described, the plant has only inorganic food at its command; in particular, its carbon-containing food is available only in the form of the carbonic acid (CO_2) present in the air. *Animals cannot build up organic compounds from simple inorganic food*; this power is confined to plants.

CHAPTER XVI

ABSORPTION OF CARBONIC ACID BY THE GREEN PLANT

IF a few green leaves, or a green branch, be placed in a closed, moistened, air-tight bottle and exposed to the light, the carbonic acid contained in the air within the bottle will disappear and an equal volume of oxygen will replace it. This shows that *green leaves, or green parts of a plant, can obtain carbon from the carbonic acid of the air.* If, however, the bottle and the contained leaves be placed in darkness, the carbonic acid will not disappear. This experiment illustrates the fact that *light is required in order to enable the green parts of plants to obtain carbon from carbonic acid.* Again, if the leaves be killed (by steaming, freezing, drying, or poisoning by chloroform) before they are placed in the bottle, the carbonic acid will not disappear even in the presence of light. This demonstrates that the *green parts must be living if they are to obtain carbon from carbonic acid of the air.* But if, instead of placing green parts of plants in the bottle, we put parts without the green colouring-matter, such as petals, roots, pieces of fungus, the carbonic acid does not vanish. This serves to show that *only parts containing green colouring-matter can obtain carbon from carbonic acid in the atmosphere.*

We have not yet seen how the green parts obtain the carbon from carbonic acid, or how it is that an equal volume of oxygen appears in the atmosphere in place of the carbonic acid. This is most easily shown by experiments on green submerged water-plants. If we cut across the shoot of such a water-plant, and leave it in the water exposed to light, a stream of bubbles will arise from the cut end of the stem (fig. 238). These bubbles consist of oxygen which is being exhaled by the plant. No bubbles of oxygen will be given off in darkness, nor if the plant be killed, nor if the water contains no carbonic acid, nor if the roots which are without green colouring-matter be used instead of the green shoot. Consequently we conclude that the oxygen is given off only from the parts which are receiving carbon from the carbonic acid. In other words, the **living plant exposed to the light takes in carbonic acid by means of its green parts, it retains the carbon as food but gives the oxygen back to the air.**

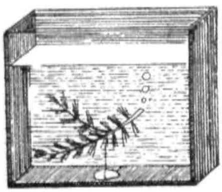

Fig. 238. — Evolution of bubbles of oxygen from the cut end of a stem under water. (Based upon A. Mayer's figure.)

Influence of Temperature on the absorption of carbonic acid and on the evolution of oxygen by green parts. — If the experiments just described are to be successful, the green parts must be exposed to a proper temperature. If the bottle or the water be kept too cold, or too hot, there will be no absorption of carbonic acid, and no evolution of oxygen. There are three important temperatures—(i.) the lowest temperature, or *minimum*, at which the plant can still absorb carbonic acid and exhale oxygen; (ii.) the highest temperature, or *maximum*, at which these processes still go on; (iii.) the best or most suitable temperature, or *optimum*, at which the plant is performing these processes most rapidly. Of course, the optimum temperature lies between the minimum and maximum.

Influence of the intensity of Light on the absorption of carbonic acid and evolution of oxygen by green parts.—Light is essential to the process. Commencing with darkness, as we increase the intensity of the light to which the plant is exposed the two processes become more and more active. This may be illustrated by a simple experiment made on the cut shoot of the water-plants. We note that near the window, exposed to the sun, the bubbles of oxygen come off rapidly, but when the plant (in the water) is transferred to a gloomier part of the room the bubbles appear more slowly, till in absolute darkness they cease entirely.

Chlorophyll, or the green colouring-matter.—The substance which causes the green colour of leaves and stems may be termed chlorophyll. Placing leaves in water, the chlorophyll is not removed from them, for it is insoluble in water.

But an impure solution of chlorophyll may be obtained by extracting the leaves by the aid of methylated spirits. The leaves in time become whitish in colour, and the solution becomes coloured. The solution is green in colour when we look through it; whereas it appears to be blood-red if we inspect it when placed before a dark background. Light decomposes the chlorophyll in the alcohol-solution, also in plucked leaves themselves. This is all the more curious because chlorophyll does not form in flowering plants unless the latter be exposed to the light. A plant grown in darkness has whitish or yellowish leaves. Bringing this bleached plant into the light, the leaves soon assume a green colour; *light is essential* to the formation of chlorophyll. If the bleached plant be killed before being exposed to the light it will not produce chlorophyll: *the plant must be living* if it is to make chlorophyll. Again, if a germinating seed be supplied with the solution mentioned on page 191, excepting that the iron be omitted, the plant grows for a time, but is yellow. If we now supply the iron, it becomes green. Therefore *iron is required* for the formation of chlorophyll. Finally, a *certain degree of warmth* is essential for the manufacture of chlorophyll. Probably the autumn tints of leaves are partially associated with the decomposition of the chlorophyll under the influence of light and the slowness of the production of new chlorophyll because of the low temperature prevailing.

CHAPTER XVII

ASSIMILATION OF CARBON

In the previous chapter it has been shown that the green parts absorb carbonic acid and return to the air the oxygen contained in the carbonic acid. The green parts, therefore, act as a reducing mechanism,* and it follows that in them some organic compound is formed at the expense of the carbon obtained. For let us remember that our definition of an organic compound is a carbon-containing body which is capable of combining with oxygen. The first step, in following the career of the absorbed carbonic acid, is to ascertain what organic bodies are found in the plants.

First, there is no pure free carbon found in plants, so that the absorbed carbonic acid does not simply lose its orygen, and thus lead to the formation of pure carbon. There are three universally present and important classes of organic compounds found in all flowering plants. They are **Proteids** (**Albuminoids**), **Carbohydrates**, and **Fats** or **Fatty Oils**. These show their organic nature in being able to burn—that is, they are able to combine with the oxygen of the air and give off carbonic acid.

I. **Proteids** are very complex compounds of carbon, containing also hydrogen, oxygen, nitrogen, sulphur, and sometimes phosphorus. The white of an egg is a good example of a proteid, and the "lean" of meat is mainly proteid. Proteids stain deeply with many dyes: they assume a yellow or brown colour with iodine. There is one substance which is mainly composed of proteids, and which is the most important part of a plant or animal—in fact, it is the only living part of living beings, and is termed **protoplasm**. Continued growth of a living being (plant or animal) implies an increase in the amount of protoplasm. Hence, if a plant is to continue growing, it

* By a "reducing mechanism" is meant a mechanism which wholly or partially deprives certain oxygen-containing compounds of their oxygen.

will require constant supplies of carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus, all of which are required to build up protoplasm. In addition, protoplasm contains water. In flowering plants the living protoplasm can be studied only by the aid of the compound microscope. It then reveals itself as a colourless, transparent, viscid substance, often with small granules in it: it is capable of growing, dividing, and moving about. All the complex processes performed by plants are due to the action of protoplasm. Therefore, in studying plants without the aid of a compound microscope, we are largely engaged in learning the properties of this living substance—protoplasm.

II. **Carbohydrates** are simpler bodies than proteids; they contain no nitrogen. **Sugars** are carbohydrates which are soluble in water. The sugar used for domestic purposes is *Cane-sugar* ($C_{12} H_{22} O_{11}$), which occurs in many plants (notedly in Sugar-Maples, Beet, Sugar-Cane). *Grape-sugars* ($C_6 H_{12} O_6$) also are found in plants. The test for grape-sugar is to warm Fehling's blue solution, which, on the addition of grape-sugar, forms a yellow precipitate. **Starch** ($C_6 H_{10} O_5$) is a solid body which is insoluble in water. By the use of dilute acids, or of certain "ferments," starch may be converted into sugar. Starch is easily recognised by its character of becoming blue on the addition of iodine. A drop of iodine placed on the cut surface of a potato-tuber, on ground rice or corn, causes a deep blue spot, thus showing that these bodies contain starch. **Cellulose.**—The solid framework or skeleton of a plant is mainly constituted of cellulose, or bodies allied to cellulose. Cellulose is a solid, colourless substance insoluble in water. When treated with sulphuric acid, it swells up and forms a substance like starch-paste, and then it will turn blue when treated with iodine. More prolonged treatment with the dilute acid causes the cellulose to change into sugar. Unchanged cellulose is stained yellow by iodine. *Wood* and *Cork* may, for the present, be regarded as peculiarly modified celluloses. Thus the familiar carbohydrates are all sugars or substances easily convertible into sugars.

III. **Fats** and **Oils.**—These might be included under one name, as a fatty-oil is merely a liquid fat. They are composed of carbon, hydrogen, and oxygen, but contain no nitrogen.

They are poorer in oxygen than are carbohydrates. They will not dissolve in nor mix with water.

Formation of Starch at the expense of the carbonic acid absorbed by leaves.—If we cultivate a bean-seedling with the aid of the inorganic culture-solution mentioned on page 191, but keep it constantly in absolute darkness, we shall find that the organic substance in the seedling is not greater, in quantity than it was in the seed. This is due to the fact that, in the absence of light, the plant cannot absorb carbonic acid. The plant is starving. If we now pluck some of its leaves, put them in methylated spirits to decolorise them, and finally place them in a solution of iodine, the leaves will assume a yellow colour. They contain no starch. If we now expose the plant to the light for several days the leaves become green, and soon absorb carbonic acid; and when we treat these leaves as we did the others, they assume a deep blue colour (appearing black) in iodine. Therefore these green leaves contain starch. In the bean-plant *the absorption of carbonic acid by green leaves exposed to the light causes starch to be manufactured.* If we expose only the roots to the light, starch will not appear in the starved plants: this illustrates the fact that chlorophyll is essential for the formation of starch at the expense of carbonic acid. Again, if we expose the leaves of the starved plant to the light, but remove the carbonic acid from the air surrounding the plant, no starch will appear. This proves that it is the carbonic acid which supplies the carbon essential to build up the starch. The same experiments may be performed on a green bean-plant which has been grown in the presence of light but subse-

Fig. 239.

quently darkened for some days. A pretty experiment may be made on a single large leaf of a sunflower. The leaf should be encased in tinfoil and kept flat, a pattern then cut out from the upper face of the tinfoil. For instance, the words "starch" and "light" in capital letters may be cut out. The leaf must be left for some days (still attached to the plant). It is then removed and tested for starch, and it will be found that, after treatment with methylated spirits and subsequently with iodine, the pattern will be marked in dark blue, whereas the rest of the leaf will be yellow in colour. Only those parts of the leaf which have been exposed to the light have manufactured starch (fig. 239). If we use a plant with variegated leaves which have patches of white, after darkening the leaves for several days, and then exposing them to the sunlight for one day, we find that starch is present only in the green parts of the leaf. This again illustrates the fact that only the green parts absorb carbonic acid and build up starch by its aid. If we kill the leaves they will not manufacture starch.

How does the carbonic acid get inside the leaves? If we fit a leaf into an air-tight india-rubber stopper, and place it in connection with the apparatus as given in figure 240, and we then suck at the tube, the suction drains away the air from above the water in the bottle, and we see bubbles of air coming from the cut end of the leaf-stalk to the surface of the water. We can continue this experiment for a considerable time, thus proving that the air which bubbles from the leaf-stalk is not simply air which was inside the leaf; but that it has come from the atmosphere outside the bottle, passing in by the lamina, and travelling down the leaf-stalk. The leaves of the majority of ordinary plants absorb carbonic acid by their lower surfaces, and only slightly or not at all by their upper faces. Hence a leaf coated with vaseline over its whole surface, or over only its lower face, does not manufacture starch at the expense of carbonic acid. But if only the upper surface of the leaf be painted with vaseline, the carbonic acid can enter by the lower face of the leaf, and starch will appear.

Fig. 240.

Green parts which do not produce starch.—Some plants produce little or no starch in their green leaves. The onion, for instance, produces sugar. Some other plants produce oils at the expense of the carbonic acid.

Why is Light essential to the production of organic matter at the expense of Carbonic Acid?—If we apply a light to organic material (say wood) we know that it will burn. We make the burning wood (or leaves or coal) do wórk by setting it to drive an engine. The work is done because heat is given out by the combination of oxygen with the organic material. The oxygen and organic material combine and produce compounds including water, carbonic acid, and ammonia. Now, if we want to make these latter substances once more form organic substance, we must remove the oxygen with which their carbon is combined. In order to remove the oxygen it is necessary to restore the heat (or its equivalent) which was given away when the organic matter combined with the oxygen. In other words, to tear the oxygen of carbonic acid apart from the carbon, force must be applied; and this force (or, more properly, energy) is supplied to the leaves in the form of sunlight. The *green part of a plant is a machine for collecting and holding sunlight, by the aid of which to force apart the oxygen and carbon of carbonic acid, with the object of building up organic matter* (starch, sugar, fats, etc.). Put into rough words, a leaf is a "trap to catch a sunbeam."

The transport of Carbohydrates in a Plant.—Starch and sugar are not only found in the green parts of plants, but they also occur in parts which have not been exposed to light and which do not contain chlorophyll. For instance, the subterranean tubers of the Potato contain much starch; the fleshy roots of the Beet and *Dahlia* are rich in sugars. Starch and sugar can appear in these underground parts even when the plant has obtained its carbon solely from carbonic acid. Yet we have learned that if plants be compelled to obtain their carbon from carbonic acid, starch and sugar are formed only in the green parts exposed to light. This proves to us that the starch or sugar in the roots or tubers must have been derived from the organic material manufactured in the green parts; it is therefore evident that organic material can travel inside the plant. This is easily shown by simple experiments on leaves which manufacture starch. If we pluck some leaves which we know to be rich in starch, and keep them for one or two days in a moist, dark place, we shall find that the starch will disappear, but an equivalent amount of sugar will appear. The insoluble solid starch has changed into soluble sugar. If we perform this experiment on a leaf still attached to the plant, the starch will disappear, but an equivalent amount of sugar will not be present in the darkened leaves. In this case the starch has changed into sugar, but the sugar has travelled away into the stem. In other words, *carbohydrates travel through the plant in the form of sugar*. In the potato-plant, when the sugar reaches the tubers it changes once more into starch; whereas, in the case of the beetroot, the sugar is deposited as sugar in the root.

Starch, Sugar, and Fats are food-substances.—We at once ask of what use to a plant are starch, sugar, and fats which have been manufactured by the leaves? The question is easily answered by reference to observations on seeds and plants grown from them. We find that in a bean-embryo in the seed there is much starch, and some proteid, as well as a little cellulose. If we germinate this seed in darkness with the aid of an inorganic culture-solution (page 191), when the seedling stops growing we shall find that it contains little or no starch, but has relatively more cellulose, sugar, and proteids, than was possessed by the embryo inside the seed. This proves that the starch has been used up in the manufacture of the cellulose framework and in building up new protoplasm. In fact, the starch in the seed is changed to sugar and travels to the growing parts of the shoot and root, and there acts as food to the developing organs. Similar observations can be made on potato-tubers which contain starch. Again, if the seed contains much fat (or oil), as is the case with the castor-oil seed, it is the oil which disappears and aids in the construction of new plant-substance. All the chemical processes involved in the building up of protoplasm from simpler substances are described under the name of *assimilation*. In the process of assimilation of carbon, the earliest easily detectable products in green parts are sugar, starch, or oil. These substances may be consumed at once in the manufacture of new protoplasm and new plant-substance; or they may be transported to some distant part of the plant and deposited there for future consumption. In the latter case they are described as *reserve-substances*. The proteids, starch, and oil stored up in seeds are reserve-foods, to be used later on by the developing seedling. Swollen subterranean stems and roots are storehouses of starch (*e.g.* Potato), or sugar (*e.g.* Beet), etc., which will feed the sprouting shoot in the following year.

Nutrition of Plants possessing no chlorophyll.—Some plants, such as Fungi and the Dodder, are devoid of chlorophyll. Consequently they are incapable of obtaining their carbon from carbon dioxide: they require supplies of organic carbon-compounds. Some of these plants absorb their organic food from other living plants, upon which they prey. They are then described as **parasites** (*e.g.* Dodder, Broom-rape). Other plants which possess no green colouring-matter obtain the needful carbon-compounds from the dead remains and products of plants and animals; these are described as **saprophytes** (*e.g.* Bird's Nest Orchid, *Monotropa*). It must be noted, however, that some parasites, such as the Mistletoe, and some saprophytes, have green leaves.

CHAPTER XVIII

ABSORPTION OF WATER AND INORGANIC SALTS

Plants take in and give out water.—If flowering plants be not supplied with water, they not only cease growing, but they droop, wither, and finally die. This familiar fact demonstrates that the plants both absorb and give off water.

The roots are the water-absorbing organs.—If we supply water to the leaves and stems of an ordinary flowering-plant, but keep the soil dry, the plants wither. This proves that the shoot is not able to absorb sufficient water. It is easy to show that roots absorb water; we merely have to watch the diminution of the water from culture-solutions in which the roots are growing. By the aid of the simple apparatus given in fig. 241 it is possible to measure exactly the rate at which the roots are sucking water in.

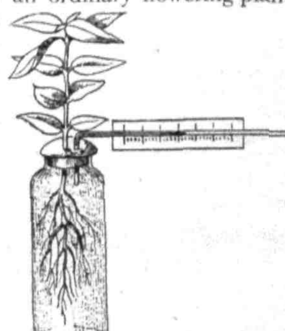

Fig. 241.—A thin, bent glass-tube filled with water, and a plant, are fixed, as figured, by means of an air-tight cork, into a bottle full of water. As the root absorbs, the rate at which the water is sucked along the tube is noted by the aid of a graduated piece of cardboard.

The roots also absorb salts dissolved in water.—This statement is easily proved by observing that the salts in culture-solutions decrease in amount as the roots absorb water.

Salts can be taken in by a root only when they are dissolved in water.—It is not easy to prove this statement without the use of the compound microscope; but three experiments illustrate the truth. If, instead of growing seedlings with the help of a culture-solution, we give them water to which have been added insoluble salts of all the chemical elements required by the plant: we shall note that the root will absorb the water but the salts remain as a powder in the vessel, and soon the plants cease to grow. If we get some powdered eosin, and add it to the water, the eosin will dissolve and form a red solution. Now, putting the uninjured roots of a plant to dip in this solution, the roots become red externally and internally, and the red colour will extend for some way up their interior. Trying the same experiments with red particles of carmine, the carmine does not dissolve, it remains suspended in the water in the form of fine granules (like red mud), nor will any red colour pass into the root. Thus the eosin passes into the root because it is dissolved in water; the carmine remains outside the root because it is still solid and undissolved. *A flowering plant can absorb only liquids or gases: it cannot take in solid bodies.*

Roots pour out an acid substance which can dissolve some minerals in the soil.—If the roots of a plant be made to grow over and against a slab of marble, in time they make a pattern of themselves on the surface of the marble. This is due to the fact that the roots excrete a substance which corrodes the marble by dissolving it wherever the young root touches the surface. Placing a piece of blue litmus-paper against the absorbing part (see next paragraph) of a root, the paper gradually assumes a red colour, thus proving that the substance poured out by the root is of an acid nature.

Only the terminal portions of roots absorb liquids.—The region of the root a short distance behind the tip is the part which absorbs. This region is usually marked out by the possession of numerous root-hairs, which aid in the process of absorption. Sometimes the roots do not possess root-hairs; this is often the case with plants grown by means of culture-solutions, but still it is the same region of the root which takes in liquid. Hence, if we cut off all the younger terminal parts of roots the plant is liable to die.

CONDITIONS INFLUENCING THE ABSORPTION OF WATER BY ROOTS.

(Use the apparatus given in fig. 241 for these experiments.)

The **Temperature** of the soil, or of the culture-solution, affects the rate of absorption by roots. If we cool the culture-solution (by dropping pieces of ice into it or otherwise) the roots absorb more slowly. There are *minimum*, *optimum*, and *maximum* temperatures for absorption (see page 194). During summer roots absorb more rapidly than in winter, for one reason, because the soil is warmer.

Strength of the solutions.—If we make the culture-solution gradually stronger and stronger, we find that, after a certain strength is attained, the root absorbs more and more slowly as the strength of the solution increases, till finally it practically ceases to take in any liquid. We thus see that *the root can take up only weak solutions of salts.*

Transpiration.—Again, carrying the plant into a better-lighted spot, or where there is a drier atmosphere, absorption increases in rapidity (see next chapter).

CHEMICAL ELEMENTS ESSENTIAL TO PLANT-LIFE, AND THEIR ABSORPTION.

It has already been stated that a plant may be successfully cultivated if supplied with the simple inorganic culture-solution, mentioned on page 191, if the atmospheric air is also accessible. In the solution and the atmosphere together there are the elements carbon, oxygen, nitrogen, hydrogen, sulphur, phosphorus, iron, calcium, magnesium, potassium (as well as common salt, which the plant can dispense with). Every plant requires all these elements: if it be deprived of one of them it cannot continue to live and grow. The first six elements are essential to build up protoplasm. Iron is required for the formation of chlorophyll. The carbon is taken in as carbon dioxide by the green parts. The last six elements must be absorbed by the roots, because they are not found in the atmosphere: they are absorbed in the form of salts in solution. Hydrogen and oxygen are taken in as water (H_2O). But oxygen and nitrogen, so far as we have yet learned in this book, might be absorbed from the air or from the soil, as they occur in both. The oxygen will be dealt with in a future chapter. There only remains nitrogen.

Absorption of Nitrogen.—Does the plant absorb the free nitrogen from the atmosphere by its shoot, or does it take nitrogen in by its roots? If we take away all the combined nitrogen (nitrates) from the culture-solution already described, and endeavour to grow a seedling of a Sunflower in the culture-solution thus impoverished, the plant remains stunted and soon dies (fig. 242). It dies for want of nitrogen, though it has an inexhaustible supply of free nitrogen in the air around it and in the air dissolved in the culture-solution. This proves that the plant cannot obtain from the air the nitrogen it requires. The plant must have combined nitrogen—preferably nitrogen containing salts—supplied to its roots. Hence the roots absorb all the elements required by the plant with the exception of carbon.* The members of the Bean-family (*Leguminosæ*) form an apparent exception to this rule. They have peculiar swellings on their roots — the so-called *tubercles* or *nodules*—which are caused by microscopic fungi or bacteria. These *Leguminosæ* can live and grow vigorously when the nitrogen is supplied to them only in the form of free nitrogen gas. But if the roots of a leguminous plant are not infected with the tubercle-bacterium, the plant remains stunted and soon dies when not supplied with nitrates or other compounds of nitrogen. In some way the bacteria enable leguminous plants to employ free nitrogen as food.

Fig. 242. — Sunflower-plants. The two left-hand plants have been cultivated in a soil containing combined nitrogen in the form of potassic nitrate. The two right-hand plants have been cultivated in a soil similar, excepting that there is no combined nitrogen in it. (After A. Mayer.)

CURRENT OF WATER AND SALTS UP THE STEM TO THE LEAVES.

If we observe the amount of water absorbed by the roots dipping in a culture-solution, we see that it is many times as great as the volume of the roots. The roots are not large enough to have retained all the water they absorbed; it is therefore evident that some of the liquid must have passed up into the stem. Salts also are carried up into the stem and to the leaves, as is shown by the fact that large quantities of the

* The roots can also absorb organic carbon-compounds, though they cannot take in carbonic acid.

elements absorbed only by the roots are found in the stem and leaves. The water travels up the woody part of a stem. This can be demonstrated by cutting a ring of bark (right

Fig. 243.—Branch of a tree from which a ring of bark has been cut, with its lower end dipping in water.

down to the wood) from the stem or branch of a tree (see fig. 243). In spite of this injury to the stem the water continues to travel up, as is evident from the fact that the leaves attached above the ring-like cut do not wither (see next chapter) and the base of the stem or root continues to absorb water. It is not easy to prove that the salts dissolved in the water go up the wood with the water. But we can illustrate the process by putting the cut end of a branch in a coloured watery solution (say of eosin). The colour gradually passes up the wood, and finally extends along the nerves of the leaves: thus showing that the colouring-matter travels up the wood with the water in which it is dissolved. If the branch has no general woody body, but possesses separate strings (vascular bundles) of woody tissue, the water and colouring-matter will travel up the isolated bundles.

CHAPTER XIX

TRANSPIRATION

If we measure the amount of water absorbed by a green plant grown by the aid of a culture-solution, we see that it soon exceeds the volume of the whole plant. This proves that not only does the plant absorb water by means of its roots, but that it also gives some water back to the air by the aid of its shoot. This fact is also shown by the familiar experience that a plant, or a cut shoot, withers if it be not supplied with water. In these cases the water passes off in the form of an invisible vapour: it is evaporated from the shoot of the plant. **The evolution of water in the form of a vapour from those parts of living plants which are in contact with the air is termed transpiration.** It is important to note especially that transpiration refers only to water given off in the form of a gas, and that it does not include water which exudes in the form of drops. As we shall see later, the leaves of some plants, in addition to transpiring, excrete liquid water.

How to measure transpiration.—(i.) *Method of weighing.*—We take a potted plant, cover the earth in the pot around the base of the plant's stem with a piece of tinfoil, and now weigh the plant, together with the pot and its contents. We weigh a second time after the lapse of an hour or two. The weight has decreased because the plant has lost water by transpiration. The loss of weight does not exactly represent the weight of water transpired, because the plant has become slightly heavier by reason of the carbon which it has absorbed from the atmosphere. But the gain in weight due to the absorbed carbon is so excessively small, compared with the weight of water transpired, that we may neglect it and regard the loss of weight as measuring the amount of water transpired. The tinfoil is placed over the soil in the pot in order to prevent water from evaporating from the surface of the soil. [This experiment is best performed on a fine day or in a dry room: see later.]

(ii.) *Cobalt-paper method.* — If we soak some white filter-paper in a weak solution of cobalt chloride, and dry it near a fire or in the sunlight, the paper will assume a blue colour. When this blue paper is brought into contact with damp air it gradually assumes a red colour, and the damper the air is, the quicker does the red tint appear. Therefore, held near a transpiring leaf, the rate at which the blue paper turns red affords us a means of judging the speed at which the leaf is making the air around it damp, or, in other words, it shows us how fast the leaf is transpiring.

Leaves are the chief transpiring organs of a plant.—If we compare (by weighing) the rate at which two branches of a tree transpire, we find that a branch bearing many leaves transpires much faster than the branch having few leaves. Again, if we cut the leaves off a branch, we ascertain that the branch transpires very much more slowly than when the leaves were present. We therefore conclude that the leaves, exposing a large surface to the air, are the parts of a plant which are mainly responsible for transpiration; a green stem does transpire to a certain extent, but a woody stem scarcely transpires at all.

Usually the lower face of a leaf transpires more rapidly than the upper face.—We can easily prove the truth of this statement by experiments by the cobalt method on leaves of a plum, cherry, pear, oak, etc. The leaf is placed between two pieces of glass, with a piece of cobalt paper on part of each face. The cobalt paper in contact with the lower face soon becomes red, whereas the piece touching the other face remains blue for a longer period. This rule generally holds true only for leaves which are extended so as to have one surface pointing upwards and one facing downwards; leaves like those of the onion, which are nearly erect, transpire equally on all faces.

The rate of transpiration varies with the temperature of the air.—A plant placed in a warm position in a room transpires more rapidly than in a cool position in the same room. A rise of temperature causes a plant to transpire more rapidly, and a fall in temperature retards the process.

Light favours transpiration.—This may easily be illustrated by comparing the rate of transpiration of a plant or leaf at first placed near a window for a time and then taken into a darker part of the same room.

The rate of transpiration depends upon the moistness of the surrounding air.—A plant placed under a glass bell-jar soon begins to transpire very slowly, because the air becomes saturated with moisture; whereas if pieces of calcium chloride be suspended near the plant it transpires rapidly, because the calcium chloride sucks the moisture from the air and renders it dry. Thus we find the drier the air is the more rapidly a plant loses water by transpiration.

Movements of the Air (Wind) often increase the rate of transpiration.—This is not as easily proved in a simple manner, but a familiar fact illustrates its truth. Plants placed in draughty passages in a house are liable to wither and fade sooner than those placed in ordinary rooms, because they transpire more rapidly without being able to make up by a corresponding increase in the rate of absorption of water.

These facts explain various more or less familiar phenomena. Plants transpire more rapidly at daytime than by night, because the air is warmer and often drier, and because the leaves are exposed to light. Again, if cut flowers or shoots be placed at once in a dark box they remain fresh for a longer time than if they are exposed and carried for the same length of time in the hand. The fading is due to transpiration without corresponding absorption. In the dark box, transpiration is slower because of the absence of light and the stillness of the air inside the box, also because the air in the box soon becomes damp.

Function of Transpiration.—We have seen that the root absorbs water and dissolved salts, and that this solution is then carried up the stem to the leaves, and finally a large part of the water is returned to the air. Why should the plant take the trouble to drink in so much water, carry it up to the leaves, and then throw most of it away? Transpiration confers at least two important benefits on the plant. In the first place, the water transpired brings with it salts in solution: the salts are required as food. But the available salts are only present in the soil in the form of very weak solutions; and even if they were present in the form of strong solutions the roots could not absorb them. The result is that the plant is compelled to absorb a great quantity of salt-solution in order to obtain the salts it requires. The water is taken in largely in order that the plant may have the salts. When the solution has travelled up to the factories of the plant—the leaves—the water has performed its carrying work and can be thrown away to make room for fresh supplies of salt-solutions. In the second place, transpiration helps to draw the salt-solution up the stem, and even causes the root to absorb liquids more quickly. It is easy to show that transpiration influences the rate at which the root takes in water: for if we place a glass bell-jar over a plant fitted into the apparatus figured on page 203, the root will gradually absorb more and more slowly as transpiration is retarded by the increasing moisture of the air under the bell-jar. Again, if we remove the bell-jar and transfer the plant and apparatus to a well-lighted window, the roots will absorb more rapidly than ever, because transpiration has been accelerated by the strong light. We can indeed use this fact as a rough method for judging of the rate at which transpiration is going on, merely measuring the speed at which absorption by the root, or the cut end of a stem, is proceeding. It is important to remember, however, that the root does not necessarily absorb the same quantity of water as the leaf transpires. Plants not watered, and plants whose roots are kept colder than the shoot, are liable to fade—that is, to lose more water than they absorb.

Fig. 244.—Apparatus for inducing the excretion of drops of water from cut shoots. The clear space below the plant-stem is occupied by water inside the short arm of the glass-tube: the water is being forced into the stem by mercury (which is shaded in the figure).

EXCRETION OF LIQUID WATER FROM LEAVES.

Early on a summer morning pearl-like drops of water may be seen glistening on the leaves of many plants. These are usually described as dew-drops—that is, they are supposed to have been derived from the air. Frequently, however, this description is incorrect, because the drops have been pumped out from the leaves. For instance, water is thus excreted from the leaf-teeth of many plants (Buttercups, Poppies, Violet, Strawberry, Gooseberry and Currant trees, Foxglove, Daisy); from the leaf-tips of others (Grasses, Stitchwort); from spots on the leaf-margin (garden "Nasturtium"); or from the upper faces of the leaves. These drops appear especially when transpiration is slow, though absorption by the root is rapid. Consequently, if we place a potted plant under a bell-jar and warm the roots, we can easily induce the excretion of liquid water from the leaves. In most cases the water will not ooze from the leaves if the leaves or branches are removed from the plant, even if their ends are dipping in water. If, however, we force water up the cut end of the stem, by means of a column of mercury, as shown in fig. 244, water will more or less rapidly come from the leaves. This suggests that the root in some way pushes the water up the stem and forces it out of the leaves. But in some cases the water will appear even if the leaves are separated from the roots, as in the Fuchsia, just as sugar-solution will pour out of the nectaries of cut flowers.

ROOT-PRESSURE.

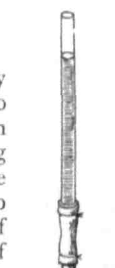
Fig. 245.

If we cut across the stem of a Vine in early spring, the cut surface of the stump attached to the root will "bleed": in other words, a solution is forced out of the cut surface. By fixing a long vertical glass tube to the stem, as in fig. 245, we see that the root is able to push the water high up the tube. The power which the root possesses of forcing water upwards is termed *root-pressure*. If we warm the roots the root-pressure is rapidly increased; cooling the roots has the opposite effect, so that the column of water remains stationary or rises slowly. Thus root-pressure depends on the rate at which the root is absorbing water. If the leaves of a plant are transpiring rapidly and we cut the stem across, we shall see no "bleeding," there is at first no sign of root-pressure, though in many plants it will appear after a time if the roots be kept warm and transpiration be arrested.*

* This absence of root-pressure in rapidly transpiring shoots does not imply that the force which causes root-pressure has stopped.

CAUSE OF THE ASCENT OF THE WATER UP THE STEM.

So far nothing has been said concerning the forces which cause water to travel from the root-stem up to the leaves. This question cannot be fully answered. There are two forces which aid the process—(i.) *Root-pressure* pushing the water up from the roots; (ii.) *transpiration* pulling the water to the leaves. Beyond these two bare statements it is impossible to go at present.

CHAPTER XX

RESPIRATION

In all the experiments previously described we have assumed that the shoot of the plant is supplied with atmospheric air. The green parts can take carbonic acid from the air. The free nitrogen of the air can be dispensed with. The question now arises "Does the plant require or use the free oxygen of the air?"

If we put a number of moistened germinating seeds, or young flowers (not green), into two bottles which we close up by means of air-tight corks, after a lapse of some (say twenty-four) hours changes have taken place in the air inside the bottle. We open one bottle, pour in some lime-water and shake it up. The lime-water becomes milky: thus showing that there is more carbonic acid in the contained air than there was at first. At the commencement of the experiment the lime-water would not become milky. We open the other bottle and thrust a lighted taper into it. The taper is at once extinguished: a fact which proves that the free oxygen inside the bottle has, wholly or partially, disappeared. These experiments illustrate the fact that growing flowering plants consume oxygen and give out carbonic acid. Another simple experiment proves the same. Before closing the bottle containing the seeds, we place in it a vessel containing a solution of potassic hydrate; we also fit a bent glass tube into the cork (as in fig. 246) and pour a coloured liquid into the tube. The liquid will stand at the same level in both arms of the tube. We then fit the cork into the bottle. The carbonic acid present in the air of the bottle will be constantly absorbed by the potassic hydrate. Now, if the seeds merely gave out this gas without taking in any other gas from the air, the amount of air inside the bottle would remain the same throughout the experiment and the liquid in the two arms of the tube would remain at the same level. (For, the decrease of the amount of gas due to the absorption of the minute amount of carbonic acid present in the air at the commencement of the experiment would be imperceptible.) But we find that, on the contrary, the liquid rises in that arm of the tube which is in direct communication with the air inside the bottle (see fig. 246). This proves that the seeds are absorbing gas from the contained air. The absorbed gas is oxygen. The evolution of carbonic acid implies that the organic substance of the plant is being split up into simpler constituents, one of which is carbonic acid. Though it is not capable of simple proof, water is also produced as a result of this decomposition. The fact that the plant loses some of its solid substance by this process is well illustrated by the following experiment. Seeds or potato-tubers are germinated in darkness, being supplied only with air and pure (distilled) water. Growth continues for a time, but the plants are growing at the expense of the reserve-foods contained in their substance, for they are receiving no food capable of building up organic matter. After they have grown for a time we examine them chemically, and find (by calculation) that they contain less organic substance than they did in the seed- or tuber- condition. They have lost substance, particularly carbon, because of the evolution of carbonic acid gas derived from their organic substance. All the facts above cited prove that in actively-living plants there is a process going on by which the **organic matter of the plant is being broken down and carbonic acid is being evolved, and that the decomposition is accompanied by an absorption of oxygen. This process is termed respiration.**

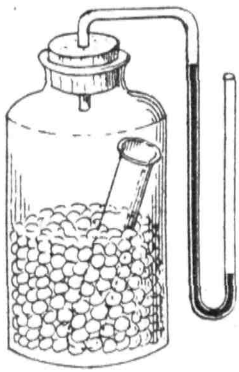

Fig. 246.

It will be noted that the process of respiration involves an excretion of carbonic acid and an absorption of oxygen. The assimilation of carbon by green parts exposed to light involves processes which are just the reverse. Hence it is not easy to prove that green parts of plants exposed to light are respiring; for, carbonic acid is being absorbed much more rapidly than it is being excreted. Still, green parts can be shown to respire if they be kept in darkness. Respiration is always going on in actively-living parts, and in all parts of the plants. The absorption of carbonic acid by the plant only takes place in green parts, and only when the parts are exposed to light. There is another difference between respiration and the assimilation of carbon from carbonic acid. The volume of oxygen absorbed is not necessarily equal to the volume of carbonic acid released during respiration—in fact, the plant may for a time respire and evolve carbonic acid, when it is not provided with oxygen. Whereas, when carbonic acid is absorbed in the process of assimilation, an equal volume of oxygen is always released, and no oxygen is evolved unless carbonic acid is absorbed.

Free oxygen is essential to maintain the active life of a flowering plant.—Oxygen is not only absorbed by a plant, but it is absolutely indispensable. A pretty experiment illustrates this. Two bottles are obtained. Into one a little water is poured, and into the other pyrogallic acid dissolved in an equal amount of water. Two small moist sponges are selected, and cress seeds sown in the small holes of the sponge. The sponges are now suspended from the under-surface of the corks, which are fitted air-tight into the two bottles (see fig. 247, which shows the complete apparatus). The seedlings soon germinate on the sponge which hangs in the air over the water. On the contrary, the seeds suspended over the pyrogallic acid do not germinate: the pyrogallic acid has absorbed all the oxygen from the air and so prevented growth. If we place a plant in an atmosphere devoid of oxygen, all the movements of the leaves and flowers which are signs of active life cease (see next chapter). We can now explain why land-plants which are too freely watered die. Gardeners say that their roots "rot away." The truth is that the earth becomes saturated with water which drives out the air contained in the soil, and in consequence the roots cannot obtain sufficient oxygen and die of suffocation.

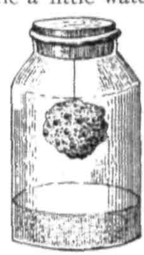

Fig. 247.

Conditions affecting respiration.—(i.) *Plants respire in light and darkness.* (ii.) *Oxygen.* In the absence of oxygen, respiration continues for a time, but finally stops. This proves that *the absorption of oxygen increases respiration.* (iii.) *Temperature.* A rise in temperature up to a certain extent favours respiration. This can be proved by keeping germinating seeds in a cold place, when they will respire slowly. (iv.) *Rapidly-growing parts respire vigorously.* Any circumstances (fall in temperature, stopping supply of oxygen) calculated to stop growth, retard respiration. This is really putting "the cart before the horse," because the stoppage of growth is largely caused by the arrest of respiration, not *vice versâ.* A passive resting-seed or tuber respires very slowly indeed, but when growth commences, its respiration is rapid. (v.) *Only living parts of plants respire.* This is the most important fact of all, though not easy to prove. We can illustrate it by killing moistened seeds by means of boiling water, and comparing their effect on the air in a closed bottle with the effect produced by germinating seeds which are living.

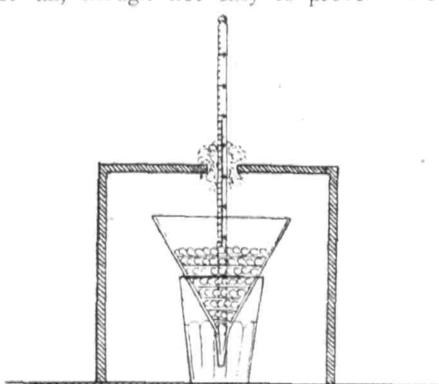

Fig. 248.—*Apparatus to show the rise of temperature during respiration.* A thermometer-bulb is surrounded by germinating peas, which are in a glass funnel. Outside is a reversed box, of wood or cardboard, through a hole in which the thermometer-tube passes.

Respiration causes a liberation of heat from the plant.—If a thermometer be plunged amongst a number of germinating seeds, or young flowers, the mercury will rise, thus showing that the seeds are warmer than the surrounding general atmosphere. If the seeds be killed, there will be no appreciable change in the level of the mercury of the thermometer, thus proving that the rise of temperature is dependent on the parts being alive. In general, any conditions which retard respiration will cause the rise in temperature to be smaller.

CHAPTER XXI

GROWTH

Definition.—It is not easy to say exactly what we mean by the word growth. It does not denote simple increase in size or change in shape. A dead, dry bean-seed will swell when supplied with water; but if the dead bean-seed be dried once more, the bean shrinks to its former dimensions. If we supply water to a living bean-seed the latter does not merely become larger; a great change in the form ensues. The little embryo develops roots and stem and leaves. We know perfectly well that if we take away the water from the bean-seedling we cannot once more change it into a bean-seed. **Growth is a permanent change in the form of the plant, and can take place only in living parts.**

CONDITIONS ESSENTIAL TO GROWTH.

(i.) The plant must be **living.** (ii.) Only parts of a plant which are in a **youthful** (embryonic) **condition,** or can be brought into a youthful condition, are capable of growing. This statement can be proved only by the aid of the compound microscope, but it may be illustrated by examples. We know, for instance, that we continue to grow in height only up to a certain age. Again, the young growing points of roots and stems are the only parts of them which grow in length. In the grasses there is an apparent exception to this last statement, for the tissue just above the old nodes can grow; but this tissue really remains in a "youthful condition" in spite of age. (iii.) A supply of **water** is essential. Water is required, first, because it is a constituent of the living substance. Furthermore, it is a food-substance. In the third place, it serves to carry the nutrient substances to the growing parts. Finally, it keeps the fresh green parts of plants in a stiff and extended condition, as is proved by observing the process of fading or withering of drying parts of plants. (iv.) **Oxygen** is required for respiration (see previous chapter). (v.) **Appropriate food material** is essential. The plant must have some food-bodies which it can convert into protoplasm and other substances constituting the body of the growing parts. This does not imply that the food-bodies must come from outside the growing plant. They may be already there, stored up as reserve material. Growth does not therefore necessarily imply an increase in the amount of solid substance composing the plant. Indeed, we have learnt that there is no increase in the dry weight of seedlings grown in darkness and supplied with only pure water and oxygen. (vi.) The **temperature** must be **suitable.** A plant placed in too hot or too cold a place will not grow.

GROWTH IN LENGTH.

It is more convenient and instructive to study growth in length of stems and roots than to follow their growth in thickness.

CIRCUMSTANCES INFLUENCING THE RATE OF GROWTH IN LENGTH OF STEMS AND ROOTS.

Temperature.—If we keep a plant in a very cold place its stem will not elongate; if we gradually raise the temperature, a point is reached at which the plant is just warm enough for the stem to commence to elongate. This is the *minimum* (or lowest) temperature for growth in length of the stem of that particular plant. Warming the plant still further, the stem elongates faster and faster as we raise the temperature up to a certain point. At this particular temperature the growth in length is most rapid; it is the best, or the *optimum*, temperature for growth in length (for that particular plant). If we still continue to place the plant in warmer and warmer places, every rise in temperature above the optimum causes growth to become slower and slower. We are, so to speak, overheating the plant. Finally, a temperature is reached which is the highest at which the stem can elongate—this is the *maximum* temperature. Placing the plant in a place the temperature of which is higher than the maximum, the stem does not elongate.

Effect of water supply.—If we do not supply water to a plant, growth in length of stem becomes gradually slower and slower till it ceases.

Effect of light.—We might expect that a stem exposed to the light would grow more rapidly than one kept in darkness. But our anticipations are not realised. Light retards the growth in length of a stem. In the case of the majority of plants which possess stems having internodes of easily perceptible length, the stem grows more rapidly in darkness. The plants grown in absence of light have thin stems with long internodes and small leaves; furthermore, they are devoid of chlorophyll. Such plants are said to be **etiolated**. In the case of plants like the Iris or Onion, with more or less erect radical leaves, the stem does not elongate abnormally in darkness, nor are the leaves dwarfed.

Nutation.—Even if every external influence (light, temperature, etc.) be kept unchanged, a stem does not grow evenly at its tip. Just behind the apex it grows more rapidly on one side than on the other, so that at this region the stem becomes a little longer on the more rapidly-growing side, and therefore bends over towards the opposite side. Soon the elongating part of the stem proceeds to grow more rapidly on another side, and the bend takes a new direction. Thus the end of the stem may be said to nod slowly, and the word *nutation* (nodding) is used to denote this phenomenon. Each growing part of the stem, which was originally bent by nutation, finally straightens itself before ceasing to elongate, so that a mature stem does not show the zig-zag course which it executed. This nutation of the stem may be seen especially clearly in twining plants.

All these variations in the rate of growth in length may be followed by using the method of making equidistant ink marks along the elongating parts of the stems (see page 5).

CIRCUMSTANCES INFLUENCING DIRECTION OF THE GROWTH IN LENGTH OF STEMS AND ROOTS.

Various external agencies influence not only the *rate* at which stems and roots elongate, but, to a certain extent, determine the *direction* in which those organs shall grow.

Heliotropism.—If potted plants be left for days undisturbed in front of a window, we know that their stems tend to point towards the window—that is, towards the light. Ordinary stems of flowering plants tend to grow towards the light, and to place themselves in a straight line with the source of the light.

To a certain extent many roots are affected also by the direction of the light falling on them; like the stems, they tend to place themselves (or rather their young growing parts) in the same line as the rays of light, but, unlike the stems, they grow directly away from the source of light. This influence of the *direction* of the rays of light upon the *direction* of the growth of parts of plants is described as *heliotropism*. The roots and stems thus affected are said to be *heliotropic*; the stem is described as *positively heliotropic*, because it grows towards the light, whilst the root is said to be *negatively heliotropic*, because it grows directly away from the source of light. Many roots, however, display only very slight, if any, heliotropism; many stems which are not erect are not positively heliotropic.

Geotropism.—We know that all bodies are attracted to the centre of the earth by the force of gravity. This force also influences the direction of the growth of stems and roots. If a bean-seed be germinated in absolute darkness, in whatever manner the seed be placed the main root will bend downwards, whereas the young stem will curve and grow vertically upwards. This behaviour is evidently not caused by the directive influence of light, because the seedling is in darkness. The end of the root does not bend downwards because of its weight, nor does it bend downwards because it is attracted by solutions of salts or water, for the root will force its way down into mercury which is much heavier than itself. If the bean-seedling be germinated on a slowly rotating vertical wheel, the roots and stems will not grow in any definite fixed direction, because gravity no longer acts on them in a constant direction. The influence which gravity exerts on the direction of growth on plants is described under the word *geotropism*. A main root is said to be *positively geotropic*, because it tends to place itself in the direction of the action of gravity and grows towards the centre of the earth. Many main stems and flowering axes are said to be *negatively geotropic*, because they tend to place themselves in the direction of the action of gravity but grow away from the centre of the earth. Lateral roots and lateral stems are influenced by gravity in a manner which cannot be discussed here.

Hydrotropism.—Many roots grow towards moisture in the soil, and are said to be *positively hydrotropic*.

In all these directive effects it must be noted that it is only the young elongating parts which respond to external influences (light, gravity, water), by curvatures or continued growth in one direction. Further, it must be noted that the ultimate direction assumed by a stem or root depends on the sum of all these influences (together with others not treated here). For instance, we often find that the directive influence of water on a main root frequently overpowers the directive influence of gravity, if the two influences are not working in the same direction. The consequence is that the root may not grow vertically downwards.

CHAPTER XXII

IRRITABILITY AND MOVEMENTS OF LIVING PARTS OF PLANTS

WHEN plants or animals are influenced by a disturbance in the world outside them, the effect produced is not so simple as is the case when dead bodies are acted upon. We may illustrate this statement by an example: Supposing we push a book along a table, we notice two facts with reference to the behaviour of the book. (i.) The amount of movement is exactly proportionate to each push we give. (ii.) The book moves in the direction of the push. We now consider an influence operating on a living organism. Suppose a tiny particle of food to enter the windpipe of a man, it may cause the man to cough so violently that many of the muscles of his body are called into play by the paroxysms. There is no proportion between the insignificant disturbing external cause (the particle in the windpipe) and the very great response. Again, if we place a bean-seedling on moist earth in a dark place in such a manner that its main root and main stem lie horizontal, when growth begins, the end of the stem will bend up, but the tip of the root will curve downwards. Thus the same disturbing cause (gravity), acting in same direction on the root and stem, occasions a different and even opposite response in the two parts of the plant. **This property of responding in a peculiar manner to external changes, and which is possessed only by living plants and animals, is termed irritability.** A disturbing external influence which is able to call forth a response is termed a *stimulus*.

PERIODIC MOVEMENTS OF LEAVES AND FLOWERS.

At night-time many leaves place themselves in postures different from those which they assume during the day, and execute movements to attain their day-position and night-position. These movements may be seen in the cotyledons of certain plants (*e.g.* seedlings of the Sunflower and of *Stellaria media*), which either rise or sink as night sets in. The foliage-leaves of *Stellaria media* also move: at night the opposite leaves at each whorl incline towards each other with their tips pointing more or less towards the apex of the stem: at daytime these leaves diverge and stand out more nearly at right angles to the stem. In compound leaves the movements of the leaflets are even more striking. By day the three leaflets of a leaf of the Woodsorrel (*Oxalis acetosella*) are fully expanded and horizontal (fig. 249); but at night-time the leaflets droop vertically downwards, something like a closed umbrella (fig. 250). The leaves of the Dutch Clover (*Trifolium repens*) are expanded by day (fig. 251); but at night the three leaflets composing a leaf bend and fold so that the terminal leaflet forms a roof over the two lateral leaflets (fig. 252). The pinnate compound leaves of many Leguminosæ either rise or sink at night-time, and the opposite leaflets bend towards each other in pairs either upwards or downwards.

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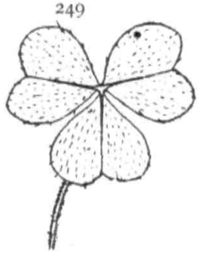

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Fig. 249. — Compound leaf of Woodsorrel: day-position.
Fig. 250.—Ditto: night-position.

251

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Fig. 251.—Compound leaf of Clover: day-position.
Fig. 252.—Ditto: night-position.

Many flowers and some inflorescences have different day- and night- positions. In most cases the flower or inflorescence (usually capitulum) is open at daytime (fig. 253), but closed by night (fig. 254); but each flower has its own opening and closing time. The accompanying table shows the opening and closing times of some flowers and inflorescences; it also shows that some flowers (*e.g. Lychnis vespertina*) are closed by day but open by night.

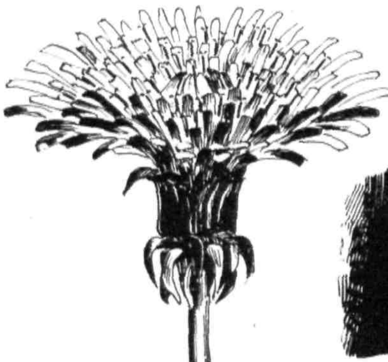

Fig. 253.—Capitulum of Dandelion open.

Fig. 254.—Ditto closed.

NAME.	Opening Time.	Closing Time.
Capitulum of *Tragopogon pratense* ("Go to bed at noon").	4-5 A.M.	9-10 A.M.
Capitulum of *Taraxacum officinale* (Dandelion).	5-6 ,,	5 P.M.
Flower of *Anagallis arvensis* (Scarlet Pimpernel, Poor-man's Weather-glass).	8 ,,	
Capitulum of *Calendula arvensis* (Marigold).	9 ,,	
Flower of *Lychnis vespertina* (Evening *Lychnis*).	7 P.M.	

IRRITABILITY OF MOVING ORGANS.

These regularly recurring (periodic) movements of leaves and flowers are liable to be disturbed by changes in the temperature or moisture of the air, or by changes in the illumination of the plant. These changes act as stimuli and cause "*induced movements.*" If at daytime we put a Clover plant or a Daisy-plant in a dark place, the leaves of the former and the capitula of the latter will close up. Here the sudden removal of light acts as a stimulus, and the irritable part of the plant responds by closing. Bringing these plants back into the light, the leaves and inflorescences open. Again, if we put a Tulip-plant with fully-developed but closed flowers into a warm place, we can cause the flowers to open. When the flowers are open and the plant is transferred to a cold place, the flowers commence to close. Here the rise or fall of temperature acts as a stimulus. (Similar observations may be made on the *Crocus*.) Finally, we know that the flowers of *Anagallis arvensis* (the Poor-man's Weather-glass) will close at daytime if the air be damp and the weather dull.

These movements induced by stimuli enable us to illustrate the meaning of irritability. If we kill the plants before trying these experiments, the leaves and flowers will not respond to the stimuli (of light, heat, etc.). This illustrates the fact that only living plants (and animals) are irritable. But we can render plants non-irritable without killing them. If, for instance, we expose them to chloroform-vapour, or keep them in a cold place, or in darkness for a considerable time, they are rendered incapable of responding to stimuli: they are no longer irritable. Restoring these plants to their ordinary surroundings, they may soon re-acquire their irritability and execute movements when stimulated by light, heat, etc. These experiments incidentally show us that light and heat may act on a green flowering plant in two different manners. In the first place, light and heat serve to keep the plant healthy, so to speak, and thus enable it to respond to stimuli. A green plant immured in darkness for a considerable time or kept in a cold place becomes ill and loses its irritability. Thus we may say that heat and light exert a *tonic* influence on plants. In the second place, when the plant is in a tonic (healthy) condition sudden changes in temperature or light act as stimuli and may cause movements. Thus light and heat also exercise *stimulating* influences on the plant.

APPENDIX *

ON TECHNICAL TERMS

PLANT.

I. **Arboreous** or **arborescent** plant = a tree. **Fruticose** or **frutescent** plant = a shrub. **Suffruticose** or **suffrutescent** plant = an under-shrub, a sub-shrub—*i.e.* a plant having deciduous herbaceous upper parts and a perennial woody base. **Bush** = a low much-branched shrub. **Terrestrial** = growing on land. **Aquatic** = growing in water. **Parasite** = a plant growing attached to, and deriving food from, another living plant or a living animal. **Epiphyte** = a plant living attached to another plant, but deriving no food from the latter. **Saprophyte** = a plant feeding upon decaying animal- or vegetable-remains.

ROOT.

II. **Root-fibres** = the slender elongated portions of roots. **Tap-root** = a stout vertically-descending main root, with or without small branches. A root is **fibrous** when it is devoid of a tap-root and consists of a number of long fibres. A root is **tuberous** when it is thickened to form short swollen masses termed **root-tubers.** **Fusiform** = spindle-shaped. **Spongiole** = the root-tip. **Pileorhiza** = root-cap. **Coleorhiza** = an additional sheath encasing the root and root-cap of a grass-embryo in the seed. **Endorhizal** = having the root of the embryo encased in an additional sheath. **Exorhizal** = not having the root of the embryo encased in an additional sheath.

STEM.

III. **Tigellum** = the main stem of the embryo in a seed; sometimes is used as a synonym of the word plumule, which denotes the shoot of the embryo in the seed.

IV. Adjectives denoting the direction of growth of stems which are above ground.—**Erect** = upright. **Flexuous** = zig-zag. **Procumbent** or **prostrate** = trailing along the ground. **Diffuse** = procumbent and copiously,

* This Appendix is intended merely for use as a Dictionary in case of necessity; on no account should it be studied: for it contains not only many terms which are useless or obsolete, but also some which are actually incorrect or misleading.

also loosely, branched. **Creeping** = trailing and giving off adventitious roots from the stem; the term creeping is also sometimes applied to subterranean horizontally elongated rhizomes. **Tufted** or **cæspitose** = when a number of *short stems, closely set, spring from the rhizome.* **Scandent** = *climbing.* **Voluble** = twining.

V. Characteristic types of stems.—**Flagellum** or **runner** = a creeping stem with long whip-like internodes, and with foliaged tufts at the nodes. **Offset** is similar to a runner, but has shorter internodes. **Stolon** = a trailing or descending branch which dips into the soil and gives off adventitious roots. **Stoloniferous** = possessing stolons. **Sucker** = a new stem rising *above the soil from, and produced by, a subterranean horizontal stem or* root. The term sucker is also applied to the sucking root-like organs by means of which parasites absorb food from the plants on which they live. **Phylloclade** = cladode. **Culm** = a jointed stem like that of a grass. **Fistular** stem or leaf is one which is hollow along its whole length. **Scape** = a stem rising from the ground, not bearing any cauline foliage-leaves, but terminating in a flower or an inflorescence. **Bulbils** = small *axillary buds which separate from the mother-plant and become distinct* individuals.

VI. Growth in thickness of stems.—**Endogenous** = not undergoing secondary increase in thickness; an **Endogen** is a Monocotyledon. **Exogenous** = undergoing secondary increase in thickness; an **Exogen** is a Dicotyledon. These obsolete meanings attached to the words Endogenous and Exogenous are widely different from the meanings given to them in *the body of this book and in other modern text-books.*

VII. A plant is **acaulescent** when it possesses no foliaged stem rising appreciably above the ground. **Root-stock** = rhizome.

LEAVES.

VIII. **Phyllotaxis** = leaf-arrangement. **Opposite** = whorled with only two leaves at each node. **Decussate** = opposite with the leaves at the successive nodes alternating. **Verticillate** = whorled. **Scattered** = alternate. **Di-, tri-, tetra-, penta-stichous** = *alternate, and forming two, three,* four, five longitudinal rows respectively. **Cauline** leaves, as opposed to radical leaves, are leaves inserted on a distinct sub-aerial stem.

IX. Adjectives referring to the base of a leaf.—**Amplexicaul**, the leaf sessile and embracing the stem at right angles. **Sheathing** = forming a sheath round the stem. **Perfoliate**, the stem appears to pierce the base of the leaf. **Connate**, the bases of opposite leaves joined together. **Decurrent**, the margins of the leaf seem to be continued down the stem as ridges.

X. Stipules.—**Foliaceous** = leaf-like. **Adnate**, as in the Rose. **Axillary**, when only one is present and it is on the axillary face of the leaf. **Interpetiolar**, when one stipule is present between each two adjacent leaves in whorled types. **Ochreate** = tubular and embracing the stem; an ochreate stipule is termed an **ochrea.** **Caducous** = falling when the leaf completely unfolds from the bud. **Persistent** = lasting as long as the other parts of the leaf.

XI. Petiole.—**Phyllode** = a flattened leaf-like petiole of a leaf which is usually devoid of a lamina.

XII. Shape of the lamina.—**Capillary** = thin and flexible, like animal hairs. **Filiform** = thread-like. **Acicular** (fig. 264). **Linear** (fig. 265).

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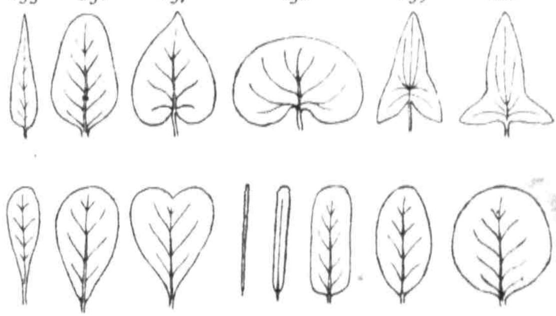

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Subulate = awl-shaped. **Lanceolate** (fig. 255). **Oblong** (fig. 266). **Elliptical** (fig. 267). **Ovate** (fig. 256). **Orbicular** or **rotund** (fig. 268). **Angular** = having three or more angles. **Deltoid** = like the Greek letter Δ. **Obovate** (fig. 262). **Cuneate** = wedge-shaped and attached by its point to the petiole. **Spathulate** (fig. 261). **Cordate** (fig. 257). **Obcordate** (fig. 263). **Reniform** (fig. 258). **Auriculate,** when the base of the lamina assumes the form of two ear-like processes (**auricles**). **Sagittate** (fig. 259). **Hastate** (fig. 260). **Ensiform** = sword-shaped. **Falcate** = sickle-shaped. **Peltate** = shield-like (as in *Tropæolum*).

XIII. Apex of the lamina.—**Acuminate** (fig. 269-IV). **Acute** (fig. 269-III). **Obtuse** (fig. 269-II). **Truncate** = ending abruptly as if cut across. **Emar-**

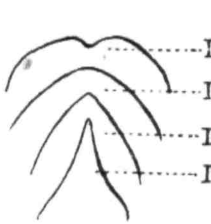

Fig. 269.

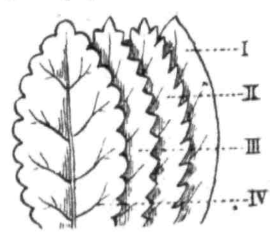

Fig. 270.

ginate (fig. 269-I). **Mucronate** = ending in a special pointed prolongation of the mid-rib. **Apiculate** = ending in a short small point.

XIV. Margin of the lamina.—**Entire** (fig. 270-I). **Serrate** (fig. 270-II). **Dentate** (fig. 270-III). **Denticulate** = with very small teeth. **Crenate** (fig. 270-IV). **Sinuate** = wavy. **Ciliate** = fringed with hairs.

XV. Division and lobing of the lamina.—**Cleft,** or termination **-fid,** when the incisions reach half-way, or nearly so, to the middle of the leaf and divide the leaf into **laciniæ**; **pinnatifid** (fig. 21), **palmatifid** (fig. 25). **Runcinate** = pinnatifid with the pointed lateral sub-divisions directed towards the base of the leaf (*e.g.* Dandelion). **Pectinate** = pinnatifid in a comb-like manner. **Parted**, or the termination **-partite** = when the incisions reach more than half-way, but not more than three-quarters of the distance, to the middle of the lamina and divide it into **partitions**: **pinnatipartite** (fig. 22), **palmatipartite** (fig. 26). The termination **-sect** = when the incisions reach more than three-quarters of the distance towards the middle of the lamina and divide it into segments which are not yet leaflets. **Lyrate** = lyre-shaped, when sub-divided in a pinnate manner with a long terminal sub-division. **Laciniate** = divided by deep and irregular incisions into a great number of unequal sub-divisions. **Lobed**: in some books a lamina divided to any depth in such a manner that the sub-divisions have rounded ends is said to be lobed: and the sub-divisions are **lobes**: **pinnately-lobed, palmately-lobed. Pinnate-leaves** = pinnately compound: **Rhachis, rachis**, the part of a pinnately compound leaf which corresponds with the mid-rib of a simple pinnately-nerved leaf; **imparipinnate** = pinnately compound with a terminal leaflet; **paripinnate** = pinnately compound without a terminal leaflet; **bipinnate** = doubly or twice pinnately compound. Palmately compound = **digitate**; **ternate** = having three leaflets; **quinate** = having five leaflets.

XVI. **Præfoliation** = vernation. **Plane** = flat (figs. 29, 32). **Reclinate** = with the upper half of the leaf folded transversely upon and against the lower half. Folded sideways: **conduplicate** (figs. 30, 33); **plicate** = **plaited** (fig. 34). **Circinate** = the apex of the leaf rolled transversely upon the more basal parts. Rolled sideways: **convolute** (fig. 37); **involute** (fig. 35); **revolute** (fig. 36).

XVII. Vernation and æstivation.—**Induplicate** (fig. 31) when the leaves are open or valvate, and have their margins rolled inwards. **Equitant** when each leaf, or its base, embraces its successor just as a saddle fits on a horse's back.

TEXTURE—CONSISTENCE OF PLANT PARTS.

XVIII. **Scarious** = thin, dry, and stiff. **Membranous** = thin, easily flexible, and more or less transparent. **Coriaceous** = tough, leathery. **Succulent** = juicy. **Rigid** = resistent.

SURFACE, HAIRS, ETC.

XIX. **Glabrous** = without hairs. **Smooth** = without hairs or any roughness. **Pubescent** = downy, coated with soft short hairs. **Pilose** = with scattered long soft hairs. **Hirsute** = with numerous long rather soft hairs. Hairs **adpressed** = when lying flat against the surface. **Silky** = with long shining close-pressed hairs. **Tomentose** = cottony = with matted soft hairs. **Woolly** = with curly wool-like soft hairs. **Hispid** = with stiff bristly hairs. **Setose** = with very stiff bristles. **Echinate** = **aculeate** = furnished with prickles. **Spinose** = furnished with spines: or being a spine. **Spinulose** = with minute spines. **Rugose** = wrinkled. **Tuberculate** = beset with many small wart-like outgrowths. **Punctate** = dotted. **Striate** = with parallel lines, either slightly raised or specially coloured. **Sulcate** = with parallel furrows. **Costate** = with parallel ribs or ridges. **Winged** = with longitudinal flap-like ridges along the sides. **Scabrous** = rough. **Viscous** = **viscid** = sticky. **Glaucous** = covered with a whitish layer of "bloom" which modifies the tints of the underlying surface (*e.g.* Plum-fruits, Cabbage-leaves).

INFLORESCENCE.

XX. Axis.—**Peduncle** = the main axis of an inflorescence, whether the latter consists of many flowers or of one solitary flower. **Pedicel** = the stalk of one single flower in an inflorescence. **Rhachis, rhachis** = the elongated flower-bearing part of an inflorescence-axis.

XXI. Bracts.—**Bracteoles** = the bracts on a single flower-stalk in an inflorescence. **Phyllaries** = the bracts forming the involucre amongst Compositæ. **Paleæ** = chaffy bracts on the receptacle of capitula, and in spikelets of Grasses.

XXII. Inflorescence.—**Centrifugal** = with flowers opening from the centre outward, as in cymose types. **Centripetal** = with flowers opening from without towards the centre—*i.e.* in acropetal succession, as in most racemose types. **Uniparous** cyme = a monochasium. **Helicoid** cyme = a kind of monochasium. **Biparous**, or **dichotomous**, cyme = a dichasium. **Fascicle** = a crowded cymose inflorescence resembling an umbel and corymb combined (*e.g.* Sweet William). **Glomerule** = a crowded cymose inflorescence resembling a capitulum or a shortened spike. **Verticillaster** = an inflorescence consisting of opposite axillary sessile cymes which form a false whorl. **Thyrsus** = a panicle-like cyme; or more accurately an inflorescence the main type of which is racemose, but the secondary or ultimate branches of which are cymes. **Strobilus** = **cone**, as applied to Angiosperms, is a spike with large bracts; as applied to Gymnosperms, it is a single flower conical in form. **Locusta** = spikelet. **Corymb** = an inflorescence like a simple raceme, except that the stalks of the lower flowers are longer than those of the upper ones, so that all the blossoms of the inflorescence reach about the same level.

FLOWER.

XXIII. **Dichlamydeous** = with a perianth consisting of two whorls. **Monochlamydeous** = with a perianth consisting of one whorl. **Achlamydeous** = naked = without a perianth. **Asepalous** = without sepals. **Complete** = having all four kinds of floral leaves. **Incomplete** = not having all four kinds of floral leaves. **Perfect** = **bisexual** = **hermaphrodite** = monoclinous. **Imperfect** = **unisexual** = diclinous. Sometimes the words perfect and imperfect are used as synonyms of complete and incomplete respectively. **Male** = staminate. **Female** = **pistillate** = carpellary. **Neuter** = devoid of stamens and carpels. **Barren** or **sterile** = incapable of producing seeds: sometimes used as synonyms of staminate. **Fertile** = producing seeds: sometimes employed as a synonym of carpellary. **Dimorphic** = having monoclinous flowers of two kinds. **Trimorphic** = having monoclinous flowers of three kinds.

XXIV. Number of parts.—A flower or a whorl is **di-**, **tri-**, **tetra-**, and **penta-merous**, when its floral leaves are in twos, threes, fours, and fives respectively. **Isomerous** = in number equal to the sepals or petals forming one whorl. **Anisomerous** = in number unequal to sepals and petals which form one whorl.

XXV. Duration of floral leaves.—**Anthesis** = the time during which a flower is in the blossoming (open) stage: or the act of opening of the flower. **Persistent** = remaining until the fruit is matured. **Marcescent** = withering without falling. **Deciduous** = falling before the fruit forms. **Fugacious** = falling or decaying in one day. **Caducous** = falling as the flower opens.

RECEPTACLE.

XXVI. **Torus** = **thalamus** = receptacle. **Calyx-tube** = concave receptacle. **Carpophore** = that portion of the axis which is prolonged between the carpels of a syncarpous ovary in the fruiting stage (*e.g.* *Geranium*, Parsley). **Stipitate**: any part of a flower which is usually devoid of a stalk is said to be **stipitate** when it is specially stalked (*e.g.* stipitate pappus of the Dandelion).

SHAPE OF THE PERIANTH (INCLUDING THE CALYX AND COROLLA).

XXVII. **Mono-**, **syn-** = gamo- -sepalous or -petalous. **Chori-**, **dialy-** = poly-sepalous or -petalous. When a sepal or petal has a narrow claw it is said to be **unguiculate**. When gamosepalous or gamopetalous the combined portion is the **tube**, the free portions form the **limb**, and the region at the junction of the limb and tube is the **throat** (**faux**).

XXVIII. Regular forms.—**Rotate** = wheel-shaped (fig. 271). **Campanulate** = bell-shaped or cup-shaped. **Urceolate** = pitcher-shaped, with the

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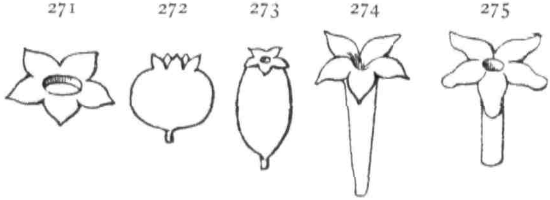

tube swollen in the middle and narrowed at the top (fig. 273). **Bladdery** = **inflated** = dilated like a bladder (fig. 272). **Infundibulum** = funnel-shaped (fig. 274). **Turbinate** = top- or pear-shaped. **Crateriform** = saucer-shaped. **Tubular** = cylindric. **Hypocrateriform** = salver-shaped (fig. 275).

XXIX. In regular or irregular forms.—**Calcarate** = **spurred** = having a deep pointed bag termed a **spur**. **Saccate** = having a shallow rounded bag. **Gibbous** = having a slight projection.

XXX. Irregular forms.—**Bilabiate** = two-lipped. **Ringent** = gaping, is a term applied to a two-lipped gamopetalous corolla when the entrance to the tube is clearly open. **Personate** = masked, is a term applied to a two-lipped gamopetalous corolla when the entrance to the tube is blocked by a projection—the **palate**—from one of the lips (*e.g.* Snapdragon).

ANDRŒCIUM.

XXXI. **Male** parts or organs of a flower = stamens.

XXXII. Number of stamens.—**Isostemonous** = equal in number to a single whorl of the perianth. **Diplostemonous** = having twice as many stamens as there are members in one whorl of the perianth, and the stamens alternating correctly. **Mon-**, **di-**, **tri-**, **pent-**, **dec-**, or **poly-androus** = having one, two, three, four, five, ten, or indefinite (more than twelve) stamens respectively in a flower.

XXXIII. Length of the filaments.—**Included** = with the anthers not reaching beyond the corolla. **Exserted** = with the anthers protruding beyond the corolla or corolla-tube. **Declinate** = with the stamens exserted and all bent to one side. **Didynamous** = when the andrœcium consists of four stamens, two of which have longer filaments than the other two. **Tetradynamous** = when the andrœcium consists of six stamens of which four have longer filaments than the other two.

XXXIV. Cohesion.—**Mon-**, **di-**, **tri-**, or **poly-adelphous** = with the filaments united to form one, two, three, or many bundles respectively. **Syngenesious** = with the anthers combined.

XXXV. Anther.—**Cells** = the chambers of the mature anther. **Quadrilocular** = four-celled, when the four pollen-sacs remain distinct in the ripe anther. **Bilocular** = two-celled, when two cells are formed by the fusion in pairs of the four pollen-sacs. **Unilocular** = one-celled, usually because only half the anther is present and its two pollen-sacs combine. **Theca** = anther-lobe. **Dithecous** = with two lobes, therefore being a complete anther. **Monothecous** = with one anther-lobe, therefore representing only half an anther. **Dimidiate** = having only one lobe, because the other is suppressed or nearly so. **Adnate** = **dorsifixed** = when the direct continuation of the filament appears to run up the whole length of the anterior or posterior surface of the anther: the anther is therefore either introrse or extrorse in insertion. **Innate** = **basifixed** = when the continuation of the filament appears to run up the centre of the anther, and the anther seems to constitute the actual end of the stamen: dehiscence is usually marginal. **Versatile** = when the anther is attached to the filament only at a single point so that it can swing freely. **Apicifixed** = **suspended** = when the anther hangs so as to appear to be fixed by its top to the filament. The direction of the two anther-cells or two anther-lobes is either **parallel** or **diverging** at an angle. **Divaricate** = when the two lobes diverge so much that they appear to be placed end to end. **Didymous** = when the two lobes combine at a point above their middle. **Two-horned** = when the two erect anther-lobes diverge above. **Sagittate** = when the anther-lobes diverge below so that the anther is shaped like an arrow-head. **Appendiculate** = bearing appendages. **Sutural** dehiscence = longitudinal dehiscence. **Opercular** dehiscence = valvular dehiscence.

GYNÆCIUM.

XXXVI. **Pistil** = gynæcium: in some books, however, the term pistil is used to denote a single ovary with a style and stigma, in which case the Buttercup-flower, for instance, has a number of pistils. **Female** parts or organs of a flower = carpels. **Mono-**, **bi-**, **tri-**, and **poly-carpellary** = gynæcium consisting of one, two, three, and many carpels respectively.

Mono-, **bi-**, **tri-gynous** are vague terms occasionally used as synonyms of terms explained in the preceding sentence.

XXXVII. Style.—**Terminal** = attached to the top of the ovary. **Lateral** = **ventral** = attached to the side of the ovary. **Basilar** = attached to the base of the ovary. **Gynobasic** = when the ovary has several distinct lobes but only one single style, which is attached to the base of the lobes at their central point of junction (*e.g.* Labiatæ).

XXXVIII. Stigma.—**Capitate** = ending in a rounded head.

XXXIX. Ovary.—**Simple** = consisting of one carpel. **Compound** = syncarpous. **Loculus** = cell = chamber. **Uni-**, **bi-**, **tri-**, **quadri-**, and **pluri-** or **multi-locular** = having one, two, three, four, and many chambers respectively. **Dissepiment** = **septum** = partition.

XL. Ovule.—**Nucleus** = nucellus. **Foramen** = micropyle. **Chalaza** = the region at which the integuments are attached to the base of the nucellus. **Hilum** = the region of attachment of the ovule to the funicle. **Raphe**, **Rhaphe** = the ridge which denotes the course of the funicle up the side of an inverted ovule; it connects the hilum and chalaza: the raphe is **ventral** when it is on that side of the ovule which faces the placenta, and consequently is between the placenta and micropyle; it is **dorsal** when it is on the side away from the placenta, so that the micropyle is situated between the placenta and the raphe; finally the raphe is **lateral** when it lies between the ventral and dorsal positions. **Primine** (testa) = the outer integument. **Secundine** (tegmen) = the inner integument. **Amphitropous** = half-inverted —that is, between anatropous and orthotropous. **Erect** = standing upright from the floor of the ovary-chamber. **Ascending** = directing obliquely upwards from an axial or parietal placenta. **Horizontal** = directed horizontally from an axial or a parietal placenta. **Pendulous** = directed obliquely downwards from an axial or a parietal placenta. **Suspended** = hanging vertically downwards from the roof of the ovary-chamber.

POLLINATION AND FERTILISATION.

XLI. **Fecundation** = fertilisation. **Fertilisation** = a term used in many books to denote pollination. **Autogamy** = self-pollination. **Allogamy** = cross-pollination. **Geitonegamy** = pollination by pollen from another flower on the same individual plant. **Entomophilous** = insect-pollinated. **Anemophilous** = wind-pollinated. **Dichogamy** = the ripening of the stamens and carpels of one flower at different times.

SEED.

XLII. **Spermoderm** = **testa** = the coat of a seed; or if the coat be double it is the outer layer, and the inner layer is the **tegmen** or **endopleura.** **Albumen** = the endosperm or perisperm, or both together, in a seed. **Albuminous** = possessing albumen. **Exalbuminous** = devoid of albumen. **Aril** = a special accessory envelope outside the testa and partially encasing a seed. **Strophiole** and **caruncula** = peculiar single outgrowths on seeds (*e.g.* Violet).

FRUIT.

XLIII. **Aggregate** fruit = compound fruit. **Multiple** or **collective** fruit = infructescence. **Pseudocarp** or **false fruit**; in some books a fruit is defined as being the ripened seed-containing carpels of a single flower, and fruits into whose composition other parts enter are described as pseudocarps or false fruits (*e.g.* Strawberry, Rose). The **pericarp** of a fruit is often distinguishable into two or three layers; an outer one—the **epicarp** or **exocarp**; an inner one—the **endocarp**: and when a third layer is present, a middle one—the **mesocarp.** **Putamen** = a stone-like endocarp. **Pyrene** = a stone of a drupe. A **capsule** with longitudinal dehiscence along the ventral sutures is **septicidal**; along the dorsal sutures is **loculicidal**; and finally, when dehiscing so that the valves separate from the partitions of the ovary it is **septifragal.** **Pyxis** = **pyxidium** = a capsule with transverse (**circumscissile**) dehiscence. **Lomentum** = a pod-shaped fruit which breaks transversely into closed one-seeded joints. **Glans** = a nut with an involucre. **Cypsela** = an inferior achene like that of the Compositæ. **Nucule** = nutlet (*e.g.* Labiatæ). **Cremocarp** = **diachenium** = the schizocarp of Umbelliferæ. **Carcerulus** = an indehiscent several-chambered dry fruit (*e.g.* Labiatæ). **Pepo** = a berry like a cucumber or gourd. **Hesperidium** = a berry like an orange. **Æterio** = **eterio** = a compound fruit like that of the Buttercup (an æterio of achenes) or that of the Blackberry (an æterio of drupes). **Drupel** = a drupe of a compound fruit. **Cynarrhodium** = a compound fruit like that of the Rose. **Syconium** or **syconus** = an infructescence like the "Fig-fruit." **Sorosis** = an infructescence like a "Pine-apple" or a "Mulberry."

TERMS APPLIED TO VARIOUS PARTS.

XLIV. **Arcuate** = bent like a bow. **Aristate** = having a thread-like, usually stiff, termination or appendage: having an awn. **Articulate** = jointed. **Elongate** = at least three times as long as broad. **Globose** = approximately spherical. **Inflexed** = bent inwards or towards the upper face. **Reflexed** = bent outwards, backwards, or towards the lower face. **Rostrate** = ending in a straight elongated beak-like process.

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