Text Book of Elementary Botany.

Charlotte L. Laurie.

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TEXT-BOOK OF ELEMENTARY BOTANY

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A TEXT-BOOK

OF

ELEMENTARY BOTANY

BY

CHARLOTTE L. LAURIE

ASSISTANT-MISTRESS AT CHELTENHAM LADIES' COLLEGE

WITH ILLUSTRATIONS BY

W. L. BOYS-SMITH

LATE SCHOLAR OF GIRTON COLLEGE, CAMBRIDGE, AND SCIENCE LECTURER AT
CHELTENHAM LADIES' COLLEGE

LONDON:
ALLMAN & SON, LIMITED,
67, NEW OXFORD STREET, W.C.

PREFACE

THIS book consists of three parts. In Part I., the structure and growth of the Flowering Plant is given; Part II. treats of the classification, distribution, and habitat of Flowering Plants, and the characteristics of a few Orders; whilst Part III. deals with the Physiology of the Plant.

Part I. begins with germination, traces the growth of the plant from the seed, describes its component parts, root and shoot, and, lastly, the formation of the flower — a shoot modified for the production of fruit and seed.

In Part II., those Orders are selected which are required for the Junior Oxford and most Elementary Examinations in Botany.

The Physiology of Plants, in Part III., is treated experimentally, as far as is possible in a book of this scope. Students should repeat the experiments for themselves.

It is hoped that the book will be especially useful to those preparing for the Junior Oxford and Cambridge Examinations, and, above all, that it may interest beginners in the study of Botany. As far as possible, technical language has been avoided, in order that beginners may not be discouraged by terms, which are often mere names to them. When such terms are used, they have been carefully explained, and, if helpful, their derivation has been given.

A list of the authorities I have chiefly consulted will be found on page x.

The illustrations have been drawn especially for this book by Miss W. L. Boys-Smith, to whose artistic skill, knowledge of botany, and kindly interest, I am much indebted. Many of the specimens for the illustrations were most kindly supplied me from the Cheltenham Botanical Gardens by Mr. W. L. Mellersh.

Lastly, I wish to express my warmest thanks to my friend and colleague, Miss Amy Johnson, B.Sc., whose help has been invaluable. The experiments described in the section on Physiology are those which she has found practicable for class demonstration; and, indeed, there is not a single chapter which does not owe much to her suggestion.

CHARLOTTE L. LAURIE.

CHELTENHAM.
August, 1901.

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LIST OF AUTHORITIES

"The Natural History of Plants." *Kerner.*

"A Student's Text-Book of Botany." *Vines.*

"Handbook of the British Flora." *Bentham.*

"The Fertilisation of Flowers." *Müller.*

"Physiology of Plants." *Darwin and Acton.*

"Flowering Plants and Ferns." *Willis.*

"British Wild Flowers and Insects." *Lord Avebury.*

"Buds and Stipules." *Lord Avebury.*

"Structural Botany." *Asa Gray.*

"Climbing Plants." *Darwin.*

PART I

STRUCTURE OF THE FLOWERING PLANT

TEXT BOOK OF ELEMENTARY BOTANY.

CHAPTER I

GERMINATION

In order to watch the process of germination, seeds should be soaked for twenty-four hours and, if possible, grown in damp air. This can be managed in the case of such seeds as pea or bean, by pinning them to the cork of a glass bottle with a wide mouth; the bottle should be kept half filled with water, in order that the air may be constantly moist. (See Fig 12.) Mustard and cress may be conveniently grown on flannel, or on a sponge, and seeds grow well in sawdust or cocoanut fibre; but under these conditions it is not possible to watch the whole process of germination, as it is when the seed is grown in damp air in a bottle. Acorns germinate well in little specimen vases nearly filled with water.

Structure of Bean Seed. The bean seed is convex on one side, and more or less straight on the other; it is enclosed in a brown coat, called the *testa*. On one side is a black scar, denoting the attachment of the stalk of the seed. Along the straighter side of the bean a triangular structure is easily seen through the testa, the apex of the triangle pointing towards the scar. This is the *radicle*, from which the first or primary root arises. A little hole, through which water is seen oozing out when the bean has been previously soaked, should be noticed between the apex of the radicle and the black scar; through this the radicle pushes its way out. A bean which has been soaked for twenty-four hours will be considerably larger than it was in the dry condition, owing to the water taken in; and the testa, which in the dry condition was wrinkled, is now tightly stretched.

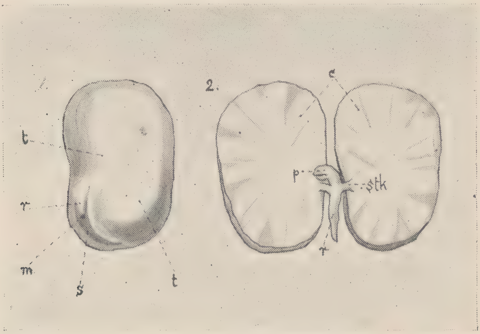


FIG. 1.—BEAN SEED (EXTERNAL). FIG. 2.—EMBRYO OF BEAN.

t, testa; *s*, scar of attachment of seed stalk; *m*, hole through which radicle protrudes (micropyle); *p*, plumule; *r*, radicle; *stk*, stalk of cotyledons (*c*).

The testa may be removed by cutting it along the convex side of the bean. It will then be seen that the greater part of the seed is occupied by two thick, fleshy lobes; these are the *cotyledons;* they are the first leaves of the young plant, and in this case contain the food for the young seedling. The cotyledons easily separate, and if held apart without breaking them, as in Fig. 2, it is possible to make out a yellowish structure continuous with the radicle and lying between the two cotyledons. This is the *plumule*, which will give rise to the young shoot. The plumule, therefore, is the first bud of the plant.

The radicle, plumule and cotyledons together form the *embryo*, so that the bean seed contains nothing but the young plant.

The time required for the development of radicle and plumule depends, amongst other things, on the time of year. In a bean grown in damp air in November, the radicle did not burst through the testa until the third day from the time it was first soaked; in spring, the process would be much more rapid.

Growth of Embryo. The radicle, having burst the testa, grows downwards, giving off branches laterally, whilst the plumule is pushed out from between the cotyledons owing to the growth in length of their stalks. The main root which arises from the radicle is the primary root; its branches are lateral roots.

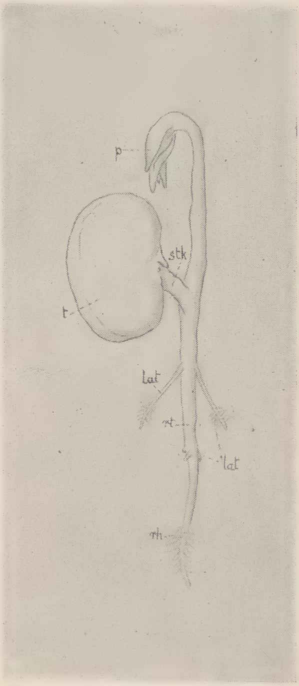


FIG. 3.—BEAN SEEDLING.
t, testa; *stk*, stalk of cotyledon; *rt*, primary root; *lat*, lateral roots; *rh*, root-hairs; *p*, plumule.

Structure of Grain of Maize. With the germination of a bean seed may be compared that of maize. A grain of maize is not merely a seed; it is the seed and the seed-vessel, so that it answers not only to the seed of the bean, but to the seed and the pod. Its seed-coat has become united to its seed-vessel; the skin of the grain of maize, therefore, represents testa and seed-vessel.

A grain of maize is rather longer than it is broad; at the pointed end may be observed the rough edge, by which it was attached to the cob; the two broad surfaces are smooth, but in the centre of one of them a greyish line is visible. This denotes the position of plumule and radicle. Round that is a shield-like, white substance, called from its shape the scutellum

(Latin *scutum*, a shield); this answers in part to the cotyledon. The rest of the grain, chiefly yellow, is food material.

FIGS. 4 TO 7.—MAIZE.

4.—EXTERNAL VIEW OF GRAIN. 5.—EMBRYO, REMOVED FROM GRAIN. 6 AND 7.—SEEDLINGS.

x, remains of style; *y*, stalk of attachment to cob; *sc*, scutellum; *p*, plumule; *r*, radicle; *sh*, root-sheath; *rh*, root-hairs; *e*, food-material.

Stages in Germination. The first step in germination is invariably the swelling of the seed owing to the taking in of water; then the skin bursts in consequence of the pressure of the radicle against it; this soon protrudes, and the skin goes on splitting until the plumule also emerges. The radicle soon gives off branches forming lateral roots. In maize, two other roots, called secondary, arise from the scutellum. The first root has a little sheath at its base, so that it is possible to tell which the primary root is.

The plumule grows into the shoot; in maize the leaves ensheathe the stem.

COMPARISON OF SEED OF BEAN AND GRAIN OF MAIZE.

BEAN.	MAIZE.
1. A seed.	A seed + seed-vessel.
2. Brown skin is testa.	Skin is testa + wall of seed-vessel.
3. Two fleshy cotyledons, containing food.	One cotyledon.
4. Food stored within the young plant.	Food supply external to the young plant.
5. Radicle develops into primary root, bearing lateral branches.	Radicle develops into primary root with lateral branches; in addition there are two other roots, which are soon as long as the primary root.
6. Plumule grows into shoot.	Plumule grows into shoot.

Conditions necessary for Germination. In all cases the conditions of germination are similar. The seed must have water; it must first be soaked and then kept constantly moist, for without water growth cannot take place.

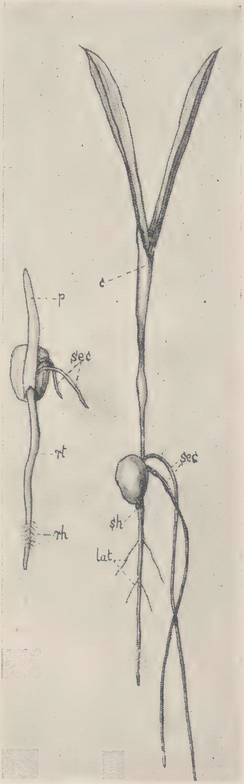
Secondly, it must have air.

Thirdly, it must have food. This may be contained within the embryo, as in the cotyledons of the bean; or it may be external to the embryo, as in maize.

Fourthly, a certain temperature is necessary. Seeds do not germinate when exposed to a low temperature; a cold spring keeps back the germination of the seeds planted in our gardens.

Lastly, light, though not necessary for the first stages of germination, is essential for the healthy development of the plant.

Mustard and cress, and seeds which have two cotyledons, develop as the sunflower or bean; seeds of grasses, and those which have only one cotyledon, resemble maize in their development.



FIGS. 8 AND 9.—SEEDLINGS OF MAIZE.

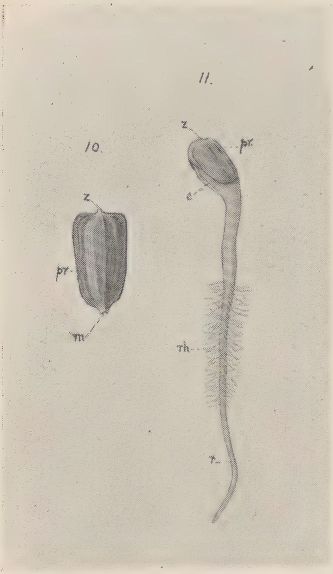
rt, primary root; *rh*, root-hairs; *lat*, lateral roots; *sec*, secondary roots; *sh*, root-sheath; *c*, cotyledon; *p*, plumule.

Structure of Sunflower "Seeds." The so-called "seeds" of sunflower, those that are bought from nurserymen, represent not only the seed, but also the seed-vessel. The brown, brittle shell is the wall of the seed-vessel, and answers to the pod of the bean; within this is a delicate whitish layer, the testa.

Comparing the germination of sunflower with that of bean, there is this difference to note: the two cotyledons do not remain in the ground as they do in the bean, but are borne upwards by the growth in length of the stem beneath the cotyledons, generally carrying the seed-vessel with them. This soon falls off; the cotyledons then expose their inner surfaces to the sunlight, turn green, and begin to make food for the seedling.

The plumule emerges from between the cotyledons, and grows into the shoot.

The portion of the stem beneath the cotyledons is called the hypocotyledonary stem (Gk. *hypo* = under).



FIGS. 10 AND 11.—SUNFLOWER.

pr, wall of seed-vessel; *z*, attachment of parts of flower; *r*, radicle; *p*, plumule; *c*, cotyledons; *m*, micropyle; *rh*, root-hairs.

COMPARISON OF GERMINATION.

BEAN.	SUNFLOWER.
1. A seed.	A seed + seed-vessel, the brown shell being wall of seed-vessel.
2. The brown skin is the seed coat.	The seed coat is the thin, white skin within the brown shell.
3. Embryo { radicle. plumule. two cotyledons.	Embryo { radicle. plumule. two cotyledons.
4. Cotyledons remain in the ground, and do not turn green.	Cotyledons come above ground and turn green.
5. One main root with lateral branches.	One main root with lateral branches.

CHAPTER II

ROOTS

Growth of Root from Radicle. If a seed is put to germinate in moist air (p. 3), the growth of the first root from the radicle may be observed. The first thing to notice is, that the root always grows *downwards;* if even the seed is pinned to the cork in such a way that the radicle is uppermost, the primary root will curve, so as to grow towards the centre of the earth.

Then when the root is about an inch and a half in length, if it is marked to its very tip with black lines in Indian ink and two millimetres apart, it will be seen at the end of twenty-four hours that the distances between the lines which were at first the same now vary, the greatest distance occurring near the tip of the root. This shows that growth is most active near the apex of the root; the growing point is just behind its tip, which consists of a root-cap, a structure that protects the root as it comes in contact with the soil. The portion of the root a little way behind the tip is covered with hairs, which are more or less dense according to the circumstances under which the root is growing; if exposed to moisture, for instance, they will be more abundant than they would be in dry soil.

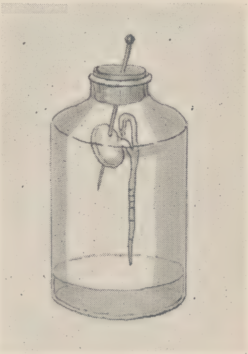


FIG. 12.—SEED GERMINATING IN MOIST AIR, SHOWING GROWTH OF RADICLE.

Branches of Roots. A primary root soon begins to put forth branches; these always arise laterally, sometimes in two rows, sometimes in four, three, or five, or even more. They originate *within* the root, as is clearly shown in the accompanying figure, and are, therefore, said to arise *endogenously*. (Gk. *endon* = within, and *ginomai* = to grow.) Each branch, like the main root, develops root-hairs behind its tip, and is protected by a root-cap. When the primary root grows to a greater length than any of its branches, the plant is said to have a tap-root; but when, as has already been mentioned in maize (p. 6), secondary roots, arising from other parts of the stem, soon equal the primary root in length, there is no tap-root.

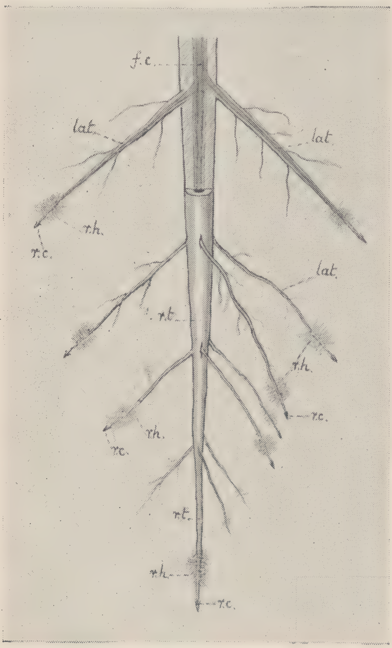


FIG. 13.—MAIN ROOT, SHOWING LATERAL ROOTS ARISING ENDOGENOUSLY (diagrammatic).

rt, primary root; *lat*, lateral roots; *rh*, root-hairs; *rc*, root-cap; *fc*, inner tissues.

A root system, in which there is no main root, is described as fibrous.

Primary roots may be very varied in shape, as may be seen by comparing the carrot with the turnip; or they may be irregularly swollen, as in the dahlia.

Functions of a Root.

A root has two main functions to perform in the life of the plant; the primary root, which grows to considerable length, and is thick and stout in the portion nearest the stem, fixes the plant in the soil; whilst the extremities of the root and its numerous branches are, owing to the root-hairs with which they are covered, specially concerned in taking in food and water for the plant from the soil. In transplanting, a lump of soil should be taken up with the plant, in order that the root-hairs may not be injured and the plant not wither away.

Definition of a Root. A root of a land plant may now be defined as that part of the plant which fixes it in the soil, and absorbs nourishment for it through its branches, which are developed laterally, and are exactly similar to it in structure.

Adventitious Roots. Roots which do not arise from the radicle are said to be *adventitious*. They may be developed from the stem, as in ivy, where they become climbing organs through their clasping power. "Cuttings" put out roots from the cut stem, and even flowers in water will send out roots from their cut stalks: Marguerite daisies commonly do this.

FIG. 14.—FIBROUS ROOTS OF GRASSES.

The *aerial* roots of tropical Orchids are also adventitious; in this case the dust and drops of dew and other moisture falling on the root furnish the plant with food. Thus, an Orchid with aerial roots, although it lives on another plant, generally some tree, does not in any way injure it, for it gets its nourishment from the air and not at the expense of the tree. Some tropical trees, the Banyan-tree, for example, give out roots from their trunk; these hang down like long streamers, at first swinging freely in the air, but eventually taking root in the ground. It is said that the island of Barbados received its name from these trees, the Portuguese sailors likening them to old men's beards.

Roots of Parasites. Many plants live on other plants, and obtain the whole of their food from them; Dodder and Broom-rape are typical instances. Dodder lives on clover, hemp, flax; broom-rape on the roots of beech and other trees. These all send processes from their roots into the plant on which they are living, and thus suck nourishment from them.

Fig. 15.—Orchid, showing Aerial Roots.

Mistletoe, eyebright, and red rattle get only part of their nourishment from the plant on which they live, a good deal being obtained through their own leaves. It may be noticed that where the eyebright is abundant, grass is scarce, as on exposed moors in Yorkshire and Scotland. The German name for this flower is *milchdieb*, or milk-thief, for owing to the fact that it lives on the roots of grasses, pasturage is poor in its neighbourhood.

Duration of Roots. Plants which have roots that live only for a year are said to be *annuals*. Such plants as, for instance, poppy, spring from the seed, flower the same year, and then die.

Biennials, on the other hand, are plants which spring from the seed, form leaves during the first season, but do not flower until the following year. During the first year's growth the plant is storing up nourishment for the second year, either in the root or underground stem, as in beet, carrot, turnip; during the second season it flowers and seeds.

A *perennial* is a plant which lives and sometimes blossoms year after year; its roots may be perennial, but very often they last only two years, and growth then proceeds from the underground stem. Some perennials flower every year, others only occasionally.

Rootstocks must not be confused with roots; they are underground stems, and will be discussed later.

CHAPTER III

BUDS

Plumule, the First Bud. THE plumule is the first bud. As soon as the plumule has begun to appear above the cotyledons, if it is cut lengthways through the middle and examined with a hand lens, it will be seen to consist of a central portion, the stem, and of lateral outgrowths, the leaves.

All buds consist of: (1) This stem-like portion; (2) leaves. Thus a bud is the germ of a shoot.

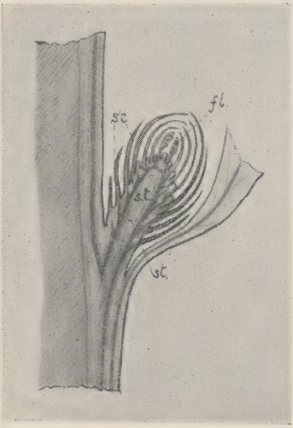


FIG. 16.—SECTION OF AXILLARY BUD.

st, stem portion; *sc*, scales; *fl*, foliage leaves.

The stem portion of the bud is very short, and the leaves are crowded together. The part of the stem from which the leaves come is called the *node* (Latin *nodus*, a knot), and the part between the leaves the *internode.*

Apical Buds. The stem of a plant always ends in a bud—the apical bud; here the nodes are very close together and the internodes short. As the stem grows, the nodes become further apart, owing to the growth in length of the internode.

Axillary Buds. Other buds arise in the angle which the leaf makes with the stem, *i.e.*, in the axil; these are, therefore, called *axillary* buds. A section through an axillary bud shows, as in the plumule, stem and leaves. If all these buds developed, then wherever there was a leaf there would be a branch; but a great many of them remain dormant. Sometimes an axillary bud, which has been dormant for a long time, may form a branch in order to replace one which has been injured;

this is specially the case where the apical bud has been destroyed, as in the trimming of hedges. In this way not only are hedges prevented growing too high, but their growth in thickness is ensured.

Winter Buds of Ash. The best way of realizing the position and the number of buds present in a plant is to examine trees in winter. If a twig of the Ash be carefully observed, it will be seen that the apex ends in a bud, that close to the apical bud are two axillary ones; the fact that they are in the angle which the leaf makes with the stem being clear from the scar left by the fallen leaf just under each bud. The next two buds are on opposite sides of the stem, and so on.

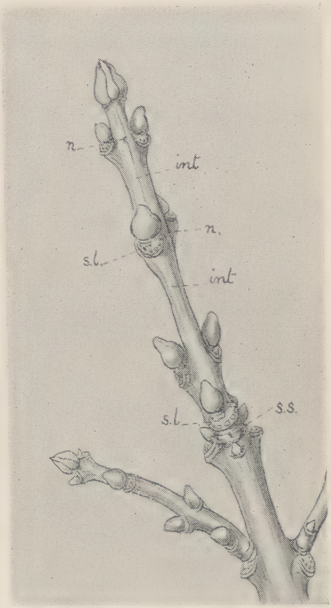


FIG. 17.—TERMINAL PORTION AND SIDE TWIG OF BRANCH OF ASH.
n, node; *int*, internode; *sl*, scar of attachment of last year's leaves; *ss*, scars left by scales of last year's bud, marking limit of one year's growth.

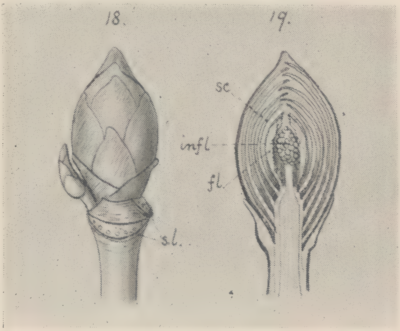
The length of the internodes varies very much. When the twig has developed normally it may be considerable, about an inch and a half; but very often development has been arrested, and the stem has not grown much in length, so that the nodes are closer to each other. A normal condition shows short internodes near the apex; then longer and longer ones, until the end of that year's growth has been reached; below that the internodes become closer again, and again lengthen out. A terminal branch, about twelve inches in length, may show three years' growth. These winter buds are specially adapted for the protection of the young leaves from the cold and damp. The buds of the Ash have thick, olive-green, almost black, scales, which are leaves that have become developed for purposes of protection. Each bud has:

1. Four outer black scales which overlap, completely enclosing

2. The young leaves covered with down. These may be, not only the green foliage leaves, but also those which develop into the flower. Generally, one axillary bud develops into a branch, and the opposite bud into a flowering shoot.

3. The stem portion, which bears the scales and leaves just described.

Winter Buds of Horse-chestnut. A twig of the Horse-chestnut shows even more plainly than that of the Ash the scar left by the fallen leaves, and the buds are particularly well protected from the winter cold and damp. The outer brown scales are covered with resin, so that it is particularly difficult to get them off without breaking them, unless the resin is first dissolved in methylated spirits. Underneath these brown scales are green covering scales; then come the young foliage leaves so entirely covered with down that they look quite white. Within these, in a terminal bud, are the flowers, looking rather pinker. All these are borne by the short stem of the bud.



FIGS. 18 AND 19.—WINTER BUD OF HORSE-CHESTNUT. 18. EXTERNAL VIEW. 19. LONGITUDINAL SECTION.

infl, inflorescence; *fl*, foliage leaves; *sl*, scar of attachment of last year's leaves; *sc*, brown covering scales.

Buds of Plane. In a Plane, the buds are found inside the leaf-stalk, for at the base of each winter bud there is a little ridge, which extends all round the bud. This is the remains of the leaf-stalk, which has grown all round the bud, completely enclosing it.

In the summer, when the leaf is still on the tree, the way in which it protects the bud is best seen. The leaf-stalk has grown out all round the bud, and has become hollowed out to form a little cap, which exactly fits over the bud. In the autumn, when the leaf falls, the bud is exposed, and then scales protect it.

FIGS. 20 AND 21.—BUDS OF PLANE.
20. WINTER BUD. 21. SUMMER BUD, PROTECTED BY LEAF-STALK.

There are many other ways in which buds are protected, as Lord Avebury has described in his "Buds and Stipules."

The buds of some young hardy shrubs and trees are not protected by specially developed scales; in this case they are often very minute, and may lie hidden under the bark.

Abnormal Buds. Under certain circumstances, buds are neither apical nor axillary, but they arise from any part of the stem, or even from leaves. Thus, in trees which have been pollarded, buds may arise from the sides of the trunk;

and in the Begonia a leaf will root and buds will be produced on the blade. Buds of this kind are irregular and abnormal.

Arrangement of Leaves in a Bud.

It is interesting to see how leaves are arranged in a bud. The accompanying figure (22) is a drawing of a terminal bud of the Ash cut across and drawn from the microscope.

On the outside lie the four outer scales; in the centre are two leaves, opposite to each other, and each showing seven little leaves. At right angles to these are two more leaves, each also composed of seven leaflets; again, at right angles to these, two more, and so on. Each leaflet is bent on itself, like the covers of a book. In the section only seven leaflets are seen, although the leaf of the ash consists of eleven little leaves; these, lying at different levels, will not all be cut through; the outermost leaves, for the same reason, show five instead of seven leaflets.

Fig. 22.—Transverse Section of Terminal Bud of Ash.

With this may be compared the Horse-chestnut bud, which, being very large, can be seen without the microscope. The terminal bud should be examined early in March before it opens. If it is cut across about the middle, the outlines of the outer brown and inner green scales are quite clear; then follow, in quite a young bud, four green crescent-shaped masses, forming, as it were, the four sides of a square. With the help of a lens each crescent-shaped mass is seen to be a foliage leaf, and in a slightly older bud seven leaflets can be made out, all being packed in layer upon layer of wool. Within these are the flowers, pinkish in colour. If the outer scales and the wool attached to the leaves are carefully removed, the way in which each leaflet is bent on itself is seen; it is folded like the leaves of a book, as in the Ash. It entirely depends on the state of development of the bud how many leaves can be detected, for it must be remembered that the growing point in the bud is continually producing new leaves.

The separate leaves in a bud may be bent or folded, or they may be rolled. In the Ash, the two halves of the leaf are merely folded on each other (Fig. 22); in the Sycamore, the leaf is thrown into plaits, and is therefore said to be plicate (Lat. *plicare*, to fold). In Apricot, the leaf is rolled from one edge to the other, so that one margin is inside, the other outside; this is described as convolute (Lat. *con* and *volvo*, to roll). The two margins of the leaf may be rolled inwards, as in the Violet, and the leaf is then involute, whilst in the Dock they are rolled outwards, and the leaf is therefore revolute. In Ferns, the leaf is rolled from top to bottom lengthwise, and is said to be circinate, from its resemblance to a crozier.

As many buds as possible should be examined and drawings made of them, in order to get some idea of the great variety of arrangement of leaves in the bud.

CHAPTER IV

STEMS

Stems compared with Roots. We have already noticed in the seed the young stem bearing leaves. This is the most striking characteristic of stems as compared with roots. Leaves always come off laterally, and are dissimilar in appearance to the stem; a root, it is true, does have lateral outgrowths, but these always resemble the root and are not entirely different in appearance from it, as the leaf is from the stem.

Again, when a stem branches, the branch is formed from the outer portion of the stem, not from the inner part as in the root. Branches are therefore said to arise exogenously in the stem and endogenously in the root.

Lastly, the apex of a stem always consists of a bud, whilst the apex of the root is occupied by the root-cap.

TABLE OF COMPARISON.

STEMS.	ROOTS.
1. Bear leaves.	Never bear leaves.
2. Branches formed exogenously.	Branches formed endogenously.
3. Apex consists of bud.	Apex consists of root-cap.

Underground Stems distinct from Roots. Some stems do not come up above ground, but these may be distinguished from roots by noting the following details:

1. Whether the underground structure consists of nodes and internodes.
2. Whether it bears scales, or anything answering to leaves.
3. Whether it forms buds.

The stem of Solomon's Seal, or Scirpus, shows these points of structure very well. It does consist of nodes and internodes; it bears brown scales; it gives off roots at the nodes, and forms buds; therefore, it is a stem, not a root.

The structure of the bulb, corm of crocus, tuber of potato, shows that they, too, are all of the nature of stems.

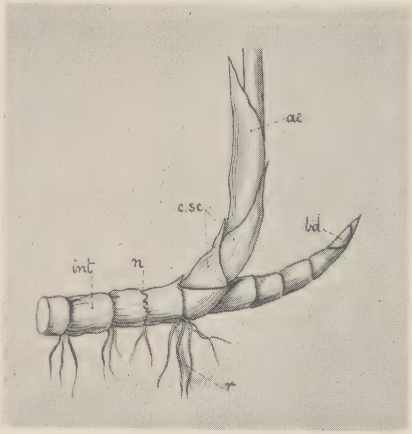


FIG. 23.—UNDERGROUND STEM OF SCIRPUS. *n*, node; *int*, internode; *c.sc*, covering scales; *r*, roots; *bd*, bud; *ae*, aerial shoot.

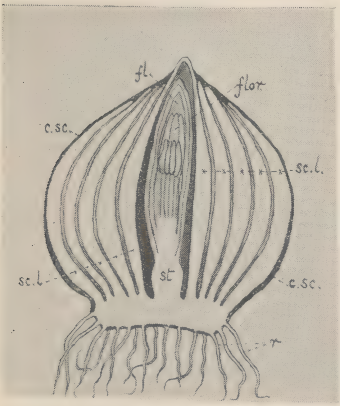


FIG. 24.—BULB OF HYACINTH, LONGITUDINAL SECTION.

st, stem portion; *r*, roots; *c.sc*, brown covering scales; *sc.l*, white fleshy scales; *fl*, foliage leaves; *flor*, floral leaves.

Structure of Bulb. The bulb of a tulip or hyacinth is covered with brown scales. When these are taken off there are numbers of thick, white, fleshy scales, arranged one over the other. Within these are the floral leaves. All these leaves are borne by a small central portion, the stem.

Structure of Corm. A corm which is beginning to form the flower shows the following parts:

1. Roots springing from the circumference on the underside.
2. A few covering scales, which are found to be attached to
3. A solid white portion, the stem.

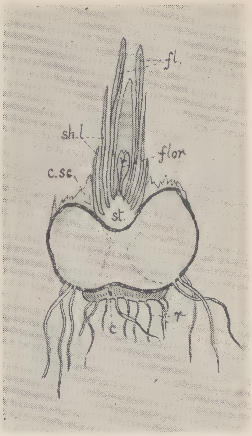


FIG. 25.—CORM OF CROCUS, LONGITUDINAL SECTION.

c, corm of previous year; *r*, roots; *st*, stem; *c.sc*, covering scales; *sh.l*, sheathing leaves; *fl*, green leaves; *flor*, floral leaves.

4. The bud arises in the axil of similar brown scales at the top of the stem, and consists of

(*a*) a succession of sheathing leaves;
(*b*) a few green leaves;
(*c*) floral leaves enclosed in the sheath.

Generally a corm contains many buds, and the previous year's corm, very much shrunk, often remains attached to its under surface.

Tuber of Potato. A tuber arises as a swelling on a branch, which is formed in the axil of the leaf, but makes its way underground. If this underground structure be made to grow in the light, it will bear ordinary green leaves and produce no tubers. The tuber bears on its

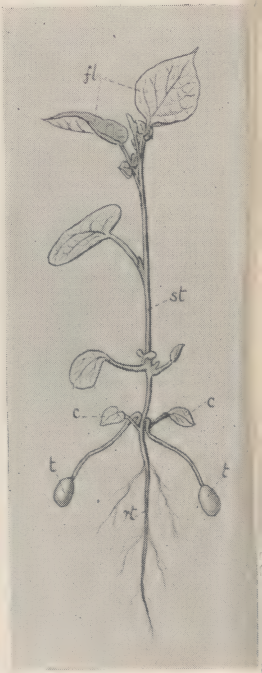


FIG. 27.—SEEDLING OF POTATO.

t, tuber; *c*, cotyledon; *st*, stem; *fl*, foliage leaves; *rt*, root system.

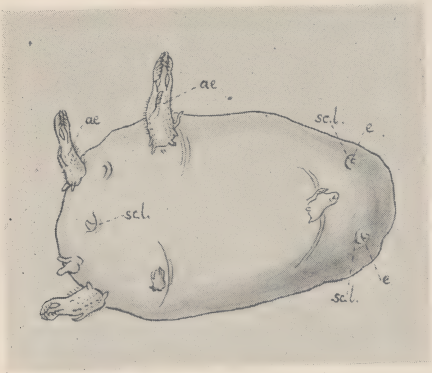


FIG. 26.—TUBER OF POTATO.

e, eyes; *sc.l*, scaly leaf; *ae*, aerial shoot.

surface buds, the so-called "eyes," each situated in a minute scale-leaf; these buds will under certain circumstances sprout and give rise to a potato plant. It is clear, therefore, that a tuber is a stem.

Food is stored in the tuber in the form of starch.

Aerial Stems. Stems which come up above ground are said to be aerial, in order to distinguish them from those which are underground. Aerial stems may grow straight upright; or they may begin by being upright, and then their upper part may curve and trail along the ground; or they may creep along the ground, rooting as they go.

The runner of the strawberry is an example of a creeping branch of a stem, which takes root at its nodes, where leaves are also given off, thus producing a new plant.

Some stems are both subterranean and aerial; this is the case in the sucker, so well known in the raspberry. It arises from the stem below the ground, pursues a horizontal course for some way, then comes above ground, and finally becomes an independent plant.

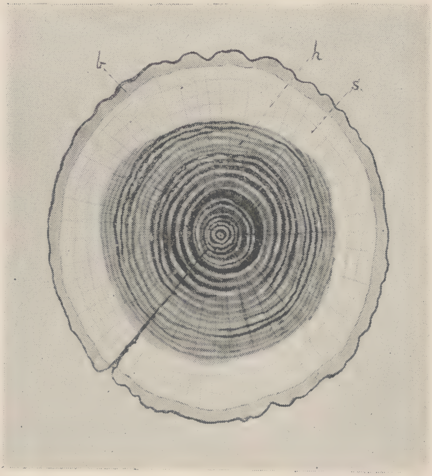


FIG. 28.—TRANSVERSE SECTION OF BRANCH OF LABURNUM, SHOWING RINGS OF WOOD. *b*, bark; *s*, sap-wood; *h*, heart-wood.

By means of underground stems, runners, suckers, etc., plants propagate themselves independently of seed.

Herbs, Shrubs, Trees. The stems of some plants never become woody, but after a year's growth die down to the earth; these are usually green, and plants with such stems are described as herbs. When a stem becomes woody, it usually forms a shrub or tree. These stems generally increase in thickness every year owing to the growth of the wood. If a branch of any tree is cut across, it is possible to count the rings of wood, and thus to tell the age of the tree, for the growth of the wood formed during the autumn is closer than that of spring, and as the spring growth of one year comes next the autumn growth of the previous year, distinct rings are formed. The younger wood is on the outside, and as it is permeated with sap, it is known as sap-wood, whilst the inner wood is harder and is called heart-wood. This is very well seen in the Laburnum, of which a drawing is given in Fig. 28.

In the Natural History Museum at South Kensington, there is a section through the trunk of a tree which was more than 500 years old when it was cut down. Oaks have been known to reach 1,500 years; Yews, 3,200; whilst a tree called Adansonia, a native of Cape Verd Islands, is said to reach 5,000 years.

Branching of Stems. The branching of stems is closely connected with the position of the leaves, for, as we have already seen (page 14), buds arise in the leaf-axil. If the leaves are opposite, the branches will be opposite; if alternate, then the branches will be alternate. It is very seldom, however, that all the axillary buds develop; as a rule they remain undeveloped during the first season, then the following spring some of them grow into branches.

It is interesting to notice that the form of trees to a very great extent depends on which buds develop. Thus the Horse-chestnut is, on the whole, low and wide-spreading, whilst the Ash is tall and tapering, yet both have opposite leaves and, therefore, the branches will be opposite; so that at first sight it might have been expected that these two trees would have been more or less alike in form. In the Horse-chestnut, however, the terminal bud develops into the flower and the axillary buds into the branches; as soon as the terminal bud has formed a flower, growth in the upward direction ceases and must be continued by the axillary buds.

The tree therefore spreads. In the Ash, on the other hand, the terminal bud does not develop into a flower, but one of each pair of axillary buds becomes the flower; consequently continued growth in height is possible, and the tree is tapering rather than broad.

Modifications of Branches. The branches may be modified into spines, as in the Blackthorn; or into tendrils, as in Virginia creeper. When examining a plant with spines or tendrils, in order to decide whether these structures are modified branches or modified leaves, it must be carefully observed whether they come off *laterally*, as leaves do, or in the *angle* which the leaf makes with the stem. In the blackthorn, the spines or thorns are all branches; in gorse, some are branches, others represent leaves.

A spine or thorn must not be confused with a prickle. The so-called "thorns" of a rose-bush are prickles; they differ from thorns in not being developed in any particular order, and as far as their origin is concerned they may rather be compared with hairs. They are not modifications of branches, as the thorn is.

Climbing Stems. The Hop and Kidney-beans are plants which climb by means of stems. Darwin has described his experiments on the hop. He found that the first two or three internodes of a young hop plant were quite straight; the fourth was the first that began to revolve, at first slowly, taking twenty-four hours to make one revolution; then gradually it went faster, until it accomplished the ninth revolution in two and a half hours. He found that in the hop three internodes revolved at the same time; when the oldest of these three became too stiff from age to go on revolving, the next youngest internode began. In many other plants, however, only two internodes revolve together. Curiously enough, the revolution is not in the same direction in all plants; the growing tip of the stem of hop revolves from right to left, like the hands of a watch; so, too, does honeysuckle. Kidney-beans and convolvulus revolve in the opposite direction.

Whilst the stem is revolving, it also becomes spirally twisted on its own axis. The Hop twists three times whilst making thirty-seven revolutions. The amount of twisting seems to depend chiefly on the nature of the surface up which the plant is climbing. Darwin allowed Kidney-beans to run up stretched string or smooth rods of iron and glass, and found that they were much less twisted than when they had climbed up rough uneven sticks.

Description of Stems. In describing a plant, the following details should be noticed with regard to the stem:

1. Kind.—(*a*) Underground.
   (*b*) Aerial, herbaceous, shrubby, or woody.
2. Direction.—Upright, creeping, or climbing.
3. Shape.—Square, round, angular.
4. Colour.
5. Branches and their modifications, spines, etc.
6. Surface.—Smooth or hairy.

CHAPTER V

LEAVES

Definition of a Leaf.

The poet-philosopher Goethe was the first to point out in 1790 that cotyledons, bud scales, foliage and floral leaves are structures of the same nature, for they stand in the same relation to the stem. The term "leaf," in botany, includes all structures other than branches, developed as lateral appendages of the stem, however unlike they may be in appearance.

Cotyledons

The first leaves of the plant are the cotyledons; these are always different in shape from the foliage leaves which follow. Those of mustard are kidney-shaped, whilst the foliage leaves are very deeply divided. Sycamore has two narrow blade-like cotyledons whilst the leaf is broad and spreading. Lord Avebury thinks that the shape of the seed has, on the whole, the greatest influence in determining the shape of the cotyledons, but many other factors have to be taken into consideration; for instance, the presence or absence of food material, as this affects the amount of room left in the seed for the cotyledons, and therefore, the way in which they are folded.

Some seeds have only one cotyledon; for example, maize, wheat, date. Plants with only one cotyledon form the large group known as Monocotyledons; those with two cotyledons are called Dicotyledons.

Covering Leaves.

Covering leaves include bud scales and bracts. The former have already been sufficiently described (Chapter III.). *Bracts* are the leaves on the flower-stalk; they may enclose a single flower, as in snowdrop; or a group of flowers, as in arum. They vary very much in shape; sometimes they are sheath-like, as in crocus; sometimes they resemble narrow foliage leaves, arranged in whorls and completely enveloping the flower, as in daisy. The term *involucre* (Lat. *involucrum*, a wrapper) is applied to bracts which thus surround the flower. In hedge parsley, the bracts forming the involucre are thin, narrow, and green; in the oak, the involucre is cup-like, forming the well known acorn cup. In wood anemone, the bracts of the involucre are easily mistaken for foliage leaves; but the true foliage leaves are borne by the underground stem, and the leaves on the flowering stem are bracts.

Foliage Leaves. If foliage leaves arise from the base of the stem, or from a root-stock, they are described as radical; if from the whole length of the aerial stem, as cauline. Foliage leaves, borne by the aerial stem, are arranged according to two main types: spiral and whorled. When leaves come off singly at the nodes, the arrangement is spiral; when two or more leaves come off at a node, the arrangement is whorled. The best way of forming an accurate idea of the spiral arrangement is to examine a succession of plants; for example, rose, almond, golden rod, dead-nettle. In rose it will be found that the sixth leaf is the one which comes exactly above the first; the seventh above the second; and so on. If now a piece of twine is fixed to the first leaf, and passed over the bases of the intervening leaves until the sixth is reached, the twine will have passed round the stem twice. The leaves being exactly at an equal distance from each other, it follows that twice the circumference of the stem divided by the number of leaves will give the distance of one leaf from the other. In this case each leaf is separated from the succeeding one by $\frac{2}{5}$ of the stem. This is known technically as the divergence of leaves. In almond, the divergence is $\frac{3}{8}$; in golden rod, $\frac{5}{13}$; in dead-nettle, $\frac{1}{2}$. The denominator denotes the number of leaves between those which lie exactly above each other; the numerator, the number of times the twine must be passed round the stem before the leaf, which is exactly above the one to which it is attached, will be reached.

Leaves which are spirally arranged are described as alternate; those arranged in whorls are described as opposite, if only two come off at the same node, and whorled if more than two come off together.

Arrangement of Leaves connected with Shape of Roots. The arrangement of leaves is to some extent connected with the kind of root. Those plants, like rhubarb, which have tap roots that occupy but a small space have leaves that turn inwards, so that the water which they collect passes down to the centre of the plant. On the other hand, in plants that are much branched and have spreading leaves, the watershed is such that water passes to the circumference of the area to which the fibrous roots extend, and then it is absorbed by the root hairs. Thus, in a slight shower, it is possible to be quite

FIG. 29.—COMPOUND, PALMATE LEAF OF LUPINE.
l, lamina ; *p*, petiole ; *sh*, sheath ; *st*, stipules.

sheltered if walking under trees, for the water drips from one leaf to the next below, until the outermost and lowest leaves are reached, and then it falls to the ground; the area that remains dry is that occupied by the roots.

Structure of a Foliage Leaf. A foliage leaf usually consists of (1) a sheath; (2) a stalk; (3) a blade.

In many leaves the sheath has lateral outgrowths, known as stipules. These are sometimes very small, although occasionally they are very conspicuous; thus, in a species of pea

(*Lathyrus aphaca*), they perform the function of the blade of the leaf, which is undeveloped (Plate I., Fig. 33).

In woodruff, the stipules are also blade-like and similar to the true leaves, which bear their branches in their axils and are thus distinguished from the stipules. The function of stipules varies with their form; when blade-like and green, they often perform the work of foliage leaves and help feed the plant. In some cases they protect young buds, and drop off when the leaves unfold.

The leaf-stalk, or petiole, is not always present. If absent, the leaf is described as sessile; if present, as petiolate. The petiole is often modified; thus in *Lathyrus aphaca* (Fig. 33) it is developed into a tendril by means of which the plant climbs. Clematis also climbs by means of its petioles, which intertwine with other leaves of adjoining branches of clematis, or with blackberry stems, covering our hedges in autumn with a dense growth. Nasturtium (*Tropæolum*) also climbs by means of its petioles.

The leaf-substance of the blade, or lamina, is traversed by veins. If the leaf of a grass or hyacinth be compared with that of a violet, it will be noticed that the veins of the leaf are very differently arranged. In the hyacinth they are parallel to each other, an arrangement characteristic of Monocotyledons; in the violet they branch out from the central vein, called the midrib, forming a network throughout the leaf-substance. This arrangement is characteristic of Dicotyledons; so that Monocotyledons are said to be parallel-veined, Dicotyledons net-veined.

If now a sycamore leaf be compared with that of lilac, it will be seen that they are both net-veined. In the sycamore, however, the main veins spring from the same point, spreading out like the fingers of a hand; the venation is, therefore, *palmate* (Lat. *palma*, a palm). In the lilac, on the other hand, the veins branch out from the midrib, which runs the whole length of the leaf; this venation is *pinnate* (Lat. *pinna*, a feather).

The blade of a leaf varies very much in shape. It may be

PLATE I.

Fig. 30.—Barberry, showing Leaves modified into Thorns or Spines.

Fig. 31.—Simple divided Leaf of Geranium Pratense.

Fig. 32.—Pinnately compound Leaf of Sweet Pea.
p, petiole ; *t*, tendrils (modified leaflets).

Fig. 33.—Leaf-like Stipules of Lathyrus Aphaca.
st, stipule ; *p*, petiole modified into tendril.

of the same breadth throughout almost its entire length, as in grasses; or such a leaf may terminate in a sharp point like a needle, as in Scotch fir. It may be broadest in the middle, tapering gradually towards both base and apex, as in wall-flower; or its lower half may be broadest, as in lilac; or again, it may be broadest at its apex, as in daisy. Sometimes the blade of the leaf is hollowed out at its base into two rounded lobes, whilst the apex is pointed; the leaf is then heart-shaped. The opposite of this is seen in the leaflet of the wood-sorrel, where the base is pointed and the apex lobe-like. In ground ivy, the apex is convex and the base concave; the leaf is then kidney-shaped.

The margin of the blade may be indented, forming fine teeth pointing towards the apex; it is then said to be serrate (Lat. *serra*, a saw); if the teeth are coarser and point irregularly, the margin is dentate (Lat. *dens*, a tooth); if the indentations are rounded, the margin is crenate (Lat. *crena*, a notch); when not indented at all, but lying perfectly flat, the margin is described as entire. In the beech, the margin bears delicate hairs, and is then said to be ciliate (Lat. *cilium*, an eyelash).

Simple and Compound Leaves. In some leaves, as for instance, a species of geranium (*Geranium molle*), the blade of the leaf is not cut up at all; in others, as the oak, it is only slightly indented; whilst in some others, as certain of the geraniums, it is very much cut up. When the incisions reach to the midrib, the leaf is described as compound; when the incisions do not reach the midrib, the leaf is still simple, but if cut up it is described as simple divided (Plate I., Fig. 31).

Compound leaves consist of distinct leaflets, borne by a common petiole; they are either pinnate or digitate (Fig. 29). A compound leaf must be carefully distinguished from a stem, bearing leaves; unlike the stem, it has no growing point; its growth is, therefore, limited. It has no buds in the axils of the leaflets.

It is interesting to notice that leaves in water are often much more cut up than ordinary foliage leaves. An example of this occurs in water crowfoot, where the leaves above the water are round and at least an inch in diameter, whilst the leaves in the water are narrow and filamentous.

Modifications of Lamina. The blade of a leaf may be modified into tendrils; this is very common in the pea family; thus, in sweet pea, the last two pairs of leaflets and the terminal one have become tendrils, by means of which the plant climbs (Fig. 32). In some few instances the leaves may become spines; this is well seen in barberry, where the lower leaves are foliaceous, the upper ones spiny (Plate I., Fig. 30).

In plants which feed on insects the blade is usually furnished with arrangements for entrapping the insect and for manufacturing a juice by which it can digest the insect. In sundew the leaves have hairs. As an insect alights on the leaf, it curls up, the hairs serving to hold the insect; each hair has at its tip a little gland, which makes the juice that is poured out on the insect.

Functions of Foliage Leaves. The functions of foliage leaves will be discussed in connection with the physiology of the plant.

Description of Foliage Leaf.

Position.—Radical or cauline.

Arrangement on Stem.—Alternate, opposite, whorled.

Petiole.—If present, the leaf is petiolate.
If absent, the leaf is sessile.
Length of petiole as compared with length of lamina.

Sheath.—Stipulate or ex-stipulate.
Size of stipules.

Lamina—
(*a*) Simple (divided or undivided).—Compound.
(*b*) Venation.—Pinnate or palmate.
(*c*) Shape.—This may be indicated by an accurate drawing.
(*d*) Margin.—Entire or indented; if indented—serrate, dentate, or crenate.
(*e*) Apex.—Pointed or blunt; rounded or hollowed out.
(*f*) Surface.—Hairy or smooth.
(*g*) Modifications of Lamina.—Tendrils, spines, etc.

Floral leaves, namely: sepals, petals, stamens, carpels, will be described in the next chapter.

CLASSIFICATION.

- Cotyledons
- Covering Leaves
  - Bud Scales
  - Bracts
- Foliage Leaves
  - Simple
    - Pinnate
    - Palmate
  - Compound
    - Pinnate
    - Digitate
- Floral Leaves
  - Sepals
  - Petals
  - Stamens
  - Carpels

CHAPTER VI

THE FLOWER

A Flower, a Modified Shoot. If the flower of a buttercup is examined, it will be seen to consist of four sets of leaves, arranged on a central stem; this stem is the apex of the flower stalk, and is called the *receptacle*. The leaf, in the angle of which the flower stalk is situated, is a bract; it is not always present. A flower is thus a modified shoot, differing from the ordinary foliage shoot already described as having:

FIG. 34.—VERTICAL SECTION OF BUTTERCUP. *rc*, receptacle; *s*, sepals; *p*, petals; *a*, stamens; *c*, carpels.

1. Very short internodes.
2. No buds in the axils.
3. Leaves frequently whorled and specially modified for the production of seed.

Floral Leaves. The outermost leaves of the flower are called *sepals*, and together form the *calyx* or cup, in which the rest of the flower is, as it were, contained. This is best seen in the bud where, as in poppy, the calyx forms a complete covering for the other floral leaves and, as soon as the flower opens, drops off.

The next leaves are the *petals*, forming the *corolla*. The calyx and corolla are not essential for the development of fruit and seed, and are often absent, especially in the flowers of trees.

The essential leaves of a flower are: (1) the *stamens*, the third whorl of leaves, and (2) the *carpels*, the innermost leaves.

These are not necessarily both present in the same flower, although they often are. In the hazel, the stamens are alone present in the catkin flowers (lambs'-tails), whilst the carpels are in other flowers on the same branch (Plate III., Fig. 58).

Some plants have flowers which bear only stamens, the carpels being not only in a separate flower, but on a different plant, as in the willow (Plate III., Figs. 55, 56).

The stamens together form the andrœcium, the carpels the gynæcium, or pistil. The stamens produce pollen and the carpels bear little, white bodies, the ovules, which eventually form seeds. The only parts of a flower essential for the production of fruit and seed are the stamens and carpels.

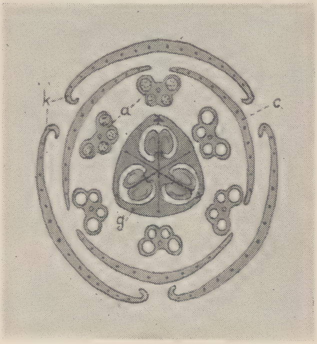


Fig. 35.—Transverse Section of Bud of Tulip.
k, calyx ; *c*, corolla ; *a*, anthers ; *g*, gynæcium.

The Calyx. A comparison of different flowers, such as the buttercup, violet, larkspur, marsh marigold, sweet pea, shows that the calyx and corolla are of very great variety. The calyx is usually green. Sometimes, as in the primrose, the sepals are joined to each other, forming a tube; very often, as in the buttercup and wallflower, they are free. As a rule, the sepals are small and insignificant compared with the petals; but sometimes they are the most conspicuous part of the flower, as in the marsh marigold, globe flower, Christmas rose, larkspur. In these the corolla is either absent or very much reduced, and the calyx performs some of the work of the corolla; it attracts insects. Again, in many flower-heads, composed of a number of little flowers, as the dandelion, the sepals are merely hairs which serve as organs of dispersion for the fruit, the flowers being protected, not by the calyx, but by the involucre of bracts (Plate V., Fig. 89).

The Corolla. The corolla is generally the most conspicuous part of the flower. Its colour is of great importance in connection with the visits of insects to the flower. (See Chapter IX.) In many flowers the petals are similar to each other, as in the buttercup, wallflower, geranium; the flower is then said to be *regular*. In others, the petals differ from each other: one may form a spur which contains honey, as in the violet; or a petal may be specially developed to form a resting-place for the insect when it visits the flower, as the lower lip of the dead-nettle. Such corollas are described as *irregular*, and the irregularity is usually connected with insect visits. Irregular corollas are described in connection with the Orders to which they belong, in Part II.

The petals forming the corolla may be joined to each other, or they may be free.

Perianth. The term *perianth* (Gk. *peri*, round; *anthos*, a flower) denotes the two outer whorls of floral leaves, which envelop the essential leaves, the stamens and carpels It is used in describing a flower, in which the calyx and corolla are very similar in appearance, either all petal-like, as in the snowdrop and hyacinth; or all sepal-like, as in many flowers of trees.

The Andrœcium and Gynæcium. The essential leaves of a flower, the stamens and carpels, are *sporophylls*, *i.e.*, spore-bearing leaves. A stamen consists of: (1) a stalk or filament; (2) an anther. Stamens are usually free, not joined to each other; in the sweet pea and mallow the filaments are united, forming a tube, and in the daisy the anthers are united. The anther is attached to the filament in various ways. When the filament passes up between the two halves of the anther, as in the snowdrop, the anther is said to be *adnate* (Lat. *ad*, to; *nascor*, to be born); when the anther is jointed at the bottom to the filament, it is *innate*, as in the wallflower. Some anthers, for example, those of the lily, are joined in the middle, and thus swing on their filaments, and the attachment of the anther is then described as *versatile* (Lat. *verso*, to turn).

Lastly, the anther may be attached by the top to the filament and then hang down; in this case it is *pendulous.*

If an anther is cut across and examined with a hand lens, it is seen to consist of two parts, exactly similar to each other, and connected together by a continuation of the filament (the connective). (See Figs. 35 and 65, *c.*) Each half-anther contains two bags, or *sporangia*, in which pollen grains, or small spores called *microspores* (Gk. *micros*, little) are developed. When ripe, the anthers open or dehisce to let out the pollen, either by a longitudinal slit, or by pores at their apex (as in many heaths), or by valves. Occasionally they dehisce transversely. When the dehiscence takes place towards the inside of the flower, it is described as *introrse* (Lat. *introrsus*, turned in); when on the outer side of the anther, as *extrorse* (*ex*, out). Pollen has very much the appearance of fine yellow dust, and is usually taken by the wind or insects from one flower to another. (See Chapter IX.)

The carpels are floral leaves which bear the ovules generally on their edges. The ovules are sporangia, each ovule containing *one* large spore, the *macrospore* (Gk. *macros*, large). In the pea, the gynæcium consists of but one carpel, the two edges of which unite to each other to form the chamber occupied by the ovules, and therefore called the ovary. In order to understand the formation of the ovary from a single carpel, the two edges of a foliage leaf may be sewn or pinned together; a chamber is then formed. Bearing in mind that a carpel is a leaf, and remembering that a foliage leaf has a midrib running down the middle, it will be clear that when a carpel has joined by its edges, the midrib of the carpel will be opposite the side where the margins have united. This is clearly seen in the pod (Plate IV., Fig. 71).

The flower of a buttercup consists of many carpels, about thirty. The margins of each carpellary leaf unite to form an ovary, as in the sweet pea, so that in the buttercup the carpels are free, not united to each other, and there are as many ovaries as there are carpels. (See Fig. 34.)

In many flowers, however, the margins of the carpels are not free, but unite with each other, as in the violet. When the gynæcium of the violet is cut across, the ovary is seen to be a single chamber; but it is clear that three carpels have united to form it, for the ovules inside are arranged in three groups.

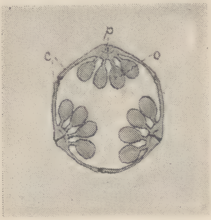


FIG. 36. — TRANSVERSE SECTION OF OVARY OF VIOLET (diagrammatic). *c*, carpels; *p*, placenta; *o*, ovules.

With the violet may be compared the hyacinth or tulip, which also has three carpels, but their mode of union is different from that of the violet. The carpels have not only united to each other, but their edges have bent in, thus dividing the ovary into a three-divisioned chamber. (See Fig. 35.) This may be realized by taking three foliage leaves and sewing the edge of one to the edge of the second, the other edge of the second to the edge of the third, and the other edge of the third to the remaining edge of the first; then these edges which have been sewn together should be bent inwards until they touch each other in the middle, and then a three-divisioned chamber will be seen.

It follows therefore, that an ovary may be formed of two, three, or more carpels, and still be only one-chambered. It depends entirely on whether the carpels have just united by their edges, or whether they have also bent in to form partitions; in the latter case, there will be as many divisions of the ovary as there are carpels.

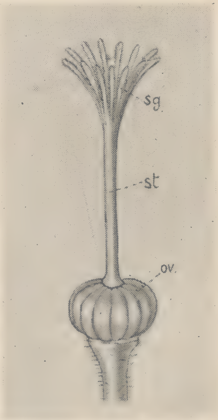


FIG. 37.—GYNÆCIUM OF MALLOW. *st*, style; *sg*, stigmas; *ov*, ovary.

An ovary may now be defined as a chamber formed by the union of the margins of one or more carpels. It may be one-, or more-chambered, according to the number of carpels which help to form it and the mode of their union with each other.

The simplest form of gynæcium usually consists of: (1) an ovary, (2) a style, (3) a stigma or stigmas.

If three foliage leaves are sewn together, as described above, it will be seen that there are three apices or ends; these represent the extreme tips of the carpels, called stigmas, which are connected with the ovary by short stalks or styles. The styles may remain free, as in the Campions; or they may be united up to the top, the stigmas being distinct, as in the dead-nettle and dandelion, where, although the styles are united, two stigmas are plainly seen. The number of styles or stigmas should always be noticed, as it is a help in determining the number of carpels. The surface of the stigma is often sticky, as in Orchids, or it may be covered with hairs, which help to keep the grains of pollen placed on the stigma.

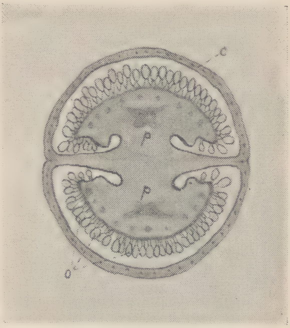


FIG. 38.—TRANSVERSE SECTION OF OVARY OF FOXGLOVE.

c, carpels; *p*, placenta; *o*, ovules.

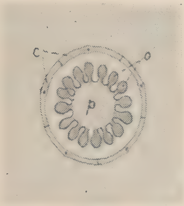


FIG. 39. — TRANSVERSE SECTION OF OVARY OF PRIMROSE.

c, carpels; *p*, placenta, *o*, ovules.

The edge of the carpel which bears the ovules is the *placenta*, and the mode of arrangement of these placentas is known as *placentation*. In the violet, the ovules are borne by the walls of the ovary, for the margins of the carpels have not bent inwards; the placentation is then said to be *parietal* (Lat. *paries*, a wall). (Fig. 36.) When the edges of the carpels bend in and meet in the centre, so that the ovules arise from a placenta in the centre, as in the foxglove (Fig. 38), the placentation is *axile*. (See also Fig. 35.)

These are the two main types of placentation, but there are modifications. The ovary of a primrose, when cut across, shows the ovules attached to the centre, but the walls of the carpels are entirely disconnected with the placenta; the placentation is then described as *free central,* in order to distinguish it from axile placentation, in which the placenta is connected with the wall of the ovary.

In the sweet pea, the ovules are borne alternately by the

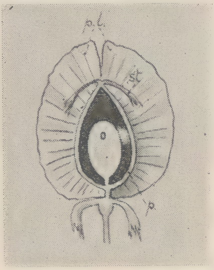


Fig. 40.—Dock (Section of Fruit).

p.l, perianth leaves (persistent); *p,* wall of ovary; *st,* style; *o,* basal ovule.

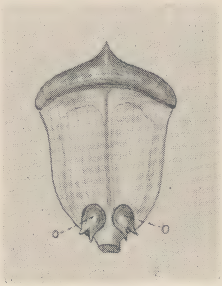


Fig. 41.—Carpellary Leaf of Pinus.

o, ovule.

margins of the carpel, where they unite; this is the form of parietal placentation known as *marginal.* (Plate IV., Fig. 71.)

An ovule may be attached to the floor of the ovary, as in the dock (Fig. 40), the placentation is then *basal;* or it may hang from the roof, and is then said to be *pendulous.* (See Fig. 44.)

In one group of Flowering Plants the ovules are not enclosed in an ovary, but are naked on the sporophyll. This is well seen in the Scotch fir (Pinus).

CHAPTER VII

THE FLOWER (*continued*)

The Receptacle. IN order to understand the structure of the flower, the form and growth of the receptacle must be carefully examined. If the sepals, petals, stamens, and carpels are removed in a buttercup, the receptacle is seen to be conical-shaped (Fig. 34), and it is clear that the carpels are uppermost, the stamens being attached to the receptacle immediately beneath the carpels, the petals beneath the stamens, and the sepals beneath the petals. The flower is then said to be hypogynous (*i.e.*, under the gynæcium; Gk. *hypo* = under), a term referring especially to the position of the petals and stamens. The calyx is described as inferior, because below the petals and stamens, and the gynæcium as superior, because it is uppermost.

This is the way in which all flowers begin to be formed, but the growth and development of the receptacle often alters the relative position of these parts. Sometimes, as in the rose, the part of the receptacle below the tip grows more rapidly, overtopping the tip, thus forming a cup, and carrying with it the sepals, petals, and stamens; the carpels being borne by the apex of the receptacle are at the bottom of the cup. The flower is then said to be perigynous (Gk. *peri* = round). The gynæcium is still described as superior as long as it is free from the receptacle, and not united to it.

In some flowers the sides of the receptacle unite with the walls of the carpels, the sepals, petals and stamens being inserted on the combined receptacle and gynæcium.

In this case the flower is described as epigynous (Gk. *epi* = upon), and the gynæcium is inferior. Thus, in what is called an inferior gynæcium, the wall of the receptacle is fused with the carpels; in all other cases the gynæcium is superior. It is important to bear in mind this use of the words superior and inferior as applied to the gynæcium.

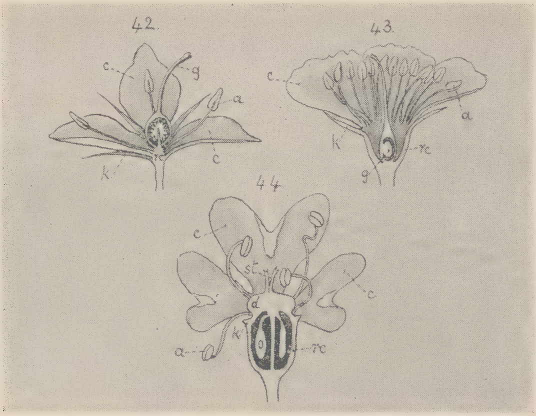


Fig. 42.—Yellow Pimpernel, Vertical Section, Hypogynous Type. Fig. 43. — Almond, Vertical Section, Perigynous Type. Fig. 44. — Cow Parsnip, Vertical Section, Epigynous Type.

k, calyx ; *c*, corolla ; *a*, andrœcium ; *g*, gynæcium ; *rc*, receptacle (in Fig. 44 adnate to gynæcium) ; *d*, disc ; *st*, styles ; *o*, pendulous ovule.

Floral Diagrams. The relation of the floral leaves to each other is usually indicated by floral diagrams. These may represent the flower as cut transversely, and then the union or non-union of the parts is seen ; or they may represent a median vertical section of the flower, and then the relation of the sepals, petals, and stamens to the gynæcium is indicated.

The simplest form of flower is one in which each whorl has the same number of leaves, which alternate successively with each other ; this is the case in many Monocotyledons. Such flowers are said to be cyclic. The accompanying figure represents a typical cyclic flower as shown in transverse section.

It will be seen : (1) that each whorl consists of three leaves ; (2) that the sepals alternate with the petals, the petals with the stamens, the stamens with the carpels.

It is evident that such a flower may be divided into two equal halves in several planes, for a line passing through the middle of any one petal cuts the flower into two exactly similar parts.

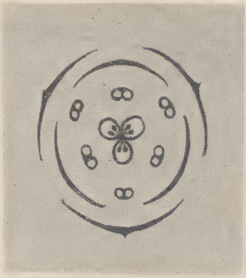


FIG. 45.—FLORAL DIAGRAM OF A CYCLIC FLOWER (TULIP), SHOWING WHORLS OF FLORAL LEAVES ALTERNATING WITH EACH OTHER.

All flowers, however, are not so simple: sometimes where we should expect to find five stamens, only four are present. In cases of this kind the place where we should expect to find the fifth stamen is sometimes indicated by some structure; thus, in the figwort, where only four stamens are present, the position of the fifth is indicated by a distinct scale. (Fig. 123.)

In the dead-nettle the fifth stamen is also absent, but the position of the other four is such that it is easily seen where the fifth would be if it were not suppressed. (See Fig. 130.)

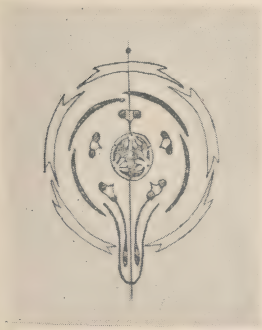


FIG. 46.—FLORAL DIAGRAM OF VIOLET, TRANSVERSE SECTION, MEDIAN PLANE MARKED.

The dot indicates the position of the stem.

The suppression of one or more parts and the unequal growth of others leads to differences in the leaves of each whorl, and the flower is therefore irregular. In the sweet pea, violet, foxglove, dead-nettle, the petals are not all the same size or the same shape: the corolla is irregular. Irregular flowers can be divided into two similar halves only in one plane. A line passing through the flower and the main stem represents the *median* plane of the flower; a line drawn at right angles to that the *lateral* plane. The sweet pea and violet can be cut into two equal halves along the median plane alone; this is the usual plane of the symmetry of the flower.

The terms *posterior* and *anterior* are used by botanists to denote the exact position of the floral leaves with regard to the stem; the side of the flower nearest the stem is the *posterior* side, that furthest away the *anterior*. In the dead-nettle, the two large petals forming the upper lip are on the posterior side of the flower; the spur of the violet is on the anterior side, for it is furthest away from the main stem; the large overlapping petal of the sweet pea is posterior.

Description of Flower of Violet.

Name of Whorl.	Number of Leaves.	Union of Leaves.	Position on Receptacle.	Remarks.
Calyx (sepals)	5	Free	Inferior	The sepals project beyond the point of attachment; the two anterior sepals allow the spur to protrude
Corolla (petals)	5	Free	Hypogynous	The anterior petal forms a spur
Andrœcium (stamens)	5	Free	Hypogynous	The two anterior stamens have appendages or nectaries, which fit into the spur
Gynæcium (carpels)	3	Joined	Superior	Placentation parietal, stigma hooked

The floral diagrams representing the median, vertical section of a flower show whether it is hypogynous, perigynous, or epigynous. (See Fig. 34.)

Floral Formulas. Instead of writing out a technical description of a flower, the union or non-union of parts, and the position of the floral leaves on the receptacle may be expressed by means of formulas as follows:

Let K represent calyx,
,, C ,, corolla,
,, A ,, andrœcium,
,, G ,, gynæcium.

Then the floral formula of the violet is $K5\ C5\ A5\ G^{\underline{(3)}}$. The figures denote the number of floral leaves forming each whorl; if joined, these are put in brackets. If the gynæcium is superior, the number of carpels forming it is placed above the line drawn horizontally; if inferior, below the line.

The floral formula of primrose is $K(5)\ C(5)\ A(5)\ G^{\underline{(5)}}$. This formula shows at a glance that in the primrose the floral leaves are all joined, that the number of leaves in each whorl is five, and that the gynæcium is superior.

The floral formula of snowdrop is $P3 + 3A3 + 3G_{\overline{(3)}}$. P represents perianth, which is composed of six leaves, arranged in two whorls, therefore written $3 + 3$ instead of 6.

CHAPTER VIII

THE INFLORESCENCE

Definition of Inflorescence. THE special branches of a plant which are modified to bear flowers form a system known as the Inflorescence. Flowers (as we have already seen, Chapter VI.) are modified shoots arising in the axil of leaves called bracts; in order to understand inflorescences, it must be remembered that the formation of a flower from a terminal bud arrests growth in length, so that if growth continues it must be by means of lateral branches.

In Flowering Plants the branching of stems is lateral, that is to say, the main stem goes on developing by means of the growing point in its terminal bud, and branches arise laterally from the buds situated in the angle which the leaf makes with the stem. There are two main types of lateral branching:

1. The main stem goes on developing upwards, giving off lateral branches, the oldest being furthest from, and the youngest nearest to, the apex.

2. The lateral branches may develop more vigorously than the primary stem, the terminal bud of which may even become suppressed, as in the lilac.

Two Main Types of Inflorescence. Inflorescences show the same two types. Thus, in the wallflower, the flowers are always lateral, never terminal; the apex of the branches bearing flowers goes on developing, so that the growth of the stem is never arrested, and the youngest flowers are nearest the apex, the oldest furthest away. This type of inflorescence is said to be indeterminate, or indefinite, because there is no limit to the growth in length of the flowering shoot. The term *racemose* (Lat. *racemus*, a cluster of grapes) is applied to it.

The buttercup or marsh marigold is an example of the second type of inflorescence. In this case the main stem terminates in a single flower, and ceases to grow in length; further growth therefore can take place only by lateral branching. The lateral branches in the same way terminate in a single flower, and cease to grow in length.

The differences between this type and the preceding are:

1. The flowers are terminal, not only lateral.

2. The growth in length of each flowering branch is arrested.

3. The youngest flowers are towards the outside.

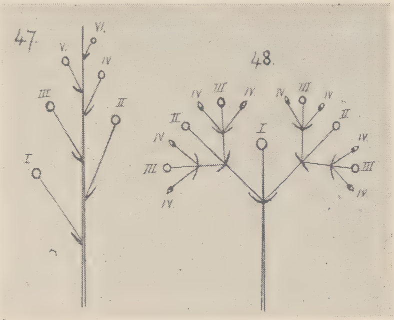


Fig. 47.—Indefinite Inflorescence (diagrammatic). Fig. 48.—Definite Inflorescence (diagrammatic).

The numbers I, II, III, etc., indicate the order of development of the flowers.

This mode of inflorescence is therefore called determinate or definite, and the term *cymose* is also applied to it.

Racemose Inflorescences. Racemose inflorescences vary considerably owing to the difference in length of the primary stem and of the flower stalks.

The *raceme* proper. Here the flowers have stalks, and are developed laterally along the main axis, one above the other, the youngest being nearest the apex, *e.g.*, foxglove (Plate II., Fig. 54). The bracts belonging to the flower are often absent, as in the wallflower; they may be seen in the hyacinth.

In the *spike* the flowers have either no stalks or very short ones, and the flowers are crowded together on the main axis—*e.g.*, plantain (Plate II., Fig. 51). In both the raceme and the spike the primary axis is elongated: in the umbel and capitulum it is shortened. In the *umbel* the apex of the main stem gives off a number of branches, each bearing a flower with a stalk of its own. The bracts beneath the flower stalks form a characteristic involucre. This is the simple umbel, but many plants have compound umbels, that is to say, the inflorescence consists of a number of simple umbels, each with its own involucre, and the whole inflorescence with a common involucre. These involucres may be wanting. This inflorescence gives its name to the order Umbelliferæ (Plate II., Fig. 50).

In the *capitulum* or head the flowers are sessile, not stalked. The apex of the main stem generally becomes dilated into a flattened receptacle, each flower in its bract, the whole receptacle being protected by an involucre of bracts. This is well seen in compound flowers. (See Fig. 118.) The receptacle here should not be confused with the flower stalk on which the floral leaves are situated.

Cymose Inflorescences. The growth of the main stem is invariably arrested in plants which have cymose inflorescences. Sometimes only one flower is borne by the stem, and the inflorescence is then said to be solitary; but as a rule growth is continued by means of lateral branches.

FIG. 53.—INFLORESCENCE OF STELLARIA GRAMINEA.
A 2-branched cyme.

In some cymes, branches are developed only on *one* side of the main axis, as in the comfrey and forget-me-not, the opposite branch being undeveloped in each case. (Plate II., Fig. 52.)

Sometimes the vigorous branches develop alternately, first on one side, then on the other.

In some inflorescences the cymes are two-sided. Thus in the stitchwort the main stem ends in a flower. This is the first flower to be formed. Underneath this two branches arise opposite each other, each terminating in a flower, beneath which two

PLATE II.

FIG. 49.—MIXED INFLORESCENCE OF FIGWORT: *a.c.*, axillary cymes forming a racemose inflorescence.

FIG. 50.—COMPOUND UMBEL OF FOOL'S PARSLEY: *s.u.*, simple umbel.

FIG. 51.—SPIKE OF PLANTAIN.

FIG. 52.—ONE-BRANCHED CYME OF FORGET-ME-NOT.

FIG. 54.—RACEME OF FOXGLOVE.

more branches arise, and so on. In a cyme of this kind the branches always arise opposite each other. (Fig. 53.)

The verticillaster (Lat. *verticillus* = whorl of a spindle) found in many flowers of the Dead-nettle Order is a modified cyme, but owing to the flowers having become sessile, it is often very difficult to see the order in which they have arisen.

Compound Inflorescences. Some inflorescences are compounds of simple ones, thus there may be a raceme of racemes, an umbel of umbels, etc.

Mixed Inflorescences. Lastly, many plants have mixed inflorescences; thus figwort has axillary cymes, developing racemosely. The youngest cyme is nearest the apex, the oldest furthest from it. (Plate II., Fig. 49.)

SIMPLE INFLORESCENCES.

- Racemose
  - With elongated primary axis
    - (*a*) Raceme
    - (*b*) Spike
  - With shortened primary axis
    - (*a*) Umbel
    - (*b*) Capitulum
- Cymose
  - Solitary
  - One-sided Cyme
  - Two-sided Cyme

CHAPTER IX

POLLINATION

Cross- and Self-Pollination. In order that flowers may make seed, the pollen from the stamen must reach the stigma. The pollen of a flower may fall on the stigma of the same flower, or pollen from one flower may be carried by some agent to another flower of the same species. In the former case the flower is self-pollinated; in the latter, cross-pollinated.

At first sight one is inclined to wonder why pollen should be carried from one flower to another, as the waste must be great, and it would seem more natural for flowers to pollinate themselves; but Darwin has shown that the waste of pollen is more than counterbalanced by an undoubted advantage. For some eleven years he made exact observations, in order to try and ascertain the relative value of cross- and self-pollination. He raised more than a thousand plants from seed which had been produced in some instances by cross-pollination, in others by self-pollination, in order to compare the results of the two processes in the same species, and he came to the conclusion that plants produced by cross-pollination had the advantage over those produced by self-pollination in being more hardy and better able to stand unfavourable conditions. Even where a species is usually self-pollinated, as in the bee orchid, it is, Darwin thought, occasionally cross-pollinated.

Instances of Cross-Pollination. (*a*) Cross-pollination must inevitably take place in those plants in which the flowers have stamens or carpels, but not both. In the willow (Plate III., Figs. 55, 56) the staminate flowers are borne on one tree, the pistillate on another. These latter have nectaries situated between the ovary and the bract of a flower. They are readily visited by insects, for, although they have no corollas,

PLATE III.

FIG. 55.—WILLOW, STAMINATE INFLORESCENCE.

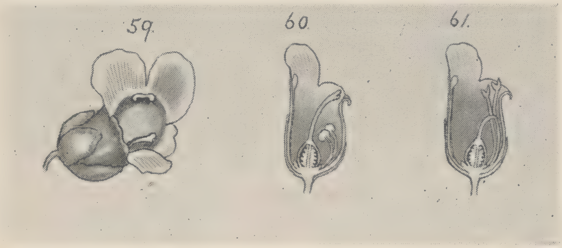
FIG. 56.—WILLOW, PISTILLATE INFLORESCENCE.

FIG. 57.—FLOWERS OF WILLOW: (*a*) stiminate, and (*b*) pistillate flower.

FIG. 58.—HAZEL: *s.c.*, staminate catkin; *p.c.*, pistillate catkin.

the flowers come out before the leaves; the anthers are golden yellow, so that the staminate flowers are very conspicuous in the hedges in early spring; whilst the pistillate flowers, owing to their nectaries, attract by their odour. In the Hazel cross-pollination is effected not by insects, but by the wind. The staminate and pistillate flowers are on the same tree (Plate III., Fig. 58). The staminate catkins hang down and produce quantities of pollen. The pistillate flowers occupy for the most part the position of axillary buds, and are distinguished from leaf buds by the protruding stigmas; they receive the pollen which is blown by the wind from the overhanging catkin.

(*b*) In some flowers, the andrœcium matures before the gynæcium, in others the gynæcium ripens first; in this way cross-pollination is insured. In many of the Compositæ—in Campions, in some Geraniums—the stamens are developed whilst the stigmas are still immature. The Figwort is an example of a flower in which the stigma becomes ripe before the

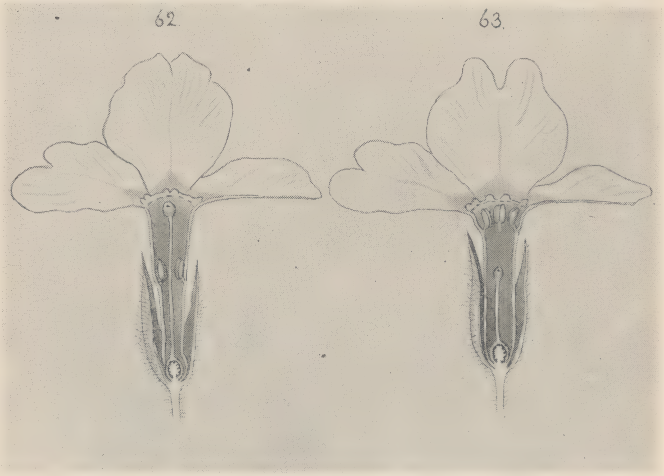


FIGS. 59 TO 61.—FIGWORT IN DIFFERENT STAGES.

59.—FLOWER WITH STIGMA PROTRUDING. 60.—LONGITUDINAL SECTION OF SAME FLOWER, SHOWING STAMENS CURLED UP IN COROLLA. 61.—LONGITUDINAL SECTION OF LATER STAGE, SHOWING WITHERED STYLE AND STAMENS PROTRUDING.

pollen is formed. If two or three inflorescences of the Figwort are examined, some flowers will be seen with the stigmas spread out at the mouth of the corolla ready to receive the pollen (Fig. 59), whilst the anthers of these flowers will be found curled up at the bottom of the corolla-tube (Fig. 60). Other flowers in a later stage of development will have the anthers at the mouth of the corolla-tube, and in these the stigmas will be hanging down quite limp and flabby (Fig. 61). An insect coming to a flower in this condition will take the pollen from the stamens (the stigma has already been pollinated and is not in a condition to receive more pollen), will carry it to other flowers, and when alighting on one with the stigmas at the mouth of the corolla-tube will pollinate it.

(*c*) Some flowers—*e.g.*, the Primrose and Loosestrife—have two or three forms, and in this way cross-pollination is insured.



FIGS. 62 AND 63.—PRIMROSE.

62.—LONG-STYLED FORM. 63.—SHORT-STYLED FORM.

In one form of primrose (Fig. 62) the style is long and the anthers are situated half-way down the corolla-tube; in the other form (Fig. 63) the style is short and the anthers are at the mouth of the corolla-tube. Obviously, it is impossible for the pollen in the stamens half-way down the tube to fall on the stigma, for this latter is above the stamens, so that the "long-styled" primrose must receive pollen from another flower; it does receive it from the "short-styled" primrose. In this latter the pollen could fall on the stigma of the same flower, and it is conceivable that self-pollination might take place; but many botanists have tried artificial self-pollination of primroses, and have found that when seed is thus produced it is not so productive as when the flowers have been cross-pollinated.

Agents effecting Cross-Pollination. Flowers are usually cross-pollinated by means of wind or insects; the former are called anemophilous (Gk. *anemos* = wind), the latter entomophilous (Gk. *entoma* = insects).

Anemophilous flowers are often small and inconspicuous, never brightly coloured. They are plentifully provided with pollen, which is powdery and readily shaken out of the flower owing to the fact that the stamens have long filaments. The stigmas are often branched and hairy or tuftlike, as in the Hazel and Grasses. As a rule, wind-pollinated plants flower early in spring.

Entomophilous flowers generally have nectaries, and by their scent attract insects. They are usually brightly coloured, as Sprengel first pointed out, and consequently very conspicuous; often they are irregular, the irregularity—as, for instance, the lower lip of the Dead-nettle, the "wings" of the Sweet Pea, etc.—being of assistance to the insect. Many flowers, too, have hairs or markings of various kinds, which serve to direct the insect to the nectary. The pollen grains of entomophilous flowers are sticky, not powdery, and the stigmas are usually smaller than in the case of wind-pollinated flowers.

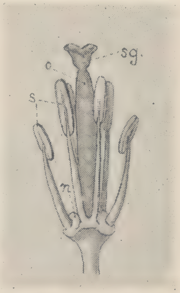


Fig. 64.—Andrœcium and Gynæcium of Wallflower.

s, stamens; *n*, nectary; *sg*, stigma; *ov*, ovary.

Nectaries. Nectaries may be found in almost any part of the flower. In the Buttercup, at the base of each petal a little scale may be seen; the nectary lies just under this. In the Wallflower, the nectaries are little green swellings at the base of the two short stamens (Fig. 64). In the Violet, two of the stamens have appendages which make honey, that is collected in the spur of the corolla into which the appendages fit (Fig. 65). In the Marsh Marigold, the nectaries occupy little depressions, one on each side of the base of the carpel (Fig. 102). In the Columbine, Christmas rose, Hellebore, the petals have become transformed into tubular nectaries (Fig. 101). In the Coltsfoot, the nectary is at the base of the style, and may be seen by holding up one of the inner florets to the light, when it appears yellow through the corolla-tube. In the Primrose, the nectary is at the base of the ovary; whilst in the Iris, Mignonette (Fig. 66), and the Umbelliferæ (Fig. 44, *d*) it takes the form of a disc.

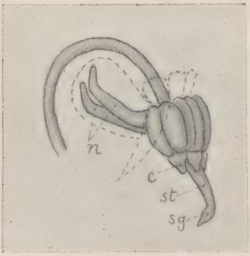


Fig. 65.—Flower of Violet, showing Stamens, with Appendages forming Nectaries. (The dotted lines indicate the position of the spur and sepals.)

c, connective; *st*, style; *sg*, stigma; *n*, nectaries.

The position of the nectary is invariably such that the insect, in the act of getting the honey, must knock against the anther and thus obtain pollen.

Only certain insects can get the honey from special flowers; when the honey collects at the bottom of a long tube, as in the Clover and in many Compound flowers, only insects with long antennæ can reach it. Some years ago clover was planted in Australia, but it never made seed, for there was no insect that could pollinate it; then the humble-bee was introduced, and now Australian clover can make seed, for the bee can reach the honey, and in getting it pollinates the flower.

Fig. 66.—Flower of Mignonette.

d, disc forming nectary.

When nectaries are in exposed places, as in the Umbelliferæ, their honey may be washed away in rainy weather, and many plants have contrivances for preventing this. Some plants in bright, sunny weather hold their corollas up, spreading them out to the sun; whilst in wet weather they hang down, and the rain cannot so easily enter them. The Herb Robert is an example of this.

Self-Pollination. Within the last thirty years numerous instances have been collected of flowers which pollinate themselves. Kerner, in his "Natural History of Plants," enumerates many hundreds, and shows that there is a certain relation between the altitude at which a plant is found and the frequency of self-pollination, no doubt owing to the comparative scarcity of insects at high levels. Cleistogamous flowers—those which never open (Gk. *cleistos* = closed)—must invariably pollinate themselves. The Violet, Wood-sorrel, many Chickweeds, many of the Leguminosæ have these cleistogamous flowers, which are formed in late summer. Many of the Cruciferæ have small, white, inconspicuous flowers which pollinate themselves: the anthers of the four long stamens slowly revolve until they are over the stigma, then they open and the pollen falls on the stigma. Groundsel generally pollinates itself, and many other instances might be given.

The interesting thing about all these flowers is that, although they are *usually* self-pollinated, insect visits have been recorded,

FIGS. 67 AND 68.—STELLARIA GRAMINEA.
67.—FIRST STAGE, SHOWING OUTER ANTHERS COVERED WITH POLLEN.
68.—LATER STAGE, STIGMAS SPREADING.

and they are apparently cross-pollinated at intervals. Even those plants which have cleistogamous flowers form, earlier in the season, other flowers which are cross-pollinated. And in the same way flowers which as a rule are cross-pollinated may, in the absence of insect visits, be self-pollinated. *Stellaria graminea*, (a Chickweed), is an instance of this. This flower has ten stamens: first, the outer five open and the anthers become covered with pollen (Fig. 67); then the five inner stamens dehisce, and as those are withering the styles which before had been bent inwards rise up, spreading out their stigmatic surfaces. The nectaries are green swellings on the base of the five outer stamens. If insects visit a flower in the condition drawn in Fig. 67, they must get pollen from the five outer stamens; if, however, the stamens have withered, then the insect will come in contact with the stigmas, and will deposit the pollen they have brought from some other flower. Supposing, however, that insect visits do not occur at all—and as the flower is inconspicuous that may often be the case—then the stigmas curling over come in contact with the anthers, and self-pollination ensues.

In the present state of our knowledge, then, it may be asserted that the majority of flowers are usually cross-pollinated; but that when cross-pollination cannot take place, owing to the absence of insect visits, self-pollination occurs more frequently than Darwin had reason to think. Further, it may be stated that the power of self-pollination has been altogether lost by some plants which have become highly specialized—as regards the colour and form of flower—for cross-pollination.

The putting out of the Pollen Tube.

When the pollen grain reaches the stigma it puts out a tube which makes its way through the style into the ovary, and eventually enters the ovule by a passage between the coats of the ovule. (See Fig. 70.) In the Crocus this passage of the pollen tube takes one to three days; in Orchids several days, weeks, or even longer; in Aloes and plants which flower but rarely, a year or more.

Pollination includes not only the transference of the pollen grain from the stamens to the stigma, but also the growth of the pollen tube until it reaches the ovule.

CHAPTER X

FORMATION OF THE SEED

THE fruit and seeds are the result of fertilisation, which is preceded by pollination. Fertilisation cannot take place until the ovule is ready to receive the contents of the pollen grain.

Structure of Ovule. When quite young an ovule consists of: (1) a stalk, (2) two integuments or coats, (3) a central portion, the sporangium or nucellus. Between the integuments a passage is left, through which the pollen tube makes its way in order to reach the sporangium. This passage is called the *micropyle*, and may usually be seen as a small hole in the testa of the seed. (See Fig. 1 *m.*) As the ovule develops a macrospore or *embryo-sac* is formed in the sporangium; from the macrospore the oosphere arises, and until this has been formed the ovule is not ready for fertilisation.

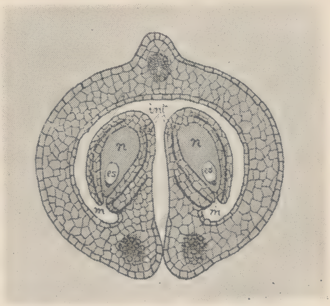


FIG. 69.—SECTION THROUGH OVARY, SHOWING OVULES.
m, micropyle; *int*, integuments; *n*, nucellus; *e.s*, embryo-sac.

When the oosphere is ready, the contents of the microspore or pollen grain, which must have previously been deposited on the stigma, pass down the pollen tube put out by the pollen grain and unite with the oosphere. After this union, known as fertilisation, the oosphere begins to develop into the embryo. The result of fertilisation is: (1) the formation of the embryo, (2) the formation of endosperm or food material around the embryo, so that the whole macrospore is used up.

Whilst developing, the embryo feeds on the endosperm. Sometimes all this food material is absorbed during the ripening of the seed, but sometimes not until germination. In the first case the seed is said to be *exalbuminous*, that is, without albumen; in the latter it is albuminous. This term "albumen" denotes the chemical composition of which the endosperm or food material is composed and is still retained in botany, because it is usual and convenient to speak of seeds as albuminous or exalbuminous. The term "endosperm" is a better one, and denotes exactly the same part of the seed as that designated "albumen." The bean seed, described in Chapter I., is exalbuminous, for it consists simply of testa and embryo. On the other hand, the maize seed is albuminous, for it contains in addition to testa and embryo, the endosperm, which occupies the greater part of the seed.

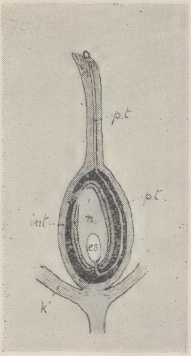


FIG. 70. — POLLEN GRAIN ON STIGMA PUTTING OUT TUBE TO OVULE (semi diagrammatic).
p.t, pollen tube; *e.s*, embryo-sac; *n*, nucellus; *int*, integuments; *k*, lower part of calyx cup.

TABLE SHOWING FORMATION OF SEED FROM OVULE.

OVULE.	SEED.
1. Stalk.	1. Stalk of attachment.
2. Usually two integuments.	2. The testa.
3. Micropyle.	3. Hole in testa, also called micropyle.
4. Macrospore or Embryo-sac.	4. Embryo + endosperm, which may, or may not, be absorbed by embryo.
5. Oosphere.	5. Embryo.

A seed is therefore a macrosporangium, enclosing a young plant, the embryo, which is set free from the parent plant in order to produce a new plant. Only Flowering Plants form seeds. From the embryo, the root and shoot of a plant arise. (See Chapter I.)

Life History of the Flowering Plant. We may now sum up what is called the *life history* of the flowering plant—that is, the chief stages of its development from the beginning of its existence until it is fully grown and able to produce another plant like itself.

1. Formation of the embryo by means of the union of the microspore with the macrospore—that is, the formation of the seed.
2. Development of the embryo into root and shoot.
3. Development of the flower—a metamorphosed shoot.
4. Formation of pollen grains, or microspores, by stamens (sporophylls).
   Formation of macrosporangia, containing macrospores, by carpels (sporophylls).
5. Pollination and fertilisation, resulting in the formation of the seed.

These are the stages through which every Flowering Plant invariably passes in the formation of the seed.

At the same time it must be remembered that many plants propagate themselves independently of seed.

The Endosperm or Albumen. The endosperm may develop in very various ways. In the Date it forms a hard stone, in the Cocoanut a white jelly, which is quite soft and flaky when the Cocoanut is young, but as it solidifies becomes hard. Sometimes the endosperm is horny.

Coffee, Caraway-seeds, Castor-oil, all contain endosperm. Where endosperm is developed the embryo is often minute, especially in Monocotyledons. In a date, for instance, the embryo may be found by cutting the stone across, through the little depression on the smooth side of the stone, that opposite the groove. When the stone is cut through there—and it must be done with a very strong knife—the embryo is found just beneath the depression, and is seen to be very small and white.

Seeds and fruits, on account of the food material stored in them, are used as articles of food. The so-called "coffee bean" is a seed consisting chiefly of endosperm ; this endosperm, when parched and ground, is the coffee bought in shops. The endosperm of the Cocoanut may be eaten in its raw condition ; Caraway-seeds are put into cakes.

Seeds with fleshy cotyledons, like those of the Pea and Bean, are specially nutritious from the albumen contained in the cotyledons. Lastly, most seeds contain a great deal of oil, especially those of nuts; it is this that makes them burn so brightly when thrown into the fire.

CHAPTER XI

FRUITS

After fertilisation, the ripened ovary forms the fruit. In many cases other parts of the flower, most usually the receptacle, are affected by fertilisation, and take part in the formation of the fruit.

A flower, which consists of one carpel, or in which the carpels are united to each other, forms a single fruit, as in the Pea, Lily, Wallflower, Violet, Foxglove; but where a flower has several carpels which do not unite to each other, one flower forms several simple fruits, and the product of each flower is then called a compound fruit: this occurs in the Buttercup, Blackberry, Rose.

Fruits may be either dry or succulent, dehiscent or indehiscent. A succulent fruit is fleshy, such as the Gooseberry, Apple, or hip of Rose; a dry fruit is one in which the seed-vessel in time becomes quite dry, as the pod of Laburnum, or the fruit of the Buttercup. A dehiscent fruit opens in late summer, or in autumn, to let out its seeds; on the other hand, in an indehiscent fruit the seed is retained in the seed-vessel until ready for germination.

Dry, Dehiscent Fruits.

The following are the chief types of Dry Fruits:

1. *Legume*, characteristic of the Pea and Bean family. If the pod of a Laburnum be examined, the remains of the calyx are seen just above the stalk: this shows that the fruit is formed from a superior ovary. When squeezed the pod splits into two pieces, called valves. The seeds are then seen to lie alternately in each valve, and to be attached along the margin, where the edges of the carpellary leaf bearing the ovules had united; the opposite edge of the fruit is the midrib of the carpel. A pod may therefore be defined as

a dry, dehiscent fruit, formed of one carpel, and dehiscing along both the midrib and the margin (Plate IV., Fig. 71).

2. A *follicle* is similar to a pod, except that it dehisces along the margin alone and not along the midrib. Follicles usually occur in compound fruits, as Christmas rose, Peony, Marsh Marigold, Columbine (Plate IV., Fig. 76).

3. The *siliqua*, characteristic of the order Cruciferæ. This may be examined in the Wallflower, or pod of almost any Crucifer, such as Mustard, Jack-by-the-hedge. At the bottom of the fruit is a ridge, where the sepals, petals, and stamens of the flower were attached; the fruit is therefore superior. It dehisces from the base upwards, along the edges of the two carpels into two valves, each having its own midrib. The seeds are attached to a thin membrane, called the *replum*, which lies parallel to the valves, and remains after they have fallen off. The replum must not be confused with the partition which is often seen between the valves of a fruit, and which is formed from the turning in of the carpellary leaf, as already described in the ovary of the Tulip (p. 38). The replum is an outgrowth from the edge of the carpel, but it is not part of the carpel itself; it is found in the majority of the Cruciferæ (Plate IV., Fig. 72). When a fruit of this kind is nearly as broad as it is long, then it is called a *silicula*, which is similar in all essential respects to the siliqua. The fruit of the Pennycress, Honesty, Shepherd's-purse is a silicula (Plate IV., Figs. 73, 74).

4. The term *capsule* is applied to those dry, dehiscent fruits which consist of two or more carpels, *e.g.*, Figwort, Violet.

Capsules proper are usually classified according to their mode of dehiscence:

1. They may dehisce lengthways along the margin, *e.g.*, Figwort (Plate IV., Fig. 75).

2. They may dehisce lengthways along the midrib, *e.g*, Iris (Fig. 81), Lily, Pansy (Fig. 78).

3. They may dehisce by teeth, *e.g.*, Chickweeds and many other Caryophyllaceæ (Plate IV., Fig. 80).

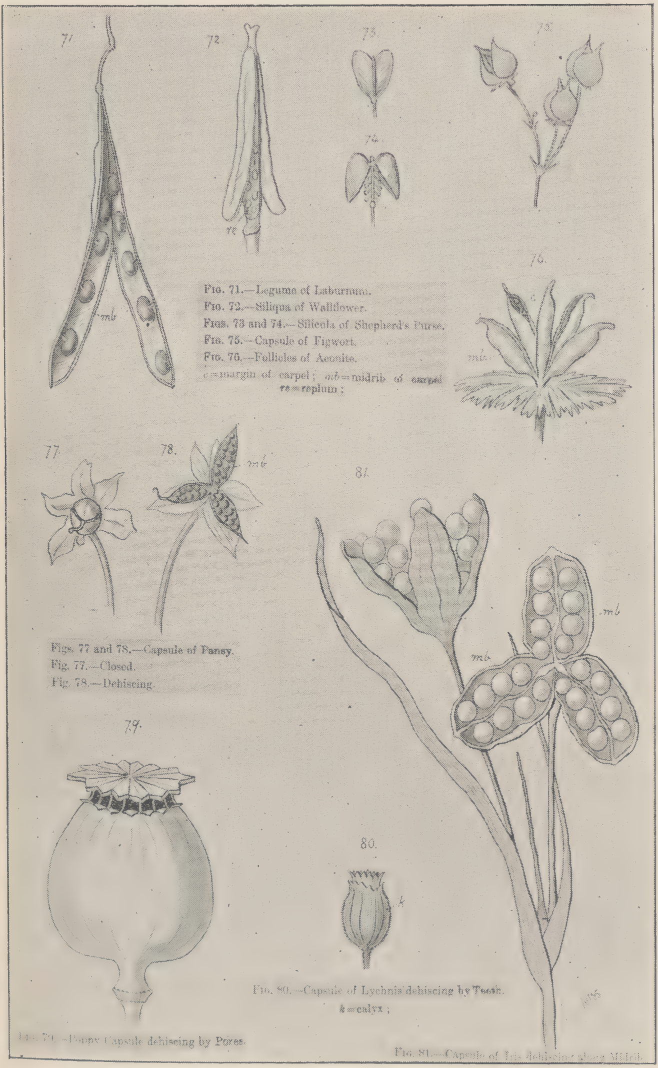


FIG. 71.—Legume of Laburnum.
FIG. 72.—Siliqua of Wallflower.
FIGS. 73 and 74.—Silicula of Shepherd's Purse.
FIG. 75.—Capsule of Figwort.
FIG. 76.—Follicles of Aconite.
c = margin of carpel; mb = midrib of carpel
re = replum;

Figs. 77 and 78.—Capsule of Pansy.
Fig. 77.—Closed.
Fig. 78.—Dehiscing.

FIG. 79.—Poppy Capsule dehiscing by Pores.

FIG. 80.—Capsule of Lychnis dehiscing by Teeth.
k = calyx;

FIG. 81.—Capsule of Iris dehiscing along Midrib.

PLATE IV.

4. They may dehisce by pores beneath the stigma, *e.g.*, Poppy (Fig. 79).

Dry, Indehiscent Fruits. The *nut* and *achene* are the two chief types of dry, indehiscent fruits. They are both one-seeded, but differ in the structure of their wall; that of the nut is very hard, that of the achene much less so. Indehiscent fruits are usually provided with appendages for dispersion; these will be described in the next chapter.

FIG. 82.—VERTICAL SECTION OF DRUPE (PLUM).

ep, outer coat (skin); *mes*, succulent portion; *end*, stone wall; *k*, seed enclosed in brown testa.

Succulent Fruits. Succulent fruits are represented by the *drupe* and *berry*, both indehiscent The drupe is a stone fruit, like the Plum and Cherry. Here, after fertilisation, the wall of the ovary gives rise to three distinct layers: the outer one forms the outside thin skin; the middle layer gives rise to the succulent portion of the fruit, whilst the innermost layer forms the hard stone. Within this is the seed or kernel. Drupes are generally superior fruits, formed from one carpel.

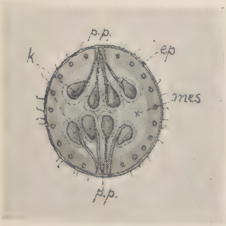


FIG. 83. — TRANSVERSE SECTION OF BERRY (GOOSEBERRY).

p.p, parietal placenta; *ep*, outer coat (skin); *mes*, succulent portion; *k*, seeds enclosed in brown testa.

A berry is something like the drupe without the hard stone; the whole of the wall of the ovary is soft and succulent; this is the main difference between the berry and the drupe. The berry may be inferior or superior. In the Gooseberry it is inferior, and consists of two carpels, for the seeds come off from two placentas; it may be formed from more than two carpels. The Horse-chestnut may be considered a succulent capsule; the wall of the ovary becomes succulent, and as the fruit dehisces, it is of the nature of a capsule.

CLASSIFICATION OF SIMPLE FRUITS.

- Dry
  - Dehiscent
    1. Formed from 1 carpel — Legume, Follicle
    2. Formed from 2 carpels — Siliqua, Silicula
    3. Formed from 2 or more carpels — Capsule
  - Indehiscent
    1. Achene
    2. Nut
- Succulent
  - Dehiscent
    - Capsule, *e.g.*, Horse-chestnut
  - Indehiscent
    1. Drupe
    2. Berry

Many succulent fruits are formed not only from the gynæcium, but from the receptacle. The Apple and Pear are good instances of this. A transverse section of an apple shows five chambers in the centre, each containing one or two seeds. Each of these chambers is an ovary, formed by the union of the two margins of a carpel, so that practically the centre of the apple shows five achenes. The succulent portion forming the greater part of the apple is the receptacle, which, after fertilisation, becomes thus enormously developed.

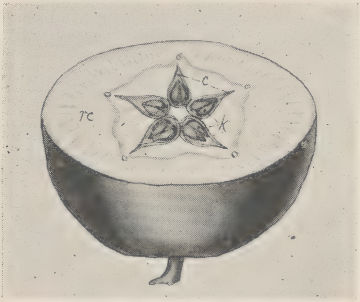


FIG. 84.—TRANSVERSE SECTION OF APPLE.
rc, receptacle; *c*, carpels; *k*, seeds (pips) enclosed in brown testa.

Similarly, in the Strawberry, the receptacle forms almost the whole fruit, the achenes being very minute.

In the Geraniaceæ and Umbelliferæ the carpels separate from each other, each containing one seed. The fruit is therefore known as a *schizocarp* (Gk. *schizo* = to split). The prolongation of the receptacle bearing the carpels, called the carpophore, persists after the carpels have dropped off (Plate V., Figs. 86, 87).

Compound Fruits. Compound fruits may consist of: (1) A number of follicles, *e.g.*, Columbine, Aconite; (2) a number of achenes, *e.g.*, Buttercup, Rose; (3) a number of drupes, *e.g.*, Blackberry, Raspberry.

There is no part of botany more perplexing to the beginner than the structure of fruits. It is essential to bear in mind that every flower forms a fruit, that it arises from the ovary, (sometimes from some other part of the flower as well), and that the seeds it contains have been developed from the ovules.

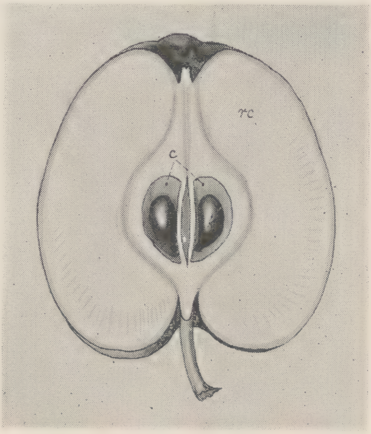


FIG. 85.—MEDIAN VERTICAL SECTION OF APPLE.

rc, receptacle; *c*, carpels; *k*, seeds (pips) enclosed in brown testa.

Then in examining a fruit it is helpful to note the following points:

1. Whether the fruit is simple or compound. If compound, it is sufficient to examine one of the simple fruits of which the compound fruit is composed.

2. The number of carpels of which the simple fruit consists.

3. Its position, whether superior or inferior.

4. Its mode of dehiscence, if any.

5. The number of its seeds.

Thus, supposing the fruit of a Columbine is being examined, it is clear that it is compound, for five or six simple fruits will be present. Each fruit must be formed of one carpel, for the fruit can only be compound when the carpels have not united. The ridge of attachment of floral organs underneath shows that the fruit is superior; it does dehisce, and only along the inner edge. In every particular this answers to the structure of a follicle, so that the fruit is finally described as compound, consisting of six, (or whatever the number may be), follicles.

Some fruits represent, not merely the product of a flower, but a whole inflorescence. That this is the case in the Mulberry is evident from the presence of the perianth leaves enveloping each section of the fruit.

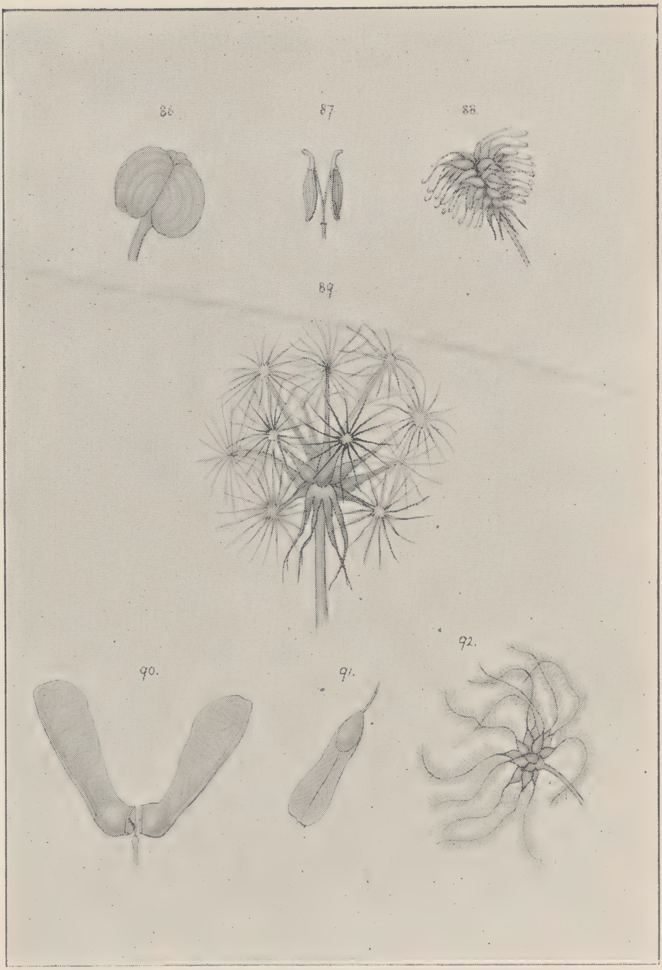


PLATE V.

FIG. 86.—SCHIZOCARP OF NASTURTIUM.
FIG. 87.—SCHIZOCARP OF UMBELLIFEROUS PLANT, WITH CARPELS SEPARATING.
FIG. 88.—ACHENES OF GEUM.
FIG. 89.—COMPOUND FRUIT OF SALSIFY.
FIG. 90.—FRUIT OF SYCAMORE, WITH WINGS.
FIG. 91.—FRUIT OF ASH, WITH WING.
FIG. 92.—ACHENES OF CLEMATIS.

CHAPTER XII

THE DISPERSION OF FRUITS AND SEEDS

EVERYONE must have noticed seedlings of trees, such as the Sycamore, even when no adult tree of the same kind was in sight; acorns have been found a mile away from the nearest Oak; rare plants are found in patches miles away from each other. How can facts of this kind be explained? Very largely by observing the way in which fruits or seeds are dispersed by the parent plant.

By Wind. Indehiscent fruits are often furnished with appendages which carry the fruit some distance from the parent plant. The achenes of the Clematis are provided with long feathery styles (Plate V., Fig. 92). In the Compositæ, the calyx becomes transformed into an organ of dispersion called a "pappus" (Fig. 89). The fruit of many trees, such as the Ash and Sycamore, is provided with wings, by which they are wafted through the air often to a considerable distance (Figs. 90, 91). In the Elm, the wing is all round the fruit and not at one end of it, as in the Ash and Sycamore.

By Animals. Fruits with a soft juicy coat, such as hips, haws, and berries, are eaten by birds and the seeds cast out of the body perhaps miles away from the spot where the parent plant was. In the late autumn, it is quite usual to see in a hedge the remains of the succulent coat of the hip or haw, many of the achenes enclosed in it having been carried off. Other fruits that are not soft or juicy have appendages (awns) with hooks or bristles, by which they become attached to the wool of sheep and other animals, and are thus carried some distance. This is the case in the Geum (Fig. 88), and a recent observer gives instances of acorns carried by rooks a mile or more from the nearest Oak-tree, generally in their cups.

Seeds scattered on Dehiscence of Fruits. Many fruits, in dehiscing, often send out their seeds with an explosive movement. This is the case in the Violet, Ivy-leaved Toadflax, Balsam, Squirting Cucumber, and Herb Robert. In this Geranium, the carpel springs from the central rod and sends out its seeds (Lord Avebury says) sometimes to the distance of 20 feet; the Dog-violet scatters its seeds 10 feet; and the Squirting Cucumber, owing to the pressure of the liquid inside, 20 feet.

FIG. 93.—FRUIT OF WILLOW HERB DEHISCING AND EXPOSING SEEDS; ALSO A DETACHED SEED.

FIG. 94.—POD OF COTTON DEHISCING AND SHOWING SEEDS; ALSO A SINGLE SEED WITH HAIRS FOR DISPERSION.

Many pods from the elasticity of their walls roll up in dehiscing, and thus jerk the seeds some little distance—for instance, the Sweet Pea; whilst in some Vetches the pod twists like a corkscrew and ejects its seeds.

By Water. Many fruits and seeds have the power of floating in water, and can thus be carried some distance. Darwin found that many seeds could resist the effect of sea-water, and would germinate even after being immersed thirty days or more; by this means vegetation must often have been carried from a continent to an outlying island.

Appendages attached to Seeds.

In some cases, appendages for dispersion are attached to the seeds and not the fruits. Many are furnished with hairs. One of the best known is the Willow-herb. The seed-vessel splits into four pieces, which twist back; the seeds are then exposed, and are seen to be provided with delicate hairs, so that the slightest wind wafts them hither and thither.

The seed of the West Indian Cotton is plentifully provided with fibres, from which cotton is made, the seed itself not being visible when the pod first bursts.

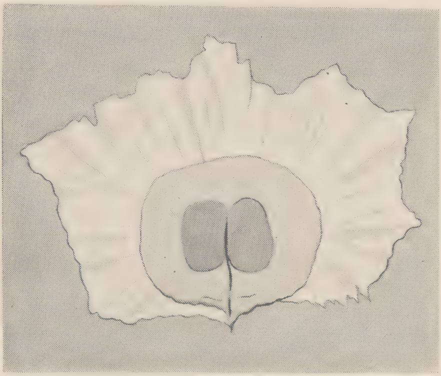


Fig. 95.—Seed of Bignonia Alba, with Wing for dispersion.

Bignonia alba is an instance of a seed with a large wing. The pod contains hundreds of these seeds.

Dispersal of Fruits and Seeds.

Agent.	*Organ.*	*Name of Plant.*
Wind ...	Feathery styles of fruit ...	Clematis.
	Calyx forming a pappus attached to fruit	Dandelion.
	Wings attached to fruit ...	Ash, Sycamore, Maple.
	Wing attached to seed ...	*Bignonia alba*.
	Hairs attached to seeds ...	Cotton, Willow-herb.
Water ...	Seeds or fruits furnished with air-spaces acting as floats	Water-lilies.
Animals	Hooks of fruit...	Geum.
	Succulent coat of fruit ...	Rose, Hawthorn, Privet, and many others.
Explosive Action	This accompanies the dehiscence of certain fruits ...	Violet, Cucumber, Vetches, etc.

PART II

CLASSIFICATION—ORDERS

CHAPTER XIII

CLASSIFICATION AND ORDERS

LIVING organisms are classified in order that it may be possible to get a bird's-eye view, as it were, of their number and extent. There are 120,000 plants known to botanists at the present time. If these thousands of plants were not grouped together in any way, it would be impossible for a botanist, even supposing that he devoted his life to the study of botany, to obtain the knowledge he now can have of the Vegetable Kingdom. When a botanist finds a plant, or reads of one that is not familiar to him, he is able at once to refer it to that group of plants which it most nearly resembles, and thus without much labour he forms a general idea of the structure of the plant, and all he has to do is to note the peculiarities in structure or growth of that particular plant. It would be quite otherwise, if each of the 120,000 plants had to be described and learnt independently of each other. Without some system of classification it is impossible to make progress in the knowledge of the immense number of forms of life that exist.

It must be remembered that a system of classification is never final; it must of necessity be more or less arbitrary and likely to vary. A plant which is to-day placed in one Order may subsequently be moved out of it, owing to the advance in the study of botany.

Linnæan System. The system of classification drawn out (1725-1730) by the Swedish botanist, Linnæus, was the one most generally used until about the middle of the last century. His system, though a great achievement for the age in which he lived, is now seen to be more or less artificial: he grouped plants together according to the number of stamens principally, and other very important resemblances or dissimilarities were neglected. Thus, plants with a single stamen were called Monandria; plants with two, Diandria; with three, Triandria; and so on. A single character of this kind is not a satisfactory basis of classification. In the present day plants with a differing number of stamens will be grouped together if they resemble each other in mode of growth, structure of andrœcium and gynæcium, and other general characteristics. The plants belonging to the Natural Order, Scrophulariaceæ, afford an instance of this. Mullein has five stamens, Figwort four, and a scale representing the fifth, Speedwell only two; but these plants are all grouped in the same Order on account of their characteristic gynæcium and fruit.

Natural System.

Flowering plants are divided into two great divisions:

1. Gymnosperms (Gk. *gymnos* = exposed; *sperma* = a seed), in which the carpellary leaves do not unite to form an ovary; the ovules are therefore exposed. (See p. 40.)

2. Angiosperms (Gk. *angos* = a vessel; *sperma* = a seed), in which the carpels do unite to form an ovary, so that the ovules they bear are contained in a chamber.

Angiosperms are again subdivided into Monocotyledons and Dicotyledons.

Monocotyledons, as the name implies, have one cotyledon; no tap-root; their stems do not as a rule increase in thickness; their leaves are parallel-veined; the floral leaves are usually three in each whorl. In Dicotyledons there are two cotyledons, often a well-marked tap-root; the stems do, as a rule, increase in thickness; the leaves are generally net-veined; and the floral leaves in each whorl may be two, four, or five, never three.

Monocotyledons and Dicotyledons are again subdivided, each subdivision including several Orders, of which only a few can be given in this book. (See table on next page.)

According to the Natural System of classification, plants which resemble each other in their chief characters are grouped together, particular attention being paid to the andrœcium and gynæcium, less attention to the number of floral leaves.

An interesting illustration of this is the Clematis, included in the Order Ranunculaceæ. The typical number of sepals and petals in this Order is five. Clematis has four sepals and no petals; it differs, too, from the rest of the Order in being a shrub, and in having compound, opposite leaves; its andrœcium and gynæcium, however, have the characters of the Order.

In identifying plants, the terms "species" and "genus" are used. Botanists are not agreed as to what exactly constitutes a species, but the ordinary use of the terms may be illustrated by comparing plants with members of a family. Each member of the family is distinguished from the rest by his or her name; this answers to the specific name of the plant, whilst the surname of the family represents the generic name. A Dog-rose is named *Rosa canina*, Rosa being the name of the genus, canina of the species. An Order may contain only one genus, or a large number of genera. In some Orders there are far more differences between the genera than in others. Thus in the Order Labiatæ there is less difference between the genera than in the Order Rosaceæ.

FLOWERING PLANTS.

- Gymnosperms
- Angiosperms
  - Monocotyledons
    - Nudifloræ (without petals)
    - Petaloidæ
      - Order: Liliaceæ*
  - Dicotyledons
    - Polypetalæ (petals free)
      - Orders: Ranunculaceæ, Cruciferæ, Caryophyllaceæ, Leguminosæ, Rosaceæ, Umbelliferæ
    - Gamopetalæ (petals joined)
      - Compositæ, Primulaceæ, Boraginaceæ, Scrophulariaceæ, Labiatæ
    - Apetalæ (without petals)

* In this table only those Orders described in this book are given.

RANUNCULACEÆ.

Type. The BUTTERCUP (*Ranunculus bulbosus*) may be taken as a type of this Order.

It is a perennial herb with a stem about a foot in height, and forming a bulb at its base. Some leaves are radical. The cauline leaves are alternate, simple, and very much divided. The *inflorescence* is a cyme; the flower is regular and hypogynous (Fig. 34).

Calyx (sepals): 5, free, inferior, turning back as soon as the flower opens. By this means it is easy to distinguish this species of buttercup from the two others which commonly occur in meadows —*Ranunculus acris* and *repens.*

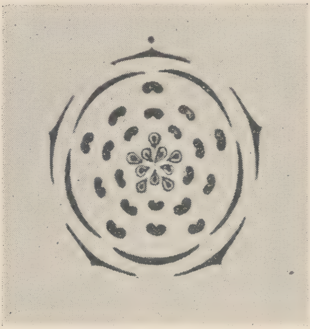


FIG. 96.—FLORAL DIAGRAM OF BUTTERCUP.
The dot denotes position of stem.

Corolla (petals): 5, free, hypogynous, glossy yellow, with a nectary at the base of each petal.

Andrœcium (stamens): numerous, free, hypogynous, spirally arranged.

Gynœcium (carpels): numerous, free, superior, one-seeded, placentation basal.

Other Plants. Other common plants belonging to this Order are: Water-crowfoot, Lesser Celandine, Spearwort, Corn Buttercup; these all belong to the genus Ranunculus.

Wood-anemone, Marsh Marigold, Clematis, are also very abundant. Columbine, Hellebore, Monkshood, Larkspur, Globeflower are found wild, but not commonly.

Rue, Pasque Anemone, Pheasant's Eye, Mousetail, Baneberry, Peony are very local, that is, they are found wild only in a few spots in Britain. Rue and Peony are much cultivated in gardens.

Characteristics of the Order. A comparison of the common plants mentioned above enables us to form some idea of the characteristics of the Order.

1. With the exception of Clematis, which is a climbing shrub, all the plants are herbs.

2. The leaves are usually simple and often very much divided. They are often radical, and when cauline they are generally alternate.

3. The flowers are mostly regular, Larkspur and Monkshood being the two chief examples of irregular flowers. All the parts of the flower are free. The stamens are numerous and often spirally arranged.

FIGS. 97 TO 100.—PETALS OF RANUNCULUS AURICOMUS, SHOWING NECTARIES.
p, pocket form ; *sc*, scale form ; *t*, tubular.

4. The fruit is compound, generally consisting of achenes or follicles. Where the carpels are numerous and one-seeded, achenes are produced; where there are few carpels with many seeds, follicles.

Comparison of Ranunculaceæ with Rosaceæ. The Order with which a beginner is likely to confuse Ranunculaceæ is Rosaceæ. Many of the flowers of these Orders are not unlike in appearance, but a careful examination shows the following differences:

(*a*) The flower is hypogynous in Ranunculaceæ, and usually perigynous in Rosaceæ.

(*b*) The stamens in Ranunculaceæ are usually spirally arranged; in Rosaceæ they are whorled.

Special Structures. The calyx is often very conspicuous; this is the case in the Marsh Marigold—the yellow floral leaves are sepals, not petals. Hellebore, Globeflower, Clematis, Anemone, all have a conspicuous calyx. When the calyx is petaloid, the corolla is either absent or very much reduced.

FIG. 101.—FLOWER OF HELLEBORE.

n, petals modified into tubular nectaries.

It is interesting to trace the development of nectaries in this Order. In the Buttercup, they are at the base of each petal, underneath a scale.

The petals of another species of Ranunculus (*R. auricomus*) show a great variety: there is the scalelike form; then each petal may have pockets at the base (Fig. 97); or, lastly, the whole petal may be tubular.

A comparison of this species with the nectaries of the Hellebore helps us to understand how the modification of the petal into a tubular nectary has arisen. In the Marsh Marigold, the nectaries occur as little depressions on the sides of the base of each carpel. Some few plants belonging to this Order are without honey.

FIG. 102.—GYNÆCIUM OF MARSH MARIGOLD.

n, nectaries on each carpel.

Clematis should be carefully observed, for it differs in many respects from the other genera. Its petioles are modified for climbing, the leaves are compound and opposite. There are no petals, and the styles are modified into organs of dispersion.

Distribution. The Ranunculaceæ belong for the most part to the temperate zone. Buttercups, Anemones, Celandines, so familiar to English children, are unknown to those living in tropical countries, for the Ranunculaceæ are hardly found in the tropics except on mountains.

CRUCIFERÆ.

Type. WALLFLOWER.

A herb, stem inclined to be woody at its base.

Leaves: alternate, sessile, exstipulate, simple, lanceolate, margin entire, apex acute.

Inflorescence: a raceme.

Flowers: regular and hypogynous

Calyx (sepals): 2 + 2, free, inferior; the lateral sepals bulge out owing to the nectaries on the short stamens.

Corolla (petals): 4, free, hypogynous, cruciform.

Andrœcium (stamens): $2 + 2^2$, free, hypogynous; four long, two short stamens. Nectaries at base of short stamens.

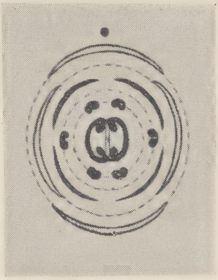


FIG 103.—FLORAL DIAGRAM OF WALLFLOWER.

Gynœcium (carpels): 2, joined, superior, stigma bifid; style much reduced; placentation parietal.

Fruit, a siliqua. (See Fig. 72.)

The number of floral leaves in each whorl may be taken as two. This is clearly seen in the calyx. In the corolla the whorl consists of four leaves (probably produced by the branching of two) in the diagonal plane (Fig. 103). The stamens are in two whorls, the outermost consisting of the two short stamens, and the innermost of the four long stamens, probably derived from a primitive form which had but two. The gynæcium consists of two carpellary leaves.

FIG. 104.—LONGITUDINAL SECTION OF WALLFLOWER

Floral formula: $K2+2$, $C \times 4$, $A2+2^2$, $G^{(2)}$.

The $\times$ before the 4 denotes that the petals are in the diagonal plane. The four large stamens are expressed by the formula 2^2 to show that they belong to the same whorl, and have probably arisen from two stamens. One reason for this theory of the structure of the Wallflower is that the Fumariaceæ, an Order closely allied to the Cruciferæ, have the stamens arranged in two groups.

Characteristics. This Order is easily distinguished from all others by the number of its petals, stamens, and carpels; but the different genera are only determined by a minute examination of the fruit and seed.

Many plants are articles of food, thus the roots of the radish and turnip, the primary shoots of the cabbage are eaten, whilst the buds in the leaf axils of the same species form Brussels sprouts. In the cauliflower, the inflorescence; and in mustard and cress, the cotyledons are articles of food.

The fruit of the Cruciferæ is either a siliqua or silicula. Shepherd's purse, Honesty, Pennycress, are, perhaps, the best known examples of the latter.

Distribution. All over the world, but scarce in the tropics. Wallflower and Alyssum, so abundant in English gardens, are not found in those of tropical regions.

CARYOPHYLLACEÆ (*the Pink Family*).

Type. STELLARIA HOLOSTEA (Great Starwort or Stitchwort).

A perennial herb, with opposite, sessile leaves.

Inflorescence: a two-sided cyme (Fig. 53).

Flowers: regular and hypogynous (Figs. 67, 68).

Calyx (sepals): 5, free, inferior.

Corolla (petals): 5, free, hypogynous. Each petal is deeply indented.

Andrœcium (stamens): 10, free, hypogynous; in two whorls.

Gynœcium (carpels): 3, joined, superior; ovary one-celled.

Fruit: a capsule dehiscing by six teeth. The fruit of the Stellaria resembles that of the Lychnis (Fig. 80), except that the latter dehisces by ten teeth instead of six, as it is formed from five carpels instead of three. In Fig. 80, the persistent calyx should be noticed.

Common Plants. The common plants belonging to this Order are the Pinks, Soapworts, Campions, White Lychnis, Corn Cockle, Ragged Robin, Starworts, Pearlworts, Sandworts, and Chickweeds. The last three are often very minute, with very small, white flowers.

Characteristics of the Order.

1. Opposite leaves.
2. A cymose inflorescence, usually two-sided (p. 48).
3. The petals, when present, are often very deeply indented.
4. The stamens are twice as numerous as the petals, and arranged in two whorls.
5. The fruit is a capsule, dehiscing at the top, usually by twice as many valves as there are carpels (p. 62).

The pollination of this Order is interesting. The majority have flowers which are wide open, and are therefore visited by short-tongued insects, which can easily get the honey secreted at the base of the stamens. Others, as for instance, the Pinks and Campions, have a tubular calyx, so that the honey is less accessible, and can be obtained only by long-tongued insects. Many plants belonging to the Order have white flowers, and are visited by insects that fly at night. These flowers open in the evening and attract by their sweet smell. *Lychnis vespertina* and *Silene nutans* (Nottingham Catchfly) are the best known instances of this.

The andrœcium is often ripe before the gynæcium, so that cross-pollination is insured in the case of insect visits (p. 51).

Distribution. Mostly in the temperate regions of the Northern Hemisphere, extending even to the Arctic circle: rare in the tropics.

LEGUMINOSÆ OR PAPILIONACEÆ.

Type. SWEET PEA.

An annual, climbing by means of its tendrils.

Leaves compound, pinnate, stipulate, the last two pairs of leaflets and the terminal one being modified into tendrils (Fig. 32).

Inflorescence axillary, two (or more) flowers on each branch.

Flowers irregular and perigynous.

Calyx tubular; the number of sepals is indicated by the teeth—three anterior, two posterior.

The *corolla* is very characteristic of this Order, as known in temperate regions. It consists of five petals: one large posterior, overlapping the others; this is the *standard*. Next two lateral petals overlapping the two anterior, and called the *wings* The two inner most anterior petals are often joined together until pollination takes place, they are boatlike in shape, and are therefore called the *keel*. The whole corolla is said to be *papilionaceous* (Lat. *papilio* = a butterfly), from its supposed resemblance to a butterfly with its wings folded.

FIG. 105.—PAPILIONACEOUS COROLLA.
st, standard; *w*, wings; *k*, keel.

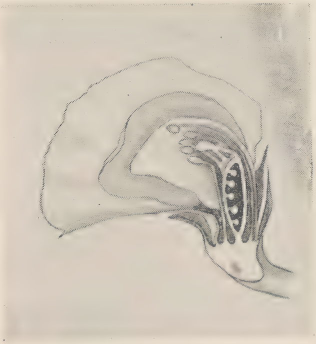


FIG. 106.—LONGITUDINAL SECTION OF SWEET PEA.

FIG. 107.—FLORAL DIAGRAM OF SWEET PEA.

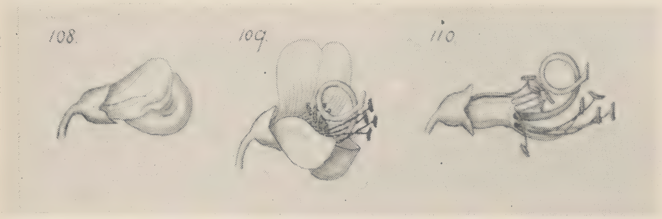
The *andrœcium* consists of ten stamens, nine of which in the Sweet Pea are joined by their filaments, forming a tube enclosing the gynæcium. The posterior stamen—that is, the one opposite the standard—is free.

In order to see that the corolla and andrœcium are perigynous, the flower should be cut vertically in the median line (Fig. 106). It will then be evident that the petals and staminal tube are attached to the edge of a shallow cup-shaped receptacle.

Gynœcium: one carpel, superior.

Fruit: a pod or legume.

Pollination. This may be observed in the Broom (*Cytisus scoparius*). Fig. 108 shows the flower unopened, with the keel in a state of tension almost parallel to the standard. An insect alighting on the wings of the corolla, and thrusting its head below the standard, presses down the



FIGS. 108 TO 110.—POLLINATION OF BROOM (*Cytisus scoparius*).
108.—KEEL IN STATE OF TENSION. 109.—KEEL DEPRESSED AND FOUR STAMENS PROTRUDING. 110.—SIDE VIEW OF ANDRŒCIUM AND GYNÆCIUM AT SAME STAGE.

keel (Fig. 109), the upper edge of which splits; the four outer stamens spring out, and the under side of the bee's body gets dusted with pollen. Meanwhile the keel goes on splitting, and as soon as the split reaches the part where the point of the style lies, it springs up, striking the back of the bee, which is covered with pollen from another flower; thus the stigma is pollinated.

The other five stamens then explode more violently than the first, depositing more pollen on the bee's back; this will be carried to another flower. Cross-pollination does therefore take place, and Darwin noted that if insects did not visit this flower, it seldom made seed. ("Fertilisation of Flowers," Muller, p. 195.)

Other Plants. The plants belonging to this Order are very varied in their growth; some are creeping—*e.g.*, Clover; others are climbing, some by means of their tendrils—

Sweet Pea, Vetch; Scarlet Runner by means of its stems; *Lathyrus aphaca* by its petioles (Plate I., Fig. 33). Some are shrubs—Genista, Broom, Gorse, and these three are spinous; others are trees, as Laburnum and many tropical genera.

Special Structures. The papilionaceous corolla is an invariably constant feature of this Order in Britain. In South Europe and in the tropics, many shrubs and trees belonging to the Order have not a papilionaceous corolla. Of these the best known in England is the Mimosa, or Sensitive plant, characterised by its day and night movements (Figs. 149, 150).

In some genera of this Order the ten stamens are all joined, as in the Furze, Broom, Genista, Rest-harrow, Lady's-fingers. In the Clover the corolla is attached to the staminal tube, not to the receptacle.

The fruit is usually a legume, but in the Acacia and some other genera the pod dehisces transversely, each portion containing one seed. The black, spirally twisted fruit of the Medick may be noticed.

Distribution. Next to the Compositæ this is the most extensive Order of Flowering Plants, and is distributed over the whole globe.

ROSACEÆ.

The genera included in this Order differ from each other more than is usually the case, owing to the varied forms of the receptacle. The flowers are, with the exception of the Apple group, perigynous; the receptacle is often hollowed out, enclosing the carpels.

The following plants, Blackthorn, Rose, Apple, may be taken as types of the three tribes into which many botanists group the different genera belonging to the Order.

Type I. BLACKTHORN.

To this division belong the Plum, Cherry, Almond. Blackthorn is a shrub, or tree, with branches converted into spines, or thorns (p. 25). The flowers come out before the leaves, are therefore very conspicuous, and attract insects.

Flower. *Calyx* (sepals): 5, free, perigynous.
Corolla (petals): 5, free, perigynous.
Andrœcium: stamens numerous, free, perigynous.
Gynæcium: one carpel, enclosed in the receptacle, but not united to it, therefore superior; two ovules.

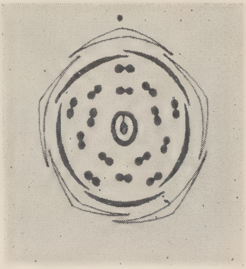


Fig. 111.—Floral Diagram of Cherry.

Pollination. This is an example of a plant in which the gynæcium is ripe before the andrœcium, and as the flowers are very conspicuous, insects are attracted, and cross-pollination usually takes place. In the absence of insect visits self-pollination may occur, the pollen from the shorter stamens which dehisce later, falling on the stigma.

The fruit of the Blackthorn, Plum, and Cherry, is a drupe (Fig. 82). After pollination the receptacle drops off, the wall of the ovary becomes differentiated into three layers, which give rise respectively to the skin, the succulent portion and the hard stone. Within this is the seed or kernel. One of the two ovules does not develop.

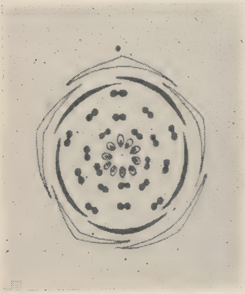


Fig. 112.—Floral Diagram of Rose.

Type II. Dog-rose.

The differences between this type and the former are:

1. The number of carpels, which are usually numerous, though sometimes only two or three, seldom one.

2. The receptacle does not drop off after pollination, consequently it forms a part of the fruit; thus in the hip, the red tube containing the hard nutlets is the receptacle. The nutlets are formed from the carpels, and are of the nature of achenes.

In other respects the Rose resembles the Blackthorn; its sepals, petals, stamens are perigynous; its stamens are numerous and its gynæcium superior.

For median vertical section of the Rose see Plate VI., Fig. 113.

This tribe includes a large number of genera, the most common of which are given in the following table for reference.

ORDER, ROSACEÆ—TRIBE II.

NAME.	NUMBER OF CARPELS.	RECEPTACLE.	FRUIT.	REMARKS.
1. Spiræa	3 to 5	Flat	Follicles	Fruit spirally twisted
2. Geum	Numerous	Conical and dry	Achenes crowded on receptacle	Fruit provided with hooked awns for dispersion (Fig. 88)
3. Blackberry and raspberry	Numerous	Conical and dry	Little drupes (drupels) crowded on receptacle	Plate VI., Fig. 114
4. Dog-rose	Numerous	Succulent, urnlike	Achenes enclosed in receptacle	
5. Potentilla	Numerous	Slightly swollen	Achenes on receptacle	
6. Strawberry	Numerous	Very much swollen & succulent	Achenes on receptacle	
7. Ladies' mantle (*Alchemilla*)	1 or 2	Hollowed out	Achenes enclosed in receptacle	No petals
8. Great Burnet (*Sanguisorba*)	1 or 2	Hollowed out	Achenes enclosed in receptacle	No petals
9. Salad Burnet (*Poterium*)	1 or 2	Hollowed out	Achenes enclosed in receptacle	No petals
10. Agrimony	2	Hollowed out	Achenes enclosed in receptacle	Fruit covered with bristles

PLATE VI.

FIG. 113.—MEDIAN VERTICAL SECTION OF FLOWER OF ROSE.
FIG. 114.—MEDIAN VERTICAL SECTION OF FLOWER OF BLACKBERRY.
FIG. 115.—MEDIAN VERTICAL SECTION OF FLOWER OF PLUM.
FIG. 116.—MEDIAN VERTICAL SECTION OF FLOWER OF APPLE.

rc, receptacle ; *ov*, ovary ; *o*, ovule.

Type III. APPLE.

This genus has epigynous flowers, for the walls of the carpels are united with the receptacle, which grows enormously and is succulent. The gynæcium is thus inferior (Plate VI., Fig. 116).

For structure of fruit see p. 64 and Figs. 84, 85.

Hawthorn differs from the apple in the number of carpels, generally two, and in the hardness of their walls, so that the haw cannot so easily be cut across with a knife as the apple.

Pear is similar in structure to the apple.

General Characteristics.

1. Many are shrubs, or even trees.
2. Leaves alternate, usually stipulate.
3. With the exception of apple and its allied genera the flowers are epigynous.
4. Many have an epicalyx, formed from appendages of the sepals.
5. The flowers are regular.

Distribution. Very wide, but not so extensive as that of Leguminosæ. On the whole, this Order is more abundant in temperate than in tropical regions.

UMBELLIFERÆ.

Type. COW PARSNIP (*Heracleum sphondylium*).

A coarse herb, with stout stem and hollow internodes; simple pinnately divided leaves, of which the sheaths are very large.

Inflorescence: a compound umbel (p. 48, Plate II., Fig. 50).

Flowers: epigynous (Fig. 44) and irregular, the anterior petal being larger than the posterior ones.

Calyx (sepals): reduced to a mere rim above the gynæcium.

Corolla (petals): 5, free, epigynous; the petals are notched.

Andrœcium (stamens): 5, free, epigynous; the stamens alternate with the petals, the anthers dehisce introrsely.

Gynæcium (carpels): 2, joined, inferior; seeds two; the styles unite at their base to form a disc—the nectary.

Fruit: a schizocarp (p. 64, Fig. 87).

The wall of the fruit has canals filled with an oily substance; the seeds are albuminous.

Characteristics of the Order. 1. The leaves are usually coarse and pinnately divided.

2. The inflorescence is usually a compound umbel, hence the name of the Order.

3. The flowers are small and white.

4. The gynæcium is inferior.

5. The fruit is a schizocarp.

Although the Order is quite easily recognised, the identification of the genera which belong to it is far more difficult, for the distinctions between them depend on minute differences in the fruit and seed, such, for instance, as the number of the oil canals, the presence or absence of ridges in the fruit, etc.

This Order is largely visited by insects, for its honey is exposed, and therefore easily accessible. Then the flowers, though usually minute, are crowded together in umbels; this renders them conspicuous, and allows of many being fertilised at the same time. As regards frequency of insect visits, this Order ranks next to the Compositæ, but the honey is not so well protected from rain, therefore the arrangements for pollination have reached a greater state of perfection in the Compositæ than in the Umbelliferæ.

Many of the Umbelliferæ are used for food; for instance, the root of Carrot and Parsnip, the leaf-stalks of Celery, the seeds of Caraway and Coriander; but, as a rule, the Umbelliferæ are poisonous.

Distribution. All over the world, especially in West Asia and along the Mediterranean. The Order is less abundant in the tropics and northern latitudes.

COMPOSITÆ.

The so-called flowers of the plants belonging to this Order are all inflorescences; the true flowers are sessile on a dilated, flattened receptacle, protected by an involucre of bracts, which plays the part of a calyx to the whole flower-head, protecting the bud and the young fruit. The *inflorescence* is a capitulum, or head; the flowers are often small, and are therefore called florets.

Type of Ligulatæ. In some of the Compositæ these florets are all like each other. Thus in the dandelion, each floret consists of hair-like sepals; of a corolla of five petals indicated by the teeth at the apex of the corolla; of five stamens joined by their anthers, and therefore described as syngenesious (Gk. *syn* = together, with; *genesis* = growth, origin); and of an inferior gynæcium, of two carpels forming an unicellular ovary, containing one ovule. The style passes through the tube formed by the anthers and then divides, so that there are two stigmatic surfaces. The flower is epigynous.

FIG. 117.—FLORET OF DANDELION.
ov, ovary; *p*, pappus, representing calyx; *c*, corolla; *f*, filaments of stamens; *a*, anthers; *sg*, stigmas.

Plants which have capitula bearing only one kind of florets belong to the division of the Compositæ, called Ligulatæ, from the strap-shaped corolla. Dandelions, Hawkweeds, Hawkbits, are the chief representatives of this group.

Many of the Compositæ, however, have inflorescences bearing two sets of florets; the inner ones are known as the disc florets, the outer as the ray florets. The corollas of these latter are often strap-shaped, whilst the disc florets are usually tubular

Those Compositæ which have some or all the florets tubular belong to the division Tubulifloræ, to distinguish them from those genera in which all the florets are ligulate. In some of the Tubulifloræ the ray florets are absent, as in Groundsel. Very often the ray florets have no stamens, as in the Daisy (*Bellis perennis*), Coltsfoot, Yarrow, Cornflower, and in these instances the corollas are specially developed to attract insects. Sometimes, as in the Cornflower, the outer florets have neither stamens nor carpels, and their only function is to attract insects.

The disc florets are provided with stamens, and usually with

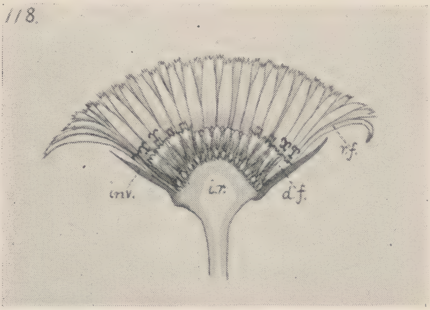


FIG. 118.—MEDIAN VERTICAL SECTION OF CAPITULUM OF DORONICUM.

r.f, ray florets ; *d.f*, disc florets ; *i.r*, inflorescence-receptacle ; *inv*, involucre.

carpels, so that they make fruit. In Coltsfoot, the disc florets do not make fruit, only the ray florets.

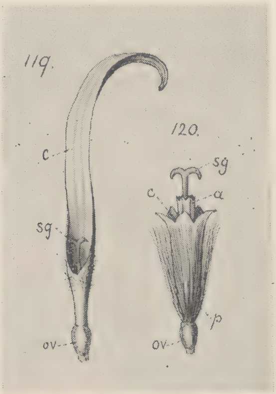


FIG. 119.—RAY FLORET OF DORONICUM.

c, corolla ; *sg*, stigmas ; *ov*, inferior ovary.

FIG. 120.—DISC FLORET OF DORONICUM.

c, corolla ; *p*, pappus, representing calyx ; *a*, anthers ; *sg*, stigmas; *ov*, ovary.

On the whole, then, we may say that division of labour has taken place in the Compositæ: the ray florets attract insects, the disc florets make pollen and produce fruit.

Type of Tubulifloræ. In Leopard's bane (*Doronicum*), both disc and ray florets are present.

Inflorescence: a capitulum.

Involucre: composed of linear bracts.

Receptacle: without scales.

Ray floret: Calyx absent; petals 5, joined, epigynous; stamens absent; Gynæcium (carpels), 2, joined, inferior.

Disc floret: Calyx, consisting of hairs, forming a pappus. Corolla (petals) 5, joined, epigynous; Andrœcium (stamens), 5, syngenesious, epipetalous; Gynæcium (carpels), 2, joined, inferior; Ovary one-celled, ovule 1, styles 2.

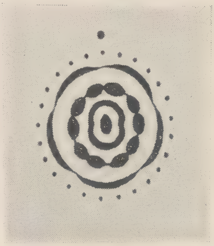


Fig. 121.—Floral Diagram, Disc Floret Doronicum.

Pollination. The Compositæ are particularly well adapted by the structure of the flower for insect-pollination. (1) The flowers are associated together in heads, so that an insect can pollinate many in a short time. (2) The honey is secreted by the nectary at the base of the style, and collects in the corolla tube, gradually rising towards the mouth, so that all insects, except very short-lipped ones, can reach it. (3) There is no waste of pollen, for the anthers dehisce introrsely. If even insects are scarce—and after a long severe winter this may be the case—the Compositæ stand a better chance of being visited than almost any other flowers, for their being associated together in heads renders them very conspicuous.

Cross-pollination is insured in some cases by the andrœcium developing before the gynæcium, but as a rule the Compositæ can pollinate themselves if cross-pollination does not take place. This is well seen in the Dandelion. The style, which is covered with hairs on its surface, pushes its way up through the tube formed by the union of the anthers, and thus gets covered with pollen, for the anthers dehisce introrsely. Then emerging from the anther cylinder, the style divides, exposing its stigmatic surfaces—the inner ones. In the case of insect visits the stigmas are cross-pollinated, but if insect visits do not occur the stigmas bend outwards, curving until their tips touch the hairs on the outer surface of the style, and self pollination then takes place.

Characteristics of the Order. 1. Usually herbs; trees and shrubs are comparatively rare. This is remarkable when the enormous number of plants belonging to the Order is remembered.

2. Inflorescence, a capitulum. Each so-called flower is an inflorescence.

3. Stamens united by their anthers (*syngenesious*).

4. Gynæcium inferior, ovary one-celled, containing one basal ovule.

5. Fruit is generally called a cypsela (Gk. *kupsele* = a hollow vessel), to distinguish it from those achenes which are formed from a single carpel and a superior ovary.

6. Calyx forms a pappus and becomes an organ of dispersion of the fruit.

Distribution. This is the most widely distributed of all Orders, and is also the most extensive; it includes as many as 800 genera, many of which are cultivated plants, as Sunflower, Jerusalem Artichoke, Dahlias, Zinnias, Marigolds. The number of genera indigenous to Britain is over forty.

It is interesting to inquire why this Order should be so abundant. It has been suggested that the reason lies in the perfection of its arrangements for pollination, due (1) to the massing of the flowers in heads, and (2) to the structure of the flower, which is adapted for visits from all insects except the very short-lipped ones, and which at the same time protects the honey and pollen.

The provision of the Compositæ for the dispersion of their fruits must also be taken into consideration in accounting for the extensive distribution of the Order.

PRIMULACEÆ.

Type. The Primrose (*Primula veris*).

A herb, with radical, simple, undivided leaves.

Inflorescence: flowers apparently solitary, but really forming an umbel, the common stalk being short and concealed by the leaves.

Flowers: regular and hypogynous.

Calyx (sepals): 5, joined, inferior.

Corolla (petals): 5, joined, hypogynous.

Andrœcium (stamens): 5, free, upon the petals; opposite to, not alternate with, the petals.

Gynœcium (carpels): 5, joined, superior; placentation free central (Fig. 39).

It is not possible to see that there are five carpels without the microscope, but as the fruit dehisces by ten teeth, it may be assumed that there are five carpels. Compare with this the number of carpels and dehiscence of the capsule in the Order Caryophyllaceæ, p. 80. In the Pimpernel five carpels may be seen.

The Primrose has two forms of flowers, and is, therefore, said to be dimorphic (Gk. *di* = two; *morphos* = form), Figs. 62, 63. This insures cross-pollination (p. 52).

The Cowslip, another species of the genus Primula, has an umbel of flowers. The Oxlip differs from the Cowslip in having a broader and flatter corolla; it is much less abundant than the Cowslip, requiring richer soil. The Cowslip, Oxlip, and all the species belonging to the genus Primula, have dimorphic flowers.

Other common plants belonging to this Order are the Pimpernels (Fig. 42), the Lysimachias, of which the Creeping Jenny and Wood Lysimachia are, perhaps, the best known. The latter closely resembles the Common Pimpernel, but is yellow, not red.

Cyclamen, found wild commonly in Switzerland, is much cultivated in England; its drooping flowers, with the petals turned upwards, easily distinguish it from other genera.

Sea-milkwort (*Glaux maritima*) is common on British coasts.

Characteristics of the Order. 1. Each whorl of the flower consists of five leaves.

2. The stamens are opposite to, not alternate with, the petals, which are always joined.

3. Gynæcium superior; placentation free central.

4. Fruit, a capsule, usually dehiscing by teeth.

Distribution. Chiefly in the Northern Hemisphere. Primroses and Cowslips are not found in the woods and meadows of tropical countries.

BORAGINACEÆ.

Type. Common Borage (*Borago officinalis*).

A hairy plant, with simple oblong leaves.

Inflorescence: a one-sided cyme (Fig. 52, p. 48).

Flowers: blue, regular, hypogynous.

Calyx (sepals): 5, joined, inferior.

Corolla (petals): 5, joined, hypogynous. The tube of the corolla is very short, with scales at the mouth.

Andrœcium (stamens): 5, free, on the petals, and alternating with them. The anthers form a cone and dehisce introrsely.

Gynæcium (carpels): 2, joined, superior; ovary four divisioned.

Fruits: four nutlets, as in Labiatæ.

Borage is largely cultivated for bee-feeding.

Other common plants belonging to this Order are: Viper's Bugloss, Gromwell, Forget-me-not, Comfrey, Hound's Tongue. They all have rough, coarse, hairy leaves, usually alternate and exstipulate. Alkanet and Heliotrope are commonly grown in gardens.

Pollination. The structure of the flowers shows adaptation for insect visits. The corolla tube is short, generally with scales at the mouth, so that the honey is protected. The corollas are conspicuous, being usually red, violet, or blue, so that insects are attracted; there are often special markings or "path-finders" to direct the insect. The anthers dehisce introrsely. The insect, in getting the honey from the bottom of the corolla-tube beneath the ovary, gets dusted with pollen, which it deposits on the stigma of another flower; thus cross-pollination takes place.

This Order is closely allied to Labiatæ, but is easily distinguished from it by the regular corolla. The essential differences which separate these two Orders are given on p. 98.

Distribution. Chiefly in the Northern Hemisphere; rare in the tropics.

SCROPHULARIACEÆ.

Type. FIGWORT.

A herb, with square, upright stem; leaves opposite and decussate—that is, one pair of leaves is on two sides of the stem, the next pair on the other two sides, and so on.

Inflorescence: axillary cymes; flowers irregular and hypogynous.

Calyx (sepals): 5, joined, inferior.

Corolla (petals): 5, joined, hypogynous.

Andrœcium (stamens): 4, free, epipetalous. The fifth stamen is represented by a staminode on the posterior side of the flower.

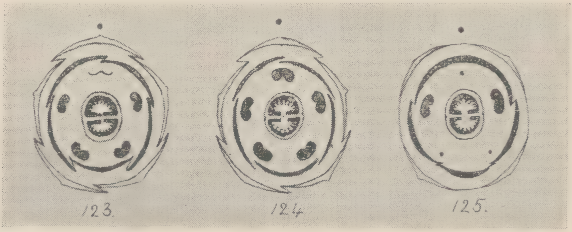
Gynœcium (carpels): 2, joined, superior. Stigma bifid, placentation axile.

FIG. 122.—LONGITUDINAL SECTION OF FOXGLOVE.

Fruit: a capsule with persistent calyx (Plate IV., Fig. 75).

Pollination. The gynæcium matures before the andrœcium (p. 51).

A comparison of the different genera shows that in this Order the stamens are often suppressed. The number that



FIGS. 123 TO 125.—FLORAL DIAGRAMS OF SCROPHULARIACEÆ.
123.—FIGWORT. 124.—MULLEIN. 125.—VERONICA.

one would expect to find is five, for there are five sepals and five petals. Mullein has five stamens; Figwort four and a staminode; Veronica two only. Comparing Veronica (Figs. 125 and 126) with a typical scrophulariaceous flower (Fig. 124), we note that the anterior petal is the smallest; the posterior probably represents two petals. The posterior median sepal is missing. The fifth stamen, the posterior one, is naturally suppressed, as in many of the Scrophulariaceæ, and in addition the two anterior ones.

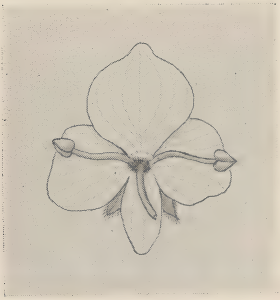


FIG. 126.—COROLLA OF VERONICA.

This Order is also characterised by its variety of corolla; often it is two-lipped, as in Figwort, Cow-wheat, Rattles, Bartsia, Snapdragon, Toadflax, Foxglove, Eyebright. In Veronicas and Mulleins it is rotate; Toadflax is spurred.

Many are semi-parasitic plants, having green leaves, but swellings on their roots by which they attach themselves to other plants and obtain nourishment from them. Eyebright, Cow-wheat, the Rattles, Bartsia, are the best known examples of this.

Many plants belonging to this Order are cultivated in

Fig. 127.—Corolla of Mullein.

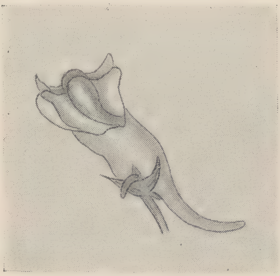


Fig. 128.—Corolla of Toadflax.

gardens—Calceolaria, Snapdragon, Gloxinia, Foxglove.

Distribution. Over the whole globe, but more especially in the temperate zone.

LABIATÆ.

Type. Dead Nettle.

A perennial herb with square stem, leaves opposite and decussate.

Inflorescence: axillary cymes, generally described as verticillasters or false whorls, because the flowers are so numerous and crowded together that they appear at first sight to come off from all sides of the stem.

Flower: irregular, hypogynous.

Calyx (sepals): 5, joined, inferior.

Corolla (petals): 5, joined, hypogynous. The corolla is bilabiate, or two-lipped; one anterior petal forms the lower lip. There are two lateral petals and two posterior which form the upper lip.

Andrœcium (stamens): 4, attached to the petals. If carefully pulled down it will be seen that they are attached to the two lateral and the anterior petals, none to the posterior.

Gynæcium (carpels): 2, joined, superior, two stigmas. Each carpel of the gynæcium becomes subdivided into two chambers each containing one ovule. The carpels unite in the lateral plane; this is clear from the situation of the two stigmas in the median plane. The style arises from the base of the gynæcium, and is therefore described as gynobasic.

Fig. 129.—Median Vertical Section of Dead Nettle.

Fruit: 4 achenes.

Pollination. The nectary is at the base of the ovary, which lies at the bottom of the corolla tube; this tube is long, so that the honey can be reached only by large bees. The bee alights on the lower lip, which is large and conspicuous, thrusts its head into the mouth of the corolla tube, its back being pressed against the upper lip, where the anthers are.

The stigma lies at the mouth of the corolla tube directly in the bee's path, so that it gets pollinated before the bee has had time to get any fresh pollen from the flower.

Labiatæ compared with Scrophulariaceæ. This Order is easily distinguished from all others. Some of the Scrophulariaceæ resemble Dead Nettle in having plants with square stems, opposite leaves and bilabiate corollas; but the gynæcium of the Scrophulariaceæ has invariably a two-celled, not a four-celled, ovary; and the fruit is a capsule, never four achenes, as in this Order.

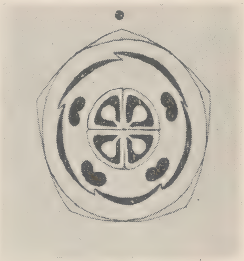


Fig. 130.—Floral Diagram of Dead Nettle.

It is true that the gynæcium of the Labiatæ is exactly similar to that of the Boraginaceæ, but this latter Order differs in having regular flowers and alternate leaves.

Although the Labiatæ are distinctly marked off from other Orders, there is comparatively little difference between the numerous genera forming the Order, far less than there is in the Rosaceæ.

Distribution. Very wide, over the whole globe.

LILIACEÆ.

This is a Monocotyledonous Order.

Type. BLUEBELL.

A perennial, bulbous herb, with radical, linear leaves, which are shorter than the flower stems.

Inflorescence: a raceme, the flowers drooping, and each having a bract.

Perianth (leaves): 3 + 3, joined, inferior.

Andrœcium (stamens): 3 + 3, free, upon the perianth.

Gynœcium (carpels): 3, joined, superior; placentation axile.

Fruit: a capsule, dehiscing along the midrib.

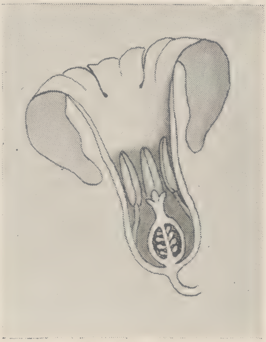


FIG. 131.—MEDIAN VERTICAL SECTION OF BLUEBELL.

The floral diagram of a Tulip (Fig. 45) is correct of a Hyacinth, except that in the Tulip the leaves of the perianth are not joined.

Other Plants. Other common plants belonging to the Order are Solomon's Seal (*Polygonatum multiflorum* only; the other species are local. Plate VII., Fig. 133), Wild Garlic, Fritillary, Meadow Saffron, and Bog Asphodel, abundant in bogs and wet moors.

Herb Paris, Lily of the Valley, May Lily, Asparagus, Butcher's Broom, Wild Tulip, Star of Bethlehem, Grape Hyacinth, are either very local or are mainly cultivated in gardens.

Characteristics of the Order. A comparison of these plants indicates the characteristics of the Order, namely:

1. Underground stems, bulbs or rhizomes.
2. Leaves usually radical, and generally parallel-veined.
3. Flowers regular; floral leaves usually three or multiples of three.
4. Gynæcium superior. This feature at once marks off the Liliaceæ from the two other Monocotyledonous Orders with which it may be confused: the Amaryllidaceæ, to which Snowdrop and Narcissus belong, and the Iridaceæ (Iris, Gladiolus, etc.), both of which have an inferior ovary.
5. Fruit, a capsule, or berry.

Special Plants. Herb Paris, a local plant, has net-veined leaves. The perianth consists of two whorls of four (not three) leaves each, the inner pinkish ones being more slender than the outer green ones; stamens eight, carpels four. Herb Paris may also have five, instead of four, floral leaves in each whorl (Plate VII., Fig. 135).

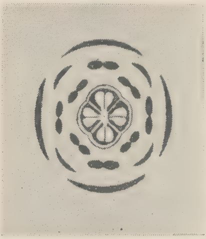


FIG. 132.—FLORAL DIAGRAM OF HERB PARIS.

May Lily has two floral leaves in each whorl—that is, four perianth leaves, four stamens.

In Butcher's Broom the apparent leaves are modified branches, for they arise in the axil of the scale leaves, and they bear scale leaves on their surface. The flowers appear to be seated on the leaf, but are borne by short stalks arising in the axil of the scaly leaf (Plate VII., Fig. 134).

So too, in Asparagus, the green branches may easily be mistaken for leaves.

Distribution. This Order is widely distributed. Lilies, for instance, are found in every part of the globe, being extensively grown in gardens. At the same time it may be noticed that many of the common English wild flowers, *e.g.*, Bluebells, are not found in the tropics.

PLATE VII.

Fig. 133.—Solomon's Seal.

Fig. 134.—Butcher's Broom: *br*, branches; *fl*, foliage leaves; *f*, flower.

Fig. 135.—Herb Paris.

CHAPTER XIV

THE DISTRIBUTION OF PLANTS

In the accounts of the Orders that have been given, some attempt has been made to indicate their distribution, and also to note the rarity of any special plant belonging to the Order. It will be noticed that some plants have a far wider range than others, that whereas some are found almost over the whole globe, others are confined to temperate regions, and are hardly known in tropical.

Zones of Vegetation. Speaking very generally, we may say that the Arctic regions are characterised by scanty vegetation, only Mosses and Lichens, and a few flowering plants—*e.g.*, Saxifrages and Gentians—being found there; whilst trees, if any, are represented by stunted Willows. Then follow the Pine forests so well known in Norway. The temperate zone is distinguished by the Oak, Ash, Elm, Sycamore, Beech, Poplar, Birch, Hazel—trees which lose their leaves in autumn and renew them in spring, and are therefore called deciduous (Lat. *de* = down, *cado* = to fall). Pine forests are also abundant. The flowers are those so well known to us in England—Snowdrops, Anemones, Primroses, Buttercups, Geraniums, etc. Comparing this region with the tropical, we may say that its vegetation is less luxuriant and more sober in colouring. Palms of all kinds, grasses which seem to reach their height in the Bamboo, tall Tree-ferns, shrubs and trees with brightly-coloured flowers such as Oleander, hedges gay with Hibiscus, forests in which Orchids by their aerial roots pass from tree to tree—these are a few of the plants characteristic of the tropics. The trees are mostly evergreens.

Altitude. In considering the distribution of plants in a particular region, one of the first things to be considered is its latitude; but this is very much modified by the presence of mountains. We see the effect of this on a large scale when comparing the vegetation of the temperate zone with that of the tropical. It is true that Buttercups and Anemones, so common in England, do not grow in the fields and woods of tropical countries; but they have been found on the highest peaks of the mountains of Jamaica; therefore not only has the latitude of a district to be borne in mind, but also its altitude. Even in an English county the plants growing in a valley will be different from those growing on the hills. In Gloucestershire, the Spiny Rest-harrow (*Ononis spinosa*) is found only in the valleys, whilst the smaller species without thorns (*Ononis arvensis*) is found on the hills. Even where the same species occurs both on the hills and in the valleys its growth is different; thus the pyramidal Orchis growing in the valley of the Severn is larger, its blossoms further apart and paler than the same species growing on the Cotswolds.

Nature of the Soil. The nature of the soil is another very important factor in the distribution of plants; some will thrive only on limestone, others cannot live on it; some require sand, and so on. Thus the Foxglove is found in Gloucestershire only in the western part of the county, because there strips of red sandstone occur. In the bogs of the same region is found the Sundew, which cannot thrive where lime is present.

Rainfall, Rivers, etc. The rainfall, direction of the watershed, nature of the rivers, whether tidal or not, all have their influence on the flora of a district. Comparing, for instance, two counties which are practically inland, if one has a tidal river and the other has not, sea plants, like Sea Lavender, Sea Aster, Sea Thrift, will be found in the one and absent in the other.

Direction of the Wind. The direction of the wind is a very important consideration, for seeds are dispersed largely by wind. It accounts for such facts as the occurrence of the same plants several miles apart from each other, and not in the intervening districts.

Adaptation to Surroundings. Even in a comparatively limited district it is possible to collect instances of adaptation, some of which have already been noticed in other connections. The part of the plant which perhaps shows the greatest power of adaptation is the leaf. In the Water-crowfoot, one kind of leaf is found in the part of the plant growing in water, another in that part of the shoot above water (p. 32).

In Lady's-mantle, the leaves of the species growing in meadows and pastures (*Alchemilla vulgaris*) are simple and undivided, whilst the species growing on the tops of mountains (*Alchemilla alpina*) has leaves deeply divided into six or seven lobes, and each lobe bends inwards as though to catch the dew and drops of water more easily.

Comparing tropical countries with temperate regions, we find a similar variety in the structure of the leaf. In the tropics, plants have to be able to resist a rainy season which may last four or five months; it is important, therefore, that the surface of the leaf should be smooth, or even polished, so that water may run off easily, as in the India-rubber plant. In deserts, on the other hand, leaves must be able to collect all the water that falls, they therefore generally slope in such a way that the water must pass towards the stem and root (p. 29).

In this connection we may notice the characteristics of plants that have to pass through a winter period (hibernation). They have stores of reserve material in the root, or stem, or leaves; their buds are also well protected. If herbs, the buds are often underground; if trees, by bud-scales, resin, wool, etc. (pp. 16, 17).

Those interested in the distribution of plants should read Willis on this subject ("Flowering Plants and Ferns," vol. i., chap. iii.).

CHAPTER XV

FIELD WORK

It may be helpful to indicate a few observations which even beginners in botany can make for themselves, and which will add very much to the interest of the subject, for it is impossible to have any first-hand knowledge of plant life merely from books. It is true that the parts of a plant can be examined in class, or at home, but little can be known of the life of the plant, of its mode of growth, apart from its surroundings.

The Habitat. The locality in which a plant is found should be carefully noted, whether it grows in hedges, in meadows, on rocks, on exposed hills, in bogs, by running streams, in stagnant water, by the sea, etc. Books, however good, cannot give an adequate idea of this. For instance, the habitat of the plant Butterwort (*Pinguicula vulgaris*) is thus described in Bentham's "Botany," "Among mountain rills and on wet rocks," and this is absolutely correct; but what a very different idea one gets of the situations in which the plant will grow, and its abundance, by walking over the high hills of the Lake District, or of the Scotch Highlands. There the plant is found literally by hundreds, on the very mountain *paths* between the stones, clinging to the sides of the rocks, and in boggy patches, though not so abundantly in this latter situation as on the rocky paths.

The Season. The month, and even the day of the month, in which a plant puts forth its leaves and flowers, and whether the flowers come out before the leaves, should be recorded. In this way some idea of the effect of climate—of a severe winter, a late spring, east winds, etc.—is obtained. Again, the same plant will flower much earlier in some parts of England than in others. In the New Forest plants are about ten days earlier than in Gloucestershire, and in Scotland there is nearly a month's difference from the time of flowering in the southern counties of England.

The Protection of Plants. The means plants have of protecting themselves offer a large field for observation. Winter buds, the protection of honey and of seeds, have already been alluded to, but it has been only possible to give a few instances; there are very many more that may be observed by those who take a real interest in plant life. A list might be made of the flowers that hang down during rain, and hold themselves up in sunlight; of those with capsules which open by pores or teeth, so that the seeds are protected within the capsule until ready for dispersion; of those in which the calyx closely envelops the rest of the flower whilst in bud, and drops off when the flower is fully formed.

Insect Visits. It is fascinating work to watch the insects that visit a flower, yet it is difficult to make accurate observations on this subject, for some rudimentary knowledge of insects is required. It is necessary, for instance, to know the difference between a Moth and a Butterfly, and it is an advantage to master the structure of the mouth parts of different insects in order to realise the close relation existing between flowers and insects. Some have mouths adapted for biting, others for licking, and others, again, for sucking. It will be found that the structure of a flower visited by a Bee is different from that of one visited by a Beetle or Fly. Some attempt has been made in the accounts given of pollination in the different Orders to trace the connection between the visits of insects and the structure of the flower; but this is a very wide subject, and one of which it is only possible to get any real idea by one's own observation. Lord Avebury's book, "British Wild Flowers and Insects" is the most helpful for those beginning observations of this kind.

The Dispersion of Seeds. This is a subject in which a great deal of work may be done. The arrangements for dispersion in the structure of the fruit or seed should be observed (Chapter XII.). Whenever a fruit or seed is picked up it should be examined, in order to see whether it has wings, hooks, hairs, etc., by which it could have been blown or carried to the place where it was found. Then, secondly, the distance from the adult plant should be noticed; sometimes this is not great, but it may be a mile or more. Thirdly, the agent of dispersion should be observed, and it is often very difficult to ascertain this. Hazel-nuts, for instance, are sometimes found broken open and tightly wedged in the bark of trees some few hundred yards away from the parent tree. How do they get there? The seed-cases are generally empty. The most natural supposition is that an animal has been feeding on the seeds of the nut, but what animal? Probably some bird, and one might be fortunate enough to see the bird and recognise it. At any rate, any book containing observations on trees would be sure to mention that the Nuthatch is in the habit of doing this. The part that animals, especially birds, play in the dispersion of seeds is perhaps hardly yet fully realised.

Mode of Growth. Any special feature in the growth of a plant should be noticed, whether by underground stems, by creeping along the ground, or by climbing. If climbing, the organ adapted for this purpose should be observed, roots, stems, petioles, leaves modified into tendrils, etc.

The Colour. This often helps to indicate whether the plant is parasitic or not. Broomrape is whitish, so, too, is Toothwort. A plant with pale stems and leaves would in all probability be parasitic, although it must be remembered that semi-parasitic plants often have green leaves.

Plants in a given Area. A list of the plants in a particular area may be made. In this connection the nature of the soil, whether clay, sand, limestone, the height above the sea, the prevailing winds, should all be observed. A beginning may be made by observing accurately the plants of one's own neighbourhood. Darwin recommended the making a list of the plants that grew in a particular field during the course of the year. His idea was that an exact plan of the field should be made, every important feature being inserted, as, for instance, the position of a pond, or marshy part, or furrow. Then the exact spot in which a plant was found was to be noted, its time of flowering, and so on.

Members of a class might find it interesting to make a list of the plants they found in the spring and summer holidays, and then to compare results when returning to school. In this way some rough idea would be gained of the flora of different counties, and of the plants that inhabit mountainous districts compared with those found in flat counties, such as Cambridgeshire. Johns' "Flowers of the Field" is a useful book for the identification of plants.

A great deal of time is sometimes spent in drying plants, and getting together a herbarium. This does help one to gain a knowledge of many plants, but the time spent in pressing may perhaps be spent to greater advantage in making observations such as those that have been indicated here. More real knowledge of plant life is obtained by observations of this kind than by the making of collections. Miall's "Round the Year" suggests many observations, not only on plants, but on Nature generally.

PART III

THE PHYSIOLOGY OF THE PLANT

CHAPTER XVI

THE LIFE OF THE CELL

A PLANT is a living organism and therefore capable of performing all the functions characteristic of life. It can breathe, take in food, respond to its surroundings, reproduce itself, just as much as any animal can. In some cases it can even move; in fact, it becomes increasingly difficult to say in what the difference between a plant and an animal consists, for the more the life of plants and animals is studied, the greater are their resemblances to each other found to be, especially in the lowest forms. At the present time, there are organisms which are claimed by both zoologists and botanists.

Protoplasm. The properties connected with the presence of life are always found associated with a substance to which the name *protoplasm* has been given (Gk. *plasma* = material; *protos* = first). The very simplest organisms, animal as well as vegetable, are merely masses, often too minute to be seen without the microscope, of this substance. One of the simplest green plants known is *Protococcus*; it may be obtained from the mud which accumulates in roof-gutters and water-butts. Very often the water in these cisterns looks green or reddish from the millions of Protococci it contains.

Examined under the microscope, it is found that a Protococcus consists of protoplasm bounded by a transparent membrane, the cell-wall. The protoplasm is granular, and shows a denser portion, called the nucleus, within which is a nucleolus. Confined to certain parts of the protoplasm, not evenly distributed through it, is a colouring matter called *chlorophyll* (Gk. *chloros* = green ; *phyllon* = a leaf), because it is most abundant in leaves. Some Protococci are found without cell-walls ; the cell-wall is, therefore, not an essential part of their structure.

Protococcus is described as a unicellular organism, for it consists of a single cell or mass of living protoplasm. It takes in food from the water in which it lives, digests it, builds it up into its own substance, protoplasm. It breathes, that is, it takes in oxygen and gets rid of carbon dioxide. It grows and reproduces itself by splitting into two, thus giving rise to separate organisms. Since Protococcus consists only of protoplasm, these properties characteristic of life must be the properties of protoplasm.

It is very difficult to say exactly what protoplasm is ; it is impossible to ascertain its exact chemical composition, for when chemists apply different reagents to it the living protoplasm is killed, so that although they can to some extent find out the composition of dead protoplasm, that of living protoplasm is still unknown. We do, however, know that it consists of certain elements—carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, and some mineral salts, and we shall see (Chapter XVIII.) that these substances must enter into the food of plants in order that they may be able to build up their protoplasm.

We may now define a cell as a mass of living protoplasm, containing a nucleus which is the most important part of the cell. It must be remembered that a cell is a solid structure having length, breadth, and thickness ; it is often very minute, not $\frac{1}{1000}$ of an inch in diameter. Many of the lowest plants are made up of a number of cells, similar to each other, and each resembling in its chief features a Protococcus cell, each therefore capable of performing, independently of each other, the functions necessary to life. Such an organism is described as multicellular.

Differentiation. As plants develop they become gradually differentiated into : (1) A root portion, and (2) a shoot portion, each having its special work. The highest plants of all still show these two portions, but with far more differentiation. The root and the shoot each consists of its various members; a root has lateral branches, a shoot, stem and leaves, and each member is composed of thousands of cells arranged in groups known as tissues; thus in the Flowering Plant there is the wood, a tissue not existing in such a lowly organised plant as the Moss. This process of differentiation, by which groups of cells become set apart for a particular work, is the feature that marks off a higher from a lower plant; the higher the plant the more marked is its differentiation. This is most strikingly seen in reproduction. In Protococcus, the whole unicellular plant divides, giving rise to two (or more) organisms. In the Flowering Plant, a particular shoot is modified for the production of the seed.

The important point to emphasise here is, that every plant, however highly organised, and every part (member) of a plant consists of cells.

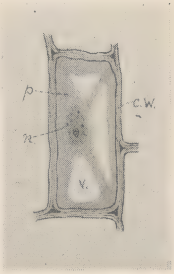


FIG. 136.—A TYPICAL VEGETABLE CELL. *p*, protoplasm; *c.w*, cell-wall; *v*, vacuole; *n*, nucleus, showing nucleolus.

Fig. 136 shows a typical vegetable cell, such as may be obtained from the pith of Elder in early spring. It consists of protoplasm with nucleus and nucleolus, of a cell-wall, and as it is a young cell the protoplasm, which is saturated with cell-sap, fills, or almost fills, the whole cell. As the cell grows older the cell-wall grows more rapidly than the protoplasm can be built up, so that the protoplasm comes to form merely a lining to the cell-wall. The space thus formed within the cell is the vacuole, and is completely filled with cell-sap.

In the following chapters, the processes that go on in the plant as a whole are described as far as possible experimentally, and without reference to the minute structures of the tissues which cannot be satisfactorily studied without the constant use of a microscope; but it has been necessary in this introductory chapter to Plant Physiology to try and give some idea of the structure of a cell, and of what protoplasm is; for the plant, as we have seen, is built up of cells, and without protoplasm the functions of breathing, digestion, assimilation, etc., which will be discussed in the following chapters, would be impossible.

CHAPTER XVII

THE PASSAGE OF WATER THROUGH THE PLANT

Necessity of Water. WATER is essential to the life of every organism, whether plant or animal; it enters into the composition of the protoplasm and cell-wall, and therefore must form part of the food of the plant; no vital process can go on without it, growth cannot take place without it, and in very many cases it is essential to reproduction. In certain Flowering Plants, pollen grains are conveyed by water, and in many cases it is an agent for the dispersion of seeds.

It is a matter of common observation that plants will die without water. In this chapter we will consider how water is taken in by the plant, and its passage through the plant, leaving its connection with respiration and other vital processes until later.

Experiment I. Take a seedling and fit it into a hole in the cork of a glass bottle containing water, in such a way that the roots dip into the water. Mark the level of the water in the flask.

Result. After some time the level of the water falls.

Conclusion. The plant is taking in water through its roots.

The question then arises, How is it that water can pass into the roots? We have already noticed (Chapter II.) that root-tips are covered with root-hairs; it is these that drink in the water and pass it on to the cells of the root. The root-hair of a flowering plant usually consists of a cell with a cell-wall, so that the question now narrows itself to this: How can water pass through the cell-wall? The following experiment illustrates the nature of the process:

Experiment II. Take a thistle funnel and tie tightly over the end of it a piece of pig's bladder, and partly fill with sugar solution. Immerse the end covered with the bladder in water.

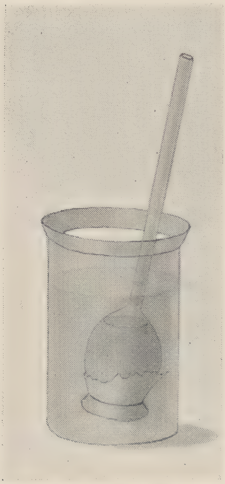


Fig. 137.—Thistle Funnel with Bladder.

Result. The level of the water in the funnel gradually rises.

Conclusion. The sugar solution in the funnel attracts the water from without through the bladder.

This experiment illustrates the way in which water passes through the cell-walls of the plant. The acid cell-sap in the cell of the root-hair may be compared with the contents of the funnel, the sugar solution; the cell-wall with the bladder; the water in the soil with the water outside the funnel. The water is absorbed from the soil by the cells of the root-hair, and is handed on in the same way to the branches of the root, and thence to the main root. (See Fig. 13.)

The next two experiments illustrate the passage of water from the roots to the leaves.

Experiment A. Take a flowering shoot of Narcissus, and immerse the cut end for some time in water coloured with red ink.

Result. The veins on the petals and leaves become red, and cutting the stem across it will be seen that the threads of the stem are also coloured.

Conclusion. The water has passed up through certain threads or strands, which form part of the wood of the plant, to the petals and leaves.

Experiment B. Take a Laurel shoot and cut off the outer tissue until the wood is exposed; immerse the cut end of the shoot in a vessel of red ink.

Result. The shoot remains fresh and the exposed wood is coloured red.

Conclusion. The stripping off of the bark has not interrupted the passage of water through the plant, and as the wood is coloured red, it is clear that the water travels through the wood. Further, if the stem of the shoot is cut right across, it will be seen that the pith is not coloured. This shows that water travels through the wood alone and not through any other part of the stem.

So far, then, we have seen that the water is taken in by the root-hairs; owing chiefly to the physical process of diffusion, it travels from cell to cell through the wood of the stem of the plant, then through the leaf-stalk into the veins of the leaves.

The next series of experiments relate to the giving out of water by the leaves, a process known as Transpiration, which may be compared with the perspiration of animals.

Experiment I. Take some leaves of a shoot, the younger the better, and pass the leaf-stalks through holes in a piece of cardboard which rests on the top of a vessel containing water so that the leaf-stalks are in the water and the blades of the leaves resting on the cardboard. Cover over with a bell jar.

Result. Soon the sides of the jar become covered with drops of water.

Conclusion. Leaves give off water.

In order to see which side of the leaf gives off most water the test of cobalt paper may be applied.

Experiment II. Take a dry duster, which should first be warmed so that it may be thoroughly dry. Lay it out flat, and on it place two ivy leaves, one with the under side uppermost, the other with the upper surface exposed. On these place cobalt paper, which, it is well known, changes from blue to red if exposed to damp. Cover with a sheet of glass.*

* This is Darwin and Acton's modification of Stahl's Cobalt Method. See 'Physiology of Plants,' p. 105.

Result. The cobalt paper over the leaf with the under side uppermost turns red rapidly; that over the upper leaf remains blue, or, at any rate, turns red far more slowly.

Conclusion. More water is given off from the lower than from the upper surface of the leaf.

To see if there is any difference in structure in the two surfaces of the leaf, strip off the skin from the upper and lower surfaces and examine under a microscope. Little openings are found in the skin of the lower surface which are absent from the upper (*cf.* Figs. 138, 139). These openings or mouths are called stomata (Gk. *stoma* = a mouth).

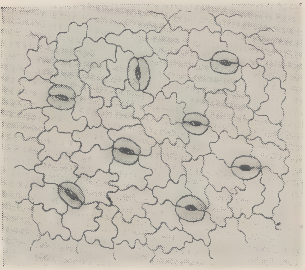


Fig. 138.—Lower Epidermis with Stomata.

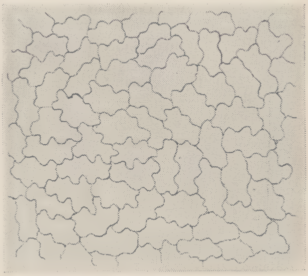


Fig. 139.—Upper Epidermis without Stomata.

We may therefore conclude that the water passes off from the leaf by these stomata. Some leaves have the stomata scattered equally over both surfaces, but those which have the stomata only on the lower surface will give off water chiefly from the under side. This giving out of water hardly occurs in water plants; it is owing to the fact that land plants are in contact with an atmosphere that water is constantly passing from them, not only from the leaves, but also from the surface of the stem, which is also provided with stomata.

The amount of water given off varies with the conditions of the atmosphere, just as the perspiration of animals does. When it is dry and hot more water is given off than when the temperature is low and the air moist. When the plant is giving off a great deal of water the stomata are more widely open than when little is being given off.

By means of the next experiment some idea of the rate at which water travels through the plant is obtained.

FIG. 140.—APPARATUS SHOWING RATE OF ABSORPTION OF WATER.

Experiment. Take a glass vessel with rubber stopper with two holes; into one fix a laurel shoot, into the other a bent tube with a graduated scale attached. Fill the vessel and bent tube quite full with water.

Result. It will be found that the water moves along the bent tube.

Conclusion. Water is being gradually absorbed by the shoot. Now, if the amount of water between two successive graduations in the scale is known, the rate of absorption may be calculated. Thus, if the amount of water between two graduations is $\frac{1}{14}$ cubic centimetre, and if the water in the bent tube passes through six graduations in one hour, it is clear that $\frac{6}{14}$ cubic centimetre of water have been absorbed by the plant in the given time.

The rate of absorption, as said above, varies.

Absorption of Water from Atmosphere. Lastly, it must be noted that, although plants do for the most part take in water through the soil, there are certain plants, especially in dry countries, where there may not be even a slight shower for months, which take in water from the atmosphere. This is the case in plants with aerial roots (Chapter II.).

CHAPTER XVIII

RELATION OF THE PLANT TO THE SOIL

In estimating the relation of the plant to the soil the following experiments may be performed:

Experiment I. Weigh ten cress seeds. Compare with their weight that of ten seedlings which have been grown from similar seeds in moist earth for a week.

Result. The seedlings weigh more than the seeds.

Conclusion. The increase in weight may be due to the fact that the seedling has obtained something from the soil, or from the air, or from both the soil and the air.

The next experiment is more difficult, and involves the use of a good balance and a water-bath. It is inserted here, for if even the experiment cannot be repeated owing to the want of apparatus, it serves at any rate to show that plants grown in the light are heavier than those grown in the dark, other conditions being equal, and that therefore plants do get food from the air.

Experiment II. Weigh two quantities of mustard seed, say 10 grammes. Let one set grow in moist air *in the dark*, the other set in exactly similar conditions, but *in the light*. After these have been growing for a week compare their growths.

Those grown in the dark will be longer than those grown in the light, but more straggling, less healthy-looking. Now dry both sets in a water-bath, and after that weigh.

Result. It will be found that those grown in the dark weigh less than those grown in the light.

Conclusion. Plants grown in the light take in something from the air which plants grown in the dark do not take in.

In the next chapter, when the relation of the plant to the air will be discussed, it will be shown that this substance is carbon dioxide. The important point *now* is, that plants grown in the light do get food from the air.

Experiment III. Plant ten cress seeds, the weight of which has been ascertained, in moist earth, and keep them in the dark for a week. Then weigh the seedlings.

Result. The seedlings are heavier than the seeds.

Conclusion. The seedlings must have taken up something from the soil.

We have already seen in the preceding chapter that plants do take in water through their root-hairs. Water is not the

Fig. 141.—Seedling in Water Culture Solution.

Fig. 142.—Seedling in Distilled Water.

only substance the plant gets from the soil. To prove this experimentally plants have been grown in solutions containing those substances which enter into the composition of the plant. The solution which is generally used is the one recommended by the German botanist Sachs, see Appendix A. It will be referred to in future as the 'Water Culture Solution.'

Experiment IV. Take two healthy seedlings (Wallflower is convenient), keep one with its roots in distilled water, the other with its roots in water culture solution.

Result. The first does not thrive, and after a time dies; the second flourishes. (Compare Figs. 141, 142.)

Conclusion. A plant requires something besides water on which to live, and as the water culture solution contains those substances present in most soils, it is clear that the plant gets from the soil not only water, but lime, potash, etc. It is true that plants often grow when seeds are supplied only with tap-water, as those of the bean or pea. The reason is that these seeds contain a great deal of food in their cotyledons, and tap-water is not pure water.

The substances that are necessary for the life of all plants are: Nitrogen, sulphur, phosphorus, chlorine, potassium, calcium, magnesium, iron. And that this is the case may be proved experimentally by growing plants in water culture solution, from which one or other of these substances has been omitted. It will be found, if any one is omitted, that the plant does not thrive, and may even die.

Experiment V. Take two plants with uninjured roots, and place one in water in which there has been put a few drops of eosin; place the other plant in water containing powdered carmine.

Result. The eosin which dissolves is taken in, and if the stem of the plant is cut across, the wood will be seen to be coloured. The carmine is not dissolved, is not taken into the plant, and the wood is not coloured.

Conclusion. Plants can absorb only those substances which are in solution.

We may now sum up the chief facts with regard to the food obtained by the plant from the soil. The first necessity is water, for no solid can be taken in as solid, it must be in solution in order to be absorbed, and able to pass through the cells of the plant. Further, water is an essential constituent of the protoplasm and cell-wall.

The experiments in water culture show that certain substances, enumerated above, are necessary for the life of the plant; if any are omitted the plant will not thrive. Without iron, for instance, the plant will not be green. Many plants, however, require other substances, for instance, silica, which forms a very large part of the composition of wheat This is the reason that farmers plant a succession of crops in the same field. In Norfolk, turnips are followed by barley, barley by clover, and that by wheat. Clover requires a great deal of potash, wheat very little, so that when clover has exhausted the soil of potash, it is only wise to put in a plant like wheat, which does not require much. Clover, again, requires a great deal of lime, wheat hardly any. Farmers who wish to get as much as possible out of their land get chemists to analyse the plant they wish to grow, and also the soil of the field in which they propose to grow it, and if the soil is found to be deficient in any substance necessary for that particular plant, they get manure which is specially made to supply the deficiencies of the soil, and to provide the plant with the food it requires. During the last twenty or thirty years, land in Barbados has been made to yield crops of sugar cane nearly half as large again as it used to do before chemical manure was applied to it.

Absorption of Nitrogen. Nitrogen is taken in from the soil in the form of nitrates (compounds of nitrogen), and all higher plants must take in nitrogen in this way, for they cannot absorb the free nitrogen of the atmosphere. Leguminous plants, however, appear to get their nitrogen indirectly from the free nitrogen of the air. The facts in support of this statement are: (1) These plants will flourish in soil from which all traces of nitrogenous compounds have been removed; (2) it is found that soil in which leguminous plants have been grown is richer in nitrates at the end of a crop than it was before. It follows, therefore, that somehow or other these plants must get free nitrogen from the atmosphere—how is not yet positively known.

These plants have little swellings on the roots, which are produced by a fungus. This fungus, it is believed, can make use of the free nitrogen of the atmosphere, building up some compound of nitrogen which it hands on to the plant.

The important thing to notice is, that the plant gets the nitrogen from the atmosphere indirectly through another organism, and through its roots, not its leaves.

CHAPTER XIX

THE RELATION OF THE PLANT TO THE AIR

Air is a mixture of certain gases, chiefly nitrogen (and argon) and oxygen, with small quantities of carbon dioxide and a varying amount of water-vapour. The relation of plants to the air is threefold :

1. They take in oxygen and give out carbon dioxide. This is respiration.

2. They take in carbon dioxide and give out oxygen in connection with the manufacture of food. This is assimilation.

3. They give out water-vapour. This has already been discussed under transpiration.

Experiments show that a plant is not capable of using the free nitrogen of the air except indirectly, therefore that constituent may be disregarded.

Respiration. During this process, oxygen is taken in and carbon dioxide given out. The tests that may be applied to detect the absence of oxygen and the presence of carbon dioxide are the following: A taper will not burn in air from which the oxygen has been exhausted, and lime-water is turned milky by the presence of carbon dioxide. These tests will be applied in the experiments on respiration of plants.

Experiment I. Take an empty jar (*i.e.*, one containing only air), which we will call I., and another jar II., in which germinating seeds have been kept tightly corked for twenty-four hours. Plunge a lighted taper into each.

Result. The taper burns in I., and will not burn in II.

Conclusion. Oxygen is present in I., but little or no oxygen in II., therefore the germinating seeds have used up the oxygen in II.

Experiment II. Take an empty jar I., and another jar II., in which germinating seeds have been kept tightly corked for twenty-four hours. Pour lime-water into each jar and shake up.

Result. The lime-water does not change in I., but becomes milky in II.

Conclusion. There is little or no carbon dioxide in I. and enough in II. to be tested, therefore carbon dioxide has been given out by the germinating seeds.

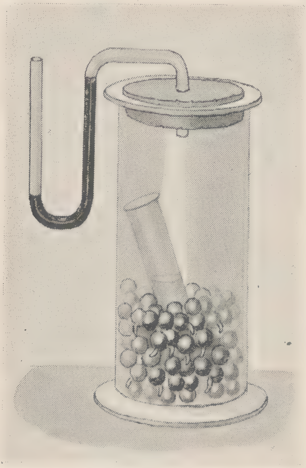


FIG. 143.—APPARATUS TO SHOW THAT PLANTS TAKE IN OXYGEN.

Experiment III. Put some germinating seeds into a jar, and also a test-tube containing caustic potash. Cork the jar with an india-rubber cork, into which has been fitted a bent tube with coloured liquid.

Result. The volume of air in the jar gets less, and the liquid gradually rises along the bent arm of the tube.

Conclusion. As caustic potash is known to absorb carbon dioxide, the volume of air in the jar is being diminished by the amount of oxygen taken in by the seeds, and the liquid rises in the bent tube to replace the oxygen.

This experiment is more satisfactory than Experiment I., for in this case the carbon dioxide being absorbed by the caustic potash, the only change going on in the air of the jar is the withdrawal of oxygen. These experiments show clearly that plants take in oxygen from the air and give out carbon dioxide.

Experiment IV. Take some germinating barley seeds and also some barley seeds which have been killed by boiling. Place them respectively in two vessels surrounding two thermometers. The vessels must stand in a dish containing caustic potash, so that the carbon dioxide given out by the germinating seeds may be absorbed. Cover with a bell-jar. (See Fig. 144.)

Result. The thermometer in the vessel with the germinating seeds is 2° above that in the other vessel.

Conclusion. Heat is given out in breathing.

Experiment V. Take some germinating seeds which have been kept in bottles *in the dark* for a day, and repeat Experiments I. and II.

Result. The same as before.

Conclusion. Respiration goes on in the dark.

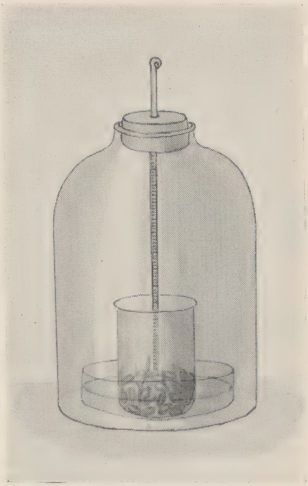


Fig. 144.—Apparatus to show that Plants give out Heat in Respiration.

The above experiments show that during respiration, plants are taking in oxygen and giving out carbon dioxide; that respiration therefore cannot take place to any great extent without oxygen; that during respiration heat is produced, and that it goes on in the dark as well as in the light.

We have already seen that a plant consists of cells, and that each cell consists of protoplasm. We must now picture all the cells of a plant breathing, and during this process taking in oxygen, which is necessary for them if they are to keep well and able to do their work, and at the same time giving out carbon dioxide, produced by the decomposition of the cell protoplasm. The respiration of plants, therefore, is similar to that of animals. If animals are shut up with an insufficient supply of air, after a time they cease to breathe, and die, as in the Black Hole of Calcutta, owing to the absence of oxygen.

The next experiment shows that carbon dioxide is given out by animals in breathing.

Experiment VI. Take a vessel with lime-water and breathe into it for some minutes.

Result. The lime-water turns milky.

Conclusion. Carbon dioxide has been given out in breathing.

Assimilation. As breathing involves the breaking down of protoplasm, there must be a building up of fresh protoplasm by the plant to repair the waste. The first step in this process is assimilation.

Green plants obtain carbon dioxide from the air. It is not easy to show this directly, because carbon dioxide is constantly being given out in respiration. It can, however, be shown experimentally that under certain conditions green plants make starch out of carbon dioxide taken from the air, and water obtained from the soil. It is therefore assumed in the following experiments that the presence of starch shows that the plant has been taking in carbon dioxide from the air. The test for starch is iodine, which turns it blue.

FIG. 145.—APPARATUS TO SHOW THAT PLANTS WILL NOT MAKE STARCH WHEN DEPRIVED OF CARBON DIOXIDE.

Experiment A. Take two pots of Clover, A and B. Cover each with a bell-jar. A has a U-tube containing caustic potash passing through the stopper of the bell-jar. Caustic potash absorbs carbon dioxide, so that the air which reaches the Clover is freed of carbon dioxide. Pot B has attached to it a U-tube open to the air.

Expose both pots to the sun for some time—an hour or two. Take a leaf off each. Boil the leaf in water for a minute, then put into alcohol in order to get out the green colouring matter of the leaf. Lastly, put the leaves into iodine.

Result. The leaf from A does not turn dark-blue, that from B does. Starch is therefore present in A, but not in B.

Conclusion. Leaves exposed to air containing carbon dioxide form starch, whilst leaves exposed to air freed of carbon dioxide do not form starch. Evidently, carbon dioxide is necessary for the production of starch.

Experiment B. Cover some of the leaflets of Clover with tinfoil on both sides, and expose the plant to the sun. Cut off leaves, boil, decolourise, and test with iodine as above.

Result. The leaflets which have been covered over, so that the sunlight could not reach them, do not form starch. The others do.

Conclusion. Plants take in carbon dioxide only in the presence of sunlight.

Young Tropæolum plants also give good results, and this experiment may be varied by cutting the tinfoil in patterns and covering only part of the leaf. The part of the leaf that is exposed makes starch, and therefore turns blue when the iodine test is applied; the covered part of the leaf does not make starch, and therefore does not turn blue.

Experiment C. Take a variegated leaf, keep in the dark for some time in order that there may be no starch in the leaf to begin with;* then expose to the light, and after some time test for starch as above.

Result. Only the green portions of the leaf turn blue with iodine—that is, starch is formed only in the green parts of the leaf.

Conclusion. Carbon dioxide can be taken in only by the green parts of a plant.

Experiment D. Take a leaf with stomata on one side only; smear this side with vaseline, expose the leaf

* It is always better in experiments on assimilation to keep the plant in the dark for some little time to secure there being no starch.

to the influence of sunlight for some hours, and then apply the iodine test as above.

Result. No starch detected.

Conclusion. Starch is only formed when the stomata are open.

Experiment E. Place a shoot of watercress in a beaker of water; cover it with an inverted funnel over the end of which is a test-tube filled with water. Place in sunlight.

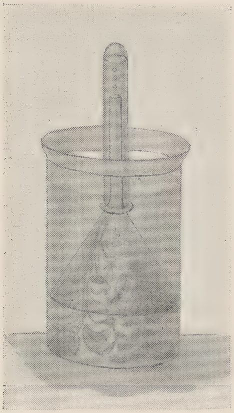


Fig. 146.—Apparatus to show that Green Plants give out Oxygen when making Starch.

Result. Bubbles of gas are given off from the watercress and pass up the test-tube, where they may be collected. If tested, the gas is found to be oxygen.

Conclusion. Oxygen is given off by green leaves in sunlight—that is to say, under the same conditions necessary for the taking in of carbon dioxide by the plant.

We may now assert that starch is formed by the green parts of leaves, which take in carbon dioxide from the air, but only in the presence of sunlight, and if the stomata of the leaf are open.

Starch, chemists tell us, is built up from carbon and water; the green part of the leaf has the power of separating the carbon from the carbon dioxide and keeping it for the purpose of making starch, the oxygen of the carbon dioxide being at the same time given back to the air. The water necessary for the making of starch is absorbed by the roots, passes through the plant (Chapter XVII.) to the leaves; thus with carbon and water the leaf makes starch.

Plants in using up carbon dioxide help to keep the air pure; this is the reason that it is good to have them in the room during the day, but it is unhealthy to have them in a bedroom at night; for then, sunlight being absent, they are not using carbon dioxide at all.

When the starch is made in the leaf it is changed into sugar, and in this form is distributed through the plant, passing especially to the seeds and tubers, where it is reconverted into starch and stored up. It must be remembered that although seeds, bulbs, and tubers contain plenty of starch, they do not make it in the first instance: they are the chief storehouses of the plant. Thus, if the leaves of Snowdrops are cut off as soon as the plant has flowered, the next year's corm is not formed, owing to its not having received food through the leaves.

The making of starch from carbon dioxide and water is commonly spoken of as assimilation, but this is only one of many instances of the building up of substances that is constantly going on in the plant.

COMPARISON OF THE PROCESSES OF RESPIRATION AND ASSIMILATION.

RESPIRATION.	ASSIMILATION.
1. Carbon dioxide given off.	1. Carbon dioxide taken in.
2. Oxygen taken in.	2. Oxygen given out.
3. Goes on in all parts of the plant, and at all times.	3. Goes on in green parts of the plant, and only in sunlight.
4. A process common to plants and animals alike.	4. Takes place in plants alone, and only under certain conditions.

CHAPTER XX

GROWTH

We have seen in the previous chapters that a plant breathes and takes in food material, including water, from the air and the soil. Out of the food material thus taken in, the plant builds up its own protoplasm, which is present in every living cell. There is thus constant chemical change taking place in a plant. Unfortunately it is impossible in this book to give the experiments by which this may be demonstrated, as they are very complicated, and need much apparatus; but from what has already been said it will be clear that the chemical processes going on in a plant may be grouped under two heads:

1. There is the building up of complex substances from simpler ones.

2. The breaking down of complex substances into simpler ones.

The making of starch, the building up of the cell-wall and of protoplasm—the most complex substance in the plant—are instances of the building up of complex substances common to all green plants. To these may be added the building up of special substances by certain plants, *e.g.*, asparagin by Asparagus, olive-oil by the Olive plant; resin, gum, etc.

The breaking up of protoplasm which is going on in living cells, and the consequent giving off of carbon dioxide, which is given out in respiration, is the most conspicuous instance of the second group.

When the building up of substances exceeds the breaking down, or, in other words, when the income of a plant—that is, the food taken in—is greater than its expenditure, then growth takes place.

The following experiments illustrate the conditions under which growth takes place:

Experiment I. Take some seeds, soak in cold water, and plant either in sawdust or cocoanut fibre. Leave for a few days.

Put some other seeds in boiling water and treat as above.

Result. After a few days the seeds soaked in cold water will be found germinating. Those put first in boiling water will show no signs of germination or of life; they are, in fact, dead, having been killed by the boiling water.

Conclusion. Growth is possible only when the plant is living.

Experiment II. Take two seedlings. Water one (A) carefully every day, but do not water the other (B).

Result. A grows, B does not.

Conclusion. Water is necessary for growth.

Experiment III. Take two growing beans, suspend from corks of two jars (Fig. 12). Put a little water at the bottom of one jar (A), so that the roots are in moist air, whilst in jar B the water covers the cotyledons.

Result. The plant in jar A grows much faster than that in jar B.

Conclusion. Plants grow best when exposed to free oxygen. This experiment also shows the necessity of a certain amount of water for a plant, and the disadvantage of overwatering; it explains, too, why draining is necessary.

Experiment IV. Take two air-tight jars, to the cork of each of which a moist sponge on which cress seeds have been sown is fastened.

In the bottom of one jar there should be a little water, in the other pyrogallic acid, which takes the oxygen out of the air.

Result. The seeds will not grow in the jar with pyrogallic acid.

Conclusion. As pyrogallic acid has taken the oxygen out of the air in the jar, it is clear that oxygen is necessary to growth.

Growth cannot take place without food; this has already been shown in the water-culture experiments (Chapter XVIII.). Seeds, bulbs, tubers, are able to grow at the expense of the reserve material stored up in them, but when this is exhausted plants must have food material supplied to them, and must be in contact with the air; so that they can get not only the oxygen, but also the carbon dioxide, which they require for the formation of starch.

Plants which live either on decaying material, or on living organisms, obtain their food from the substance or organism on which they are living.

To sum up, the conditions of growth are: (1) The plant must be living; (2) the plant must have water; (3) the plant must have free oxygen; (4) the plant must have food, both from the air and soil.

The rate of growth should be measured day by day. This may be done in the case of the root by marking, with a camel's-hair brush and Indian ink, the tip in millimetres (Fig. 12), and measuring exactly the additions of every twenty-four hours. In the same way the growing point of a stem may be marked and measured.

The next series of experiments illustrates the effect of external conditions on plant-life.

Experiment A. Plant seeds in moist earth, grow some in the dark, others in the light, and note the difference. They must be kept watered. At the end of a month they may be compared.

Or, instead of seeds, it is interesting to compare two Hyacinth bulbs of identical species. They should be put in hyacinth glasses filled with water, so that the bottom of the bulb is just above the water, towards the end of October or the beginning of November; both should be left for about six weeks in the dark until the roots are fully formed. Then one may be kept in a dark cupboard, the other, if possible, in the same room in a window. Care must be taken that there is always water in the hyacinth glass; but as the bulbs contain food material, it is not necessary to supply them with food. Some time in February the Hyacinths will probably flower, and then they may be compared. It will be found that the one grown in the dark has a longer and more straggling stem than the one grown in the light. The leaves are yellow, not green, for, owing to the absence of light, the dark green colouring matter has not been formed. The one grown in light has dark blue flowers, and the other a very pale bluish flower, almost colourless.

Sometimes Hyacinths which have been grown in the way just described do not give the expected results, and then it will be found that the other conditions have not been similar. Perhaps the one in the window has been exposed to a different temperature than the one in the cupboard, or the latter may not have had as much free oxygen as the former. It is very important in comparing the effect of light and darkness on growth to try and secure that the other conditions be exactly similar. A good way of securing this is to take a growing plant, such as a Vegetable Marrow or Potato, and to introduce the growing point of the stem into a cardboard

Fig. 147.—Seedling of Pea grown in Light.

Fig. 148.—Seedling of Pea grown in Dark.

box, and then after some days to compare the stem and leaves of that part of the plant grown in the box with the growth of the part outside. It will be found in all cases that light (*a*) retards growth in length of stem; (*b*) makes the leaves

FIG. 149.—MIMOSA LEAF (DAY POSITION).

FIG. 150.—MIMOSA LEAF (NIGHT POSITION).

bigger and diverge further from the stem; (*c*) prevents the formation of the dark green colouring matter of leaves.

Experiment B. Grow plants in a window in order to note the effect of the direction of light. Nasturtium, Dead Nettle, Mustard, give good results.

Result. The stems curve towards the light, and the leaves will be found to place themselves at right angles to the direction in which the light is falling.

Conclusion. Leaves place themselves so as to secure as much light as possible.

This principle to some extent explains the arrangement of leaves of a certain shape on a stem. (See Chapter V.) Seedlings may be put to grow under double wall bell-jars, one of which may contain a solution of potassium bichromate (yellow), the other a solution of copper sulphate (blue). The difference in the two should be carefully noticed.

Experiment C. Cover up a plant of Wood Sorrel (Oxalis) under a bell-jar.

Result. During the day the three leaflets are spread out; as evening approaches they close up.

Conclusion. Some plants are affected by alternation of day and night. These sleep movements, as they are called, are very well seen in Mimosa (Sensitive plant). It is most fascinating to watch the Mimosa bushes in a garden hedge closing up as evening approaches, as can be done in the tropics, where Mimosa is a common outdoor plant. During the day the delicate leaves spread out; at sunset they fold up, so that not a blade is visible.

Experiment D. Attach a young Bean seedling to the cork of a bottle with water in the bottom, in such a way that the radicle points upwards.

Result. The radicle will curve round so as to grow towards the centre of the earth.

Conclusion. The radicle is affected by gravity in such a way that the tip grows towards the centre of the earth.

It would be interesting to know *why* the radicle should be affected by gravity when the lateral branches of the root are not. At present it is only possible to state the facts.

Experiment E. Grow seedlings of Mustard in a sieve containing damp sawdust.

Result. The roots will grow downwards vertically in the sawdust, then when they make their way through the holes of the sieve, they will cease to grow vertically, but will curve towards the sieve.

Conclusion. Moisture attracts roots more powerfully even than gravity.

Experiments show that growth is most active at a temperature of 37° C., that is to say, the temperature of the human body. Too low a temperature, such as freezing-point, kills; a late spring, as everyone knows, destroys early blossoms.

Too high a temperature, as we have seen in the experiment of boiling seeds, kills and renders growth impossible.

All these experiments show that a plant is affected by external conditions, such as light, temperature, moisture; thus it can adapt itself to varying conditions. A land plant, for instance, does thrive if grown in water, its roots being able to adapt themselves to the different medium. This power of adaptability is characteristic of all living things.

APPENDICES

APPENDIX A

METHOD OF WATER-CULTURE

DARWIN and Acton, in their 'Physiology of Plants' (p. 59), give the following composition of water-culture solution from Sachs:

Potassium nitrate ...	...	...	1·0	gramme.
Sodium chloride ...	...	...	·5	,,
Calcium sulphate ...	...	...	·5	,,
Magnesium sulphate	...	...	·5	,,
Calcium phosphate	...	...	·5	,,
Water	...	..	1,000	c.c.

'One part of the mixture of salts is dissolved in 50 parts of water. For use it is diluted to 2 or 3 per mille. A drop or two of iron chloride must be added.'

They recommend the use of glass cylinders not less than 700 c.c. capacity; also the thorough cleansing of the cylinders first with strong commercial nitric acid, removed by distilled water; then rinsing with a strong aqueous solution of mercuric chloride, and lastly with distilled water which has been boiled for some time immediately before use.

The culture solution should be boiled rapidly for half an hour, the water lost by evaporation being replaced by pure distilled water and transferred to the cylinder as soon as cooled.

The plant may be fixed in the cork in cotton-wool, though Darwin and Acton find soft asbestos better. Air is let into the cylinder through a tube inserted into the cork. If the plants are to keep healthy for weeks, the water-culture solution should be renewed at the end of each week.

All these precautions are necessary to prevent the plants being attacked by fungi.

APPENDIX B

LIST OF APPARATUS REQUIRED FOR EXPERIMENTS GIVEN IN PART III.

HALF A DOZEN glass bottles, 500 c.c.

Half a dozen glass cylinders, 750 c.c.

Funnels, one of which should be a Thistle Funnel.

Two dozen test-tubes.

One dozen india-rubber corks (caoutchouc bungs), some solid, some with one hole, some with two holes.

One dozen ordinary corks.

Glass tubes, U-shape—about two or three.

Half a dozen beakers.

Half a dozen glass rods.

Glass tubing.

A sheet of glass.

Bell-jars—about two or three.

Two double bell-jars.

A water-bath.

Two thermometers.

A balance.

Also lime-water, caustic potash, vaseline, eosin, powdered carmine, cobalt paper, pyrogallic acid, potassium bichromate, copper sulphate.

It is impossible to give an exact estimate of the cost of this apparatus, so much depends on the quality of the glass chosen.

The most expensive pieces of the apparatus are the balance and the double bell-jars, but these are necessary only for two or three of the experiments given. The rest of the apparatus can be procured for about £4, and most of it is also necessary for the study of chemistry.

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PROPOSITION I.—PROBLEM.

General Enunciation. *To describe an equilateral triangle on a given finite straight line.*

Specific Enunciation:

a. What is given. **Let AB be the given finite straight line.**

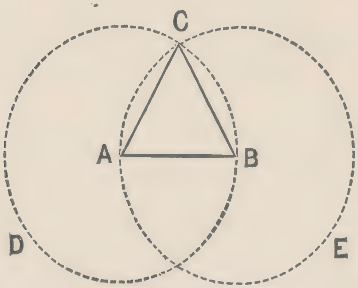
b. What we want to do. **It is required to describe an equilateral triangle on AB.**

How to do it. From the centre A at the distance AB describe a circle BCD. *Post.* 3.

From the centre B at the distance BA describe a circle ACE. *Post.* 3.

From the point C where the circles cut one another, draw straight lines CA, CB to the points A and B. *Post.* 1.

Then ABC *shall be the equilateral triangle required.*



Proof. Because A is the centre of the circle BCD, AC is equal to AB. *Def.* 15.

Because B is the centre of the circle ACE, BC is equal to AB. *Def.* 15.

Therefore AC and BC are each equal to AB.

Therefore AC, BC, and AB are all equal. *Ax.* 1.

Therefore ABC *is the equilateral triangle required.*

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