ELEMENTARY BOTANY

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PREFACE

Although there are many useful text-books of Botany, yet I have found during several years' experience in teaching the subject, that it is difficult to obtain one suitable, at moderate cost, for the middle and lower forms in secondary schools.

I have endeavoured to put the subject-matter of the book in as simple a form as possible.

The book is divided into four parts:

Part I dealing with the seed, germination, and the general morphology of the plant;

Part II with simple structure;

Part III with the physiology of the plant, taken experimentally;

Part IV with classification, and a brief description of some of the more important natural orders.

In Parts I and II, dealing with simple morphology and structure, paragraphs intended for a second year's course are indicated by an asterisk, and for a third year's course by two asterisks.

Many of the diagrams are taken (with the permission of the publishers) from Professor Oliver's *Elementary Botany* and *Systematic Botany*, from Kerner's *Natural History of Plants*, and from other sources; others have been drawn from nature. Some of those on structure are diagrams of observations with the microscope.

In writing this book, I have obtained help from many sources. Some of the chief works consulted are: *A Student's Text-book of Botany*, by Vines; *The Elements of Botany*, by Darwin; *Physiology of Plants*, by Darwin and Acton; *Structural Botany*, by Scott; *Handbook of the British Flora*, by Bentham and Hooker.

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ELEMENTARY BOTANY

PART I
GENERAL MORPHOLOGY

CHAPTER I
SEED AND GERMINATION

Examine a bean seed (fig. 1), after soaking it in water for about twenty-four hours.

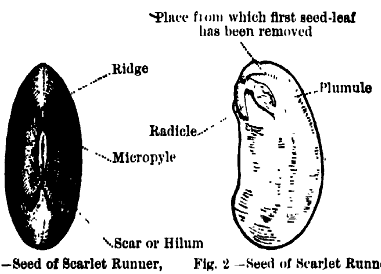


Fig. 1.—Seed of Scarlet Runner, external view

Fig. 2—Seed of Scarlet Runner, one cotyledon removed

It will be found to consist of:—

(1) An outer brown covering called the **testa**; on one side is a scar, called the hilum, where the seed was attached to a stalk, and just beside it a small hole, the **micropyle.**

The testa encloses:—

(2) the **embryo** or young plant. The embryo in this case consists of:—

(*a*) two thick fleshy leaves called **cotyledons** which contain nourishment for the young seedling;

(*b*) a young **radicle**, which forms the first root;

(*c*) the **plumule** or first bud.

Germination.—Allow bean seeds to germinate in damp soil or on cotton-wool (fig. 3). The radicle bursts the testa, grows downwards giving off root branches from its sides; the plumule grows upwards from between the cotyledons, and forms the first stem bearing foliage leaves. The cotyledons remain below the soil, feeding the growing plantlet on the food which they contain, and finally they shrivel up.

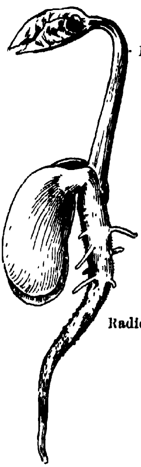


Fig. 3.—Germinating Bean

* **Maize or Indian Corn.**—A grain of Indian corn is not merely a seed, but what is termed a fruit, the outer covering or skin being the testa and the wall of the fruit combined. On examining a grain (fig. 4), a whitish portion is observed near the base.

on one side; this denotes the position of the **embryo,** the remainder of the seed being occupied by a store of food-material called **endosperm.** On cutting a grain through the middle, so as to cut through the

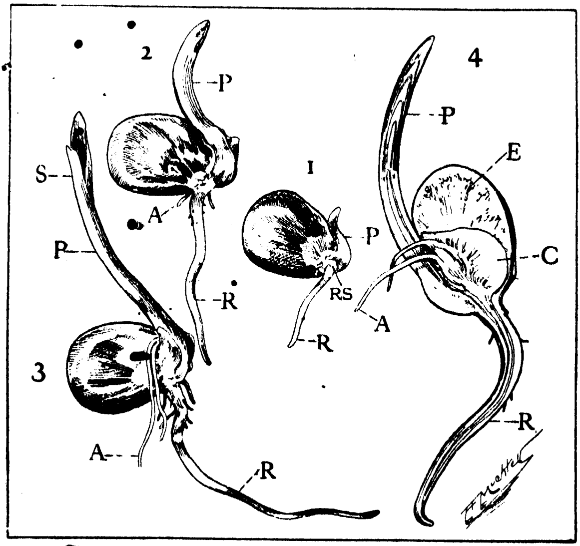


Fig. 4.—Young Plants. 1, 2, 3, Showing the growth; 4, The plant cut through downwards

P, Plumule; R, radicle; A, adventitious roots; C, cotyledon; RS, root-sheath; S, upper part of cotyledon; E, endosperm

embryo, and examining with a lens, the embryo is seen to consist of:—

(*a*) a **radicle** at the lower end:
(*b*) **plumule** at the upper end, surrounded by—
(*c*) **one cotyledon,** which in this case is called the **scutellum.**

* **Germination of Maize.**—In germination the contents of the seed swell, the radicle bursts through the base of the cotyledon and the outer covering of the seed, and grows downwards (fig. 4, 1). Other roots are also produced from the base of the plumule, breaking through the base of the scutellum; these are called **adventitious roots** (fig. 4, 2, 3, 4). The plumule curves upwards, consisting of leaves which sheathe the stem. The lower part of the cotyledon remains inside the seed, absorbing the endosperm, and passing it on to the growing radicle and plumule, but the upper part elongates slightly and sheathes the base of the plumule. The bottom of the cotyledon, ruptured by the radicle, is called the root sheath.

Mustard or Cress.—The seed (figs. 5-9) consists of:—

(1) an outer covering, the testa, enclosing—

(2) the embryo. The embryo consists of:—

(*a*) the radicle,

(*b*) the plumule,

(*c*) two cotyledons, but in this case the cotyledons are not thick and fleshy, and in germination the cotyledons are carried above the ground, covered by the testa. They throw off the testa, expand, turn green, and act as the first foliage leaves, preparing food for the young plant. The plumule appears as a small bud in between the two cotyledons.

Fig. 5.—A Dry Seed of Cress, showing the ridge corresponding to the radicle within

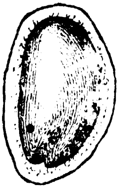


Fig. 6.—A Moistened Seed of Cress surrounded by its swollen, mucilaginous seed-coat

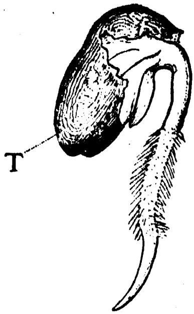


Fig. 7.—A Cress Seedling, showing the radicle, root-hairs, and the seed-leaves, not yet freed from the seed-coat (testa = T)

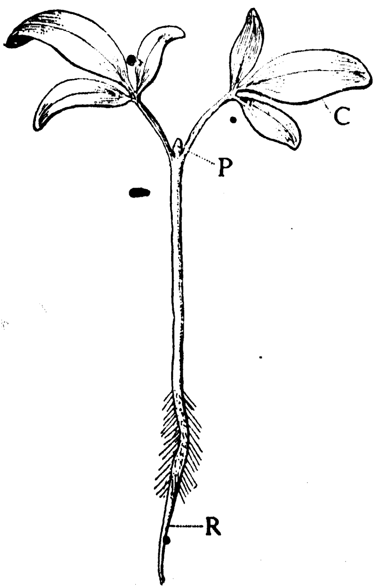


Fig. 9.—A Cress Seedling showing the plumule (P), and with the seed-leaves (C) expanded and ready to work. R = radicle

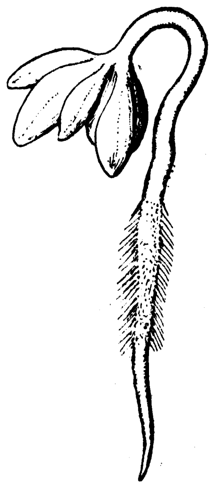


Fig. 8.—A Cress Seedling before the lobes of the seed-leaves are quite expanded

**** Buttercup.**—This seed (fig. 10) differs from the mustard in that it contains, in addition to the embryo, a certain amount of food-material or endosperm.

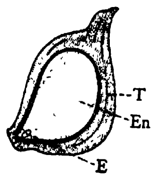


Fig. 10.—Buttercup Fruit
E, Embryo; En, endosperm; T, testa and pericarp

In germination, the cotyledons remain in the seed until the food-material is absorbed; they then come above the ground, turn green, and act as foliage leaves.

** Comparison of the Bean and the Maize.

Bean	Maize
1. A seed.	1. A fruit containing the seed.
2. Outer skin is the testa.	2. Outer covering is the wall of the fruit and the testa combined.
3. Two cotyledons, seed therefore dicotyledonous.	3. One cotyledon, seed therefore monocotyledonous.
4. Food-material stored up in the cotyledons, seed therefore exalbuminous.	4. Food-material stored up outside the cotyledon, seed therefore albuminous.
5. Radicle develops into primary root, bearing root-branches.	5. Radicle does not develop strongly; its place is taken by root-branches and adventitious roots.
6. Cotyledons remain below the ground.	6. Cotyledon remains in the seed.
7. Plumule becomes first stem bearing leaves.	7. Plumule consists of stem and sheathing leaves.

** Comparison of Mustard and Buttercup.

Mustard	Buttercup
1. Seed dicotyledonous and exalbuminous.	1. Seed dicotyledonous and albuminous.
2. Cotyledons come above the ground.	2. Cotyledons absorb the endosperm and then come above the ground.

Conditions necessary for germination.

1. *Warmth.*—If seeds are kept below a certain temperature they will not germinate.

2. *Air.*—Seeds require oxygen for germination, therefore they must have a supply of air.

3. *Moisture.*—Seeds will not germinate if kept dry.

Light is not necessary for germination, as seeds germinate more quickly if kept in the dark, but after germination, for the healthy growth of the plant, light is required.

CHAPTER II

THE ROOT

The root is developed from the radicle of the seed, and always grows downwards.

The uses of the root are:—

1. To fix the plant firmly in the ground.
2. To send out an acid to dissolve certain salts in the soil.
3. To absorb food-material for the plant.
4. Some roots store up food.

The ends of the main root and its branches are provided with numerous delicate hairs, through which the plant sends out an acid to dissolve various salts, and then they are absorbed in solution in water.

In transplanting, these root-hairs are frequently injured, and consequently the plant droops, but fresh ones are formed, and in a few days the plant revives.

The tip of the root is called the **growing point**, and as it has to force its way through the particles

Fig. 11.—Fibrous Roots. 1 Buttercup; 2, Wheat

of soil, it is protected by a **root-cap**. When the radicle develops into a main root the plant is said to have a **tap-root**, but when the radicle remains small, and the secondary roots grow to a greater length, the root is said to be **fibrous** (fig. 11).

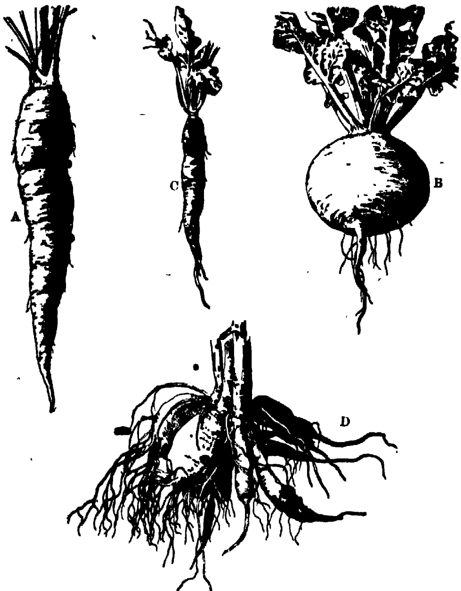


Fig. 12.—Tap-roots

A, Carrot (conical); B, Turnip (napiform); C, Radish (fusiform); D, Dahlia (irregularly swollen)

Fibrous roots therefore consist of numerous slender branches called fibres.

Tap-roots are generally very much swollen, as they frequently contain a store of food-material. They may be—

(a) Conical, as in the carrot (fig. 12, A).

(*b*) Napiform, as in the turnip (fig. 12, B).

(*c*) Fusiform, as in the beetroot, or radish (fig 12, C).

(*d*) Irregularly swollen, as in the Dahlia and Orchid (fig. 12, D).

Plants which have tap-roots generally live for more than one year.

Plants which live for one year are called **annuals** —for instance, Mignonette, which grows from seed. flowers, produces fresh seed during the same season, and then dies.

Biennials, on the other hand, spring from seed, produce leaves the first year, and store up food in the root or underground stem. The second year they produce flowers and seeds. Carrots, turnips, and parsnips are examples of biennials. **Perennials** are plants which live for more than one year. Perennials may flower continually.

* Some plants, such as Dodder and Mistletoe, produce sucking roots, which penetrate the tissues of other plants to obtain their nourishment. These plants are called **parasites**.

* Ivy develops **adventitious** roots on the stem, by means of which it clings to the wall.

* In cuttings, adventitious roots are produced from the cut surface.

CHAPTER III

BUDS

The **plumule** is the first bud of the plant. If the plumule is examined carefully, it will be seen to consist of:—

1. A central portion, the stem.
2. Young leaves inserted on it.

In the bud the leaves are crowded together near the end of the stem, but in growth they are carried apart by the growth of the stem in length.

The place on the stem from which the leaves spring is called a **node**, and the space between two nodes is called an **internode.**

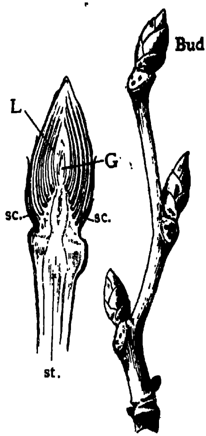


Fig. 18.—Branch of Elm, and section of Bud

G, Growing point; L, leaves; st. stem; sc. outer scale leaves

The bud formed at the end of a stem is called a **terminal** bud, but buds are formed also in the angle between the leaf and the stem, that is in the axil of the leaf, and they are then called **axillary** buds.

Branches therefore should spring from the axil of every leaf, but this is not the case. Many buds remain dormant, and the stronger ones develop, but if the expanding buds are killed, as sometimes happens by late frosts, the dormant buds replace them.

Winter Buds.—Most of our forest trees form buds (fig. 13) during the summer, which remain dormant through the winter, to expand the following spring into branches bearing leaves.

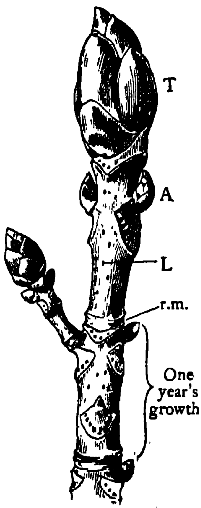


Fig. 14.—Horse Chestnut Branch, showing T, large terminal bud; A, small axillary bud; r m, ring-like markings left by scale leaves; L, lenticel.

Horse-chestnut Buds.—If a Horse-chestnut branch (fig. 14) be examined in the early spring, it will be seen to consist of a stem, with a bud at the apex, and one, two, or more pairs of buds at intervals on the stem. The bud at the apex is the **terminal** bud, and that the others are **axillary** is seen from the horse-shoe-shaped scars just below them. These **scars** are left by the leaves, in the axils of which the buds were formed.

Bud Structure.—In cutting through the terminal bud (fig. 15), in the centre is seen:—

(1) the **short stem** or axis, terminated by—

(2) the **flowers**, surrounded by—

(3) **two or** sometimes only one pair of **green foliage leaves**, covered with downy hairs, and—

(4) numerous green, and on the outside brown **scale leaves.**

The scale leaves are covered with resin to protect the bud from the rain and frost during the winter. On the approach of spring, the scale leaves fall off and leave **ring-like markings.** From one set of markings to the next indicates one year's growth.

The bud expands, the inter nodes lengthen, and the leaves are carried apart, and a branch is formed. All buds do not contain flowers.

If all the buds on a tree developed, a branch would be formed in the axil of every leaf. The position of the leaves, therefore, determines the position of the branches, for if the leaves are opposite the branches will be opposite, if the leaves are alternate the branches will be alternate; but many buds remain undeveloped.

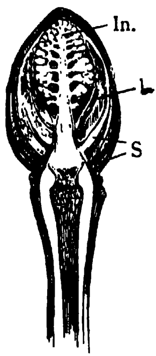


Fig. 15.—Section of Horse-Chestnut Bud

In., Inflorescence; L, foliage leaves; S, scale leaves.

** The buds of the Beech, Ash, and Plane-trees should be examined and compared with the Horse-chestnut bud. In the Plane-tree the bud is protected and completely covered by the hollowed-out base of the petiole.

CHAPTER IV

STEMS

The stem bearing leaves makes its appearance first as a bud.

The uses of the stem are:—

(1) To bear the leaves and flower-stalks, and to hold them in a favourable position.

(2) To act as a passage through which the food materials travel.

(3) Some stems store up food.

Comparison of Roots and Stems.

Roots	Stems
1. Roots grow downwards.	1. Generally grow upwards.
2. Avoid the light.	2. Generally seek the light.
3. Never bear buds.	3. Bear buds.
4. Roots are not, but—	4. Stems are, divided into nodes and internodes.
5. The apex of the root is protected by a root-cap.	5. The apex of the stem is protected by a bud.
6. Root-branches arise differently from stem branches.	

Underground Stems.—Some stems grow underground, but these may be distinguished from roots by the fact that they bear buds and leaves.

The different types of underground stems are:—

(*a*) Bulbs, (*b*) corms, (*c*) tubers, and (*d*) root stocks.

(*a*) **Bulbs** (fig. 16).—The bulb of the **Daffodil** consists of:—

(1) A few brown scaly leaves on the outside, surrounding—

(2) Numerous white fleshy leaves, and in the centre—

(3) A bud, and at the base—

(4) A short flattened stem from which the leaves and flowers spring.

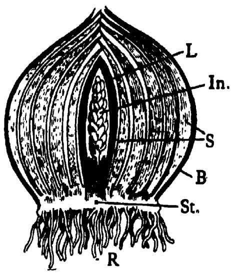


Fig. 16.—Section of Bulb of Hyacinth

L, Foliage leaves; In., inflorescence; S, fleshy scale leaves; B, brown scale leaves; St, stem; R roots.

The bud develops into the foliage leaves and flowers.

(b) **Corms.**—The corm of a crocus (fig. 17 A and B) consists of:—

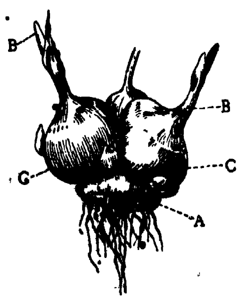


Fig. 17.—Corm of Crocus

A. Old corm; B, Bud on C, New corm.

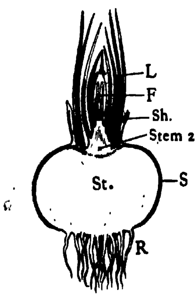


Fig. 17B.—Longitudinal Section of Corm of Crocus

L, Leaves; F, flower; Sh. sheathing leaves; St., stem S, brown scale leaves; R, roots (Stem 2 will become next year's corm.)

(1) A fleshy stem, surrounded by—
(2) A few brown scale leaves, and at the top of the stem—
(3) A bud borne in the axil of scale leaves. The bud consists of (1) one or two flowers in the centre, (2) numerous green foliage leaves, and ( ) a few sheathing leaves. After flowering, a new corm may be seen forming on the top of the old one, at the base of the foliage leaves. The old corm shrivels up. The roots, as in the bulb, are formed from the base of the stem.

Fig. 18.—The Potato Plant, showing tubers

(c) A **tuber** (fig. 18) arises as a swelling on a stem branch which grows underground. The buds are the so-called eyes; under favourable circumstances the eyes grow into stems bearing leaves, and produce new potato plants.

Underground stems contain a store of food material; in the case of the bulb it is stored in

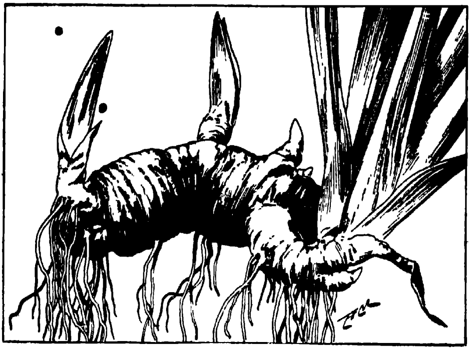


Fig 19.—Root-stock, or Rhizome, of Iris

the fleshy leaves; in the corm and tuber in the fleshy stem. The food material in the potato is largely starch.

(d) A **root-stock** (fig. 19), or rhizome, is a creeping underground stem, which sends roots from its lower surface, and stems and leaves from its upper surface. *Ex.* Iris.

Aerial Stems.—Stems which grow above the ground are called aerial. They may be either—

Fig. 20.—Stem of Ivy, showing rootlets

(1) **upright**, when they need no support;
(2) **climbing**, as in the Ivy (fig. 20);

Fig. 21.—Twining stem of Hop

(3) **twining**, as in the Hop (fig. 21);
(4) **creeping**, as in the Strawberry (fig. 23).

Climbing Plants.—Climbing plants have weak stems. Various means of support are developed on them to enable them to grow upwards into the light and air.

Some of these are:—

1. **Rootlets** (fig. 20), as in Ivy—adventitious roots

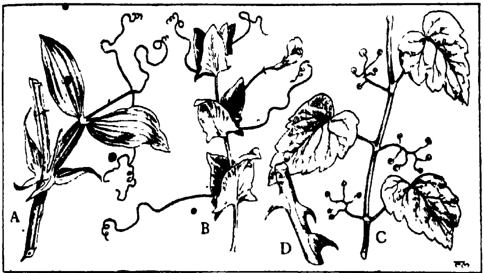


Fig. 22.—

A, Tendrils and stipules of Pea; B, Tendrils and stipules of *Lathyrus Aphaca*; C, Suckers of Creeper; D, Prickles of Rose.

springing from the stem; they cling to the wall or other support.

√2. **Tendrils** (fig. 22)—curling threads which twine round any support.

** Tendrils are sometimes—

(*a*) altered leaflets, as in the pea (fig. 22, A);

(*b*) altered branches, as in the vine;

(*c*) sometimes the petioles twine and act as tendrils, as in Clematis. The nature of tendrils is indicated by their position on the plant;

(*d*) stipules, as in Smilax.

3. **Suckers** (fig. 22, c).—These are little disc-like growths at the end of tendrils, by means of which the plant clings to the wall, as in Virginia Creeper.

4. **Prickles** (fig. 22, D), as in the Blackberry or Rose. These are little outgrowths from the outer skin of the stem.

Creeping Stems.—The Strawberry stem (fig. 23) grows along the ground, and at the nodes sends

Fig. 23.—Strawberry Runner

roots into the soil, and leaves into the air, thus producing a new plant. This stem is called a **runner.**

In the Houseleek the creeping stems are shorter and are called **stolons.**

Spines and Thorns.—Sometimes stems and leaves are modified into thorns, as in Hawthorn and Gorse. The thorns of Hawthorn are altered branches, for they arise in the axils of leaves, and sometimes under cultivation they bear leaves.

Vegetative Reproduction.—By means of underground stems, runners, and stolons, &c., plants are able to reproduce themselves without seeds.

CHAPTER V

LEAVES

A leaf is an outgrowth from the stem. (Fig. 24.)

A leaf consists of:—

(1) The broad expanded part called the **blade** (or lamina).

(2) The **petiole**, or leaf-stalk.

The petiole is not always present. If present, the leaf is petiolate; if absent, sessile.

(3) **Stipules**, little expansions at the base of the petiole. (See fig. 28.)

** Sometimes the stipules become large and leaf-like, and perform the function of the blade, as in some species of Lathyrus. (Fig 22, B.)

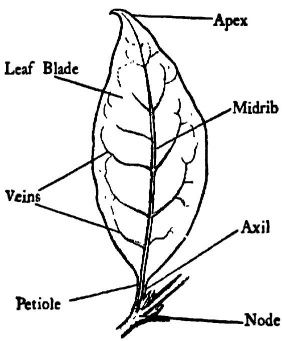


Fig. 24.—Diagram of Simple Leaf (Privet), showing parts

The functions of a typical leaf are:—

(1) Leaves act as the **breathing organs**. They

take in certain gases from the air, and give out gases.

(2) They **manufacture food** for the plant, from the gases taken in by the leaves, and the substances absorbed by the roots from the soil

(3) They **give off the unnecessary water** as vapour into the air.

Venation.—The blade of the leaf is crossed by numerous veins.

(1) Sometimes, as in the Iris, the veins run

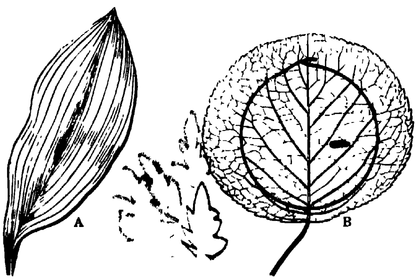


Fig. 25.—A, Parallel-veined Leaf. B, Net-veined Leaf.

throughout the length of the leaf, parallel to each other. (Fig. 25, A.) **Parallel-veined** leaves are characteristic of plants belonging to the class Monocotyledons.

(2) In the Elm or Beech, the veins branch from one principal vein, called the midrib, forming a net-work throughout the blade. (Fig. 25, B.) This arrangement is called **net-veined**, and is characteristic of Dicotyledons

Simple and Compound Leaves.

(*a*) A **simple** leaf has the blade in one piece *Ex.* Violet.

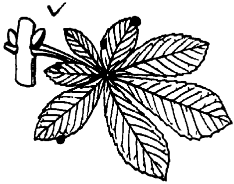


Fig. 26.—Palmate Leaf of Horse-Chestnut

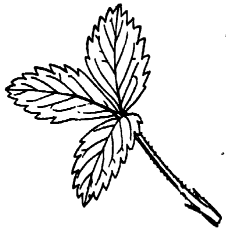


Fig. 27.—Ternate Leaf of Strawberry

(*b*) A **compound** leaf has the blade cut up into a number of leaflets.

Compound leaves are divided into two classes:—

(1) When the leaflets all spring from the same place, when they may be **palmate** or **ternate**.

A **palmate** leaf has five or seven leaflets springing from the same place. (Fig 26.) *Ex.* Horse-chestnut.

A **ternate** leaf has only three leaflets springing from the same place. (Fig. 27.) *Ex.* Clover or Strawberry.

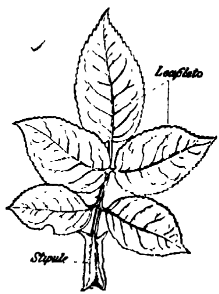


Fig. 28.—Pinnate Leaf of Rose

(2) When the leaflets do not spring from the same place, as in a **pinnate** leaf, which has a midrib and leaflets springing from either side of it. *Ex.* Rose

* The leaflets of a compound leaf can be clearly distinguished from leaves by the fact that buds do not arise in their axils.

* **Shape.**—The blade of the leaf varies very much in shape. Some of the principal forms are:—

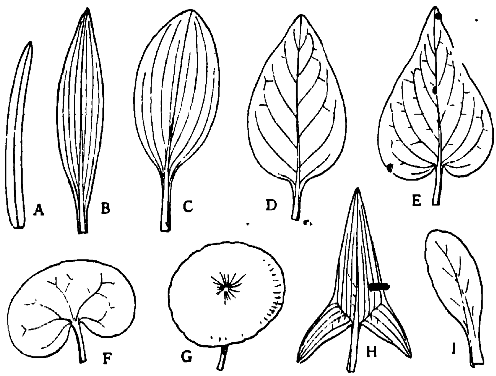


Fig. 29.—Shape of Leaves

A, Linear; B, Lanceolate; C, Oval; D, Ovate; E, Cordate; F, Reniform; G Round, or orbicular; H, Sagittate; I. Spathulate, or spoon-shaped.

* **Margin.**—The margin may be:—

(1) **entire** (fig. 29, A);
(2) **serrate**, like a saw (fig. 27);
(3) **dentate**, with coarse teeth (fig. 30. B);
(4) **crenate**, with rounded teeth;
(5) **ciliate**, hairy margin;
(6) **sinuate**, with a wavy outline (fig. 30, A).

Arrangement of Leaves.—If leaves spring from an underground stem, they are said to be **radical**; if from a stem above ground, **cauline**.

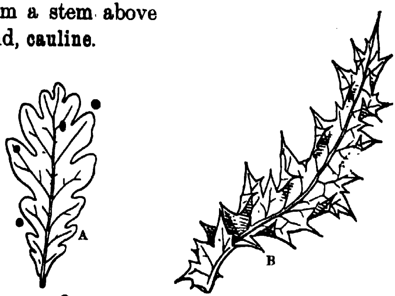


Fig. 30.—A, Sinuate leaf of Oak; B, Dentate leaf of Thistle

Cauline leaves may be:—

(1) **alternate**, when one leaf springs from each node;

Alternate Opposite Whorled

Fig. 31.—Cauline Leaves

(2) **opposite**, when two leaves spring from each node on opposite sides of the stem;

(3) **whorled**, where several leaves spring from a node.

** **Modifications of Leaves.**

(*a*) **Scale leaves** are found on the outside of winter buds, as already described.

(*b*) **Bracts** are leaves, often scaly, found on the flower-stalk. Sometimes they enclose a single flower, as in the Snowdrop; sometimes a number of flowers, as in Garlic.

They may be large and scaly, as in the Daffodil, or leaf-like, as in Dandelion. In the latter case the flowers are surrounded by numerous bracts, forming what is called an **involucre.**

(*c*) **Cotyledons.**—These are seed-leaves, and have already been described in the chapter on Germination.

(*d*) Leaves are variously modified to perform different functions, as:—

(1) **Tendrils**, aids to climbing.

(2) **Carnivorous Organs.**—The leaves of the Sundew and other plants are provided with glandular hairs, which are sensitive to a certain degree. When an insect alights on the leaf, the hairs close over it, and send out a fluid, which digests it.

(3) **Spines**, means of protection.

CHAPTER VI

THE FLOWER

The flower consists of several whorls of leaves. (Fig. 32.) There are generally present four whorls:—

1. The **sepals**, forming the **calyx** of the flower.

These leaves are generally green, and they protect the flower when in bud.

2. The brightly-coloured leaves, the **petals**, form-

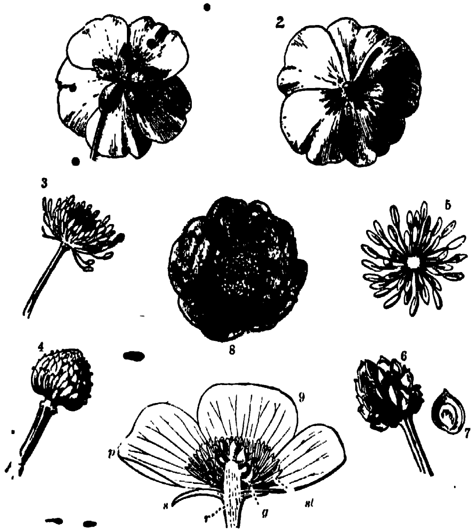


Fig. 32.—1, Buttercup, from behind, showing sepals; 2, Buttercup from behind, with sepals removed; 3, Buttercup, with sepals and petals removed; 4, Pistil; 5, Stamens, with pistil removed; 6, Seed-cases; 7, Single seed-case cut through; 8, Buttercup; 9, Section of a Buttercup (on larger scale), showing the arrangement of its parts. *r*, Receptacle or torus; *s*, calyx; *p*, corolla; *st*, stamens: *g*, pistil.

ing the **corolla.** Their chief use is to attract insects to the flower.

When the calyx and corolla are the same colour, they are called collectively the **perianth.**

* Sepals and petals are not necessary for the production of seed, therefore they are sometimes absent.

3. **The stamens.**—A stamen consists of a stalk or **filament**, and a head or **anther.** The anther contains a yellow dust called **pollen.** The stamens form the **andrœcium.**

4. The **carpels** form the **pistil** (or **gynæceum**). There are three parts in the pistil:—the bottom part, **the ovary**; the middle part, the **style**; and the top part, the **stigma.**

The ovary contains small bodies called **ovules.**

Calyx. — If the sepals remain free from each other they are called **polysepalous**, if united **gamosepalous.**

Corolla.—Petals free = polypetalous.
Petals united = gamopetalous.

** **Andrœcium.**—The stamens, like the other parts of the flower, are modified leaves; the filament corresponds to the leaf-stalk, and the anther to the blade.

The blade is folded, forming two anther lobes, each of which contains two cavities, in which are minute grains called pollen. The pollen is carried by means of insects, or by the wind, from the stamens to the pistil of the flower.

The anther is joined to the filament by a delicate thread called the **connective.**

In the Buttercup, this thread runs up the back of the anther, between the lobes; this mode of attachment is called **adnate.** (Fig. 33, A.)

More frequently the thread is attached to one end of the anther, when it is said to be **innate** (fig. 33, B); if attached to the middle of the anther, **versatile** (fig. 33, C). When the attachment is innate or versatile the anther swings when touched.

The anther opens to shed its pollen when ripe. If the opening is towards the inside of the flower, the dehiscence is **introrse**; if towards the outside of the flower, **extrorse**; if down the sides, **lateral**. The

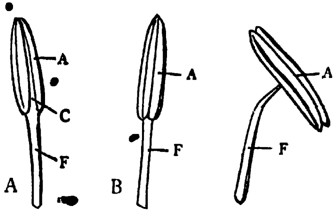


Fig. 33.—A, Adnate. B, Innate. C, Versatile A, Anther: F, Filament; C, Connective.

openings of the anthers are generally longitudinal slits, but sometimes they are pores (as in heaths), or sometimes valves.

** **Gynæceum.**—The carpels are leaves folded in various ways to form a closed chamber, in which the ovules are produced.

The simplest type of pistil consists of one carpel (as in the pea) joined by its edges, forming a cavity—the ovary. (Fig. 34, A.) Along the join of the two edges the ovules are produced.

The apex of the carpel is prolonged beyond the top of the ovary forming a style, and the end of the style forms the stigma.

The gynæceum may be formed from many carpels. These may remain free from each other, when several ovaries are formed, each containing one or more ovules. This is called an **apocarpous** pistil, as in Buttercup or Columbine. (Fig. 34, B.) More frequently the carpels combine, forming one ovary; this is a **syncarpous** pistil. (Fig. 34, C.) Sometimes the apices of the carpels join, forming

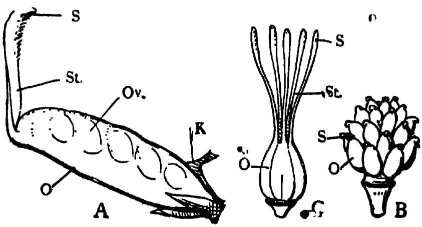


Fig. 34.—A, Pistil of Pea; B, Apocarpous pistil of Buttercup; C, Syncarpous pistil, K, calyx; O, ovary; Ov., ovules; S, stigma; St., style.

one style: sometimes they remain free, forming as many styles as there are carpels.

The surface of the stigmas is often sticky, or covered with hairs to help in retaining the pollen.

** **Placentation.**—The ovules are borne on the edges of the carpels, where a slight thickening is produced; this is called the **placenta**, and the method of arrangement is called **placentation.**

When the ovary is formed from one carpel and the ovules are placed where the edges of the carpels join, the placentation is **marginal.** (Fig. 35.) *Ex.* Pea.

When there is only one ovule, springing from the base of the ovary, the placentation is **basal.** (Fig. 36, A.) *Ex.* Buttercup.

If the ovule is suspended from the apex of the carpel, it is **pendulous.** (Fig. 36, B.) *Ex.* Cow-parsnip.

When two or more carpels join by their edges forming one cavity, the placentas are formed where the carpels join, that is on the walls of the ovary, and the placentation is said to be **parietal.** (Fig. 36, D.) *Ex.* Violet.

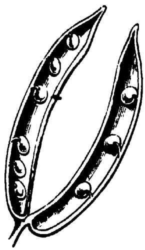
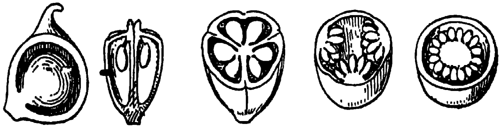


Fig. 35 —Pod of Pea, showing marginal placentation

If two or more carpels join by their edges and then fold in to the axis, forming as many cavities as there are carpels, the ovules are then placed in the centre round the axis, forming **axile** placentation. (Fig. 36, C.) *Ex.* Iris.

When the ovary is formed from several carpels,



A B C D E

Fig. 36 —Forms of Placentation

A. Basal; B, pendulous; C, axile; D, parietal; E, free-central.

and form only one cavity, and the ovules are placed on the axis in the centre of the ovary, the placentation is **free-central.** (Fig. 36, E.) *Ex.* Primrose.

** CHAPTER VII

FLOWER—(*Continued*)

The receptacle.—The end of the flower-stalk on which the floral leaves are placed is called the receptacle.

(In the Buttercup the receptacle is conical, the apex of the receptacle is occupied by the carpels.

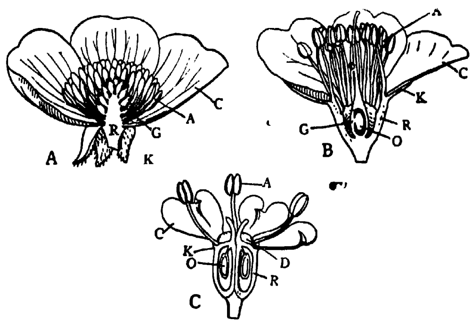


Fig. 37.—A, Vertical section of hypogynous flower; B, Perigynous flower; C, Epigynous flower; R, receptacle; K. calyx; C, corolla; A, andrœcium; G, gynæceum; D, disc; O, ovule

and the stamens, petals, and sepals respectively occupy three lower levels. (Fig. 37, A.) Such a flower is called **hypogynous** (*hypo* = below, *i.e.* petals and stamens are **below** the **gynæceum**), the term being applied to the stamens and petals; the sepals are said to be **inferior.**

If the receptacle grows more at the edges than at the apex. it becomes cup-shaped. The apex of the receptacle is still occupied by the ovary (in a hollow), but the sepals, petals, and stamens are carried up by the growth of the receptacle and occupy a position around the ovary. (Fig. 37, B.) In this case the petals and stamens are said to be **perigynous**. *Ex.* Cherry. In both of these instances the gynæceum is superior and the calyx inferior.

If the receptacle grows in the same way as the last example, but becomes combined with the ovary, and cannot be distinguished from it, the other parts of the flower appear to spring from the top of the ovary. (Fig. 37, C.) The corolla and stamens are then said to be **epigynous**, and the ovary **inferior**. *Ex.* Apple and Parsley.

CHAPTER VIII

INFLORESCENCES

An inflorescence is the arrangement of the flowers upon the flower-stalk.

The main flower-stalk is called the **peduncle**, the secondary flower-stalks branching from the peduncle are **pedicels**.

* There are two main types of inflorescence—(1) **definite**, and (2) **indefinite**.

* In a **definite** inflorescence, the peduncle or main axis is terminated by a flower, and the growth is continued by lateral branches, which spring from beneath the terminal flower. (Fig. 38.)

* In an **indefinite** inflorescence there is no terminal

flower; the axis produces flowers indefinitely, the youngest flower always nearest the top. (Fig. 39.)

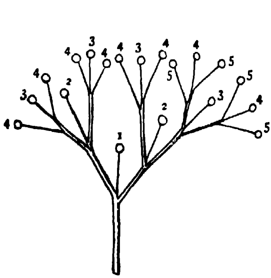


Fig. 38.—Cymose or Definite Inflorescence (diagrammatic)

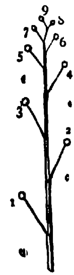


Fig. 39.—Racemose or Indefinite Inflorescence (diagrammatic)

* Comparison of Definite and Indefinite.

DEFINITE	INDEFINITE
1. Main axis terminates in a flower—growth, therefore, is definite or cymose.	1. Main axis does not terminate in a flower—growth, therefore, is indefinite or racemose.
2. Central (terminal) flower is the oldest, youngest flower on the outside.	2. Central (uppermost) flower is the youngest, oldest flowers at the bottom or outside.

* The main types of indefinite inflorescence are: (*a*) raceme, (*b*) corymb, (*c*) spike, (*d*) spadix, (*e*) umbel, (*f*) head.

(*a*) A **Raceme** bears numerous stalked flowers springing laterally up the peduncle, the youngest flower at the top. (Fig. 40.) *Ex.* Harebell or Lily of the Valley. In some racemes there are bracts at the base of the pedicels, in others they are absent.

Fig. 41. Corymb

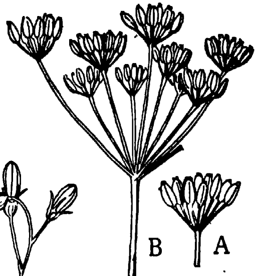


Fig. 45. Umbel

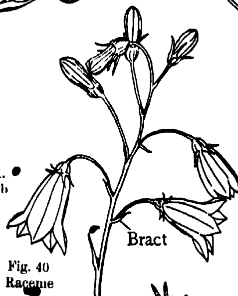


Fig. 40 Raceme

Fig. 42. Catkin

Fig. 43. Spike

Fig. 44. Spadix

Fig. 47.—Dichotomous Cyme

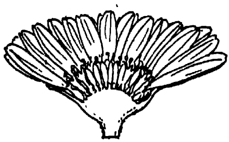


Fig 46.—Head

Fig. 48.—Scorpioid Cyme

(*b*) A **corymb** is a slight variation of the raceme. The lower pedicels elongate and grow to the same level as the upper ones, so that the top of the inflorescence is flat. (Fig. 41.) *Ex.* Candytuft.

A **catkin** is a pendulous raceme. (Fig. 42.)

(*c*) A **Spike** has numerous sessile flowers springing up the peduncle. (Fig. 43.) It is a raceme without pedicels. *Ex.* Plantain.

(*d*) A **spadix** is a spike with a fleshy peduncle. The spadix bears two kinds of flowers, staminate and pistillate. The top of the peduncle is barren, the flowers are placed near the base. The whole inflorescence is surrounded by a large bract called a spathe. (Fig. 44.) *Ex.* Arum Lily.

(*e*) An **umbel** has numerous stalked flowers springing from the top of the peduncle, the outermost flowers being the oldest. (See fig. 45, A, simple inflorescence; B, compound inflorescence.)

(*f*) A **head** has numerous sessile flowers springing from the top of the peduncle. (Fig. 46.) It is an umbel without pedicels.

* The Daisy, Dandelion, Cornflower, and similar types must not be mistaken for single flowers. They are inflorescences; the apparent calyx is an involucre of bracts, surrounding numerous flowers or florets.

* An umbel and head have shortened peduncles, the other racemose inflorescences have lengthened peduncles.

* **Cymose Inflorescences.** — The simplest form of cyme consists of an axis terminated by a flower. and a branch below bearing a flower

* A **dichotomous** cyme consists of a terminal flower with two branches below. Each branch again branches twice, and so on. (Fig. 47.) *Ex.* Stitchwort.

* A **scorpioid** cyme, characteristic of the Forget-me not and its allies, is a one-branched cyme. A terminal flower is produced, and a branch is formed below. This branching continues, and always on the same side of the axis. When fully expanded the inflorescence has the appearance of a raceme, so the branching must be examined in the expanding stage. (Fig. 48.)

Special inflorescences occur in certain families of plants, but these will be explained when the families are dealt with.

Fig. 49. — Solitary Axillary Flowers of Moneywort

* **Solitary Inflorescences.** — When the flowering axis does not branch, and bears only a single flower, the inflorescence is said to be solitary. In the Snowdrop the inflorescence is solitary terminal.

* In the Pimpernel and Moneywort, the flowers are solitary in the axils of the leaves. (Fig. 49.)

CHAPTER IX

POLLINATION

* In order that seeds may be produced, the pollen of the stamens must be conveyed to the stigma of the pistil. This is called **pollination.**

* Sometimes the pollen from the stamens is conveyed to the stigma of the same flower, giving rise to **self-pollination**; more frequently the pollen from one flower is conveyed to the stigma of another flower; this is said to be **cross-pollination.**

* It has been found by frequent experiment that cross-pollination is more advantageous to the plant than self-pollination, that more and better seeds are made, and stronger plants produced from them. Many plants, therefore, have means to ensure cross-pollination.

** 1. In the Hazel and Willow there are two kinds of flowers, one producing stamens, and the other pistils only. In this case the pollen must be carried from one flower to the other, *i.e.* they must be cross-pollinated.

Such flowers are said to be unisexual, and when both kinds grow on the same tree, as in Hazel, the flowers are **monœcious**, but on different trees, as in Willow, **diœcious.**

** 2. In the Primrose and Loosestrife there are two and three kinds of flowers respectively. The Primrose has two forms (fig. 50, A and B). One has the stamens at the top of the corolla tube (thrum-eyed flower) and the pistil short, the stigma reaching about half-way up the tube. The other form has the stamens half-way up the tube, and the stigma reaching to the top of the tube (pin-eyed).

It is very evident in the second case that self-pollination cannot take place. The flower depends upon the visit of insects for pollination.

The pollen is conveyed from the short stamens

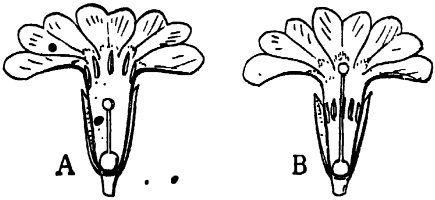


Fig. 50.—A, Thrum-eyed Flower of Primrose; B, Pin-eyed Flower of the same

to the short pistil, and from the long stamens to the long pistil.

** 3. Sometimes stamens shed their pollen before the pistil is ripe, when the flowers are said to be **proterandrous.** *Ex.* Canterbury Bell. Sometimes the pistil matures before the stamens, when the flowers are said to be **protogynous,** as in Scrophularias and Plantains. It is quite clear that in these cases the flowers must be cross-pollinated.

** 4. In many cases the shape of the flower, and the arrangement of the stamens and pistil, prevent self-pollination.

The shape of the flower bears a close relation to the visit of certain insects.

Sometimes the stamens are so arranged that they dust the insect's body with pollen, and when the insect visits another flower the pollen is deposited on the stigma.)

Various flowers should be examined and the different contrivances noted—for instance, the pea family.

The transference of the pollen from one flower to another is effected either by (*a*) the wind, or by (*b*) insects.

Wind-pollinated flowers are called anemophilous; insect-pollinated are entomophilous.

Anemophilous flowers are characterized by—

(1) being small and inconspicuous;

(2) being scentless;

(3) producing pollen in large quantities to allow for waste;

(4) pollen light and powdery, and produced generally on stamens which hang out of the flower, or the inflorescence is pendulous;

(5) stigmas branched and hairy;

(6) flowers sometimes come out before the leaves.

Entomophilous flowers are:—

(1) brightly coloured and scented. They generally contain honey secreted in some part of the flower. Sometimes the inflorescence is showy; by these means insects are attracted to the flower.

(2) The pollen is generally sticky, and is not produced in such large quantities.

(3) Stigma, when mature. is generally covered with a sticky secretion to cause the pollen grains to adhere to it.

(4) Flowers are adapted by their shape to the

visit of certain insects, and many have markings on their petals to guide the insects to the **nectaries**.

** **Nectaries.**—Honey is secreted in various parts of the flowers. Petals are often spurred, and the spur acts as a nectary, as in Snapdragon and Violet. Two of the stamens of the Violet and Pansy have appendages, which make the honey. These appendages are enclosed in the spur of the petals, and the honey collects in the spur.

The Wallflower has two green swellings in front of the short stamens; the Buttercup has small scales at the base of the petals; the Christmas Rose has tubular petals; the Sage has little glands on the receptacle below the ovary; in various members of the pea family the honey collects in the stamen tube, the entrance to which is protected by the one free stamen. When the nectaries are protected or concealed, they are generally visited by intelligent insects—as bees—and the shape of the flower adapted to the visit of such insects. This is clearly shown in the pea family, Snapdragon, &c. Butterflies and moths visit flowers with long tubes, as in Honeysuckle.

When the nectaries are exposed to view, the flowers are visited by a great variety of insects.

** **Self-pollination.**—Many flowers have contrivances to ensure self-fertilization.

The Violet and Wood-sorrel produce **cleistogamous** (closed) flowers. Since they never open they must pollinate themselves. These flowers are produced late in the year and form seeds.

Some flowers are able to pollinate themselves if cross-fertilization fails.

* **Pollen-tube.**—The pollen grain is nourished by a sticky substance on the stigma; it puts out a tube, which finds its way down the style into the ovary, and enters an ovule through the small opening, the micropyle. Pollination, therefore, is the transference of the pollen to the stigma and the production of the pollen-tube.

** CHAPTER X

FERTILIZATION

An ovule (fig. 51) consists of:—

(1) A central mass of cells called the **nucellus**, surrounded by—

(2) Two coats, called **integuments**. The two coats do not quite surround the nucellus, but leave a small opening called the micropyle.

One cell of the nucellus is larger than the others, and is called the **embryo sac**. The embryo sac contains an **oosphere** or **ovum**.

After pollination has taken place, the fertilization of the ovule follows. The contents of the pollen grain pass down the pollen-tube, which has previously entered the micropyle, and combine with the ovum. The ovum becomes an oospore, and from it is developed the young embryo plant.

Within the embryo sac is produced, as a result of fertilization, a tissue called **endosperm** or **albumen**.

This contains a store of food material for the embryo. The embryo sac enlarges gradually, enclosing the whole of the nucellus.

Sometimes the nucellus persists, and is called **perisperm**. *Ex.* Pepper.

The results of fertilization are therefore:—

(1) The development of the ovule into a seed, surrounded by the testa (two integuments), enclosing—

(2) An embryo formed from the fertilized ovum.

(3) The formation of endosperm.

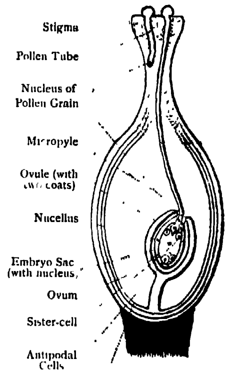


Fig 51 — Vertical Section of Ovary (with 3 coats), containing 1 Ovule

NOTE. – Three nuclei – the vegetative nucleus and two generative nuclei – go down the pollen tube. Only one of the latter brings about the fertilization of the ovule. The other sometimes joins with the nucleus of the embryo-sac, while the vegetative nucleus disappears.

In some cases, as the embryo enlarges, it absorbs the food material and stores it up in the cotyledons, so that the seed contains only the embryo. Such seeds are called **exalbuminous**. *Ex.* Bean. But if the food material remains outside the embryo, so that the seed contains an embryo and endosperm, the seed is said to be **albuminous**. *Ex.* Indian Corn.

In a few cases an extra growth develops round the seed, forming an **aril**. In the Willow this takes the form of a tuft of hairs; mace is an aril which grows round nutmegs; the red, fleshy cup ot the Yew forms an aril also.

CHAPTER XI

FRUITS

When the ovule develops into the seed, the ovary becomes the fruit, and the wall of the ovary is called the **pericarp** of the fruit.

A **true** fruit is formed from the ovary alone, but when some other part of the flower (usually the receptacle) helps in the formation of the fruit, the fruit is said to be **spurious.**

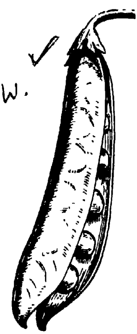


Fig. 52.—Pod of Pea (open)

Fruits may be divided into:—

(1) **Dry** fruits, having a dry pericarp.

(2) **Succulent** fruits, having a juicy pericarp.

Fruits are also either—

(1) **Dehiscent**, when they open to shed their seeds.

(2) **Indehiscent**, when they do not open to shed their seeds.

The chief dry, dehiscent fruits are (1) pod, (2) follicle, (3) siliqua or silicula, (4) capsule.

Pod.—A pod is formed from one carpel, splitting down two sides to liberate its seeds. It opens along the place where the edges of the leaf join and also along the midrib. The seeds are attached along the edges of the carpel. The pod or **legume** is the characteristic fruit of the pea family. (Fig. 52.)

Follicle. — A follicle is similar to a pod, but it only opens down one side, where the edges of the carpel join. (Fig. 53.) *Ex.* Columbine or Larkspur. The fruit consists of many follicles, because there are many carpels, and they remain free from each other, each one forming a follicle.

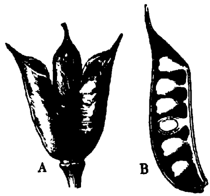


Fig. 53.—A, Follicles of Larkspur; B, Single follicle cut open

* **Siliqua.**—This is a fruit peculiar to the wallflower family. It is formed from two carpels; the carpels are joined by their edges, but there are two cavities owing to a false partition called the replum, formed between the two carpels. When the fruit ripens, the two carpels break away from the replum, from below upwards, leaving the seeds, which are attached to the edges of the carpels by slender stalks, on the replum. (Fig. 54.)


Fig. 54.—Siliqua of Wallflower

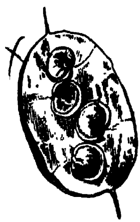


Fig. 55.—Silicula of Honesty

When the fruit is almost as broad as it is long it is called a **silicula.** (Fig. 55.) *Ex.* Honesty

Capsule.—A capsule is formed from two or more carpels, opening in various ways to shed its seeds:—

(*a*) By numerous teeth at the top, usually as

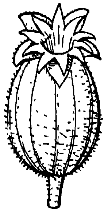


Fig 56.—Capsule dehiscing by teeth

Fig 57.—Capsule of Figwort

many or twice as many as the number of carpels. *Ex.* Campion. (Fig. 56.)

(*b*) By longitudinal slits, either along the margin

Fig. 58. —Capsule of Iris

Fig. 59.—Capsule of Poppy

of the carpels, as Figwort (fig. 57), or along the midribs (fig. 58). *Ex.* Pansy and Iris.

(*c*) By numerous pores (fig. 59), as in Poppy and

Snapdragon. As the capsule of the poppy ripens, the stigma is raised, disclosing numerous pores.

(*d*) By a little lid, as in the pimpernels (fig. 60).

Fig 60 – Capsule of Pimpernel

Centre piece of Buttercup, with Stamens.

The same enlarged, and cut through to show seeds.

Fig 61

* **Dry Indehiscent Fruits.**—The chief are (*a*) nuts and (*b*) achenes.

Both of these contain one seed; the pericarp of the achene is thin, whereas that of the nut is hard and shell-like.

The buttercup has a **head of achenes** (fig. 61), formed therefore from numerous carpels, each carpel containing one seed.

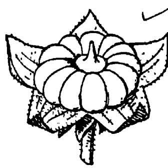


Fig. 62.—Schizocarp of Mallow

* **A Schizocarp** (Gr. *schizo* = to split).—If the pistil is formed from two or more carpels, joined to each other, and they split apart when the fruit ripens, it is called a schizocarp. (Fig. 62.) In the Mallow the fruit splits into a number of parts, each part containing one seed.

Succulent Fruits.—The two chief types of succulent fruits are (*a*) **berry** and (*b*) **drupe**.

In a **drupe** the pericarp shows three distinct layers—the outer one forms the skin, the intermediate layer is the succulent part of the fruit, and the innermost layer is the hard shell. Within this is contained the **one** seed. (Fig. 63.) The drupe

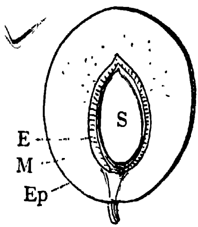


Fig. 63.—Longitudinal Section of Plum

S, Seed; E, Endocarp, or shell; M, Mesocarp, or intermediate layer; Ep, Epicarp, or skin.

Fig 64.—Blackberry, and single Fruitlet of same

The latter is enlarged and cut through to show seed.

is generally formed from one carpel. *Ex.* cherry, plum, or walnut. The blackberry and raspberry consist of a number of small drupes or drupels. (Fig. 64.) The pistil is formed from many carpels, free from each other. Each carpel forms a drupel.

Berry.—In a berry the pericarp consists of the outer layer—the skin, and the succulent part of the fruit. It contains **many** seeds, which are embedded in the succulent part of the fruit. (Figs. 65 and 66.)

Berries may be formed from two or more carpels. The gooseberry consists of two carpels, and the seeds are attached to two parietal placentas.

An orange is a berry containing numerous cavities with axile placentation.

Fig. 65. – Transverse Section of Gooseberry, showing two parietal placentas

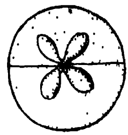


Fig. 66. – Transverse Section of Grape, showing axile placentation

Spurious Fruits.—Many fruits are formed from the gynæceum and some other part of the flower, generally the receptacle.

The apple is a spurious fruit called a **pome**. (Fig. 67.) It consists of the ripened gynæceum

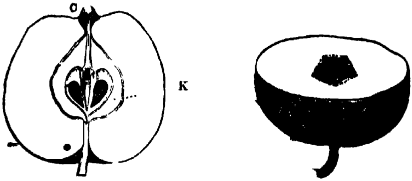


Fig 67.—Apple cut downwards and across

C, Calyx; K, Carpels. The core containing the pips or seeds is the true fruit.

surrounded by the swollen receptacle. The core of the apple represents the true fruit (the ripened gynæceum), the edible part being the swollen receptacle. When seen in cross section, there are five divisions in the centre; these are the five ovaries of the flower. and each contains one or two seeds.

The **haw** of the Hawthorn resembles a pome in some respects. (Fig. 68.) The outer portion is the

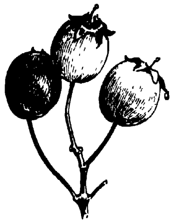


Fig. 68.—Haw of Hawthorn

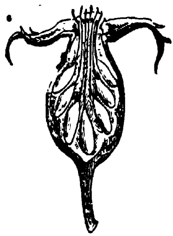


Fig. 69—Vertical Section of Hip of Rose

swollen receptacle, but the carpel or carpels become stony.

The **hip** (fig. 69) of the rose consists of the outer

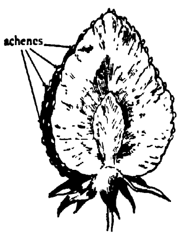


Fig. 70.—Vertical Section of Strawberry

Fig. 71.—Vertical Section of Fig

portion, the receptacle, enclosing the true fruits.—achenes covered with silky hairs.

The **strawberry** is also a spurious fruit. (Fig. 70.) The receptacle enlarges considerably, and becomes fleshy, bearing on its outer surface the true fruits —achenes.

** The fig is a peculiar fruit formed from the entire inflorescence (fig. 71); the peduncle encloses the flowers, the perianths of which become succulent. The true fruits are the small pips or achenes.

** The mulberry in appearance resembles a blackberry, but it is a fruit formed from a number of flowers; the blackberry is the fruit of a single flower.

CLASSIFICATION OF TRUE FRUITS

- 1 Dry.
  - 1. Dehiscent.
    - Formed from one Carpel
      - 1. Pod *Ex.* Pea.
      - 2. Follicle. *Ex* Columbine.
      - 3. Lomentum. *Ex.* Radish.
    - Formed from two Carpels.
      - 1. Siliqua. *Ex.* Wall-flower.
      - 2. Silicula. *Ex.* Honesty.
    - Formed from two or more Carpels.
      - 1. Capsules. *Ex* Poppy.
  - 2. Indehiscent.
    - 1 Achene. *Ex* Butter-cup.
    - 2. Nut. *Ex* Hazel.
    - 3. Schizocarp. *Ex* Mallow.
- 2. Succulent.
  - One-seeded.
    - 1. Drupe. *Ex.* Cherry.
  - Many seeded.
    - 1. Berry. *Ex.* Grape.

CHAPTER XII

** FRUITS—(*Continued*)

Means of Dispersal of Fruits and Seeds.—It is important that the seeds of a plant should have some means of distributing themselves, otherwise they would all grow up around the parent plant, and so cause overcrowding.

The four principal agents which help in the dispersal of seeds are:—

(*a*) **Wind**, (*b*) **animals and birds**, (*c*) **water**, (*d*) **some mechanical contrivance** in the fruit.

Wind.—1. In some cases the **seeds** are very

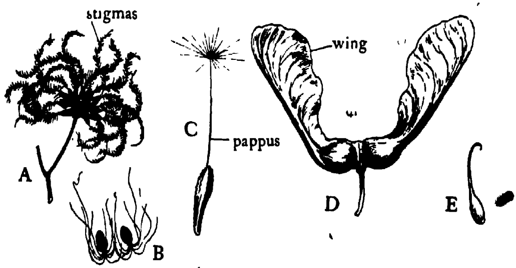


Fig. 72.—A, Achenes of Traveller's Joy; B, Seeds of Willow-herb; C, Fruit of Dandelion; D, Samara of Sycamore; E, Achene of Avens, showing hook.

light, and are easily carried by the wind on the opening of the fruit.

2. The **seeds** of the Willow and Willow-herb (fig. 72, B) are provided with hairs, which enable them to be carried easily by the wind.

3. In Wild Clematis or Traveller's Joy the style becomes feathery and aids in the dispersal of the **fruit**. (Fig. 72, A.)

4. **Fruits** are sometimes crowned with hairs, as in the Dandelion. (Fig. 72, C.) The hairy outgrowth is the pappus representing the calyx.

5. Some **fruits** have wing-like outgrowths which

enable them to be carried by the wind, as Elm, Sycamore, Ash. (Fig. 72, D.)

Animals.—1. Succulent fruits are eaten by animals, the succulent portion being digested, and the seeds rejected. The seeds may be carried, in this way, some distance from the parent plant.

2. Some fruits are provided with awns, hooked at the end, by means of which they become attached to the wool of sheep or other animals. For instance, the achenes of the Common Avens (fig. 72, E) are crowned by the stigmas, which twist and become hooked when the fruit ripens.

Fruits of Burdock, Cleavers, and others are provided with hooked hairs, which enable them to cling to any rough surface.

Water.—Some seeds and fruits are provided with air-bladders, which enable them to float on the surface of the water. *Ex.* Water-lily.

By this means islands may be provided with vegetation, the seeds of plants from neighbouring continents being carried by currents, &c. The cocoa-nut, with its fibrous outer covering and hard shell, can be carried on the water for long distances.

Mechanical Contrivances.—Many fruits open with an explosive action, and cast the seeds sometimes to great distances. Examples of such are Wood-sorrel, Balsam, Gorse, and Squirting Cucumber.

PART II

SIMPLE STRUCTURE

CHAPTER XIII

STRUCTURE

* If a thin section of a root, stem, or leaf be examined under the microscope, it presents the appearance of a net-work. The various compartments of the net-work are called **cells.**

Fig. 73.—A Cell

* A **cell** (fig. 73) consists of a living part, **protoplasm,** covered by a protecting layer called the **cell-wall.**

Protoplasm is a jelly-like semi-transparent substance, having the power of movement. In composition it is very complex, consisting of the elements carbon, hydrogen, oxygen, nitrogen, sulphur.

In the protoplasm are seen numerous small bodies, one being considerably larger than the others, this is called the **nucleus**. It is composed of dense protoplasm, and when the cell is treated with certain stains, the nucleus tends to stain to a greater extent than the rest of the cell. The smaller bodies are called—

Plastids, composed also of protoplasm. When these plastids are colourless, they are called **leucoplasts**. They are found in storage organs, and with them are associated the starch grains. In the green parts of plants a green colouring matter is diffused through the plastids, and they are then called **chlorophyll granules** or **chloroplasts**. (See fig. 73.)

Chromoplasts have various colouring matters diffused through them, as in the petals of some flowers, &c.

Cell-sap.—In a young cell the protoplasm fills the entire cell, but as the cell grows older spaces appear called **vacuoles**, filled with a watery fluid called **cell-sap**. Gradually these spaces run together, and form one large vacuole surrounded by the protoplasm containing the nucleus. the whole covered by the cell-wall.

Cell-wall.—The cell-wall consists of a dead substance called cellulose, formed from and by the protoplasm. Cellulose has the same chemical composition as starch, consisting of carbon, hydrogen and oxygen ($C_6H_{10}O_5$). During the life of the cell. the cell-wall frequently undergoes a process of change, such as:—

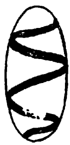


Fig. 74.—Cell showing spiral thickening

(1) **Lignification**, that is, the cellulose becomes changed into lignin, which is hard and inelastic, but permeable to water, as is also cellulose. The cell-walls in the wood tissue of plants become lignified.

(2) The cell-walls on the outer skin of plants are sometimes covered with a cuticle, or become **cuticularized.**

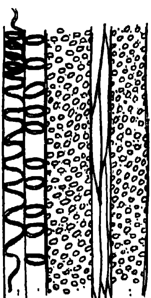


Fig. 75.—S, Spiral vessel; A, Annular vessel: P, Pitted vessel; F, Fibres in the wood of a fibrovascular bundle.

(3) In some parts of plants the cell-walls are formed of **cork.** Both the cuticle and the cell-walls of cork tissue are impermeable to water, and hence are important in that they prevent too great evaporation from the surface of plants.

* Cell-walls also undergo another kind of change. They are frequently thickened by the addition of cellulose on their inside walls. The thickening is not deposited evenly over the whole inner surface, but—

(1) sometimes in the form of a **spiral**, forming **spiral** cells (fig. 74);

(2) sometimes in the form of rings, forming **annular** cells (fig. 75);

(3) or in the form of a net-work, forming **reticulate** cells;

(4) if the cellulose is deposited over the greater part of the surface, leaving small dots unthickened, a **pitted** or **dotted cell** (fig. 75) is formed.

Tissues.—Cells are generally grouped together to form what are called tissues.

According to the nature of the cells forming them, tissues are called:—

(1) **Parenchymatous**, when the cells are more or less rounded.

(2) **Prosenchymatous**, when the cells are longer than they are broad.

(3) **Sclerenchymatous**, when the cell-walls forming the tissue are considerably thickened.

* **Vessels.**—Vessels are formed from a row of cells placed one on top of the other; the transverse walls break down or disappear, and so form a tube or vessel. (Fig. 75.) Vessels may be either spiral, annular, or pitted, &c., according to the nature of the cells from which they were formed. These vessels occur in the woody parts of plants; they generally lose their cell-contents and contain nothing but air.

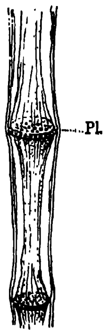


Fig. 76.—Sieve-tube, showing sieve-plate, Pl.

* **Sieve-tubes.**—In some parts of plants the transverse walls of rows of cells only become perforated, forming a vessel called a sieve-tube. (Fig. 76.) These retain their living contents, and form a channel through which the food materials travel from the leaves to various parts of the plant.

* **Fibres.**—When cells become elongated by pressure at the sides they are called **fibres**, so fibres are elongated cells. A tissue made up of fibres and vessels is called a **fibrovascular** tissue.

Cell-division.—Cells increase in number by the division of already existing cells. In cell-division the nucleus divides into two, and then probably into four; cell-walls are formed across the cell, and two or four cells, according to the number of nuclei, are formed from the original one.

A tissue in which the cells are constantly dividing is called **meristem**; one in which division has ceased is **permanent** tissue.

CHAPTER XIV

STRUCTURE OF THE ROOT

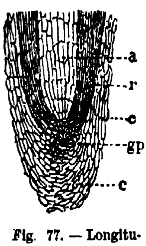


Fig. 77. — Longitudinal Section through the Apex of a Root

a, **Axis**; *r*, **cortex**; *gp*, **growing-point**; *cc*, **root-cap**

If a longitudinal section of a young root be examined under the microscope, at the tip may be seen numerous meristem cells, forming the **growing point**. (Fig. 77.)

Some distance behind the growing point the meristem cells have passed over into permanent tissue of three different kinds:—

1. An outer tissue, only one cell layer thick, except round the growing point. This is called the **epidermis**, and at the growing

point, where it becomes many-layered, the **root-cap.**

From the epidermis on the young parts of the root, **root-hairs** are developed. (Fig. 78.) These are outgrowths from single cells, and form a very

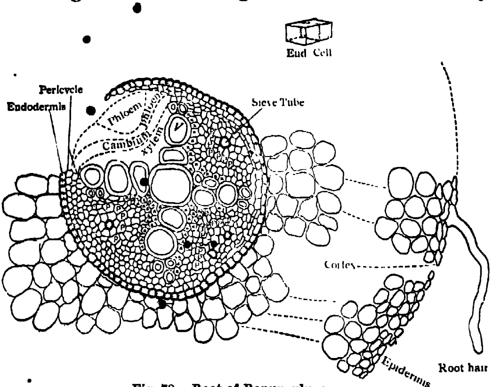


Fig. 78.—Root of Ranunculus repens

V, Vessels of wood, spiral towards outside of stem, larger pitted vessels towards the centre; P, Phloem or bast

important part of the plant, as they absorb the water containing food materials from the soil.

2. An intermediate tissue, consisting of several layers of cells more or less rounded, forming the **cortex** of the root.

The innermost layer of the cortex is called the **endodermis.** It may be distinguished by the thickening of the side-walls.

3. The central tissue or **stele.** It consists of a number of fibrovascular bundles—(*a*) xylem or

wood bundles, and (*b*) phloem or bast bundles. These are placed side by side, alternating with each other, separated by parenchyma tissue.

The outermost layer of the stele is the **pericycle.**

The xylem or wood bundles consist of spiral and annular vessels towards the outside of the bundle, and pitted vessels towards the centre of the root. and a number of fibres and cells. All the elements have their cell-walls more or less lignified.

The phloem or bast bundles consist of:—

(*a*) bast vessels or sieve-tubes;

(*b*) bast fibres;

(*c*) bast cells.

Increase in Thickness.—The cells of the parenchyma in front of the bast bundles become meristematic, forming what is called **cambium** (fig. 78); these isolated strands of cambium are finally joined by intervening cells to form a continuous cambium ring; it is at first irregular in shape, extending outside the xylem and inside the phloem. This cambium ring constantly divides and forms new tissue—new wood internally and new bast externally to itself—every year. At intervals, instead of forming wood and bast, the cambium forms parenchyma cells; these are called **medullary rays.**

Growth in Length.—The root lengthens by division of the cells of the growing point at the apex of the root; they are constantly dividing and forming fresh cells, which gradually pass over into permanent tissue a short distance behind the growing point.

As the root lengthens, the growing point has to force its way through the particles of soil, and therefore is protected by numerous cells forming a **root-cap**; the outer and older cells are constantly being worn away, but are replaced on the inside by new cells formed at the growing point.

Root-branches.—Root-branches are produced from the pericycle. This layer of cells opposite the wood

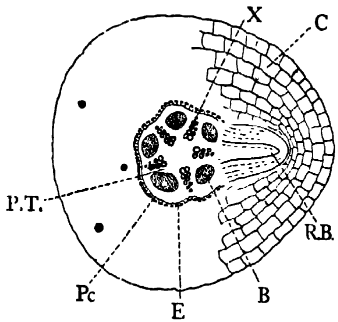


Fig. 79.—Diagrammatic Section of Root, showing root-branch

X, Xylem; C, cortex; R.B., root-branch; B, bast; E, endodermis, Pc, pericycle; P.T., packing tissue.

bundles becomes meristematic, and divides, forming little protuberances, which gradually develop into branches resembling in structure the parent root. As they are formed from an internal tissue, root-branches are said to be formed **endogenously**, and they have to force their way through the outside tissues—cortex and epidermis, &c. (See fig. 79.)

CHAPTER XV

STRUCTURE OF THE STEM

The tip of the stem, like that of the root, consists of similar cells, all meristematic, forming the growing point. The growing point is protected by young leaves.

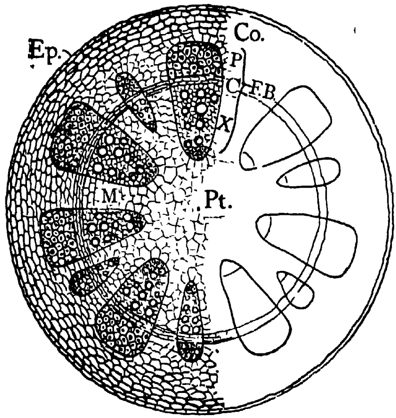


Fig. 80.—Transverse Section of Stem of Sunflower (partly diagrammatic)

FB, Fibrovascular bundle (X, xylem, C, cambium, P, phloem); Co., cortex, Ep., epidermis; Pt., pith; M, medullary rays.

A short distance behind the growing point may be distinguished three tissues (fig. 80):—

(1) the **epidermis**,

(2) the **cortex** and **endodermis**,

(3) the **stele** or **fibrovascular system** surrounded by the **pericycle**.

The structure of a young stem is different from that of a young root in the arrangement of the fibrovascular bundles. In the stem of a dicotyledon, the stele consists of an incomplete ring of **fibrovascular bundles**, separated from each other by **parenchyma.**

Each bundle consists of:—

(*a*) **wood** or **xylem**, towards the centre of the stem;

(*b*) **bast** or **phloem**, towards the outside of the stem; separated by—

(*c*) a zone of meristem—the **cambium.**

This arrangement of the wood and bast is called **collateral.** When they are on alternate radii, as in the root, the arrangement is said to be radial.

The parenchyma in the centre of the stem is called the **medulla** or **pith**, and in between the bundles the **medullary rays.**

Increase in Thickness.—Some of the cells of the medullary rays in a line with the cambium of the bundles become meristematic, and finally a complete ring of meristem or cambium cells is formed.

By division of the cells of the **cambium ring**, new bundles are formed in between the old ones, and every year a new ring of wood and a new ring of bast are added. The wood is formed on the inside of the cambium ring, and the bast on the outside. (Fig. 81.)

The rings of bast become very much compressed, but the rings of wood can be clearly distinguished if a tree trunk be cut across, and by counting them the age of the tree may be determined.

The rings of wood are all alike, but the wood formed in the spring consists of large pitted vessels, that in the autumn of smaller elements, and as the spring wood lies next to the autumn wood of the preceding year, the ring of one year can be distinguished from that of the previous year.

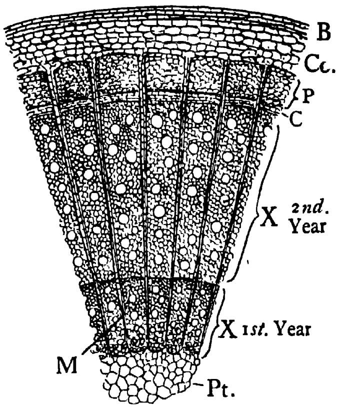


Fig. 81 – Transverse Section of Maple (two years old)

B, Bark; Co, cortex; P, phloem; C, cambium; X, xylem (two years); Pt, pith; M, medullary ray.

Medullary Rays.—As we have seen, the primary medullary rays consist of the parenchyma tissue in between the bundles and continuous with the pith. The medullary rays are added to by the cambium, which, at intervals, forms parenchyma tissue instead of wood and bast. New medullary rays may be formed in the second or any subsequent year, but these do not extend to the pith.

The medullary rays sometimes act as storehouses of food, and also convey food materials and water from the outer to the inner tissues.

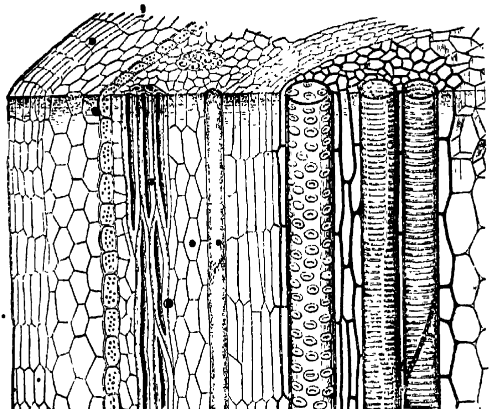


Fig. 82.—Stem Section

1, Epidermis; 2, Cork; 3, Cortex; 4, Endodermis; 5, Phloem fibres (one or two delicate cells between 4 and 5 are pericycle cells); 6, Phloem cells; 7, Phloem sieve-tubes; 8, Cambium; 9, Pitted vessels of xylem; 10, Xylem cells; 11, Scalariform vessels; 12, Medullary sheath; 13, Pith.

Xylem or Wood.—As in the root, the wood consists of:—

(1) wood vessels,

(2) wood fibres (see fig. 75),

(3) wood parenchyma.

Spiral and annular vessels occur in the wood of the first year, and are found surrounding the pith. Pitted vessels occur throughout the wood (Fig. 82.)

All the elements of the wood have lignified walls. The oldest wood is called the **heart-wood**, and is found in the centre of the stem; the vessels and fibres have lost their cell contents, and contain nothing but air. Their function is to give rigidity to the plant.

The youngest wood is found nearer to the outside of the stem, on the inner side of the cambium; it is called the **sap-wood**, as it is the means by which water is conveyed from the root to the leaves.

Bast consists of:—

(1) sieve-tubes or bast vessels,

(2) bast fibres,

(3) bast parenchyma. (Fig. 82.)

Through the bast, especially through the sieve-tubes, the food materials prepared in the leaves are conveyed from the leaves to the parts of the plants which require them. (See fig. 82.)

Bark.—A zone of meristem arises in the cortex or sometimes in the bast, which is called **cork-cambium**. The cork-cambium divides and forms outwardly a cork tissue, and inwardly a green layer of cells to replace the cortex.

The cell-walls of the cork are impervious to water, hence the tissues external to the cork are shut off from the supplies of food and die; this cork, and the decayed tissues external to it, are called **bark.**

The bark, being dead tissue, cannot stretch sufficiently as the stem increases in thickness, consequently it splits into fissures, forming the rugged bark of most of our forest trees.

The smooth bark of the Beech-tree is due to the fact that it is more elastic.

Growth in Length.—The stem grows in length

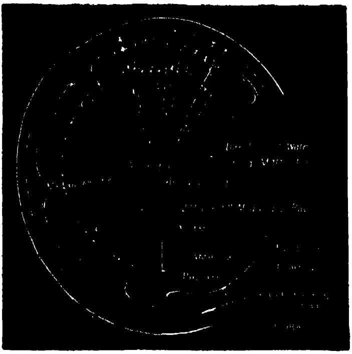


Fig. 83.—Transverse Section of Stem (diagrammatic)

by the addition of new nodes and internodes. These appear first in buds, formed at the growing points, which expand, bearing leaves at intervals.

Stem of a Monocotyledon.—The stem of a Monocotyledon differs from that of a Dicotyledon in the arrangement of the fibrovascular bundles. (Fig. 84.) In a Monocotyledon the bundles are scattered irregularly through the parenchyma tissue, so that there is no clearly-defined pith or medullary rays. Again, the fibrovascular bundles, when fully formed, contain no cambium, so that they are said to be **closed**; dicotyledonous bundles are said to be **open**. As there is no cambium in the bundles of a Monocotyledon, there is no increase in thickness by the formation of new rings of wood and bast.

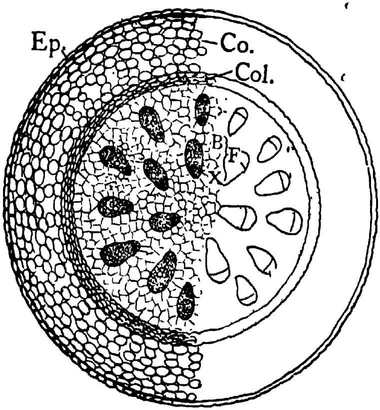


Fig. 84.—Transverse Section of Stem of Ruscus (monocotyledon)

Ep., Epidermis; Co., cortex; Col., collenchyma; F. fibrovascular bundle; B, bast, or phloem; X, xylem.

Stem branches are formed at the growing points, and from the two outer tissues of the stem. They arise as buds in the axils of the leaves. As they are formed from the outer tissues they are said to arise **exogenously**.

Lenticels.—If the bark of a stem (for instance, Horse-chestnut) be examined, small brown dots may be seen. These are lenticels, which during the summer are filled with loose cork cells, formed from the phellogen or cork-cambium. (Fig. 85.) Through these loose cells gases are able to enter

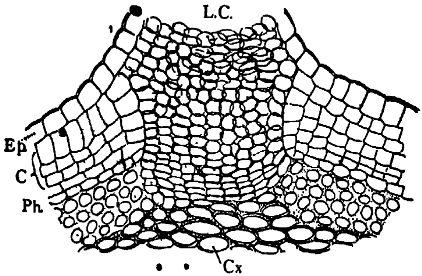


Fig 85.—Section through a Lenticel

Ep., Epidermis; C, cork; Ph., phellogen; Cx, cortex; L.C., loose cork cells

and pass out of the stem. During the winter the lenticels are filled with ordinary, closely-packed cork tissue.

CHAPTER XVI

STRUCTURE OF THE LEAF

Leaves are produced at the growing points of the stem. They consist of parenchyma, traversed by veins—fibrovascular bundles—continuous with the fibrovascular system of the stem.

If a section through a leaf be examined under the microscope (fig. 86), it will be seen to consist of:—

(1) A thin outer skin or **epidermis**. This covers the whole of the upper surface of the leaf, consisting of a single cell layer. The cells are colourless, being devoid of chlorophyll. The upper surface of the leaf is often covered with a thin layer of

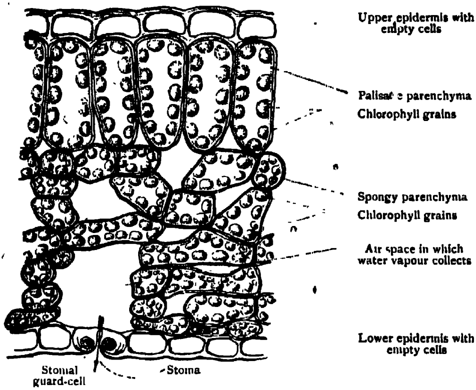


Fig 86.—Diagrammatic Section of Leaf (Winter Hellebore)

cuticle, which protects the living tissues of the leaf.

(2) One or two layers of cells, forming the **palisade** parenchyma. In the protoplasm of these cells are numerous chloroplasts, which give the green colour to the leaf.

(3) Loosely-packed cells, irregular in shape, with many spaces in between them (**intercellular spaces**). This is called the **spongy parenchyma**. These cells also contain chlorophyll, and the intercellular spaces

communicate with the outside air by means of openings in—

(4) The **lower epidermis**, a single cell layer, similar to the upper epidermis. This layer, however, is not continuous over the whole of the lower surface, but openings called **stomata** occur. (Fig. 87.) Each **stoma** or opening is surrounded by two cells (**guard cells**) which differ from the other cells

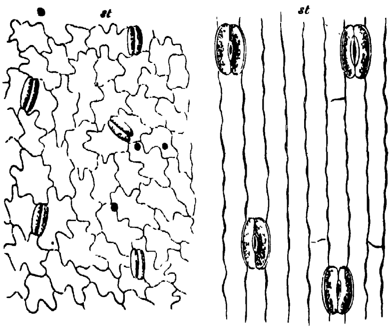


Fig. 87.—Surface View of Epidermis. *st*, Stomata.

of the epidermis, in that they contain chlorophyll. When the plant requires to give off water, the guard cells separate, and the water vapour passes from the intercellular spaces through the stomata into the air. To prevent the giving out of water the stomata close, so that they regulate—

(*a*) the transpiration of the plant, as the process of giving off of water is called; and also

(*b*) the absorption and giving out of certain gases.

Leaf-fall.—The leaves of most of our forest trees are deciduous, falling every year on the approach of winter.

At the base of such leaves a layer of cork is formed, between the leaf and the stem, practically cutting off the leaf from the food supplies, as cork is impervious to water.

The leaf, however, remains attached to the stem by means of the fibrovascular bundles; but finally these are broken, and the leaf falls, leaving a scar, which is covered over with cork.

In the Horse-chestnut this scar is in the shape of a horse-shoe, and the small dots are the veins or fibrovascular bundles. (See fig. 14.)

PART III

PHYSIOLOGY OF PLANTS

CHAPTER XVII

PHYSIOLOGY OF THE PLANTS

It has already been stated (Chapter XIII) that the plant consists of cells and vessels, and that the elements which compose the living substance of the cells—protoplasm—are carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. These elements must therefore be obtained by the plant in some form from its surroundings.

It is a well-known fact that for plants to thrive they must be supplied with a certain amount of water. Also, by drying a plant, and weighing before and after, the loss by weight after the drying process is very great, showing that a large percentage of the plant consists of water.

Experiment 1.—To illustrate the passage of water into the plant.

Take a small bottle, fill it with golden syrup or any other sugar solution, and cover it with a piece of pig's bladder. Place the bottle in a vessel containing water sufficient to cover it.

Result.—The syrup passes out into the water through the bladder, and water passes into the bottle and intermingles with the syrup.

It follows, therefore, that if two liquids of different density be separated by a permeable membrane, they flow through and intermingle until both be of the same density

Also, the less dense liquid flows through more rapidly than the other. This fact may be seen more readily by substituting a glass funnel for the small bottle, as the liquid rises in the tube of the funnel.

Applying the experiment to the plant, the cell-walls of the root-hairs may be compared with the bladder; the acid cell sap with the sugar solution, and the water of the soil with the water contained in the vessel. The acid sap passes out into the soil, and the water of the soil passes into the plant, and from cell to cell by the process of osmosis.

Experiment 2.—The acid sap passes out into the soil and dissolves some of the mineral salts. Take a piece of polished marble, and sprinkle with saw-dust. Allow cress seedlings to germinate on it.

Result.—After two or three weeks remove the saw-dust. The seedlings have made little grooves in the marble, where the acid sap has dissolved the substance of the marble.

Experiment 3.—Take a Daffodil and place its cut end in a solution of water and ink.

Result.—The veins of the petals are coloured dark green, or almost black, showing that the solution has passed up through the peduncle to the flower.

Experiment 4*a*.—To show through what part of the stem the water travels.

Take a small branch of a tree and strip off the bark, and immerse in water coloured with ink.

Result.—The outer layers of wood (sap-wood) are seen to be coloured with ink, showing that the water has passed up through them.

Experiment 4*b*.—Remove the sap-wood, and repeat the experiment.

Result.—The leaves will probably droop, owing to the removal of the sap-wood, the channel through which the water travels to the leaves.

Root Pressure.—As we have already shown, the water enters the root-hairs of the plant, and passes by osmosis from cell to cell through the parenchyma of the root. When absorption is active, the cells of the parenchyma become turgid, and the water is pressed into the wood vessels, and travels through these to the veins of the leaves.

The forcing of the water under pressure into the wood vessels is termed **root pressure.**

Experiment 5.—Cut the branch of a vine in early spring, and protect the cut surface from evaporation.

Result.—After a short time water is seen to ooze from the cut surface. This is due to root pressure.

Later in the summer, when the leaves are fully expanded, transpiration becomes more active, and this "bleeding" due to root pressure does not become so apparent.

Root pressure is also shown by grasses and other low-growing plants. In the early morning drops *of water are seen on the edges of the leaf at the* termination of the veins. The roots have absorbed water, and in the early morning the loss by transpiration is not great enough to compensate for this, so the water oozes out at the ends of the veins. Later in the day this is not observed, as transpiration keeps pace with absorption.

From the veins of the leaf the water passes into the parenchyma of the leaf, whence a large quantity passes out into the air in the process of transpiration.

There is present, therefore, in the plant a constant ascending current of water from the root to the leaves.

CHAPTER XVIII

TRANSPIRATION AND ABSORPTION

Experiment 1.—To show the giving off of water. Take a young shoot bearing leaves, and a piece of cardboard. Place the piece of cardboard over a vessel containing water. Through a hole in the cardboard insert the shoot, so that the cut end dips into water. Over the whole place a bell-jar.

Result.—In a short time drops of moisture are seen on the inside of the bell-jar, showing that the leaves have given off water.

This process, by which water in the form of water vapour is given off into the air by the leaves, is called **Transpiration**. The amount of *water vapour given off is regulated by special* organs on the under surface, and sometimes on the upper surface of the leaves, called **stomata**. (See fig. 87.) Since the stomata are more numerous on the under surface than on the upper, it follows that transpiration is greater from the lower surface.

Transpiration may also be shown by covering a growing plant with a bell-jar, but the moisture deposited on the bell-jar is in part derived from the surface of the soil.

Experiment 2.—To prove that plants require something besides water.

Take a growing seedling and allow its roots to dip into distilled water.

Result.—After a time the seedling dies, as it is insufficiently nourished

Plants, therefore, must absorb certain substances from the soil. These substances can only enter into the plant in solution in water, absorbed by the root-hairs, as solids cannot pass through the cell-walls.

By burning plants, collecting the gases given off during the process, and analysing the ash that remains, the elements which enter into the composition of the plant can be ascertained.

The gases given off during the process of burning are carbon dioxide (CO_2), water vapour (H_2O), and nitrogen. The elements contained in the ash vary in different plants, but the chief are: nitrogen, sulphur, phosphorus, potassium, magnesium, calcium, and iron.

These substances must have been absorbed by the plant in some form.

Various solutions, called **Water-culture** solutions, have been prepared containing these elements, and plants grown in them.

By omitting different elements, and observing the result on plants grown in such solutions, it has been discovered which elements are essential to the healthy growth of plants. For instance, if iron be omitted, the plant does not become green, and consequently cannot thrive.

A culture solution recommended by Sachs contains the following:—

"Potassium nitrate	...	1·0 gram.
Sodium chloride	...	0·5 ,,
Calcium sulphate	...	0·5 ,,
Magnesium sulphate	...	0·5 ,,
Calcium phosphate	...	0·5 ,,
Water	...	1000 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 to it." (Taken from Darwin and Acton's *Physiology of Plants.*)

Experiment 3.—Grow Wallflower seedlings in water culture solution, and others in distilled water.

Result.—Those grown in the culture solution thrive, while those grown in distilled water die.

Experiment 4.—To prove that plants take something from the air when in the light.

Weigh two equal quantities of cress or mustard seeds. Allow one set to germinate and grow in moist earth in the light, and the other set in moist earth in the dark for about ten days.

Result.—Those grown in the dark are long, straggling, and yellowish in colour, while those grown in the light are healthy and green. Dry both sets in a water-bath to drive off the moisture, and weigh.

Result.—(1) Both sets of seedlings are heavier than the seeds from which they were grown.

(2) Those grown in the light are heavier than those grown in the dark.

Conclusion.—Plants grown in the light, therefore, absorb something from their surroundings which those grown in the dark are incapable of doing. This is found to be carbon dioxide, which is absorbed by the leaves through the stomata from the air in the presence of light.

CHAPTER XIX

ABSORPTION OF GASES BY THE LEAVES FROM THE AIR

Air is a mixture of gases, the chief being oxygen and nitrogen (and argon) with small quantities of carbon dioxide, and varying quantities of water vapour.

Plants are not able to absorb the free nitrogen of the air, but they obtain their nitrogen from the soil in the form of nitrates.

Certain plants, however, belonging to the natural order Leguminosæ, are able to make use of the free nitrogen, by means of small fungi which live upon the roots of such plants. The fungi, apparently, absorb the nitrogen from the air, and form from it certain compounds of nitrogen, which they pass on to the plant. These plants, therefore. can live in soil devoid of nitrates, and when grown in ordinary soil, leave it richer in nitrates than it was before.

The three processes connected with the interchange of gases between the plant and the air are:—

(1) **Respiration**, (2) **Assimilation**, and (3) **Transpiration.**

(1) Respiration is the process of breathing. The breathing process, both in plants and animals, involves the absorption of oxygen and the giving out of carbon dioxide.

Carbon dioxide is produced in the breaking down of protoplasm during growth, and oxygen supplies the energy required to do this.

Tests for oxygen and carbon dioxide. Oxygen is a gas which supports burning. A lighted taper, therefore, will burn in the presence of oxygen.

Carbon dioxide will not support burning. (1) A lighted taper will be extinguished if plunged into a vessel containing an excess of carbon dioxide.

(2) Breathe into a test-tube of lime-water. The lime-water appears milky, owing to the carbon dioxide breathed into it.

Experiment 1.—Take a glass jar, and plunge a lighted taper into it.

Result.—The taper continues to burn. Oxygen is present in the air contained in the jar.

Experiment 2.—Soak some bean seeds for twenty-four hours, and allow to germinate in the bottle after corking it up.

Result.—After a few days plunge a lighted taper into the bottle. The taper goes out, showing that the germinating seeds have used up the greater part or all of the oxygen.

Experiment 3.—Repeat the above experiment, but insert a test-tube containing lime-water into the bottle, and leave for a few days.

Result.—The lime-water has a milky appearance, showing that the seeds have breathed out carbon dioxide.

Experiment 4.—Repeat No. 2, and insert a thermometer in the cork of the bottle. In a similar bottle place some damp saw-dust, and insert a thermometer in the cork, and cover both bottles with a bell-jar. Observe from time to time the temperature registered by the thermometers.

Result.—The temperature of the air in the bottle containing the germinating seeds is higher than that of the other bottle, showing that heat is given out during respiration.

Repeat experiments 2, 3, and 4, and place in the dark.

Result.—The results are the same, showing that respiration goes on equally in the light and in the dark.

Summary of facts regarding respiration:—

1. Respiration involves the taking in of oxygen and the giving out of carbon dioxide.
2. It goes on in the light and in the dark.
3. Heat is given out during respiration.

Assimilation.—The green parts of a plant, during daylight, absorb carbon dioxide from the air; by means of the chlorophyll they break up the carbon dioxide, and combine the carbon with the elements of water (hydrogen and oxygen) to form starch. Starch, therefore, is a compound, consisting of the three elements—carbon, hydrogen, and oxygen. The oxygen of the carbon dioxide is given back to the air through the stomata.

To prove experimentally that the absorption of CO_2 takes place during daylight by the green leaves is very difficult, as the giving out of CO_2 in respiration is going on side by side with it, but from the presence of starch in green leaves grown in the light, the absorption of CO_2 may be inferred.

Experiment 5.—Take some fresh leaves of a plant grown in the light. (Nasturtium or Lilac answers very well.)

Boil for a minute in water, and then place them in alcohol to deprive them of their green colouring matter; pour over them a weak solution of iodine.

Result.—The leaf has numerous blue patches on it, showing that starch has been formed in the leaf during daylight.

Test for starch. Take some ordinary starch and pour a weak solution of iodine over it. The starch turns blue.

Experiment 6.—Repeat experiment 5 with leaves of a plant that has been kept in the dark.

Result.—No blue patches are seen, therefore the leaf does not contain starch.

Conclusion.—The absorption of CO_2 takes place only in the light, and starch is formed only in the leaves of plants exposed to light.

Experiment 7.—Repeat experiment 5 with colourless leaves.

Result.—No starch is observed. Assimilation, therefore, takes place only in the green parts of plants.

Experiment 8.—Take a water plant (Elodea or any other), and place it in a beaker of water. Over it invert a funnel, and cover the end of the funnel with a test-tube filled with water, and place in sunlight. (Fig. 88.)

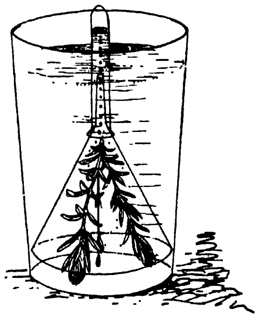


Fig 88 —Diagram showing apparatus for respiration

Result.—Bubbles rise from the leaves of the plant, and collect in the test-tube, displacing the water.

Test the gas with a lighted taper. The taper burns more brightly than in the air. The gas, therefore, is oxygen, which is given off by green leaves during sunlight, as the result of the breaking up of the carbon dioxide.

Summary of facts:—

(1) Assimilation takes place during sunlight, ceases in the dark.

(2) The presence of chlorophyll is necessary.

(3) It involves absorption of CO_2 and the giving out of O.

(4) It results in the formation of starch, from the carbon of CO_2 and the hydrogen and oxygen of the water, taken in by the root-hairs.

Comparison of—

RESPIRATION	ASSIMILATION
1. Carbon dioxide is given off.	1. Carbon dioxide is absorbed.
2. Oxygen is absorbed.	2. Oxygen is given out.
3. Takes place always, during day and night.	3. Takes place during daylight only.
4. Takes place over the whole surface of the plant.	4. Takes place only in the green parts of plants.

Respiration and assimilation go on side by side during daylight, but assimilation is greater than respiration, which therefore cannot be detected. During darkness assimilation ceases and respiration becomes evident, but the total amount of CO_2 absorbed by the plant during assimilation is greater than that given off in respiration. Plants, therefore, tend to purify the air, for they use up the poisonous gas CO_2 and give out O.

The starch formed in the leaves during daylight is removed from the leaves during darkness. Starch is not soluble in water, and therefore cannot pass through the cell-walls. It is changed into sugar, and in this form is passed from cell to cell, to be used up wherever growth is taking place, or to be stored up again in the form of starch in tubers, bulbs, or tap-roots, &c.

Microscopic Work.—Cut with a razor a thin section of potato and place on a glass slip in a drop of glycerine. Place over it a glass cover slip and examine under the microscope.

Observe the cellular structure, and the numerous starch grains contained in the cells. Stain with iodine—the starch grains turn violet-blue in colour.

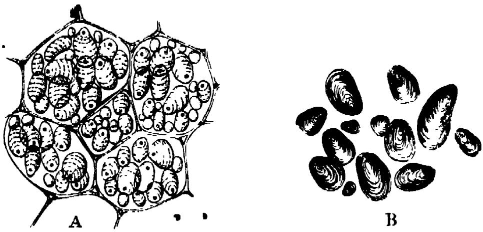


Fig. 89.—A, Cells from Potato Tuber showing Starch Granules; B, Starch Grains of Potato more highly magnified

For the building up of protoplasm a more complex food material than starch or sugar is required. The sugar is combined with certain compounds (nitrates, sulphates, and phosphates, &c.) to form what are called **proteid** substances. These form food for the protoplasm.

CHAPTER XX

GROWTH

In tracing the development of a seedling into a plant, we see that it takes in food substances from the air and soil, and out of these materials builds up its own substance, protoplasm, cell-walls, &c., thereby increasing in size and weight. This process is called growth.

The processes connected with growth have already been described, and we have seen that in assimilation there is the building up of complex substances from simpler ones, and in respiration the breaking down of complex substances into simpler ones. These two processes are always at work. When the building-up process is in excess of the breaking-down process, growth takes place.

Some of the chief products of the building-up process are starch and protoplasm.

Protoplasm is also constantly being broken down; cellulose, the substance of the cell-walls, is one result of the breaking down of protoplasm.

The conditions necessary for growth are:—

1. **Warmth.**—A suitable temperature, promotes healthy growth, all other conditions being supplied. Protoplasm, the living substance, is killed by intense heat or cold, and without the living substance no growth can take place.

2. **Air.**—The oxygen of the air is necessary, as it supplies energy, required in the building up and breaking down of substances during growth.

3. **Moisture.**—

(1) The cells of plants are kept in a healthy condition by water.

(2) Many of the substances required by the plant enter into the plant in solution in water.

(3) The elements of water enter into the com-

position of starch, and therefore of protoplasm. Without water, therefore, growth cannot take place.

Plants in dry regions adapt themselves to be able to endure periods of drought. They become succulent to retain the moisture, and very often the surface of the leaf is protected by a thick cuticle.

The leaves and transpiring surfaces are sometimes reduced to lessen transpiration—for instance, leaves may be modified into spines.

4. **Light** influences plants (*a*) chemically, (*b*) mechanically.

(*a*) **Chemical effects.**—(1) The green colouring matter (chlorophyll) cannot be formed in the absence of light. If plants, which normally contain chlorophyll, are placed in the dark, the green colouring matter disappears, and they become yellowish in colour. This condition is said to be **etiolated.**

(2) Without light the carbon dioxide of the atmosphere cannot be assimilated by the chlorophyll granules.

The amount of light necessary for the formation of starch is greater than that required for the formation of chlorophyll.

(*b*) **Mechanical effects.**—Plants grow more rapidly in the dark than in the light. Light, therefore, retards growth.

Examine a potato shoot that has been grown in the dark. It has an etiolated appearance; the stem has long internodes and small undeveloped leaves.

Plants grown in the dark, as the potato shoot, lose in weight, whereas those grown in the light gain in weight.

The chemical effects are produced by the rays of light towards the red end of the spectrum; the mechanical effects mainly by those towards the blue end. Plants devoid of chlorophyll cannot make use of the CO_2 of the air, and are therefore independent of light; but they absorb their food in a more complex form—*i.e.* they obtain their food from decaying animal or vegetable matter upon which they live, whence they are called **saprophytes** (Gk. *sapros* = rotten, *phyton* = a plant), or from living organisms, when they are called **parasites.**

Mistletoe, although a green plant, lives upon other trees, absorbing food from them. As it has chlorophyll, it can assimilate the CO_2 of the air. but it depends upon its host for the substances derived by the roots from the soil. Such a plant is a **partial parasite.**

5. **Suitable soil or surroundings.**—The plant must have presented to it in a suitable form the elements necessary for its nutrition. (See p. 84.)

PART IV—CLASSIFICATION

CHAPTER XXI

PHANEROGAMS OR FLOWERING PLANTS

Phanerogams are divided into two groups:—

1. **Gymnosperms** (Gk. *gymnos* = naked, *sperma* = seed), in which the ovules are not enclosed in an ovary, but are naked.

2. **Angiosperms** (Gk. *angos* = a vessel, *sperma* = seed), in which the ovules are contained in a closed vessel or ovary.

Angiosperms are divided into two classes:—

(1) **Monocotyledons.**
(2) **Dicotyledons**

1. **Monocotyledons** take their name from the fact that they have **one** cotyledon or seed-leaf, and are characterized by having—

(*a*) no main or tap root,
(*b*) scattered arrangement of fibrovascular bundles in the stem,
(*c*) generally no increase in thickness in the stem,

(*d*) n separable bark,
(*e*) parallel-veined leaves,
(*f*) the parts of a flower are generally three in each whorl.

2. **Dicotyledons**, with two cotyledons or seed-leaves, are characterized by having—

(*a*) a tap-root,
(*b*) fibrovascular bundles arranged in a ring in the stem,
(*c*) increase in thickness in the stems by the addition of new rings of wood,
(*d*) a separable bark,
(*e*) netted-veined leaves.
(*f*) the parts of a flower are two, four, or five in each whorl

Monocotyledons and Dicotyledons are divided into divisions, subdivisions, and natural orders.

Smaller differences in the characters divide the natural orders into genera, and genera into species.

PHANEROGAMS.

- I. GYMNOSPERMS.
  - Coniferæ.
- II. ANGIOSPERMS.
  - (1) MONOCOTYLEDONS.
    - (*a*) Nudifloræ (no petals).
    - (*b*) Petaloidæ.
      - Epigynæ.
        - 1. Orchidaceæ.
        - 2. Iridaceæ.
        - 3. Amaryllidaceæ.
      - Hypogynæ.
        - 4. Liliaceæ.
  - (2) DICOTYLEDONS.
    - (*a*) Polypetalæ (petals free).
      - *1. Ranunculaceæ.
      - 2. Papaveraceæ
      - 3. Cruciferæ.
      - 4. Caryophyllaceæ.
      - 5. Malvaceæ.
      - *6. Leguminosæ.
      - 7. Rosaceæ.
      - 8. Umbelliferæ.
    - (*b*) Gamopetalæ (petals joined).
      - 1. Compositæ (Epigynæ).
      - Hypogynæ.
        - 2. Primulaceæ.
        - 3. Boraginaceæ.
        - 4. Scrophulariaceæ.
        - 5. Labiatæ.
    - (*c*) Apetalæ (no petals).
      - 1. Cupuliferæ.

N.B.—*1, 2, 3, 4, 5 belong to Thalamifloræ. *6, 7, 8 belong to Calycifloræ.

CHAPTER XXII

RANUNCULACEÆ

Type—**Buttercup.** (*Ranunculus bulbosus.*)

Parts.	No	Joined or Free (cohesion)	Position (adhesion).	Remarks
Calyx (sepals)	5	Free (poly-sepalous)	Inferior	Reflexed, hairy.
Corolla (petals)	5	Free (poly-petalous)	Hypo-gynous (below the ovary)	Yellow, smooth, shiny; nectary at the base of each petal.
Andrœcium (stamens)	∞ (indefinite)	Free	Hypo-gynous (below the ovary)	Anther yellow, opens down the sides to shed the pollen.
Gynæceum (carpels)	∞	Free	Superior	Ovary flat, one ovule in each; stigma a point.

Floral Formula—K 5, C 5, A ∞, G $\underline{\infty}$.

Fruit—A head of achenes.

The chief characteristics of the order are:—

Fig. 90.—Floral diagram of Buttercup

1. All parts are free and on the receptacle.

2. Plants are herbs, except Clematis, which is a shrub.

Other plants are:—

Anemone—It has an involucre of 3 leafy bracts; calyx petaloid; corolla missing.

3. **Clematis**—Calyx petaloid; corolla missing. In Traveller's Joy styles are feathery.

4. **Monkshood**—Calyx petaloid; 1 sepal helmet-shaped, covering 2 petals, which are reduced to nectaries.

5. **Larkspur**—Calyx petaloid; 1 back sepal horned, 2 petals spurred and prolonged into the horn-shaped sepal; the nectaries are at the end of the spurred petals.

6. **Hellebore or Christmas Rose**—Sepals green, or petaloid; petals reduced to horn-shaped nectaries.

7. **Columbine**—Sepals petaloid: petals horned.

PAPAVERACEÆ

Type—**Poppy**. Plant a herb, with a milky juice.

Flower—Perfect, complete, regular.

Calyx—2 sepals, free, inferior; they fall off very soon.

Corolla—4 petals, free, hypogynous, crumpled in the bud.

Andrœcium—Indefinite stamens, free, hypogynous.

Gynæceum — Indefinite carpels, syncarpous, superior. Ovary is 1-celled, containing numerous projecting parietal placentas. Stigma capitate.

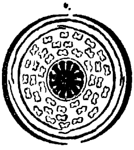


Fig. 91.—Floral diagram of Poppy

Fruit a capsule, dehiscing by numerous pores underneath the stigmas.

Floral Formula—K 2, C 4, A ∞, G ($\underline{\infty}$).

[*N.B.*—In this and the following formulæ round brackets denote cohesion, square brackets adhesion.]

The Greater Celandine has only 2 carpels.

CRUCIFERÆ

Type—**Wallflower**. Plant a perennial, woody at the base.

Inflorescence—A raceme without bracts.

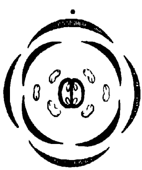


Fig. 92.—Floral diagram of Wallflower

Flower—Perfect, complete, regular.

Calyx—4 sepals (in 2 whorls), free, inferior.

Corolla—4 petals, free, hypogynous, cruciform.

Andrœcium—6 stamens, free, hypogynous, tetradynamous (2 short and 4 long); 4 in the inner whorl are probably formed from 2.

Gynæceum—2 carpels, syncarpous, superior. Ovary 2 cavities; parietal placentation. (See Fruits.)

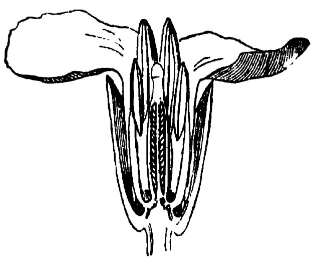


Fig. 93.—Vertical Section of Wallflower (*Cheiranthus*)

Fruit—A siliqua.

Floral Formula—

K 2 + 2, C 4, A 2 + 2^2, G $(\underline{2})$.

Characteristics:—

1. Sepals 4, in 2 whorls.
2. Cruciform corolla.
3. Tetradynamous stamens.
4. Fruit a siliqua or silicula.

Many plants of this order form important articles of food, as tap-roots of turnip and radish. buds of the cabbage, and the axillary buds in Brussels sprouts, cotyledons of mustard and cress, inflorescence of the cauliflower, &c.

CARYOPHYLLACEÆ

Type—**Greater Stitchwort.** A glabrous herb, with opposite leaves.

Inflorescence—A dichotomous cyme.

Flower—Perfect, complete, regular.

Calyx—5 sepals, free, inferior.

Corolla—5 petals, free, hypogynous, petals bifid.

Andrœcium — 10 stamens, free, hypogynous.

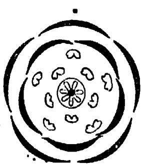


Fig. 94.—Floral diagram of Stitchwort

Gynæceum—3 carpels, syncarpous, superior. Ovary, 1-celled, placentation free-central.

Fruit—A capsule, opening by 6 valves.

Floral Formula—K 5, C 5, A 5 + 5, G $(\underline{3})$

Characteristics:—

1. Stem swollen at the nodes.
2. Leaves opposite.
3. Inflorescence a dichotomous cyme.
4. Gynæceum formed from 2, 3, or 5 carpels, with free-central placentation. Fruit a capsule, opening by twice as many valves as there are carpels.

Plants belonging to the order: Pinks, Chickweeds, Campions, Sandworts, &c.

MALVACEÆ

Type—**Common Mallow.** Herb with alternate leaves.

Flower—Perfect, complete, regular.

Calyx—5 sepals, joined, inferior, with an epicalyx of 3 bracts.

Corolla—5 petals, free, joined by short claws to the stamen tube; twisted in the bud.

Fig. 95 —Floral diagram of Mallow

Andrœcium — 5 stamens (indefinitely branched) joined into a tube round the pistil (monadelphous), hypogynous. Anther, 1 lobe.

Gynæceum—Numerous carpels, syncarpous, superior. Ovary numerous cavities, 1 ovule in each; placentation axile.

Fruit—A schizocarp.

Floral Formula—K (5), [C 5, A 5$^{\infty}$], G $(\underline{\infty})$.

Characteristics:—

1. The epicalyx of the flower.
2. Petals twisted in the bud.
3. Stamens monadelphous.
4. Fruit a schizocarp, splitting into many mericarps.

Plants belonging to the order: **Mallows, Hollyhocks.**

CHAPTER XXIII

LEGUMINOSÆ

Type—**Sweet Pea.** An annual, with alternate compound pinnate leaves, the terminal and one or two lateral pairs of leaflets converted into tendrils.

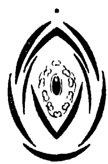


Fig 96.—Floral diagram of Sweet Pea

Flower—Perfect, complete, irregular

Calyx—5 sepals, joined, inferior.

Corolla—5 petals, free, perigynous. Corolla papilionaceous, and is characteristic of all British Leguminous plants. The back petal is called the **standard,** the two lateral ones the **wings**, and the two inner front ones combined form the **keel**. The shape of the flower is adapted to help in cross-fertilization. When a bee visits the flower, it alights on the wings and keel; the weight of the bee depresses the keel, the stigma protrudes and strikes against the under surface of the bee's body (which is probably dusted with pollen from another flower), and is therefore cross-pollinated. Afterwards the stamens project from the keel, and add fresh pollen to the under surface of the bee.

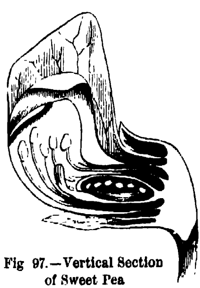


Fig 97.—Vertical Section of Sweet Pea

If cross-pollination fails, the stigma is fertilized by pollen from its own stamens.

Andrœcium—10 stamens, 9 joined by their filaments and 1 free (**diadelphous**), perigynous.

Gynæceum—1 carpel, superior. Ovary 1 cell, marginal placentation.

Fruit—A pod or legume.

Floral Formula—\|/ [K (5) C 5, A (9) + 1], G 1.

Characteristics:—

1. Flowers papilionaceous.
2. Stamens 10, monadelphous or diadelphous.
3. Fruit a pod or legume.

Plants belonging to the order are: Clover (with corolla attached to the stamen tube), Genista, Gorse (provided with spines, derived both from leaves and branches), Vetches, Medicks, &c.

ROSACEÆ

Type—**Dog-rose**. A shrub; stems provided with prickles; leaves compound, pinnate, and stipulate.

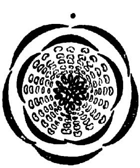


Fig. 98.—Floral diagram of Rose

Flower—Perfect, complete, regular.

Calyx—5 sepals, joined, inferior.

Corolla—5 petals, free, perigynous.

Andrœcium—Numerous stamens, free, perigynous.

Gynæceum—Numerous carpels, free, superior. Placentation basal.

The ovaries are arranged on the base and sides of the hollow receptacle, which forms part of the fruit called the **hip**. The true fruits are the achenes, covered with hairs, contained within the receptacle.

Floral Formula—[K (5), C 5, A ∞], G $\underline{\infty}$.

The number of carpels, the nature of the receptacle, and consequently of the fruit, vary considerably in the order.

Cherry and Blackthorn—Gynæceum formed from 1 carpel, with 2 ovules; the ovary is enclosed by the receptacle but not united to it. After pollination the receptacle falls off, fruit becomes succulent and forms a **drupe** containing 1 seed, as 1 ovule only develops.

Spiræa—3 to 5 free carpels on a dry receptacle, each containing 2 seeds. Fruit—a **number of follicles.**

Geum or Avens—Numerous carpels, free, on a dry receptacle. Fruit—a **number of achenes** provided with awns, hooked at the end, aiding in the dispersal.

Raspberry and Blackberry — Numerous carpels, free, on a dry conical receptacle. Fruit — the carpels become succulent forming a **number of drupels.**

Strawberry — Numerous carpels, free; the receptacle becomes very much swollen and succulent. Fruits are **achenes** on the outside of the receptacle.

Potentilla—Numerous carpels on a slightly enlarged receptacle. Fruit—a **number of achenes.**

Pear and Apple—5 carpels completely united to the receptacle, so that the ovary is inferior. The receptacle becomes swollen and succulent. Fruit—**a pome.**

Hawthorn—1 or 2 carpels. Fruit similar in structure to the pome, but differing in the bony character of the walls of the carpels.

Characteristics of the Order:—

1. Sepals 5, gamosepalous.
2. Petals and stamens perigynous.
3. Carpels 1, 2, 5, or ∞, apocarpous, and superior, except in Apple.

This order resembles Ranunculaceæ in some respects, but Ranunculaceæ has:—

1. Sepals polysepalous.
2. Hypogynous petals and stamens.

UMBELLIFERÆ

Type—**Cow Parsnip.** A tall, coarse herb with a hollow stem, pinnately-divided leaves, with a large sheath at the base of the petioles.

Fig. 99.—Floral diagram of Cow Parsnip

Inflorescence—A compound umbel.

Flowers—Perfect, complete, outer ones of each inflorescence irregular.

Calyx—5 small teeth, epigynous.

Corolla—5 petals, free, epigynous.

Andrœcium—5 stamens, free, epigynous.

Gynæceum—2 carpels, syncarpous, inferior. The two styles are united at the base to form a disc—the nectary. Ovary 2 cavities 1 ovule in each, placentation pendulous.

Fruit—a schizocarp, splitting into 2 mericarps.

Floral Formula—\|/ K (5), C 5, A 5, G $(\overline{2})$.

Characteristics of the Order:—

1. Inflorescence a compound umbel, sometimes simple.

2. Flowers epigynous.

3. Fruit a schizocarp of 2 mericarps.

Plants belonging to the order: Parsley, Carrot, Parsnip, Celery, &c.

CHAPTER XXIV

GAMOPETALÆ

Natural Order Compositæ.—The chief characteristic of this order is the inflorescence—a head or capitulum. It consists of an involucre of bracts, surrounding a number of sessile florets. The inflorescence has the appearance of a flower, the bracts representing the calyx, and the outer florets the corolla.

Tribe Tubulifloræ. Type—**Daisy.** A small herb with radical leaves.

Inflorescence—A head consisting of—

(1) An involucre of small green bracts.

(2) A number of outer white or pink **ray** florets (Fig. 100, B.)

(3) Numerous yellow **disc** florets. (Fig. 100, A.)

Ray florets—Imperfect, incomplete, irregular.

Calyx—Absent.

Corolla—Strap-shaped or ligulate, slightly toothed at the top, epigynous.

Andrœcium—Absent.

Gynæceum—2 carpels, syncarpous, inferior. Ovary 1-celled, 1 ovule, basal placentation. Style ending in a bifid stigma.

Floral Formula—\|/ K 0, C (5), A 0, G ($\bar{2}$).

Disc florets—Perfect, incomplete, regular.

Calyx—Absent.

Corolla—5 petals, joined, epigynous. Corolla tubular.

Andrœcium—5 stamens. joined by their anthers

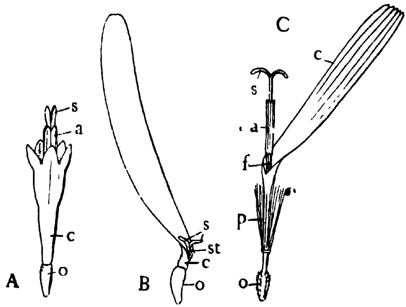


Fig. 100.—A, Disc Floret of Daisy; B, Ray Floret of Daisy; C, Floret of Dandelion; *o*, ovary; *p*, pappus; *c*, corolla; *a*, anther tube; *st*, style; *s*, stigma; *f*, filaments.

(syngenesious), forming a tube round the style epipetalous.

Gynæceum—2 carpels, syncarpous, inferior. Ovary, style, and stigma similar to those of the ray florets.

Floral Formula—K 0 [C (5), A (5)], G ($\overline{2}$).

Fruit—An achene formed from an inferior ovary of 2 carpels, and so called a **cypsela**.

The Daisy belongs to the tribe of Compositæ called Tubulifloræ, because some of the florets are tubular. This tribe includes also:—

Cornflower—Outer florets neuter (having neither stamens nor pistils), inner tubular and perfect. Calyx represented by a pappus. The outer florets serve to make the head more attractive.

Thistles—All florets tubular and perfect.

Everlastings—Some flower-heads are staminate, and some are pistillate.

Tribe Liguliforæ. Type — **Dandelion.** A low herb, with radical toothed leaves.

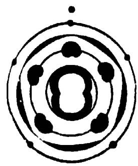


Fig 101 —Floral diagram of Compositæ

Inflorescence—A head consisting of—

(1) An involucre of bracts.

(2) Numerous ligulate (strap-shaped) florets. (Fig 100, c.)

Florets—Perfect, complete, irregular.

Calyx—A pappus, consisting of numerous fine hairs, superior.

Corolla—5 petals, joined, epigynous.

Andrœcium—5 stamens, syngenesious, epipetalous.

Gynæceum—2 carpels, syncarpous, inferior. The ovary, style, and stigma resemble those of the florets in the Daisy.

Fruit—A cypsela; it terminates in a long beak, surmounted by a brush of hairs, which aids in the dispersal of the fruit.

Floral Formula—\|/ K (pappus), [C (5), A (5)], C $(\overline{2})$.

Allied plants are Hawkweeds, Hawkbits, &c.

Type—**Primrose** A short herb with simple radical leaves.

Inflorescence — An umbel with short peduncle and long pedicels. The peduncle does not rise above the ground, so that the flowers appear to be solitary.

Flower—Perfect, complete, regular.

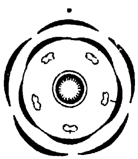


Fig. 102.—Floral diagram of Primrose

Calyx—5 sepals, joined, inferior.

Corolla—5 petals, joined, hypogynous.

Andrœcium—5 stamens, free, epipetalous; the stamens are opposite the corolla lobes, and not alternate with them.

Gynæceum — 5 carpels, syncarpous, superior. Ovary 1 cavity, free-central placentation. The 5 carpels cannot be seen without the aid of the microscope, but the fruit dehisces by 10 teeth, so that the number of carpels may be assumed. Fruit—a capsule.

The flowers are dimorphic (having two forms) to aid in cross-fertilization.

Floral Formula—K (5), [C (5), A 0 + 5], G $\underline{(5)}$.

Characteristics:—

1. Floral whorls consist of 5 leaves.
2. Stamens opposite the corolla lobes.
3. Gynæceum consisting of 5 carpels, superior. Placentation free-central.

Plants belonging to the order are:—Oxlips, Cowslips (with distinct umbels), Pimpernels (fruits dehiscing by a lid), and Cyclamen (with reflexed petals).

BORAGINACEÆ

Type—**Borage.** A rough herb with alternate leaves.

Infloresence—A scorpioid cyme.

Flowers—Perfect, complete, regular.

Calyx—5 sepals, gamosepalous, inferior.

Carollo—5 petals, gamopetalous, hypogynous. Rotate, with a short tube, the mouth of the tube closed by 5 small scales.

Andrœcium—5 stamens, free, epipetalous, alternating with the corolla lobes. Anthers form an erect cone round the style.

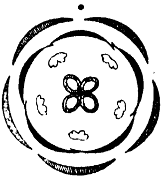


Fig. 103. — Floral diagram of Forget-me-not

Gynæceum—2 carpels, syncarpous, superior. Ovary divides into 4, with 1 ovule in each division. Placentation basal.

Fruit—4 nutlets.

Floral Formula—K (5), [C (5), A 5], G $\underline{(2)}$.

Characteristics:—

1. Plants roughly hairy.
2. Inflorescence—a scorpioid cyme.
3. Stamens 5.
4. Fruit—4 nutlets.

The order closely resembles Labiatæ, but is distinguished from it by its more regular flowers and its alternate leaves.

Plants belonging to the order are: Forget-me-not, Hound's Tongue, Bugloss.

SCROPHULARIACEÆ

Type—Figwort. A perennial with square stem and opposite leaves.

Inflorescence—Axillary cymes.

Flowers—Perfect, complete, irregular

Calyx—5 sepals, joined, inferior.

Corolla—5 petals, joined, hypogynous; two back ones form an upper lip.

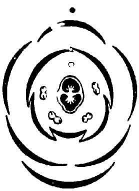


Fig 104.—Floral diagram of Snapdragon

Andrœcium—4 stamens, free, epipetalous, and didynamous (2 long and 2 short); a small scale on the upper lip represents a fifth barren stamen or staminode.

Gynæceum—2 carpels, syncarpous, superior. Ovary 2-celled, numerous ovules, axile placentation; placenta dumb-bell shaped.

Fruit—A capsule dehiscing by 2 valves.

Floral Formula—·|· K (5), [C (5), A 4 + 1 † (staminode)], G $\underline{(2)}$.

Characteristics:—

1. Flowers generally two-lipped (sometimes rotate).

2. Stamens either 2, 4 (didynamous), or rarely 5; epipetalous.

3. Gynæceum 2 carpels, syncarpous, with axile placentation; placenta dumb-bell shaped.

In the Figwort the gynæceum matures before the stamens; in the Foxglove and Snapdragon the stamens mature before the gynæceum. The shape of many of the flowers belonging to the order is adapted to the visit of certain insects; for instance, Foxglove and Snapdragon to the visit of bees.

Plants belonging to the order: Foxglove and Snapdragon with 4 stamens; Mullein with rotate

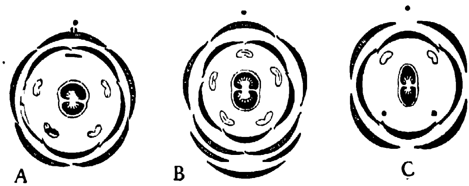


Fig. 105.—Floral diagrams A, Figwort; B, Mullein; C Veronica

corolla and 5 stamens; Veronicas, rotate corolla and 2 stamens; Toadflax (spurred corolla); Eyebright, Bartsia, and the Rattles are partial parasites.

LABIATÆ

Type — **White Dead-nettle.** A perennial with a square stem and opposite and decussate leaves.

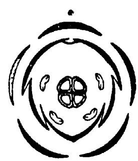


Fig. 106.—Floral diagram of Dead-nettle

Inflorescence—Verticillasters, *i.e.* shortly-stalked cymes in the axils of the opposite leaves; the flowers are so densely crowded that they appear as if in whorls round the stem.

Flowers—Perfect, complete, irregular (bilabiate).

Calyx—5 sepals, gamosepalous, inferior.

Corolla — 5 petals, gamopetalous, hypogynous; bilabiate, two petals forming the upper lip, two lateral ones, and one forming the lower lip.

Andrœcium — 4 stamens, free, epipetalous, and didynamous.

Gynæceum — 2 carpels, syncarpous, superior Ovary divides into 4, with one ovule in each division; placentation basal. Style springs from the base of the gynæceum, and is therefore called gynobasic. Stigma bifid.

Fruit—4 nutlets.

Floral Formula—\|/ K (5), [C (5), A 4], Ģ (2).

Characteristics:—

1. Stem square.
2. Leaves opposite and decussate.
3. Flowers in verticillasters.
4. Flowers bilabiate.
5. Stamens 4, didynamous.
6. Ovary 4-celled, one ovule in each; placentation basal.

Differences between Scrophulariaceæ and Labiatæ are:—

LABIATÆ	SCROPHULARIACEÆ
1. Ovary 4-celled, placentation basal.	1. Ovary 2-celled, placentation axile.
2. Fruit—4 nutlets.	2. Fruit—A capsule.

And between Labiatæ and Boraginaceæ:—

LABIATÆ	BORAGINACEÆ
1. Leaves opposite and decussate.	1. Leaves alternate.
2. Flowers irregular and bilabiate.	2. Flowers generally regular.
3. Stamens 4, didynamous.	3. Stamens 5.

In the Sage there are only 2 stamens; the connective of the stamen is long and slender, bearing at each end an anther lobe; the upper lobe contains pollen, but the lower one is barren. The two stamens with their long connective close up the entrance to the corolla tube, but on a bee visiting the flower, the lower lobe is pushed back, and the upper one comes downwards and forwards dusting the back of the bee with pollen. In an older flower the stigma has bent forward, and is in the correct position to be dusted with pollen, and hence cross-pollination is effected.

The order Labiatæ is a very large one; it contains numerous genera difficult to identify, as the differences between them are very small.

APETALÆ

Natural Order Cupuliferæ. Type—**Hazel** (*Corylus Avellana*). A shrub with alternate leaves and monœcious flowers.

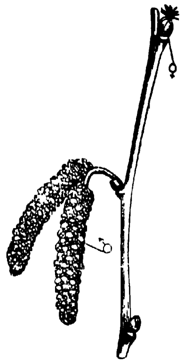


Fig. 107.—Catkins of Hazel
♂ male, ♀ female flowers.

Male flowers are arranged in catkins. Each flower consists of a bract and 2 bracteoles, with 8 stamens inserted on them.

Female flowers are arranged in a bud. The bud consists of numerous overlapping scales, of which the inner ones only are fertile. The inner scales bear 2 flowers, each surrounded by a little jagged scale. The flower consists of an ovary with a rudimentary perianth on the top of it, and 2 styles. The ovary is 2-celled, with one ovule in each; one cell only develops with its one ovule, forming in fruit a nut surrounded by the inner jagged scale which enlarges considerably.

CHAPTER XXV

CLASS MONOCOTYLEDONS

Division Petaloidæ

Natural Order Orchidaceæ.—Spotted Orchid A perennial herb, having underground tubers, which act as storehouses of food.

Inflorescence—A spike.

Flower—Perfect, complete, irregular.

Perianth—6 segments, gamophyllous (joined), superior. The segments are 3 outer and 3 inner. The back inner segment becomes the front one by the twisting of the ovary; it is spurred and much larger than the others, forming a lower lip or labellum, on which the insect alights.

Andrœcium—1 stamen and 2 staminodes, gynandrous (combined with the style).

Gynæceum—3 carpels, syncarpous, inferior. Ovary twisted, 1 cavity, numerous ovules, parietal placentation. Stigmas 3, 2 fertile ones and 1 barren one called the rostellum.

The andrœcium, style, and stigmas are united into a structure called the **Column**.

The upper part of the column is occupied by the

2 anther lobes, each of which contains a **pollinium.** A pollinium is a club-shaped mass of pollen grains connected by elastic threads, and prolonged at the base into an elastic stalk and terminated by a small sticky surface. The two staminodes are lateral projections of the column.

The 3 stigmas are at the base of the column; two are fertile and form a sticky stigmatic surface above the entrance to the spur of the labellum; the other, placed above the stigmatic surface, is barren and is called the rostellum; and on either side of the projecting rostellum are the two sticky surfaces of the pollinia.

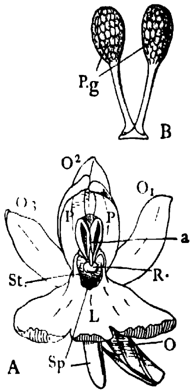


Fig 108 A, Flower of Orchid; B, Two Pollinia, much enlarged; L, Labellum, P, Two inner perianth leaves; O_1, O_2, O_3, Outer perianth leaves; Sp., Spur of labellum; P.g, Pollen-grains. *a*, anther, R, rostellum, St., stigma, forming the column.

The structure of the flower is specially adapted to cross-fertilization.

When a bee visits the flower it alights on the labellum, and in seeking the honey the two pollinia become attached by their sticky bases to the bee's head or proboscis; they then bend forward owing to the contraction of the stalks, and on the bee visiting another orchid, they are in the correct position to pollinate the stigma.

Floral Formula—\|/ P (3 + 3), [A 1 + 2†, G($\bar{3}$)].


Fig. 109.—Floral diagram of Orchis

Characteristics:—

1. The irregular shape of the flower.

2. The structure called the column.

3. The inferior ovary with 3 parietal placentas.

Plants belonging to the order:—various Orchises, Cypripedium (2 stamens, 1 staminode), Helleborines, &c.

IRIDACEÆ

Crocus—A perennial with an underground stem—a corm, and radical leaves.

Inflorescence—Solitary.

Flower—Perfect, complete, regular.

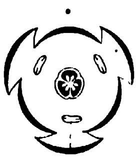


Fig 110 – Floral diagram of Crocus

Perianth — 6 segments, gamophyllous, epigynous. Perianth tube very long and slender.

Andrœcium—3 stamens, free, epiphyllous.

Gynæceum—3 carpels, syncarpous, inferior. Ovary 3-celled, axile placentation. The flower-stalk is very short, so that the ovary is underground. As the fruit ripens the flower-stalk elongates, and carries the fruit above ground to shed its seeds.

Fruit—A capsule.

Floral Formula—[P (3 + 3), A 3], G $\overline{(3)}$.

Characteristics:—

1. Stamens 3.
2. Ovary inferior.

Plants belonging to the order: the Iris, 3 petaloid stigmas, the stigmatic surface being on the under surface and protected by a lip; Freesia and Gladiolus.

AMARYLLIDACEÆ

Daffodil—A perennial with an underground stem—a bulb, and radical leaves.

Inflorescence—Solitary, flower protected by a large bract.

Flower—Regular, perfect, complete.

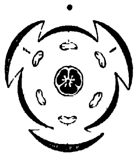


Fig 111 —Floral diagram of Daffodil

Perianth—3 + 3 segments, gamophyllous, epigynous. There is a large outgrowth from the petals called the **corona.**

Andrœcium—3 + 3 stamens, free, epiphyllous. Three stamens are on the outer perianth segments, and three on the inner.

Gynæceum—3 carpels, syncarpous, inferior. Ovary 3-celled, axile placentation.

Fruit—A capsule.

Floral Formula—[P (3 + 3). A 3+3], G $(\overline{3})$.

Characteristics:—

1. Stamens 6.
2. Ovary inferior.

Snowdrop has no corona, and perianth leaves are free.

LILIACEÆ

Bluebell.—A perennial with an underground stem —a bulb, and radical leaves.

Inflorescence—A raceme; each flower has 2 bracts.

Flower—Perfect, complete, regular.

Perianth—3 + 3 segments, joined, hypogynous.

Andrœcium—3 + 3 stamens, free, slightly epiphyllous.

Gynæceum—3 carpels, syncarpous, superior. Ovary 3 cells, numerous ovules, axile placentation.

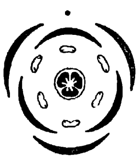


Fig 112.—Floral diagram of Bluebell

Fruit—A capsule.

Floral Formula — [P (3 + 3), A 3 + 3], G (3).

Characteristics.—

1. Stamens 6.
2. Ovary superior.

Plants belonging to the order:—Butcher's Broom is a small shrub with leaf-like branches arising in the axils of scale leaves The true leaves are scales, borne on the branches, and in the axils of the scales are the flowers. The young shoots of Asparagus are eaten, and the bulb of the Onion.

Comparison of the three orders:

Iridaceæ.	Amaryllidaceæ.	Liliaceæ.
1. Stamens 3.	1. Stamens 6.	1. Stamens 6.
2. Ovary inferior.	2. Ovary inferior.	2. Ovary superior

DESCRIPTION OF A FLOWERING PLANT

Name.—

Root.—Kind (fibrous or tap).

Stem.—Duration (tree, shrub, or herb); habit (branched or simple, tuber, corm, bulb, or rhizome); direction (erect, creeping, &c.); shape (round or angular, &c.); surface (hairy, smooth, rough, prickly, &c.).

Leaves.—Radical or cauline (if cauline, opposite, alternate, or whorled), stipulate or exstipulate, petiolate or sessile.

Blade—Simple or compound; shape, margin, apex, surface, venation

Inflorescence.—Definite or indefinite, &c.

Bracts.—Number, shape, texture, &c.

Flower.—Perfect or imperfect; complete or incomplete; regular or irregular.

Calyx.—No. of sepals, cohesion, adhesion. Shape of calyx (if gamosepalous); shape of sepals; colour, &c.

Corolla.—No. of petals, cohesion, adhesion. Shape of corolla (if gamopetalous); shape of petals, colour, nectaries (if any)

Andrœcium.—No. of stamens, cohesion, adhesion.

Filament—Shape

Anther—Shape; attachment (innate, adnate, or versatile); dehiscence (introrse, extrorse, or lateral), by slits or by pores; pollen.

Gynæceum.—No. of carpels, cohesion, adhesion.

Ovary—Shape, No. of cavities, No. of ovules, placentation.

Style—Shape and length

Stigma—Shape.

Fruit.—True or spurious, dry or succulent, dehiscent or indehiscent, &c.

Floral Formula.

Floral Diagram and diagram of longitudinal section of flower.

Classification.—Class.
Division.
Sub-division
Natural order.

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