# SOUTH AFRICAN BOTANY

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# SOUTH AFRICAN BOTANY

Scarlet Salvia (Labiatae) and
Datura (Solanaceae).

# SOUTH AFRICAN BOTANY

BY

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## PREFACE.

Although there are several books dealing with South African Botany, there is none quite suitable for the upper classes of our secondary schools. This is an attempt to remedy that deficiency. The conditions in South Africa are so different from those prevailing in Europe that quite a different flora exists, and, consequently, European text books, excellent as they may be intrinsically, are far from satisfactory as class books for South African Schools.

Although this book is suitable as a class book for those just beginning the study of Botany, the requirements of the syllabus for Botany in the Matriculation examination of the Cape University have been kept in mind, and the orders described are those prescribed in that syllabus. Also we have appended a number of questions taken from past Matriculation and Junior Certificate papers.

We are indebted to the Publishers (Messrs.

Longmans, Green & Co.) for the privilege of using illustrations from Edmonds and Marloth's "Elementary Botany for S. Africa," and from the Revd. Prof. Henslow's "South African Flowering Plants," and to Messrs. C. J. Clay and Sons (Cambridge University Press) for the privilege of using illustrations from Sir Francis Darwin's excellent manual, "The Elements of Botany".

F. W. STOREY.

BLOEMFONTEIN, 1915.

## PREFACE TO SECOND EDITION.

THE call for a new edition of the "South African Botany" has afforded an opportunity to correct a few mistakes incidental to a first edition and to remodel a few paragraphs. The only actual additions to the book are an Appendix to Chapter II. on "Turgor of the Cell" and "Experimental Work" and a new Appendix on the Potometer.

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# COLOURED PLATES.

# CHAPTER I.

## THE STRUCTURE AND GERMINATION OF FAMILIAR SEEDS.

1. **The Broad-Bean Seed.**—If we examine a soaked broad-bean seed (fig. 1) we find on the outside a tough covering, the seed-coat or TESTA, which can easily be removed. At one side of the seed is a broad scar, the HILUM, marking the place where the seed was attached to the bean pod. At the lower end of this scar is a small hole from which a drop of water will exude if the seed is squeezed. This hole is called the MICROPYLE. On removing the testa we find that the inside of the seed consists of a mass of fleshy material, which can easily be split into two lobes.

Each of these lobes is called a COTYLEDON (fig. 1 B). They are really leaves swollen by the deposition of food material. Between the cotyledons are the embryo root and stem. The embryo root, called the RADICLE, points towards the micropyle; the embryo stem, called the PLUMULE, lies between the two cotyledons.

2. **Germination.**—If we supply a dry bean seed with water, air, and a certain amount of warmth, it becomes actively alive, swells, grows, and finally develops into a bean plant. The dry bean was alive, but in a dormant state. This change of a seed from a dormant state to an

active state is spoken of as germination. Before the

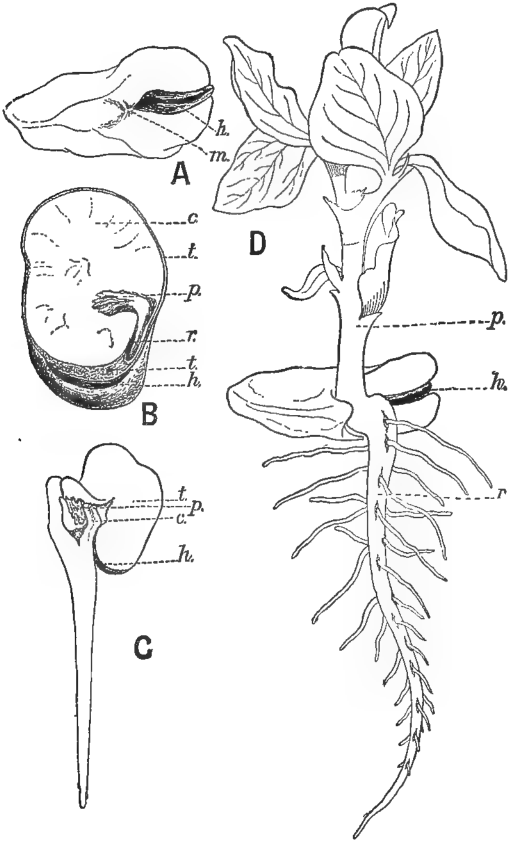



Fig. 1.

A. Broad-bean seed. B. The seed divided longitudinally. C. Germinating seed. D. Seedling plant. *h.* Hilum. *p.* Plumule. *m.* Micropyle. *r.* Radicle. *c.* Cotyledon. *t.* Testa. (From Darwin's "Elements of Botany".)

change can be brought about, three conditions have to be fulfilled. The seed must be supplied with water, the temperature must be between certain limits, in the case of the bean seed between 5° C., and 38° C., and it must have free access to oxygen. Growing plants breathe just as animals do, and hence oxygen is as necessary for their life and growth as it is in the case of animals.

The first thing that can be noticed when a bean seed germinates is the bursting of the testa by the radicle near the micropyle and the elongation of this part downward. After the radicle has reached a certain length, the plumule forces its way out from between the cotyledons, pushing aside a flap of the seed coat, but keeping its upper end curved (fig. 1 c) in order to protect the delicate tip of the plumule. After some time the plumule straightens itself and the leaves surrounding the tip of the plumule begin to unfold. The cotyledons, remain below the ground, giving up their reserve food material to the rapidly growing seedling, and consequently becoming smaller and smaller. All this time the radicle has been increasing in length and giving off lateral branches. The main root, i.e. the root produced by elongation of the radicle, is called the TAP ROOT. It not only bears lateral roots, but also gives rise to a number of fine hairs called ROOT-HAIRS just behind the tip.

3. **The Castor-Oil Seed.**—Although the external appearance of the castor-oil seed does not differ much from that of the broad bean, there are several differences in the internal structure (fig. 2). The testa itself has a hard outgrowth at one end called the ARIL. If we cut a longitudinal section of the seed we find that the

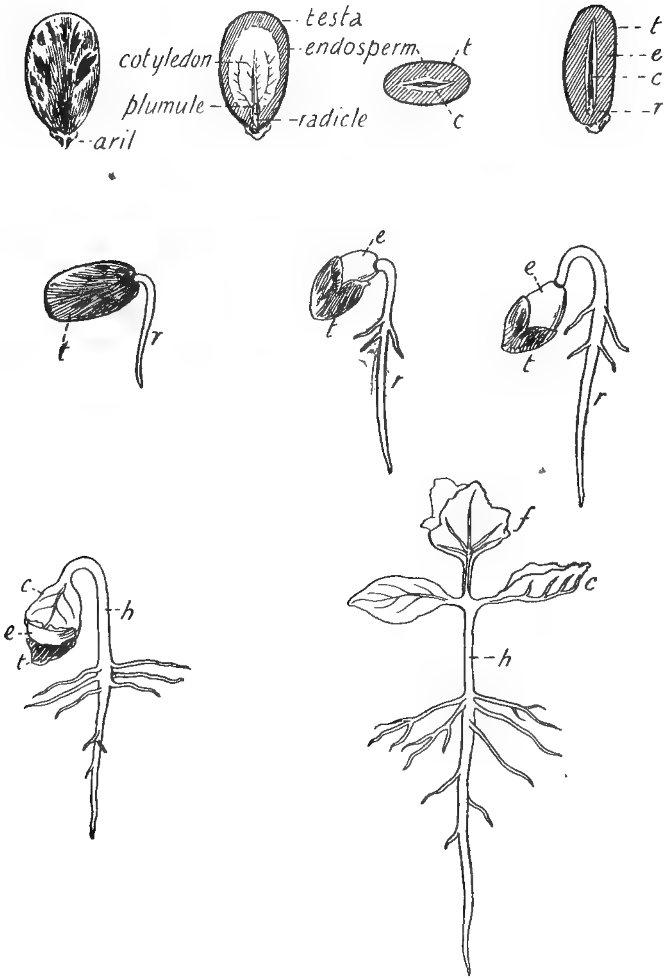



FIG. 2.—The Castor-Oil Seed and its Germination.

*t*. Testa. *e*. Endosperm. *r*. Radicle. *h*. Hypocotyl. *c*. Cotyledon. *f*. Foliage leaves.

Cotyledons do not fill the whole of the space as in the broad bean, but are thin and membranous. They are surrounded by a mass of white substance called the ENDOSPERM. It is the food material. In the case of the broad bean this food material was stored away inside the cotyledons. Here the food material is separate from the cotyledons, forming a separate tissue called the endosperm. Such seeds are known as ENDOSPERMOUS or albuminous seeds. Those like the broad bean are known as EXENDOSPERMOUS or exalbuminous seeds.

The food material in the case of castor-oil seed is not starch, as in the case of the broad bean, but oil. In germination the cotyledons do not remain below the ground as in the broad-bean seedling, but after having absorbed most of the endosperm they come above ground, turn green, and act as the first foliage leaves. Such cotyledons are called EPIGEAL.

Cotyledons which remain below the ground, as those of the broad bean, are called HYPOGEAL.

4. **Maize (mealie).**—The so-called maize seed (fig. 3) is really a fruit, as the outer covering is not the testa but a covering called the pericarp formed from the walls of the ovary. The testa is very thin and is fused to this. There is a striking difference between this seed and the two we have already described. It is an endospermous seed, i.e. the food material lies outside the embryo (cotyledon, plumule and radicle), and in this respect resembles the castor-oil seed, although the food material is starch and not oil. But the embryo contains only one cotyledon. Plants whose seeds contain only one

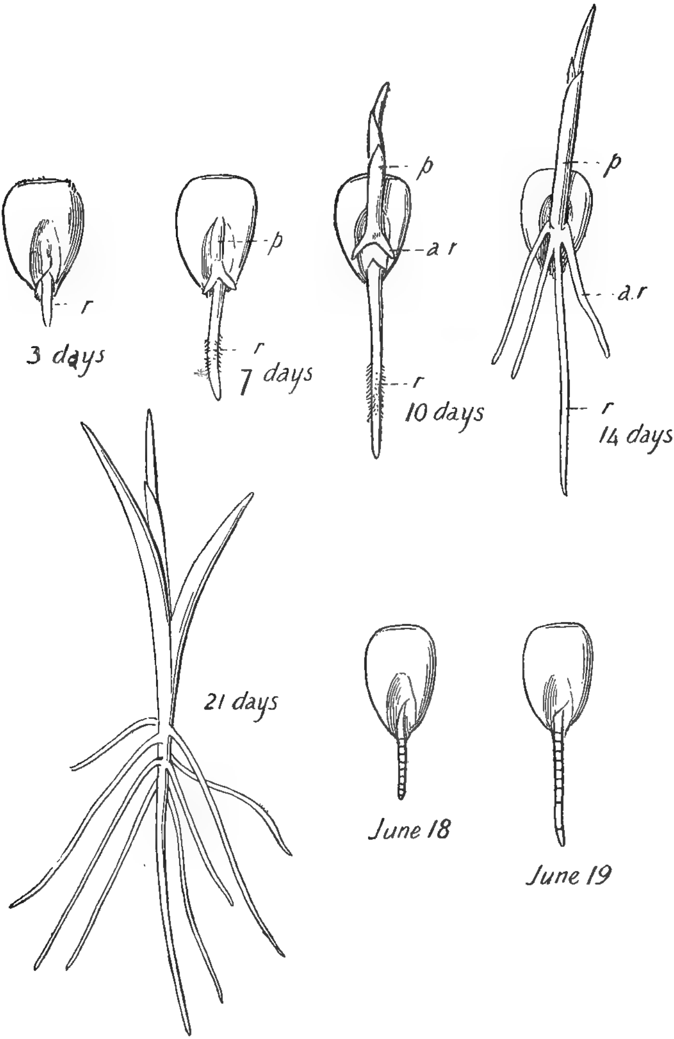



FIG. 3.—The Maize Seed and Its Germination.
*r.* Radicle. *p.* Plumule. *ar.* Adventitious roots.

cotyledon are called MONOCOTYLEDONS, those whose seeds contain two cotyledons are called DICOTYLEDONS. We shall see that along with this difference go many others, and hence the distinction between these two kinds of seeds is of fundamental importance.

The single cotyledon is a shield-like organ and is therefore called the SCUTELLUM. When the seed germinates, the cotyledon remains below the ground absorbing the food material from the endosperm. Hence the cotyledon is hypogeal. Between the scutellum and the endosperm is a layer of cells called the EPITHELIAL layer which secretes a ferment which changes the starch into sugar during the germination. The plumule and radicle are both covered with sheaths. The radicle only grows for a short time, the main root system being developed from the base of the stem by lateral branches. Hence the roots are clustered together in a bundle at the base of the stem and form a fibrous root. These roots are called ADVENTITIOUS roots, since they are not produced in the normal order by branching of the tap root.

5. **The Mustard Seed.**—This is a much smaller seed (fig. 4) than the two we have already described. The testa is yellow and mucilaginous, the cotyledons are thin and leaf-like and are folded on themselves one inside the other and enclose the radicle.

During germination these cotyledons come out of the seed-coat, unfold themselves, turn green, and act as the first foliage leaves. Hence the cotyledons are epigeal. The seed is exalbuminous.

6. **The Sunflower Seed.**—The so-called "seed" is, as in the case of the mealie, really a fruit, the hard black

covering being the pericarp (fig. 5). Inside this is the seed surrounded by a thin yellowish membrane, the testa.

It is exendospermous, the whole seed forming the embryo. It can be readily split into two cotyledons, the plumule lying between them. The pointed end of the seed is a radicle.

During germination the radicle elongates and then that part of the radicle immediately below the cotyledons,

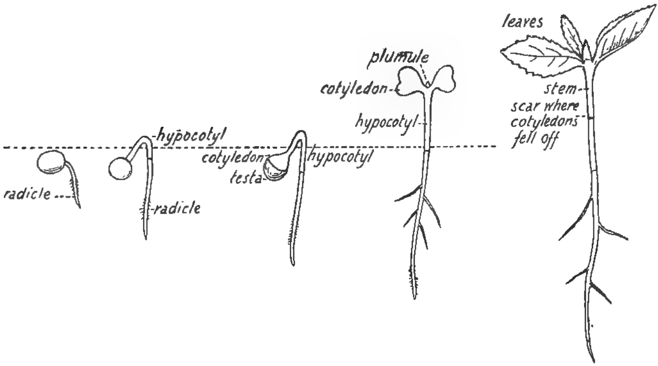



FIG. 4.—The Germination of the Mustard Seed.

known as the HYPOCOTYL, elongates and bends to form a loop. It emerges through the soil in this form and then drags the cotyledons out of the seed-case and lifts them above the ground, where they turn green and act as the first leaves. Sometimes the seed-case is carried above ground by the cotyledons, but soon drops off on their continued growth. This method of drawing the cotyledons above the soil is one often employed by dicotyledonous seeds, as obviously there is less danger to the delicate plumule than there would be by direct growth upwards.

6*a*. **The Pine Seed.**—A pine seed (fig. 6) differs much

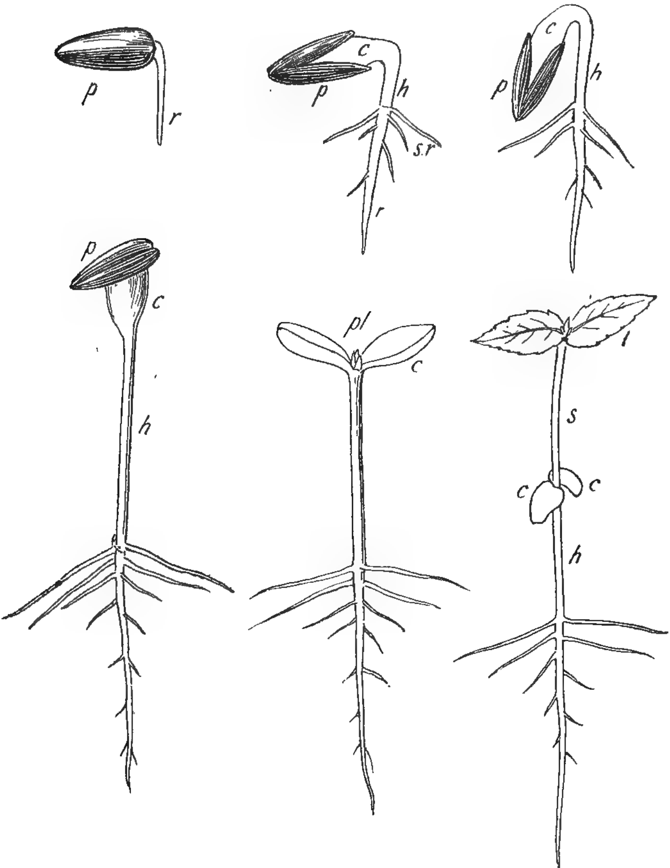



FIG. 5.—Germination of Sunflower Seed.

*p.* Pericarp. *r.* Radicle. *sr.* Secondary roots. *c.* Cotyledon. *h.* Hypocotyl. *pl.* Plumule. *s.* Stem. *l.* Leaf.

from any of those we have already described. The pine belongs to a different group of plants from the bean or

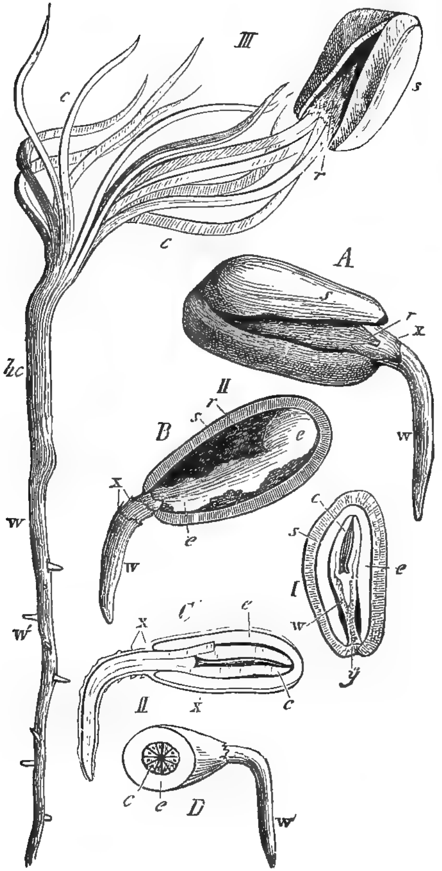



FIG. 6.—Germination of the Pine Seed (*Pinus Pinea*).

I. Longitudinal section of seed. II. Different views of germinating seed. A. Testa ruptured and radicle appearing. B. Portion of testa removed showing endosperm *e*. C. Longitudinal section showing cotyledons *c*. D. Transverse skeleton. III. Cotyledons above ground. *s*. Testa. *w*. Radicle. *y*. Micropyle. *hc*. Hypocotyl. *w'*. Lateral roots (after Sachs) mealie, called the gymnosperms, and the seed contains several cotyledons. It is a very small seed and has a wing attached which helps in fruit dispersal. The testa is a tough coat. Inside are several cotyledons, packed closely together and surrounded by endosperm. The

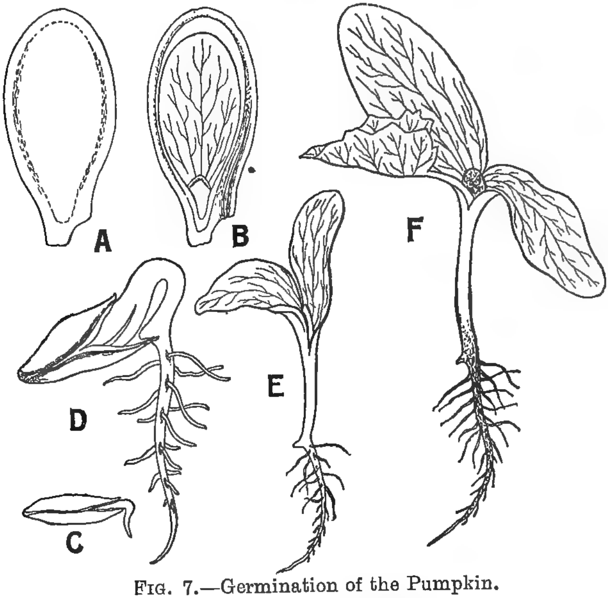



FIG. 7.—Germination of the Pumpkin.

A. The seed. B. The seed laid open showing the cotyledon. C. The seed germinating and radicle growing downwards. D. The cotyledons leaving the testa, the latter being held down by a peg. E. Hypocotyl straightened out and cotyledons fully exposed. F. The first foliage leaves appearing. (From Darwin's "Elements of Botany".)

cotyledons turn green while in the seed. They are epigeal.

7. **The Pumpkin Seed.**—This is a thin flattened seed (fig. 7), oval in outline, the hilum and micropyle being

placed at the narrow end. There are two cotyledons present, but no endosperm. The radicle is similar to that of the sunflower and is found at the pointed end of the seed. The testa is thick and tough. During germination, the radicle develops a peg which holds the

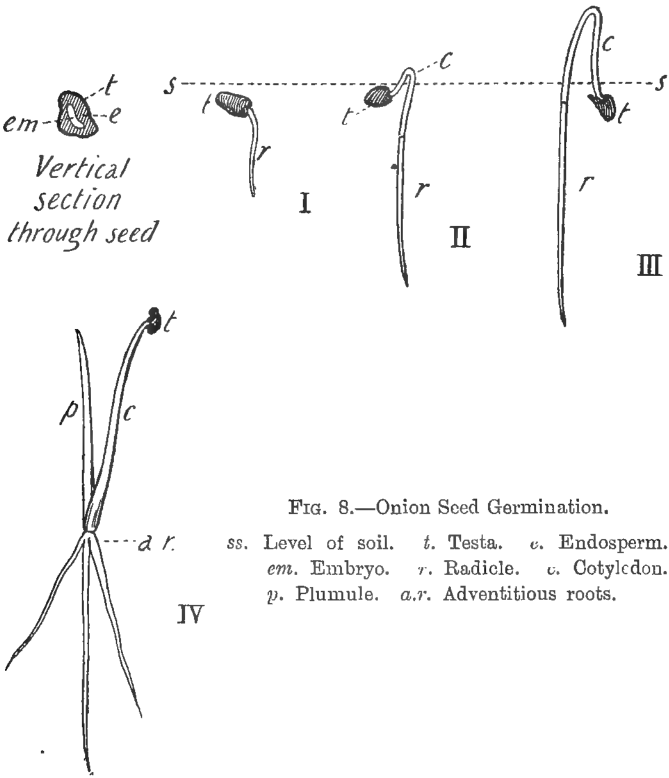



Fig. 8.—Onion Seed Germination.

*ss*. Level of soil. *t*. Testa. *e*. Endosperm. *em*. Embryo. *r*. Radicle. *c*. Cotyledon. *p*. Plumule. *a.r*. Adventitious roots.

seed-coat down, while the elongation of the looped hypocotyl drags the cotyledons out of the case and pushes them above ground. If this peg is removed the cotyledons remain in the seed, although they are finally freed by their own growth bursting the testa.

8. **The Onion Seed.**—This is a small black seed, irregular in shape, but somewhat pointed at the hilum (fig. 8). It contains one cotyledon somewhat curved and embedded in endosperm. The plumule is small and concealed within the base of the hollow cotyledon. Germination proceeds somewhat similarly to that of the sunflower. The radicle elongates but then stops growing, the usual adventitious roots of the monocotyledon being developed at the base of the stem. The lower part of the cotyledon elongates, forms a loop and comes above ground as the first leaf. The tip remains in the seed absorbing the endosperm. Later on a second leaf developed from the plumule bursts through the base of the cotyledon and comes above ground.

9. **The Date Seed.**—The so-called stone of the date fruit is the seed (fig. 9). The hard wooden case is the testa. A small protuberance on the opposite side of the stone to the furrow marks the position of the embryo. If the seed be cut across transversely at this point, a small pointed embryo can be made out surrounded by a mass of white endosperm. This food material is of a hard horny nature owing to the thickness of the cell walls. If placed in a suitably warm and moist situation the seed germinates readily. The radicle grows downward, but after a short time branches, the main-root system being developed from these branches as is usual in monocotyledons. Only the stalk and sheath of the cotyledon come above ground. The tip remains in the seed as an absorbing organ.

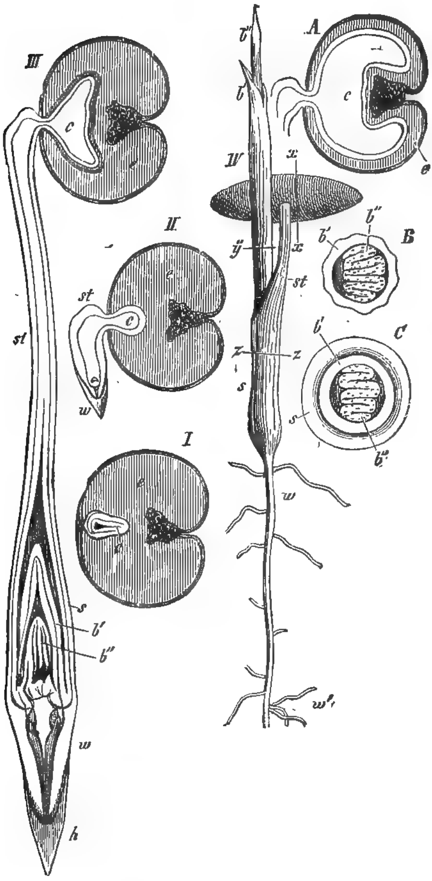



FIG. 9.—Germination of the Date Seed (*Phoenix dactylifera*).

I. Transverse section of seed before germination. II. The seed germinating, and radicle growing downwards. III. Later stage. The leaves (*b′*, *b″*) can be made out. IV. Later stage. The foliage leaves (*b′*, *b″*) have appeared above ground. A, B, and C. Transverse sections of seed in IV: A at *xx*, B at *xy*, C at *zz*. *e*. Endosperm. *s*. Sheath of cotyledon. *st*. Its stalk. *c*. Tip of cotyledon. *w*. Primary root. *w′*. Secondary root. *h*. Pileorhiza. (From Edmonds and Marloth's "Elementary Botany"; after Sachs.)

The plumule is enclosed in the sheath of the cotyledon. In time it breaks through the sheath and bears leaves which come above ground.

## PRACTICAL EXERCISES.

1. Make some iodine solution by dissolving 1 gramme of potassium iodide in 500 c.c. of water and adding iodine until the solution is dark brown in colour. This solution stains starch blue and cellulose yellow.

2. Soak a broad-bean seed in water for a few days. Then examine the external appearance. Note the testa, the hilum, and the micropyle. If the seed is squeezed a drop of water is pressed out through the micropyle. Make a sketch of the seed. Next remove the testa. Note the two fleshy cotyledons and the radicle, with its tip pointing to the micropyle. Split the seed, and note the plumule and radicle lying between the two cotyledons. Draw a sketch showing these in position. Add a drop of iodine solution to the cotyledon. It turns blue, showing that starch is present in the cotyledons.

3. Do the same with the seeds of castor oil, maize, mustard, sunflower, pine, pumpkin, onion and date plants.

4. Place a few of each of the above seeds in damp sawdust (the mustard seed is best grown on damp flannel). As the seeds germinate make sketches of the different stages, showing the ruptured testa, the radicle emerging from the seed, the plumule, first leaves, and root branches.

5. After the radicle has grown to about an inch in length, lay it alongside a rule divided into tenths of an inch and with a piece of thread dipped in Indian ink make marks on the radicle at every tenth of an inch. Now place it back in the damp sawdust. After a few days note which parts of the radicle have grown the most.

6. Place about twenty pea seeds in a bottle containing a little water and closed with an air-tight stopper. Note that germination goes on for a little time and then stops. If the stopper be then removed and a lighted taper introduced, it is extinguished, showing that the oxygen has been used up. The seeds died because all the oxygen was used up and they

could get no more. Hence this shows that oxygen is one of the conditions necessary for germination.

## QUESTIONS ON CHAPTER I.

1. Give an account of the uses and the behaviour during germination of the cotyledons in the various seeds whose germination you have watched.

2. What are the food substances commonly stored up in seeds? In what form do they occur, and by what tests would you recognize them? How do they become available to the young plant at the time of germination?

3. What conditions are necessary to ensure germination? Describe any experiments you have performed illustrating your statements.

4. Explain the terms: micropyle, testa, endospermous, plumule, hypocotyl, germination, and embryo.

5. Describe the structure of a broad-bean seed, and contrast it with that of a maize seed.

6. Compare the germination of a sunflower seed with that of the onion seed.

7. What do you understand by the embryo of a seed? Select any three of the following seeds:—

Mealie, Castor oil, Mustard, Pine,

and (*a*) describe the embryo and its parts, and sketch it; (*b*) state what happens to the different parts of the embryo on germination and mention their functions.

8. Show by means of drawings, with short explanatory notes, how the cotyledons of the pumpkin or the water-melon become freed from the seed-coat.

9. Describe the structure and germination of a pine seed. Compare its germination with that of any monocotyledonous seed you have studied, pointing out how the cotyledons differ in function and behaviour in the two seeds, and sketching stages in their germination.

10. Make sketches to show the structure of the seed of the broad bean, and write a brief description of the seed.

11. What is the difference between an albuminous and an exalbuminous seed? Give examples of each kind. State what

conditions are generally necessary for the germination of seeds until the young plants have become independent.

12. Describe the growth and functions of the cotyledons in any plant. Explain how these organs are used as a basis of classification of plants. Name some polycotyledonous plants.

## CHAPTER II.

### THE CELL.

10. **The Cell.**—The whole of the tissues of a plant are composed of units called CELLS (fig. 10). These resemble the cells of animal tissue in many respects, but

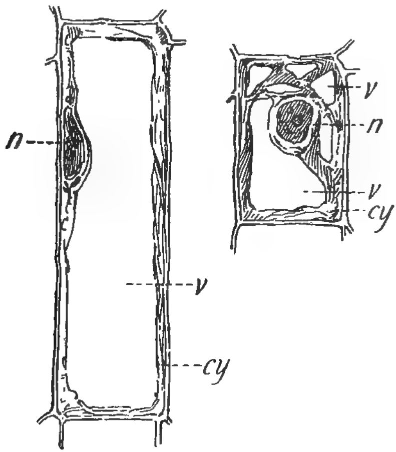



FIG. 10.—Typical Cells.

*n.* Nucleus. *v.* Vacuole. *cy.* Cytoplasm.

differ from them in that they are surrounded by a firm wall made of a carbohydrate called CELLULOSE. A typical cell is found to contain a mass of CYTOPLASM, a fluid-like substance consisting of a clear ground substance through which is distributed a number of granules. A denser part can be distinguished in the cytoplasm in the form of a round ball. This is called the NUCLEUS. Besides this comparatively large body there are present a number of colourless and highly refractive bodies called PLASTIDS.

Cytoplasm, nucleus, and chromatophores are grouped together under the term PROTOPLASM. Water is absolutely essential to the proper carrying out of the functions of protoplasm. Deprived of water it becomes hard and tenacious, without losing its vitality, however. It is in this form that protoplasm is found in seeds. Immediately this dormant form of protoplasm comes in contact with water it assumes its usual form once more.

Only very young cells and meristematic tissue cells are entirely filled with protoplasm. As soon as the cells increase in size spaces appear called VACUOLES, which become filled with cell sap, a very weak solution in water of various salts. In an older cell these vacuoles are all united into one large vacuole, so that the protoplasm simply forms a thin lining to the cell, when it is called the PRIMORDIAL UTRICLE. In other cases the cell may be traversed by threads of cytoplasm, the nucleus being then suspended in the middle of the cell. Frequently the cytoplasm exhibits streaming movements. These are well seen in the staminal hairs of *Tradescantia virginiana.*

Chemically considered, protoplasm is a highly complex mixture of organic compounds. Some albuminous substances are always present, and, when burned, fumes of ammonia are given off. Other substances always present are mineral salts, carbohydrates, fats, and sometimes ferments and alkaloids.

11. **The Nucleus.**—The nucleus is the most important part of the protoplasm. It usually has a reticulate structure, and consists of a number of threads in which lie embedded a number of granules. One or more denser bodies called NUCLEOLI are present in the network of threads, and the nucleus itself is surrounded by a thin membrane. It is usually spherical in shape, but in older or elongated cells it becomes flattened and elongated. It plays a most important part in cell division, splitting up into a number of filamentous bodies called CHROMOSOMES, each of which splits into halves longitudinally, the separate halves forming two new nuclei. In other processes the nucleus divides into two fragments. In either case division of the nucleus always precedes division of the cell.

12. **Plastids.**—These bodies may develop in various ways. If they turn green they are CHLOROPLASTS or CHLOROPHYLL corpuscles. If red or yellow, as in petals or fruits, they are termed CHROMOPLASTS. If they remain colourless they are termed LEUCOPLASTS or starch-forming corpuscles. The chloroplasts hold the green colouring matter of plants—CHLOROPHYLL—in solution. This chlorophyll is soluble in alcohol, ether, paraffin, oils and carbon bisulphide, and, consequently, a solution in alcohol can be obtained by steeping killed leaves in alcohol for a short time. Other pigments may be associated with the chlorophyll—yellow, blue, or red. Chlorophyll is only developed in the chloroplasts under the influence of light. Before leaf-fall occurs the chloroplasts undergo disorganization, and

there remains in the cells only a watery substance with a few yellow bodies. Sometimes this liquid turns red, giving the vivid tints to leaves so noticeable in autumn.

13. **The Cell Wall.**—The cell wall is chiefly composed of a substance called CELLULOSE—a carbohydrate of the general formula $n(C_6H_{10}O_5)$. It is a substance closely allied to starch, having, in fact, the same percentage composition. After treatment with sulphuric acid it is turned blue by iodine. It is insoluble in water, acids, and alkalies. When perfectly pure it is a white substance—cotton being nearly pure cellulose.

Cellulose walls may be changed in nature by the deposition of suberin, cutin or wood substance. When SUBERIN is deposited the cell walls become elastic, and give a bright yellow colour with caustic soda, and a yellow colour with chlor-zinc-iodide. The suberin also renders the wall less permeable to water. It is met with in cork. CUTIN is very similar to suberin, and is met with in epidermal cells.

*Lignification* is caused by the deposition of various substances, whose natures have not yet been determined. The wall becomes hard, inelastic and permeable to water. Lignified membranes stain yellow with chlor-zinc-iodide. They are usually met with in wood.

14. **Cell Contents.**—Besides protoplasm, a typical cell contains many other substances, mostly organic compounds, but also a few inorganic. The most important is the CELL SAP, a very dilute solution in water of the various inorganic compounds found in soil, such as phosphates, sulphates, and nitrates of calcium (see par.

84), and of the substances elaborated by the activity of the cell, such as sugar. The sap is usually acid in nature owing to the presence of various organic acids or acid salts.

Other substances found in the cell are, starch, calcium oxalate, fats and oils, tannin, and aleurone grains.

*Starch* is present in the form of small granules (fig. 11)

FIG. 11.—Starch Grains of Potato.

attached to the leucoplasts. It is the first visible product of carbon assimilation, and the food reserves of many plants consist of millions of these starch granules stored away in tubers (e.g. potato) in corms, in bulbs, in rhizomes (e.g. iris), and in most seeds. The starch grains are always stratified (fig. 11) and have a distinct centre round which the successive strata have been deposited. The size of starch grains varies from ·002 mm. to ·170 mm. The amount stored away in different parts of the plant is very considerable, e.g. 25 per cent of the whole weight of potatoes is starch, and 70 per cent of wheat grains.

*Calcium Oxalate* crystals are found in empty cells in most plants. One crystal of quite large size may be formed belonging usually to the tetragonal system, or a number of small crystals may fill the cell. In other cases, especially among lilies and orchids, the calcium oxalate assumes the form of bundles of needle-shaped crystals called RAPHIDES (fig. 12). Some botanists state that these needle-like crystals serve to ward off the attack of caterpillars and snails, etc.

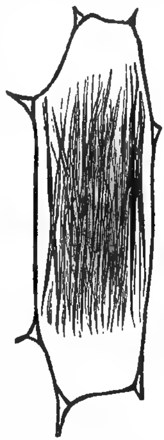


FIG. 12.—Cell of *Aloe retusa*, showing Raphides. (From Thomé's "Text-book of Botany".)

Fats and oils occur in the form of drops in the cytoplasm, and many medicinal preparations are obtained by pressing the fat and oil from the plant, and subsequently purifying it. Castor oil, oil of cloves, etc., are obtained in this way. Tannin is found in the cortex in the form of a highly concentrated solution filling the vacuoles.

*Aleurone* or proteid grains are of a nitrogenous nature, and are formed from cell sap rich in albumin. They assume the form of round grains, or, sometimes, irregularly shaped bodies. In the aleurone grains are frequently found crystals of albumin, and sometimes of calcium oxalate. In cereals the aleurone grains are found in a layer of cells just below the pericarp.

The aleurone layer is stained a yellowish-brown colour by iodine, and so stands out from the starch cells, which are stained blue.

15. **Form of Cell.**—The original form of the cell was probably spherical, but in multicellular organisms the newly developed cells are always polygonal in shape owing to the pressures set up by the adjacent cells.

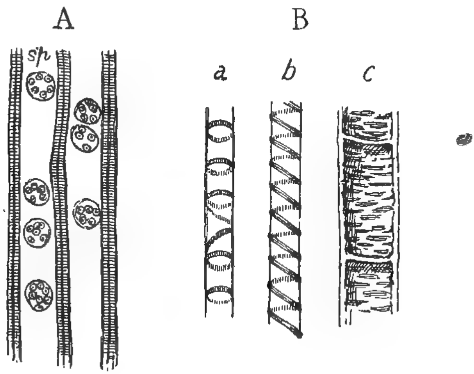



FIG. 13.

A. Sieve tubes. *s.p.* Sieve plate. B. Tracheides. *a.* Thickened in rings. *b.* Thickened spirally. *c.* Thickened reticulately.

Subsequent growth tends to change the form of the cell completely.

When the cells have the same dimensions in all directions, are thin walled, and possess a lining of protoplasm they make up a tissue called PARENCHYMA. They are usually six-sided and fit tightly together like the cells in a beehive. If, on the other hand, the cells are elongated, and possess thickened walls the tissue is called PROSENCHYMA. Usually prosenchymatous cells have pointed ends and little or no contents. These thick walled, elongated prosenchyma cells are called SCLERENCHYMA fibres. If the prosenchyma cell is shorter and wider, and not pointed at the end and provided with bordered pits it is called a TRACHEIDE (fig. 13 B). Its chief function is to carry water from one part of the plant to another. Its walls are always lignified, whereas those of the sclerenchyma may, or may not, have undergone this change. The walls of the tracheides may be thickened spirally or in rings or reticulately.

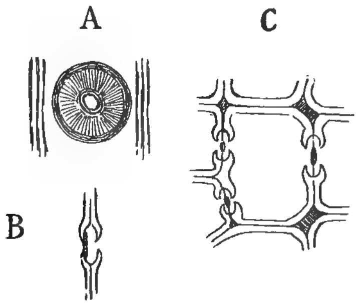



FIG. 14.—Bordered Pits.

A. Surface view. B. Tangential section. C. Transverse section of a tracheide.

16. **Pits** are formed in the cell wall by uneven thickening of the cellulose wall. They may be circular, elliptical, or elongated. Tracheides have bordered pits, the structure of which can be understood from figure 14. When a number of elongated cells fuse together to form a long tube, the latter is called a VESSEL. It is similar in nature to a tracheide, except that it has been formed from several cells instead of from one.

In the phloem we find another kind of cell called a SIEVE TUBE (fig. 15). This is a long, thin-walled, unlignified tube with specially thickened end wall. These end walls are perforated with numerous holes, and through them the contents of one cell communicates with the contents of the next. This structure resembles

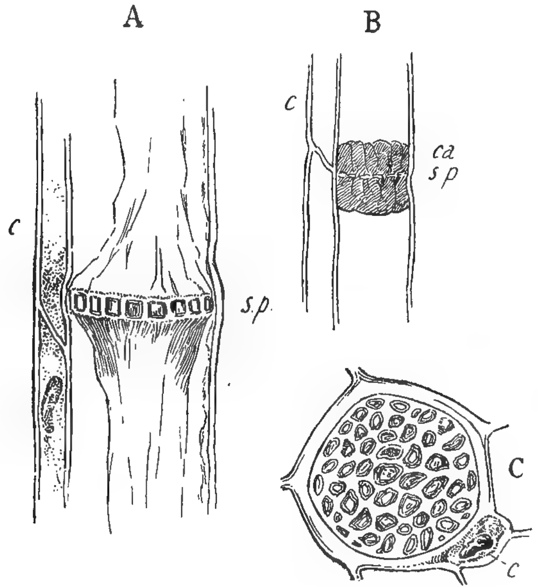



FIG. 15.—Sieve Tubes.

A and B. Longitudinal section. C. Surface view of sieve plate. *c.* Companion cell. *ca.* Plate of callus. *s.p.* Sieve plate.

a sieve, hence the name of these vessels. After a while the sieve plates become covered with a plate of callus.

The sieve tubes contain a lining of protoplasm, but no nucleus. Accompanying them is always found a small thin-walled COMPANION CELL, containing protoplasm and a large nucleus. Lastly, in many plants we find another kind of tube usually filled with a milky fluid called LATEX. These tubes are known as LATICIFEROUS CELLS and often branch extensively, forming a complete network.

## PRACTICAL EXERCISES ON CHAPTER II.

1. Mount in water a few filaments of Spirogyra, and sketch a single cell showing

(*a*) The cell wall;
(*b*) The spiral chlorophyll body;
(*c*) The cytoplasm and nucleus.

2. Cut a section of a bean seed. Mount it under the low power and note the cells packed full of starch grains. Make a sketch of same.

3. Do the same with the castor-oil seed.

4. Place a small drop of growing yeast on a slide and examine with the high power. Sketch a single cell showing the cell wall, protoplasm, and vacuoles.

5. Boil a green leaf in water for a few minutes and then steep it in warm alcohol or methylated spirits until all the chlorophyll has been extracted from it. Note the colour of the leaf so treated. Also examine the nature of the green solution obtained.

## QUESTIONS ON CHAPTER II.

1. Explain how a xylem vessel and a sieve tube differ in

(*a*) Their structure;
(*b*) Their function;
(*c*) The way they are formed.

2. Mention three substances commonly met with in large quantities in plants as reserve materials. Give examples of plants in which you have noted these substances, and state (*a*) in what part of the plant they are found; and (*b*) how you would demonstrate their presence.

3. Describe the principal kinds of parenchymatous and of prosenchymatous tissues. Illustrate the descriptions by means of diagrams, and state in which parts of plants these tissues occur.

4. What is cell sap? Where does it occur and what does it

contain? What purpose does it serve in the economy of the plant?

5. What is cellulose? How would you test whether cellulose was present in a plant tissue or not? What modifications of cellulose are often found in plants? Describe the characteristics of these modifications.

6. Of what substances do the crystals found in plant cells usually consist? Describe the appearance of any crystals you may have seen during a microscopic examination of sections of plant tissue. Why are these crystals formed by the plant?

7. Describe any experiments you may have performed to illustrate the nature and properties of chlorophyll. Under what conditions is it found, and how does it occur in the plant?

8. What is meant by cell sap? How does it occur, what are its commonest ingredients, and how can these be recognized?

9. How does sclerenchyma differ from parenchyma? Mention some places where these tissues are found. Name some of their uses.

## FURTHER PRACTICAL EXERCISES ON CHAPTER II.

6. Mount in a drop of water hairs from a stamen of Tradescantia or from stem of cucumber. Observe streaming movement of the protoplasm. Run in a few drops of chlor-zinc-iodide and note staining of the cell wall.

7. Soak hairs from cotton seed in Schultz's solution, mount in glycerine and water, and note that cell-walls made of cellulose are stained purple.

8. Cut thin sections of wood of a match, stain with aniline sulphate, note bright yellow colour. Examine sections under microscope, and note thickened cell walls.

9. Cut longitudinal sections of any young stem, and try to find annular, spiral, and pitted vessels.

10. Cut longitudinal sections of the stem of cucumber, and examine sieve tubes under low and high powers.

11. Cut sections of ordinary bottle cork, examine under microscope. Note thickened walls. Treat sections with potash and note yellow stain.

12. Cut sections of bean and castor-oil seeds, and stain with iodine. Note that starch grains in bean stain purple, aleurine grains in castor-oil do not. Examine aleurine grains under high power and find the crystalloid and globoid

NOTE.—See p. 209 for Appendix to Chapter II.

## CHAPTER III.

### THE ROOT OF THE ANGIOSPERM.

17. **Distinction between Roots and Stems.**—The root is that part of a plant which tends to grow downwards away from the light and towards water. It bears neither leaves nor buds and usually ends in a special protective structure called a ROOT-CAP. The internal structure is also different from that of the stem.

Although a root can usually be easily distinguished from a stem, there are many cases in which stem structures simulate the appearance of roots, and hence the distinctions above mentioned are important, for they enable us to distinguish such apparent roots from true roots.

18. **Familiar Forms of Roots.**—We have already mentioned that there are two kinds of roots, normal roots and adventitious roots. The former are produced by regular racemose branching of the tap root. The latter include those roots developed from other roots out of the regular order, roots developed from stems, and roots developed from leaves. Nearly all monocotyledons have adventitious roots, and plants with rhizomes, or creeping stems, usually produce adventitious roots too.

The most common form of root is that of the herbaceous dicotyledon. Here we have a fibrous tap root with slender branches produced in regular order. In other herbaceous dicotyledons the tap root is short and

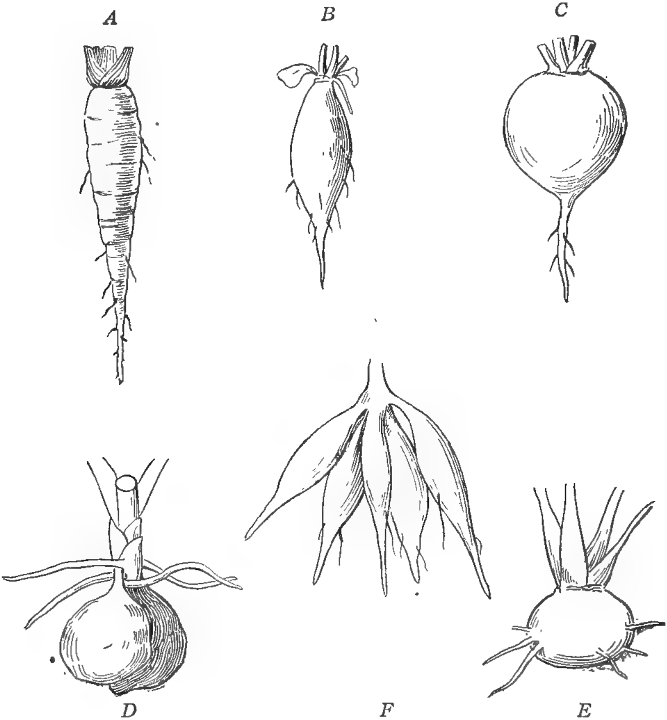



FIG. 16.—Roots.

A. Conical Root of Carrot. B. Fusiform Root of Radish. C. Napiform Root of Turnip. D. Tuberous Root of Orchid. E. Placentiform Root of Bulbine. F. Fasciculated Root of Dahlia.

thick, and the lateral roots fibrous in character. This is characteristic of surface feeders.

In many perennials the roots serve as storehouses for reserve food and the tap root consequently becomes much enlarged. If the swollen tap root tapers to a point, as in the carrot, it is called CONICAL; if it is swollen in the middle chiefly and tapers at top and bottom, as in the radish, it is called FUSIFORM, if the upper part is swollen into the form of a ball, as in the case of the turnip, it is called NAPIFORM. If the whole of the tap root becomes spherical it is called PLACENTIFORM. If a number of slender branches are given off, as in grass, the root is FIBROUS. When some of the fibres are swollen, the term FASCICULATED is employed.

19. **Branching.**—If we examine the root of a fairly old plant we notice that the branches of the main or tap root are arranged in longitudinal rows, the roots in each row being exactly above one another. This is owing to the fact that these branches, or secondary roots, spring from opposite the xylem, and as the xylem runs straight down through the tap root, it follows that the bases of the secondary roots will be in a straight line. Further, it will be noticed that the oldest secondary roots are close to the surface, while at the apex of the tap root no branches are to be seen. All root branches arise endogenously, i.e. from the interior of the main root. The first make their appearance in a sheath of cells surrounding the vascular bundles called the PERICYCLE (fig. 17). One or more cells of this tissue divide and form a mass of new cells—the young secondary root. This burrows its way through the surrounding cortex and finally breaks out at the surface, leaving a distinct cleft to mark its endogenous origin.

It will be noticed that the tap root grows vertically downwards. The secondary roots always grow out nearly horizontally. Branches of the secondary roots are called TERTIARY roots and these will grow in any direction. By this arrangement of branches the whole of the ground is parcelled out, and the most is made of the space on which the plant draws for its nourishment. This extensive system of roots also enables the plant to

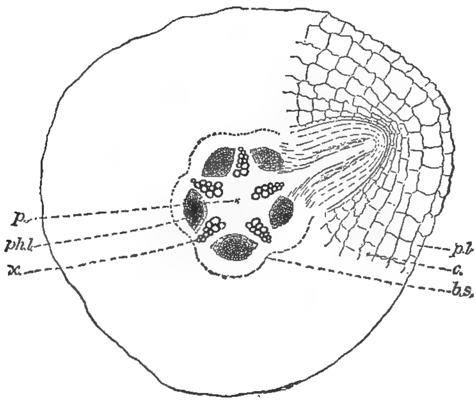



FIG. 17.—Transverse Section of the Primary Root of the Bean showing a Secondary Root developing.

*p.l.* Piliferous layer. *p.* Pith. *c.* Cortex. *phl.* Phloem. *b.s.* Endodermis. *x.* Xylem. (From Darwin's "Elements of Botany".)

possess a large surface for water absorption. In dry parts of South Africa the roots of many herbaceous plants will penetrate the soil to a depth of several feet, in order that they can draw upon a more ample supply of water.

20. **Root-Cap and Root-Hairs.**—The tip of a root ends in a cap of cells which are constantly being worn away on the outside and as constantly renewed from

the inside. This structure is called the ROOT-CAP (fig. 18), and serves to protect the delicate growing point of the young root from damage as it burrows its way through the particles of soil. Some distance behind the root-cap the outside layer of the root bears innumerable fine hairs. These hairs are called ROOT-HAIRS (fig. 18) and are chiefly organs of absorption. When

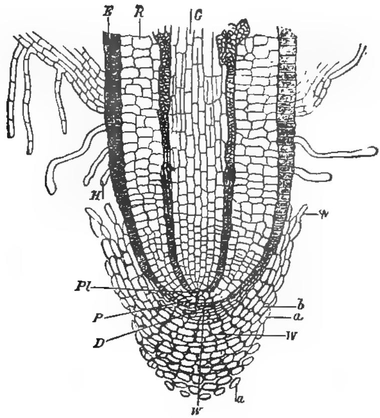



FIG. 18.—Longitudinal Section through Tip of a Young Root Showing:—

W. Root-cap. H. Root-hairs. E. Piliferous layer. R. Cortex. G. Pith.

one considers that each of the innumerable rootlets of a plant bears hundreds of these hairs, it will be understood how enormously they increase the area of absorption of the root system. Also these delicate thread-like structures can cling very closely to, and even wrap round particles of the soil, thus bringing the root in very close contact with the soil. Consequently, if a young seedling be pulled out of the soil it drags up with it round the basal part of the root a large quantity of soil particles, while the tip of the root comes out clean and bare (fig. 19). The root-hairs are only short-lived organs, dying away as the root grows older.

21. **The Tissues of the Root.**—If we cut across a young root of a bean or sunflower we can make out a number of specks arranged in a ring. These specks are the vascular bundles which run longitudinally through the root conveying liquids to and from its different parts. On the outside of this ring of bundles is a mass of tissue called the cortex. The outermost layer of this tissue is called the PILIFEROUS LAYER. Inside the ring of vascular bundles is a mass of tissue very much resembling the cortex. It is known as the pith.

FIG. 19.—Seedling Wheat with Soil Adhering to Root-hairs (after Sachs).

22. **Microscopic Structure of Root.**—If the section be examined a little more closely it will be noticed that it consists of a central cylinder surrounded by the cortex (fig. 20). The innermost layer of the cortex is known as the endodermis, or bundle sheath. The vascular tissue is seen to be of two kinds placed alternately with one another in a ring. The larger, thick-walled, empty cells make up the xylem, or wood; the smaller, living, thin-walled cells, the phloem. In the bean there are usually five xylem groups and five phloem groups. The largest xylem cell walls are no longer made of cellulose, but of a trans-

formed kind of cellulose known as lignin. The cross walls have disappeared, and so these cells form long tubes known as vessels stretching throughout the root and stem. The largest cells of the phloem, on the other hand, are still lined with protoplasm, and the cross walls instead of disappearing have become thickened and perforated

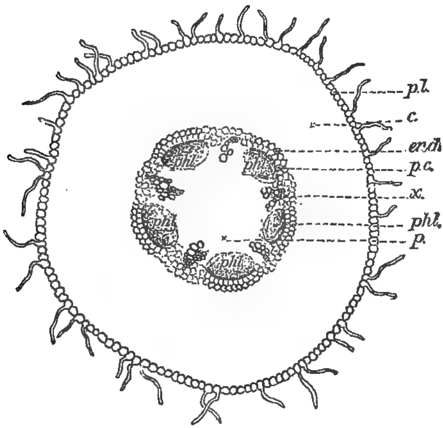



FIG. 20.—Transverse Section of the Root of the Bean.

*pl.* Piliferous layer. *c.* Cortex. *end.* Endodermis. *pc.* Pericycle. *x.* Xylem. *phl.* Phloem. *p.* Pith. (From Darwin's "Elements of Botany".)

like sieves. The walls have undergone no change and still give the characteristic reactions of cellulose. These groups of phloem and xylem are arranged around a compact tissue known as the pith, composed of cells very similar to those of the cortex. They are separated from each other by parenchymatous tissue known as conjunctive tissue. The first-formed elements of the xylem known as the protoxylem are towards the outside. A last noticeable feature of the section is a layer of cells between the endodermis and the vascular bundles, known as the PERICYCLE. It forms the outermost tissue of the vascular cylinder, and new lateral roots take their origin in this tissue.

23. **The Root of the Mealie.**—A transverse section of

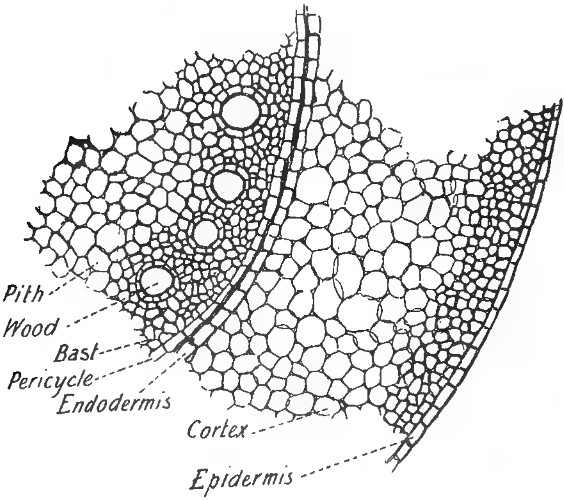



FIG. 21.—Mealie Root.

a young mealie root (fig. 21) is very similar to that of the bean described in the preceding paragraph. The xylem bundles are more numerous, however, varying from twelve to twenty, or more.

No secondary thickening takes place in monocotyledonous roots. Secondary thickening occurs in most dicotyledonous roots.

## PRACTICAL EXERCISES.

1. Sketch a longitudinal section of the apex of a maize root to show the root-cap.

2. Sketch a mustard seedling showing the root-hairs. It is best to grow the seedling in damp air, and then put the whole seedling in water, when the root-hairs separate and become obvious.

3. Sketch the root systems of—

(*a*) The maize;
(*b*) The broad bean;

showing the difference between the monocotyledon and dicotyledon root systems.

4. Cut thin transverse sections of fresh bean roots, or of one that has been hardened in alcohol. Place sections in a watch-glass of water, removing them with a moist camel-hair brush. Place a drop of glycerine on a slide, put the thinnest section in the glycerine, cover same with a glass, and examine under the low power of the microscope. Make a sketch showing—

(*a*) Piliferous layer;
(*b*) Cortex;
(*c*) Central cylinder.

Exam ne the section under high power and draw—

(*a*) The endodermis;
(*b*) Pericycle;
(*c*) Xylem strands;
(*d*) Phloem strands.

5. Repeat with maize root. Make out—

(*a*) Epidermis;
(*b*) Ground tissue;
(*c*) Vascular bundles.

## QUESTIONS ON CHAPTER III.

1. Describe the following types of roots, in each case giving an example:—

(*a*) Tap root;
(*b*) Tuberous roots;
(*c*) Adventitious roots.

Briefly describe the origin of lateral roots, and root-hairs. What are the functions of the latter?

2. Compare the root of a typical monocotyledon, e.g. mealie, with that of a typical dicotyledon, e.g. bean.

3. Give a description (accompanied by sketches) of the longitudinal section of any root you have examined under the microscope. Include the apex and the characteristic lateral outgrowths.

4. How would you be able by examination of the root alone to distinguish a monocotyledon from a dicotyledon?

5. Name three functions of the root and describe two forms of modified roots.

## CHAPTER IV.

### THE STEM.

24. **Stem.**—The stem is that portion of the plant which is developed from the plumule. It may grow underground as in the case of the potato, onion, iris, ferns, but usually grows above ground. The chief differences between it and the root are:—

(1) The growing point does not end in a root-cap, but in a bud.

(2) It bears leaves and flowers as well as branches.

(3) The branches arise exogenously (from the surface) and not endogenously as in the case of roots.

(4) The vascular bundles have the phloem and xylem contiguous, not side by side as in the roots.

The stem itself is divided into alternate regions.

(1) Regions which possess lateral out-growths.

(2) Regions which do not possess lateral out-growths. The former are called NODES, the latter INTERNODES.

25. **Principal Forms of Stems.**—A stem is usually cylindrical in section and erect. But some stems are triangular, square, five-ribbed, etc., others trail on the ground, or twine themselves round supports, or climb by means of tendrils, etc. The chief forms of aerial stems are;—

(*a*) The runner (fig. 22), a stem which creeps along the ground, and strikes the soil at different intervals, producing leaves and roots as, e.g., the strawberry.

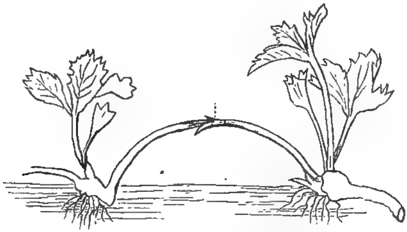


Fig. 22.—Runner of Strawberry. (From "Thomé's Botany".)

(*b*) The stolon (fig. 23), a branch given off above the ground which strikes into the earth, producing a new plant.

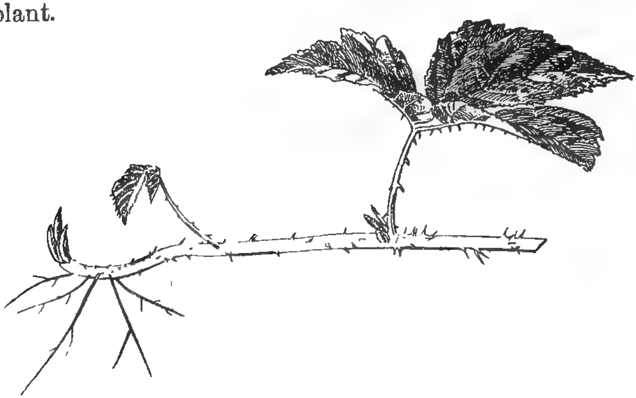


Fig. 23.—Stolon of Bramble.

(*c*) The sucker (fig. 24), a branch given off below the ground, turning up at intervals and producing a new plant.

The chief forms of subterranean stems are :—

(*a*) The rhizome (fig. 25), a thickened stem creeping just below the surface and giving off leaves from the upper surface and roots from the lower surface. It can

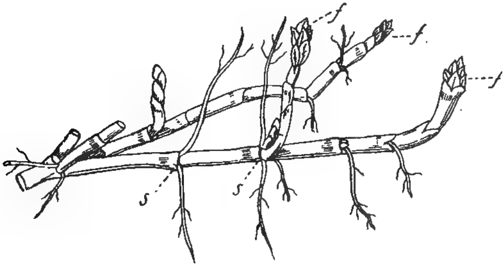



FIG. 24.—Sucker of Mint.
*f.* Foliage leaf. *s.* Scale leaf.

be distinguished from a root because it ends in a bud, not a root-cap, and scars show where previous seasons' leaves have been borne. It is a most successful method

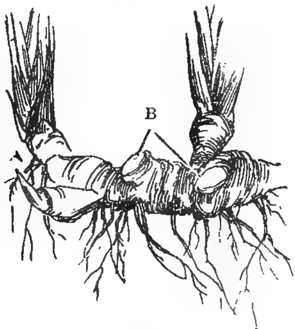



FIG. 25.—Rhizome of Iris.
A. Bud. B. Scar of previous shoots.

of growth, and plants which have developed this kind of stem are able to stand most adverse conditions of drought and cold very well.

(*b*) The tuber (fig. 26) is a portion of a stem growing underground and swollen by the deposition of food material. It differs from a rhizome in that it is only a portion of a stem, instead of a continuous stem. A potato is a good example of a tuber. It bears modified leaf buds called "eyes". These are inserted in a similar order to the leaves on the aerial part. Tubers form a valuable method of propagating plants, and this is the chief means of propagation in the case of the potato plant and Jerusalem artichoke.

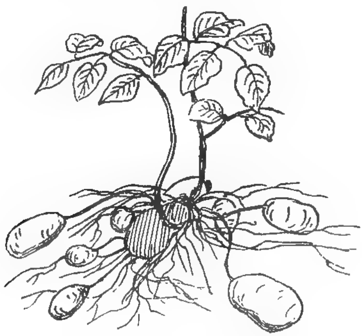


Fig. 26.—Tubers of Potato.

(*c*) The bulb (fig. 27) consists of a flattened disc-like portion of the stem, surrounded by the swollen bases of leaves. The outside is often protected by thin membranous leaves. There are two kinds of bulbs, tunicated bulbs (in which the outer leaves are large and completely ensheath the inner leaves), e.g. onion, and scaly bulbs, in which all leaves are about the same size and overlap each other, e.g. tulip. In the interior of the bulb in the axil of one of the fleshy leaves is a bud which grows in spring at the expense of the food stored

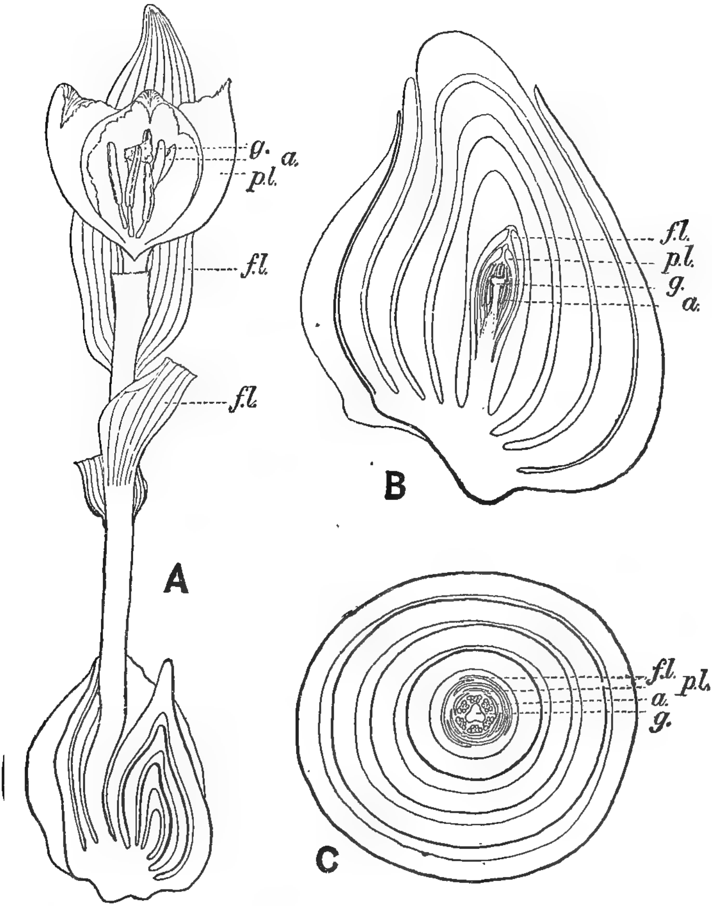



FIG. 27.—Bulb of Tulip.

A. Tulip plant in flower. B. Longitudinal section of bulb. C. Transverse section of bulb. *a.* Anthers. *g.* Gynæceum. *pl.* Petals. *f.l.* Leaves borne on the flowering stem. (From Darwin's "Elements of Botany".)

up in the bulb and produces flowers and fruit. Adventitious roots are developed at the base of the bulb. After flowering, the food is again stored up in the bases of the foliage leaves, so that a new bulb is produced.

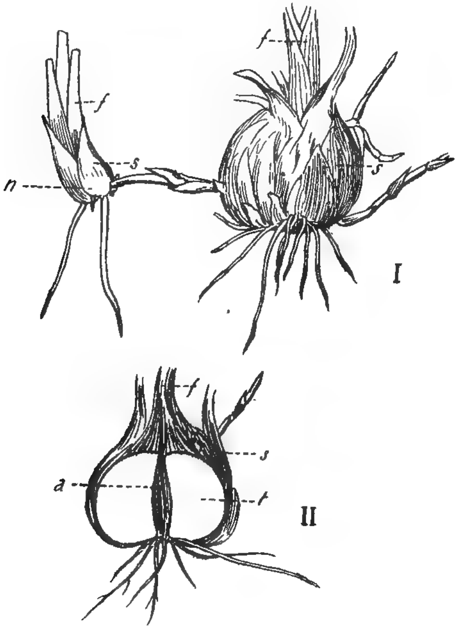



FIG. 28.—I. Corm of Montbretia.
*n.* New corm. *f.* Foliage leaves. *s.* Scale leaves.
II. Section through Corm of Montbretia.
*a.* Main axis. *t.* Swollen stem. *s.* Scale leaves. *f.* Foliage leaves.

(*d*) A corm (fig. 28) is a swollen underground portion of the stem. It resembles a bulb in appearance, but differs from it in possessing only a few scale leaves, the solid portion of it being a stem structure.

It grows in a similar manner to a bulb, the food stored up in the corm serving to nourish the flower and fruit. After flowering, the base of the stem becomes swollen and forms a new corm which lies dormant

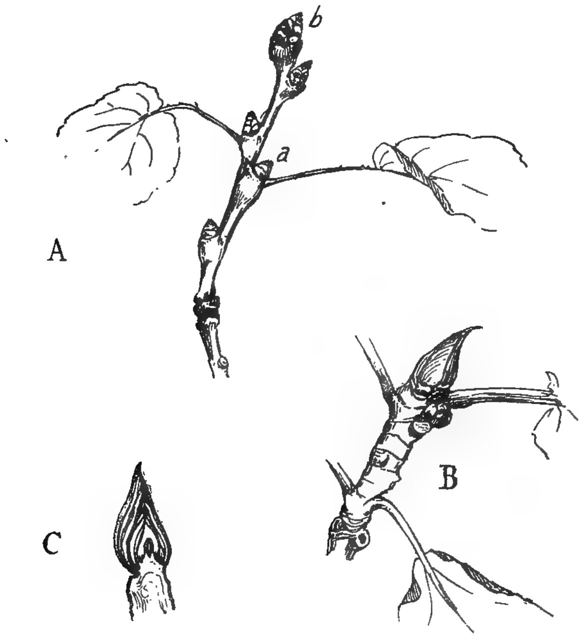



FIG. 29.—Buds.

A. Nectarine. *a.* Axillary bud. *b.* Terminal bud. B. Fig. C. Longitudinal section of fig bud.

during the winter, and produces a new plant the following spring. Examples of plants producing corms are: Gladiolus and Moraea, Montbretia.

26. **Buds.**—We have already mentioned (par. 24) that the stem ends in a *bud* (fig. 29). This is simply an

undeveloped branch, and consists of a stem structure in which the internodes are very short, and a number of leaves packed tightly together since the nodes are so close to each other. Such a bud is called a TERMINAL BUD. Similar buds occur in the axils of the leaves and are hence called AXILLARY BUDS. When these develop a new branch is produced. Axillary buds can remain dormant for a number of years, and branching on the older portions of trees is caused by the development of these hitherto dormant buds.

Buds form very conspicuous objects on deciduous trees in winter, and especially in spring, although they can be found on plants at all seasons. In winter the buds very often develop protecting scale leaves to prevent loss of heat and moisture. These scale leaves may contain resinous secretions, or be covered with hair. As the bud unfolds these scale leaves fall off, leaving very distinct scars. The age of a branch can be told by counting the number of such scar zones between its point of insertion in the main stem and its apex.

If a bud is developed on other parts of the plant besides the apex of a stem or the axils of leaves, it is called an ADVENTITIOUS BUD. Such adventitious buds may be found on roots or on leaves, e.g. begonia. Sometimes a whole plant consists of a bud, e.g. the cabbage plant, and in this case food is stored in the closely packed leaves.

The buds of different kinds of deciduous trees are very characteristic and serve to identify the tree even in winter when leaves and flowers are absent.

27. **Microscopic Structure of the Stem.**—If we cut a

thin transverse section of the stem of the sunflower and examine it under the microscope we note a resemblance between it and the transverse section of the root mentioned in par. 21. We have again a central cylinder containing a number of vascular bundles and surrounded by a parenchymatous tissue (fig. 30).

The outermost layer of cells is the epidermis. It is composed of strong cells often covered with a protective layer of cutin and they serve to protect the inside tissues of the

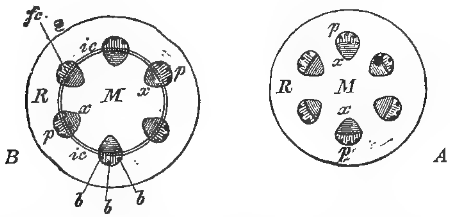



FIG. 30.—Transverse Section of Stem of a Dicotyledon.

A. Young stem. M. Pith. *x*. Xylem. *p*. Phloem. R. Cortex. B. Older stem; bundles now united by interfascicular cambium (*ic*). *fc*. Cambium of the primary bundle. *b*. Primary bast fibres (diagrammatic).

stem. Next comes the cortex, a tissue similar to the cortex of the root. The innermost ring of cortex cells forms the endodermis. It usually contains starch and shows up well as a blue wavy line in a section stained with iodine. Inside the endodermis comes a ring of vascular bundles. The space between each bundle is filled with parenchymatous tissue, and is called the PRIMARY MEDULLARY RAY. The interior is filled with a mass of pith cells similar to those found in the root. In a young stem these pith cells are soft, green, and juicy. In an older stem there are dead, spongy cells, filled with air. Sometimes they disappear.

The vascular bundles of the stem (fig. 31) differ considerably from those found in the root. Each bundle

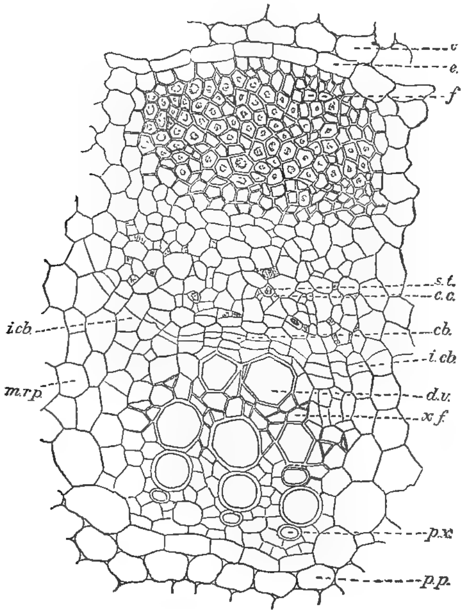



FIG. 31.—Vascular Bundle of *Helianthus tuberosus*, the Jerusalem Artichoke.

*c.* Cortex. *e.* Endodermis. *f.* Pericycle fibres. *s.t.* Sieve tube. *c.c.* Companion cell. *cb.* Cambium. *i.cb.* Interfascicular cambium. *d.v.* Pitted vessel. *x.f.* Xylem fibre. *p.x.* Spiral vessel. *pp.* Pith. *m.rp.* Medullary ray. (From Darwin's "Elements of Botany".)

consists of three parts, phloem, cambium and xylem. The phloem and xylem are exactly similar in nature to the phloem and xylem of the root, but the protoxylem and protophloem are found towards the centre, and not towards the outside, as in the case of roots. The CAMBIUM is a tender meristematic tissue separating the phloem from the xylem. The whole of these three tissues make up what is called a collateral open bundle, collateral because the phloem and xylem are placed side by side, open because of the presence of the cambium which enables further growth to take place. This cambium readily divides and produces new cells, phloem cells towards the outside and xylem cells towards the interior. Further cambium is formed out of some of the cells in

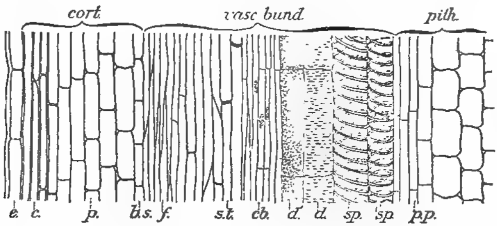



FIG. 32.—Longitudinal Section through Stem of *Helianthus tuber.*

*cort.* Cortex. *e.* Epidermis. *p.* Parenchyma of cortex. *c.* Collenchyma. *b.s.* Endodermis. *f.* Pericycle fibres. *s.t.* Sieve tube. *cb.* Cambium. *d'd.* Pitted vessels. *s.p.* Spiral vessels. *pp.* Pith. (From Darwin's "Elements of Botany".)

the medullary rays and connects the cambium of one bundle with that of the next. Consequently in time we have a ring of cambium concentric with the endodermis, and, as this divides and produces new cells, we get in an older stem a continuous ring of xylem and a continuous ring of phloem.

The new cells produced by the cambium are called SECONDARY PHLOEM and XYLEM, and the process is called SECONDARY THICKENING. It is due to the work of the cambium that tree trunks are found with a girth of one hundred feet. The cambium which appears between the bundles is called INTERFASCICULAR CAMBIUM.

28. **The Stem of the Maize.**—A section across the stem of the maize presents a very different appearance from that of the dicotyledonous stem described in the

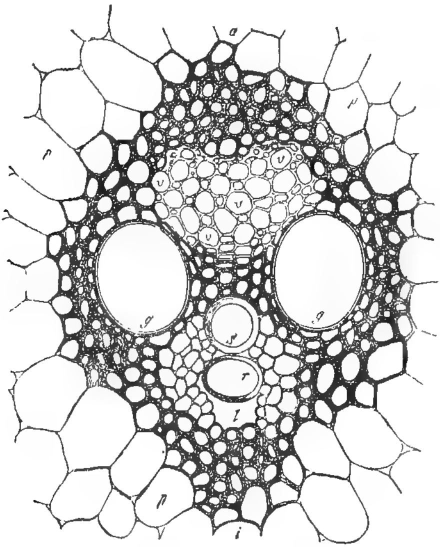


FIG. 33.—Transverse Section of Bundle from Stem of Mealie.
*p*. Ground tissue. *v*. Phloem. *g*. Large pitted vessels of the xylem. *s*. Spiral vessel. *r*. Annular vessel. *l*. Air cavity (after Sachs).

preceding paragraph. Instead of a central cylinder containing a ring of bundles we have a large number of bundles scattered irregularly about the whole section. The bundles themselves (fig. 33) also differ considerably from the open collateral bundles of the sunflower. They possess no cambium, but consist of xylem and phloem surrounded by sclerenchyma. Such bundles are called *closed bundles*. The vessels are arranged in a characteristic manner somewhat after the shape of a V. There are usually four. The phloem lies between the two largest xylem vessels. Owing to the absence of cambium no secondary growth like that occurring in dicotyledons is possible. In a few exceptional cases, e.g. Yucca, Dracaena, a cambium originates in the pericycle, and new bundles are formed, but in a manner quite different from that of dicotyledonous stems. Hence the thick woody stem characteristic of so many dicotyledons is never met with among monocotyledons.

29. **The Stem of the Oak.**—The stem of the young oak presents a similar appearance to that of the sunflower or broad bean (par. 27) and possesses a large central pith, a ring of vascular bundles, and a cortex covered by epidermis. But the oak differs from a sunflower in that it is a perennial instead of an annual and by subsequent growth the stem assumes a very different appearance. The pith may shrink, and instead of a ring of scattered bundles we have concentric rings of wood. The cortex may disappear altogether, and instead of an epidermis we have bark. All these changes are brought about by the activity of the cambium. The first step in this change is the rejuvenescence of certain cells between the vascular bundles, which cells now form interfascicular cambium. This cambium produces new phloem cells on the outside and new xylem cells on the inside, so that we get a cylindrical shell of phloem on the outside and a concentric cylindrical shell of xylem on the inside (fig. 34). Further, one ring of wood is produced each year. Hence each

concentric ring of wood indicates a year of the tree's age. Thus the age of a felled tree can be ascertained by counting the number of rings of wood—ANNUAL RINGS—as they are called. The reason why these rings can be so clearly distinguished the one from the other is that the secondary wood laid down in the spring consists of large vessels, whilst that laid down in autumn consists of small vessels. If this were not the case the wood

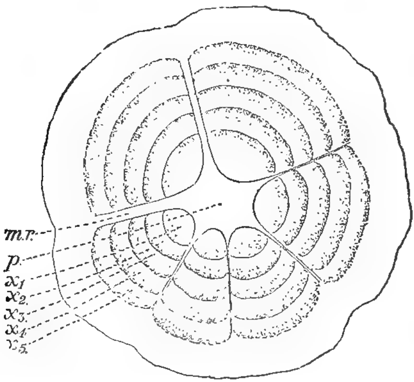



FIG. 34.—Transverse Section of a Five-year-old Oak Stem. *m.r.* Medullary ray. *p.* Pith. $x_1$ to $x_5$. Rings of xylem formed during successive years. (From Darwin's "Elements of Botany".)

would be homogeneous in nature, and no line of separation would be noticeable between one year's growth and the next. Besides the secondary xylem and phloem there are present in an old oak stem rays of tissue running radially outwards. Some—the primary medullary rays between the separate vascular bundles—were present in the seedling, the others have been produced later along with the rest of the secondary tissue by the cambium.

30. **Cork.**—The tissue outside the cambium is known as Bark (fig. 35). It consists of the remains of the original cortex, present in the seedling, the primary and secondary phloem, and a new tissue called Cork.

The original seedling possessed a strong external single layer of cells called the Epidermis. The outside wall of these cells was very thick and consisted of a transformed kind of cellulose called Cutin. In older stems, however, this epidermis has disappeared and its place taken by a new tissue called Cork. The cells immediately underneath the epidermis become rejuvenated as some in the interfascicular tissue did, and this ring of meristematic tissue, like the cambium, gives rise to two kinds of tissue, fresh cortical cells on the inside called, Collenchyma, and cork cells on the outside. This meristematic tissue is called Cork Cambium or Phellogen. The new cortical tissue is called Phelloderm. The three layers together form the Periderm (fig. 36).

The epidermis is stretched and cracked by the cork growing beneath it, and finally falls away in flakes. Also the green stem, green because of the chlorophyll present in the cortical tissue, becomes brown because of the formation of cork. The cork itself is a brown spongy tissue, the walls of the cells being made of another transformed kind of cellulose called Suberin. The cells contain no protoplasmic contents, and so render the tissue light and spongy like the pith. Also suberin is very impervious to liquids, and it is for this reason that the periderm of the cork oak is used as stoppers for bottles.

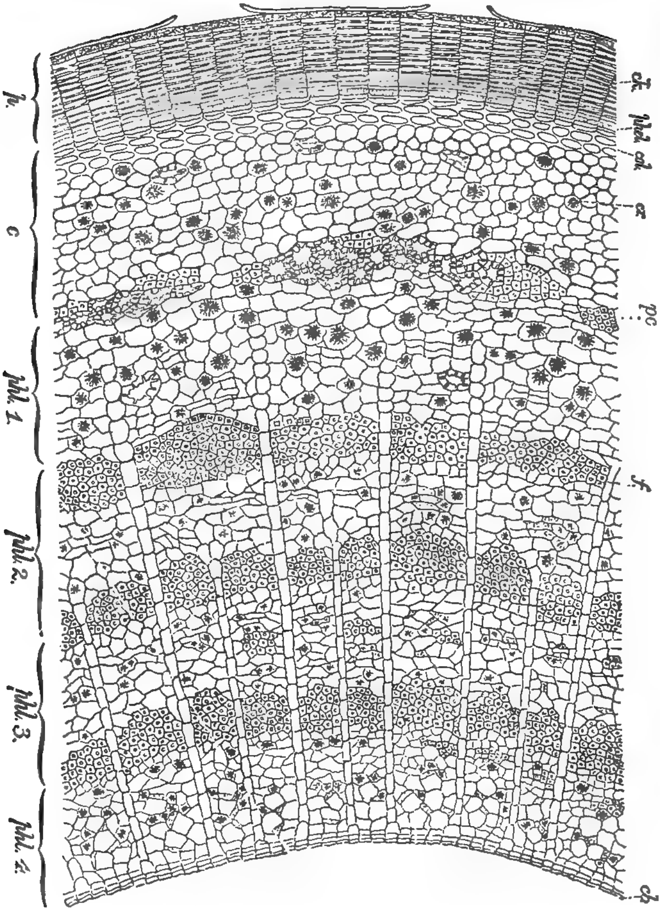



FIG. 35.—Transverse Section of Oak Bark.

*ck.* Cork. *phel.* Phellogen. *col.* Collenchyma. *cr.* Crystals. *f.* and *pc.* Phloem fibres. *cb.* Cambium. *p.* Periderm. *c.* Cortex. $phl_1$ to $phl_4$, phloem of four years. (From Darwin's "Elements of Botany".)

As the oak-tree becomes older there is a more complex formation of cork, which leads to the rough scaly appearance of the bark characteristic of full-grown trees.

31. **Lenticels.**—When cork has been formed round a stem the stomata of the stem are useless, for cork being impermeable to cell-sap all the cortex outside it dies. To replace these stomata new organs are formed

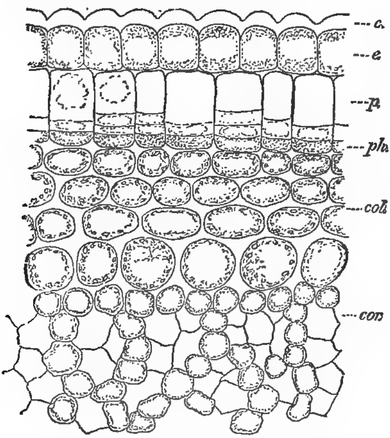



FIG. 36.—Cork Layer of Beech.

*c.* Cuticle. *e.* Epidermis. *p.* Cork. *ph.* Phellogen. *col.* Collenchyma of cortex. *cor.* Cortex. (From Darwin's "Elements of Botany".)

in older stems called LENTICELS (fig. 37). Underneath the stomata a meristematic tissue arises called the cambium of the lenticel, which gives rise on the outside to a number of cells with numerous air spaces between them called the COMPLEMENTARY CELLS of the lenticel, and on the inside to secondary cortex. The activity of this meristematic tissue soon causes the epidermis to be ruptured, and thus air can pass freely in and out of the stem. The phellogen of the periderm when formed joins on to the lenticel cambium.

It is important to notice that no cork cells are formed in a lenticel, and so air can pass freely into the stem. They can be made out by the naked eye as small specks or lines on young twigs.

32. **Branching.**—There are two chief forms of branching. (1) DICHOTOMOUS BRANCHING, and (2) MONOPODIAL

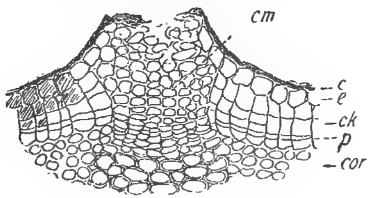



FIG. 37.—Lenticel.

*c.* Cutin. *e.* Epidermis. *ck.* Cork. *p.* Phellogen. *cor.* Cortex. *cm.* Complementary cells.

BRANCHING. In dichotomous branching (fig. 38) the growing point divides into two equal parts, then the growing points of these two branches do the same, so that we get a series of bifurcations. This type of branching is chiefly met with in the mosses and ferns. In monopodial branching there is always a persisting main axis, the MONOPODIUM, which gives off lateral branches. There are two kinds of monopodial branching, (*a*) INDEFINITE or RACEMOSE, and (*b*) DEFINITE or CYMOSE. If the monopodium continues to grow, giving off lateral branches one after the other, we have indefinite or racemose branching. If after giving off a lateral branch the monopodium ceases to grow and the branching is continued by the first lateral branch we have definite or cymose branching.

In the case of racemose branching the lateral branches are usually produced in a regular order, the youngest being nearest the apex. The branches are then said to be produced in ACROPETAL succession.

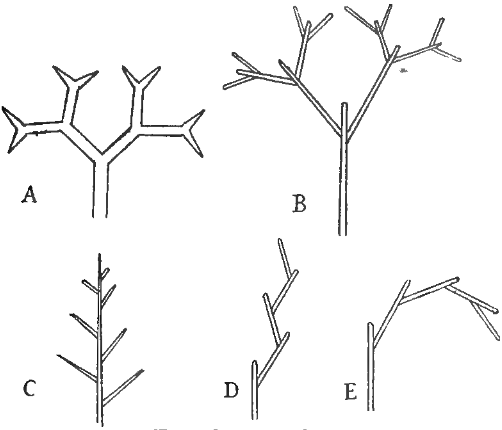



FIG. 38.—Branching.

A. Dichotomous branching. B-E. Monopodial branching. B. False dichotomy. C. Racemose branching. D. Scorpioid cyme. E. Helicoid cyme.

(In cymose branching if one daughter axis is given off at each node the term *uniparous* is used, if two, *biparous*, and if more than two, *multiparous*.)

In the case of uniparous cymose branching we may have scorpioid, helicoid forms, and a form simulating a true dichotomy called a false dichotomy.

In the scorpioid forms, the successive lateral branches are produced alternately on the left and right. The apparently simple axis is a false axis made up of a number of lateral branches which have grown in the same straight line. This false axis is called a SYMPODIUM. It can be distinguished from a true racemose form by noting the position of the leaves in the axils of which the lateral branches originated. In the helicoid cyme the lateral branches are all produced on the same side.

In the false dichotomy form two lateral branches are produced at the same level and the main axis terminates immediately after the branching.

Most trees have cymose forms of branching.

## PRACTICAL EXERCISES.

1. Examine the tuber of the Jerusalem artichoke. Note the buds which serve to identify it as a stem structure. Sketch the tuber, showing the buds and scale leaves.

2. Examine a potato in the same way. Cut a section of one of the buds, and draw it. Test the surface of a cut potato for starch with iodine solution.

3. Cut an onion bulb in half longitudinally. Sketch same, showing the scale leaves, the swollen leaf bases, the short stem and swollen disc, the adventitious roots, and the developing foliage leaf.

4. Cut transverse sections of the stem of the sunflower (*Helianthus annuus*) and of the broad bean (*Vicia faba*) preserved in alcohol. Soak the sections in water for a minute or two, and then place the thinnest section on a slide, add one drop of Schultze's solution and examine under the low power. Sketch the section showing—

(*a*) Epidermis ;

(*b*) Cortex and endodermis ;

(*c*) The central cylinder, with its ring of vascular bundles, the medullary rays, and the pith.

Also examine a single bundle under the high power, and make out and sketch the phloem (empty sieve tubes and companion cells filled with protoplasm) phloem parenchyma, cambium, and xylem.

5. Cut a small piece of stem in half longitudinally and cut

a longitudinal section passing through a vascular bundle. Make out and sketch—

(*a*) Epidermis;
(*b*) Cortex and endodermis with starch grains;
(*c*) Pericycle fibres;
(*d*) Phloem (parenchyma, companion cells and sieve tubes);
(*e*) Cambium;
(*f*) Xylem with pitted and spiral vessels;
(*g*) Pith.

6. Cut a transverse section on an oak twig of the current year. Make out the parts enumerated in 4, and compare the two sections.

7. Cut the stem of a young oak seedling transversely. Note that the bundles do not yet form a complete ring.

8. Cut the stem of a three-year-old oak transversely with a sharp knife. Examine with a lens. Note the annual rings and the medullary rays.

9. Cut transverse sections of the bark of an oak stem. Examine under the low power and make out—

(*a*) Phloem;
(*b*) Groups of sclerenchyma;
(*c*) Primary cortex;
(*d*) Cork cambium and cork cells and phelloderm or secondary cortex.

Also cut longitudinal sections of same and make out the same tissues.

10. Cut a transverse section through an apple twig, cutting across a lenticel. Examine under the low power, and sketch—

(*a*) The ruptured epidermis;
(*b*) The loose cork cells;
(*c*) The cork cambium.

## QUESTIONS ON CHAPTER IV.

1. Make a diagrammatic sketch to show the structure of the stem of a sunflower, as seen in transverse section. Describe the functions of the different tissues of the vascular bundle, and make drawings to show the form of a characteristic cell from each tissue.

2. Describe each of the following:—

(*a*) A bulb;
(*b*) A tuber;
(*c*) A rhizome;
(*d*) A tuberous root.

State what purpose they serve in the life history of the plant. Give an example and a sketch of each.

3. What are the characters of stems as distinguished from roots? What is meant by a bud? Explain the difference between terminal, axillary and adventitious buds.

4. Give an account of the characteristic features, the occurrence and functions of cork tissue.

5. Describe the structure of the stem of an aloe, and give an account of the process by which it increases up to a certain age and then no more.

6. Compare the structure of the stem of a dicotyledonous plant with that of a monocotyledon.

7. Describe with examples the various forms assumed by an underground stem.

8. What are lenticels? Mention two plants in which you have seen them. Where do they occur? Make sketches to show as exactly as possible their external appearance.

Explain precisely—

(*a*) How lenticels are formed, and
(*b*) What is their function.

9. Make diagrammatic drawings of transverse sections of the stem and root of the sunflower (or of any other dicotyledonous root you have studied) to show how the arrangement of the various tissues differs in stem and root. Label all the parts, and indicate the position of the protoxylem. Explain how the difference in the arrangement of their tissues is related to the difference in the work done by the two.

10. Make a large sketch of the cross-section of a one-year-old stem of an oak to show the arrangement of the tissues. Name the tissues shown (the detailed microscopic structure is not expected). Make a similar sketch of the same stem when four years old. Write a brief account of secondary thickening in the stem of this plant.

11. Mention the more important structural differences between roots and stems, and, as far as you can, give an explanation of these differences.

12. Explain the difference between monopodial and sympodial branching. Describe a few examples of each kind.

13. What different arrangements of the phloem and xylem are to be met with in plants? Illustrate your answer by examples.

14. What secondary changes may take place in the stem of dicotyledons?

15. Give a diagrammatic sketch of a transverse section of the stem of the oak in the third year of growth, labelling the various tissues shown.

# CHAPTER V.

## THE LEAF.

33. **The Leaf.**—A leaf is a lateral outgrowth of the stem and consists of three parts :—

(*a*) The leaf-blade or lamina ;
(*b*) The leaf-stalk or petiole ;
(*c*) The leaf-base.

The leaf-blade is the chief part of the leaf, and plays an important part in the feeding, respiration and transpiration of the plant. It is usually green, and may assume a variety of forms and shapes. In some cases the leaf-blade is not developed or dies away, and the petiole becomes the most important part. The leaf-stalk or petiole is not always present. When absent the leaf is said to be sessile, when present, stalked. The petiole is usually a cylindrical structure, but its internal structure resembles that of a leaf. In some cases it becomes expanded into a blade and usurps the function of the true lamina. It is then called a PHYLLODE (fig. 39). In other cases it may act as a climbing organ. Its chief function is to support the leaf in as advantageous a position as possible for carbon assimilation.

The leaf base is often hardly distinguishable from the leaf stalk, but in many monocotyledons it is a highly developed structure enclosing the stem in a kind of sheath. This is especially noticeable in grasses. In some cases the leaf base swells out into a cushion called the PULVINUS which acts as a sensitive organ enabling the leaf to react to external stimuli. This is the case for example with many of the Leguminosae.

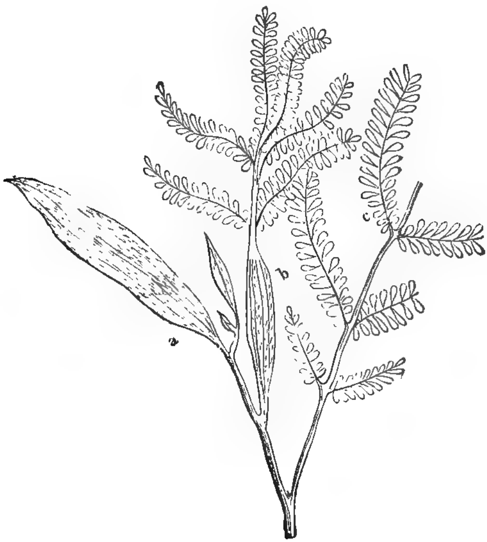



FIG. 39.—Branch of a young plant of *Acacia melanoxylon*, showing Phyllodes, *a*, *b*. (From "Thomé's Botany".)

In many plants the leaf base bears a pair of outgrowths called STIPULES. These may be small and brown, their chief function being to protect the leaf when in the bud. In other cases they are much larger, and assist the leaf-blade in its functions. If they are present the leaf is said to be STIPULATE, and if absent EXSTIPULATE.

34. **Kind of Leaves.**—Leaves may be divided according to their functions into four classes:—

(1) Foliage leaves;

(2) Scale leaves;

(3) Bracts;

(4) Floral leaves.

FOLIAGE LEAVES are the ordinary green leaves of the plant. Their chief work is to nourish the plant. This is performed by means of the green pigment chlorophyll present. They also possess numerous small holes in the epidermis called STOMATA, through which respiration and transpiration can take place. Some plants produce two forms of foliage leaves, a phenomenon known as HETEROPHYLLY, or HETEROMORPHY. For example, the *Eucalyptus globulus* (Blue Gum) bears sessile oval leaves when young and sickle-shaped stalked leaves when older. The Water Crowfoot (*Ranunculus aquatilis*) bears two kinds of foliage leaves: (*a*) submerged leaves which are finely divided, and (*b*) floating leaves which are lobed.

*Scale Leaves* are small brown sessile leaves, and are usually reduced forms of foliage leaves, as in the Oak. Their function is chiefly protective. They are found chiefly as BUD SCALES, small, brown, hard and thick leaves which protect the winter buds from cold in winter and spring. The scale leaves of the Horse-chestnut are really enlarged leaf bases, for the inner scales often possess rudimentary leaf-blades. The scale leaves of the Bird Cherry are modified stipules. Rhizomes, bulbs, and tubers always possess scale leaves, sometimes brown (e.g. onion), usually colourless and much reduced.

*Bracts* are leaves in the axils of which floral shoots are produced. They are usually green, but may be red or otherwise coloured or colourless. They resemble scale leaves in form and origin.

*Floral Leaves.*—The flowers produced by Angiosperms are formed of structures which have the same morphological value as foliage leaves. They are called FLORAL LEAVES. In a typical flower there are four series of floral leaves, the sepals, petals, stamens, and carpels. The sepals are usually green, and resemble bracts. The petals are of a more delicate structure, and are variously coloured. Stamens are generally filamentous in shape, and produce pollen in special receptacles. The carpels may be regarded as scale leaves which have closed together, producing receptacles in which ovules are borne.

35. **The Arrangement of Leaves.**—Leaves are arranged on the stem in a characteristic regular manner. The manner in which leaves are arranged on a stem is spoken of as PHYLLOTAXY. There are two kinds of phyllotaxy: (*a*) spiral, (*b*) cyclic. In spiral phyllotaxy the bases of the leaves are arranged round the stem in the form of a spiral, one leaf being produced at each node. In cyclic phyllotaxy two or more leaves forming a whorl are produced at each node. If two leaves are produced at each whorl the leaves are OPPOSITE, if more than two, VERTICILLATE (fig. 41 *a*). If the pair of leaves at one node are placed at right angles to the pair of leaves below we have the DECUSSATE arrangement (fig. 40) with four rows of leaves on the stem, e.g. Salvia. In spiral phyllotaxy the leaves are said to be ALTERNATE. If we

mark the bases of the leaves of the *Aloe ciliaris*, and trace these marks round the stem, we find that the sixth leaf is exactly over the first, and that the spiral goes exactly round the stem twice. The leaves are arranged, therefore, in five rows or ORTHOSTICHIES. This arrangement is spoken

FIG. 40.—Shoot of Privet, showing Decussate Arrangement of Leaves.

of as a phyllotaxy of $\frac{2}{5}$. Similarly in the case of the Canna, the fourth leaf is over the first, thus forming three orthostichies, and we go round the stem once to reach this leaf. This arrangement is the $\frac{1}{3}$ arrangement.

The most common arrangements are $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, etc. This series can easily be remembered, for in each fraction the numerator is the sum of the numerators of the two previous fractions and similarly with the denominator.

By means of these various arrangements the plant is enabled to expose its leaves, so that each gets a proper amount of illumination, and thus carries on the work of carbon assimilation satisfactorily.

36. **Venation.**—The vascular bundles of the root and stem are continued into the leaves in the form of strands called VEINS. They project above the leaf tissue, and give strength and support to the flat blade. They bring watery solutions from the root, and carry away the elaborated food products produced during carbon assimilation. Veins round the margin of a leaf often prevent it from being torn by the wind, e.g. Senecio.

Frequently the mid-vein is the most strongly developed, and is spoken of as the MIDRIB. Lateral veins branch out from this chief vein.

There are two chief kinds of venation :—

(*a*) Parallel venation (fig. 43 D), typical of Monocotyledons.

(*b*) Reticulate, or netted, venation (fig. 43 B), typical of Dicotyledons.

In parallel venation the veins run either approximately parallel with each other, joining on to a midrib, or in curves converging at the base and apex of the leaf, e.g. grasses. There is no irregular network between the veins.

In reticulate venation the veins branch off from one another, ultimately forming a fine, close, irregular network. If in reticulate venation there is a midrib from which several lateral veins branch off we have pinnately veined leaves. If the main vein branches at the base of the leaf-blade into several equal strong ribs, we have palmately veined leaves.

37. **Vernation.**—By this term is meant the manner in which leaves in the bud are arranged with regard to each other. Vernation may be FREE when the leaves

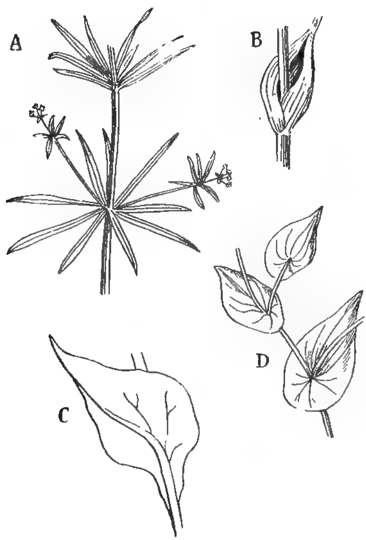



FIG. 41.—A. Verticillate arrangement of leaves. B. Amplexicaul leaf. C. Decurrent leaf. D. Perfoliate leaf.

do not touch; VALVATE when just touching; IMBRICATE when some leaves overlap others; CONTORTED when the margins overlap each other successively in one direction.

38. **Descriptive Terms.**—In order to be able to describe leaves for the purposes of information and recognition the following terms are used. When, as in the case of the Poppy, the leaf base surrounds the stem

(fig. 41 B) the leaves are described as AMPLEXICAUL; if, as in the *Borbonia perforata*, the leaf base completely surrounds the stem, so that the stem seems to grow through the leaf, the term PERFOLIATE is used (fig. 41 D).

If the bases of two opposite leaves are united, so that a cup is formed (fig. 42), they are said to be CONNATE (e.g. Crassula); when any part of the leaf adheres to the stem, e.g. Stoboea, it is said to be DECURRENT (fig. 41 C).

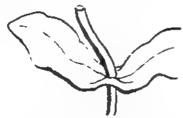


FIG. 42.—Connate Leaf.

If the leaves grow from the main stem they are termed CAULINE; if from branches, RAMAL; if from a short reduced stem (so that they appear to come from the root), RADICAL.

39. **Forms of Leaves.**—(*a*) *Composition.*—When the divisions of the leaf-blade are distinct, and have a separate insertion on the common leaf-stalk or on the midrib, then termed the SPINDLE or RHACHIS, a leaf is spoken of as COMPOUND; in all other cases it is said to be SIMPLE. Each separate part of the compound leaf is called a leaflet. The divisions of the leaf-blade are said to be PINNATE or PALMATE, according as the incisions run towards the midrib or towards the base of the leaf-blade.

(*b*) *Incision.*—A leaf is said to be ENTIRE if its margin is unbroken (fig. 43 B, D and E). When incisions extend nearly midway between margin and midrib the leaf is said to be PINNATIFID or PALMATIFID; when they reach more than half way PINNATIPARTITE or PALMATIPARTITE; when they reach almost to the midrib PINNATISECT or PALMATISECT.

(*c*) *Apex.*—The following terms are used with regard to the apex of a leaf: OBTUSE, if rounded; ACUTE, if sharp pointed; ACUMINATE, if it gradually tapers to a point;

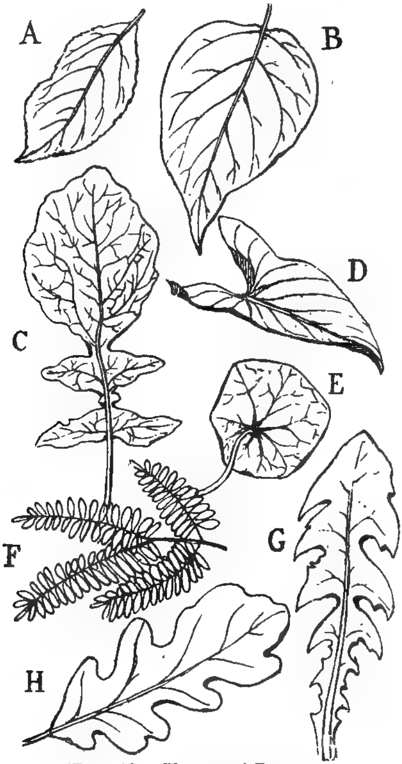



FIG. 43.—Forms of Leaves.

A. Typical net-veined leaf. B. Ovate leaf, entire margin. C. Lyrate leaf. D. Sagittate leaf, parallel venation. E. Orbicular leaf. F. Compound bipinnate leaf. G. Runcinate leaf. H. Sinnate margin.

RETUSE, if there is a rounded depression; EMARGINATE, if the depression is sharp.

(*d*) *Outline.*—The following terms are used with regard to the outline of the leaf: Oval or Elliptical, if broadest in the middle and round at the ends; Lanceolate, if ends gradually taper; Orbicular, if the leaf is nearly round (fig. 43 e), e.g. Nasturtium; Ovate, if rounded at base and pointed at the apex (fig. 43 b); Obovate, if the reverse; Reniform, if apex is rounded and leaf is notched at the base; Acerose, if sharp pointed and needle-like, as in the Pine; Linear, if narrow and with almost parallel edges; Spathulate, if apex is rounded and leaf gradually tapers towards the base, e.g. Lettuce; Cuneate, as with a spathulate leaf but more tapering towards the base (e.g. leaflets of Horse-chestnut); Sagittate, if shaped like an arrow-head, e.g. Arum (fig. 43 d); Hastate, if barbs are more at right angles to the blade than in a sagittate leaf; Cordate, if heart-shaped; Obcordate, if the reverse.

(*e*) *Margin.*—If the margin is not entire it may be Crenate, having a number of rounded processes; Dentate, if processes are sharp pointed, or Serrate if processes are sharp pointed and point forwards. The margin may be covered with hairs, in which case it is called Ciliate. The term Sinuate is used if indentations are deeper than in the case of a crenate margin, e.g. Oak (fig. 43 h).

40. **Other Terms.**—If a pinnate leaf has an even number of leaflets it is said to be Paripinnate, if an uneven number Imparipinnate. If the leaflets are completely incised so that secondary leaflets or pinnules are formed the leaf is said to be Bipinnate (fig. 43 f), e.g. Mimosa. Similarly, if these pinnules are completely

incised the leaf is said to be TRIPINNATE. If a palmate leaf has two leaflets it is said to be BINATE, if three, TERNATE, if more MULTIFOLIATE. If a simple leaf is incised so that there is a large rounded terminal division and the lobes become smaller towards the base it is said to be LYRATE (fig. 43 C). If the terminal division is pointed and the other lobes point backwards the leaf is said to be RUNCINATE (fig. 43 G).

If a palmatifid leaf has the lobes again divided it is spoken of as a PEDATE leaf.

41. **Modifications of Foliage Leaves.**—(*a*) *Leaf Tendrils.*—In some plants, especially among the Papilionaceae, the leaf or leaflets are modified into delicate tendrils which enable the plant to cling to a support.

(*b*) *Phyllodes* (fig. 39).—In some Australian species of Acacia, the leaf petioles become flattened and leaf-like and take on the functions of the undeveloped laminae. The surfaces are expanded perpendicularly instead of horizontally. This is a modification which enables the plant to reduce excessive transpiration owing to the perpendicular position and reduced surface.

(*c*) *Leaf Thorns.*—In the Barberry whole leaves become transformed into thorns, but still subtend axillary shoots bearing leaves, thus proving their leaf origin. In the *Robinia pseudacacia*, the stipules become modified into thorns. In *Acacia horrida* (Mimosa or Doornboom) the long white thorny stipules are very conspicuous; in the young leaves they are soft and succulent, but harden and dry as they grow older.

(*d*) *Pitchers, Bladders, etc.*—Some of the leaves of NEPENTHES ROBUSTA have become modified into pitchers with a lid. In Utricularia bladders are developed on the submerged leaves with valves at the mouth which allow of ingress, but not egress, of small water animals.

42. **Dorsiventral, Isobilateral and Concentric Leaves.**—In leaves which are placed horizontally the cells under the epidermis of the upper surface differ in structure and function from those under the epidermis of the lower surface. Such a leaf is said to be DORSIVENTRAL or BIFACIAL. But some leaves hang perpendicularly, and usually these have the same kind of tissue on both surfaces. Such leaves are said to be ISOBILATERAL. Examples are found in the Blue Gum, Silver tree, Iris, and some species of Mesembryanthemum and Acacia.

Lastly, some leaves have a radial arrangement of tissue, e.g. the Pine. These leaves are spoken of as CONCENTRIC.

43. **Microscopic Structure of the Leaf.**—The internal structure of the petiole resembles chiefly that of the stem. It can be distinguished from the latter owing to its dorsiventral nature.

A transverse section of the leaf-blade of the Privet under the microscope presents the appearance shown in fig. 44. The upper and under surfaces are protected by a flattened epidermis with a well-developed cuticle. The under surface possesses a large number of stomata. The cells underneath the upper epidermis are elongated and packed tightly together. They contain numerous chloroplasts. This tissue is called the PALISADE TISSUE. Towards the lower surface the cells are smaller; rounded or stellate and numerous air spaces are present between them. This tissue is known as the SPONGY PARENCHYMA. The palisade cells contain much more chlorophyll than the spongy tissue, and are especially adapted for the work of assimilation. The spongy parenchyma,

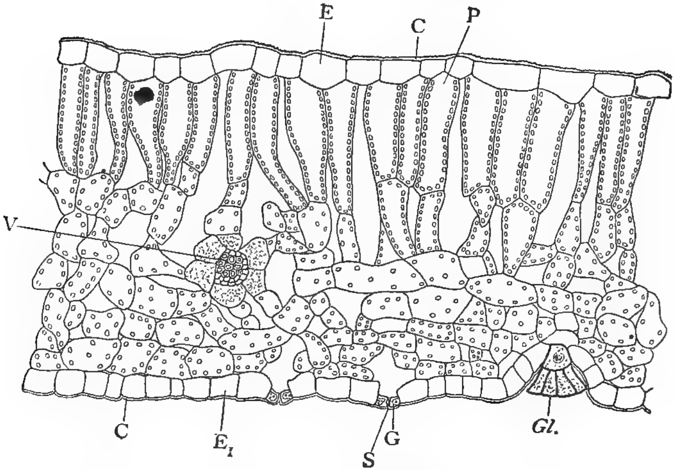



FIG. 44.—Leaf of Privet.

E. Epidermis of upper, $E_1$ of under surface. C. Cuticle. P. Palisade cells. V. Vascular bundle enclosed in its sheath. S. Stoma. G. Guard cell. *Gl.* gland. (From Farmer's "Practical Introduction to the Study of Botany".)

on the other hand, is especially adapted for the interchange of gases.

The lower ends of groups of palisade cells converge on one cell of the spongy tissue which acts as a COLLECTING CELL and passes on the products of assimilation to the bundle.

The whole of the tissue between the upper and lower epidermis is called the MESOPHYLL. Between the palisade and spongy mesophyll runs the vascular bundle containing xylem towards the upper part and phloem towards the lower. Endodermis and pericycle can be recognized in the larger bundles.

44. **Stomata.**—If the epidermal layer be torn off a leaf and mounted and examined under the microscope it presents the appearance shown in fig. 45 A. Dotted

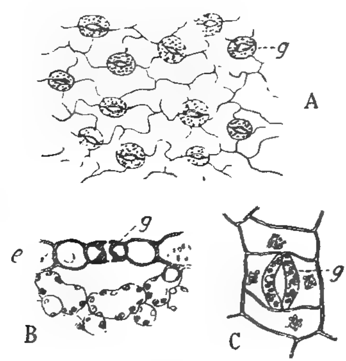



FIG. 45.—Stomata.

A. As seen in surface view. B. Transverse section. C. Stoma of Tradescantia. *g*. Guard cell. *e*. Epidermis.

about the epidermis one can notice a number of small pores, each pore being surrounded by a pair of small green cells. Each of these structures is called a STOMA (Greek—*Stoma*, a mouth). The two cells surrounding the opening are called *guard cells*. The pore communicates with a large intercellular space called the RESPIRATORY CAVITY or air chambers. These stomata are scattered about the surface of all the aerial parts of a plant, and their number may reach as high as 700 per square millimetre, although the average is

100 per square millimetre. They are so small that neither dust nor water can pass through them into the plant, but so numerous that a Sunflower leaf contains about 13,000,000 of them. In dorsiventral leaves they are usually found on the under surface. In isobilateral leaves they are distributed equally on both surfaces.

The closing or opening of the pore is effected by changes in the turgidity of the guard cells. When these are turgid the pore is opened to its widest extent. When they are flaccid the pore is nearly closed.

Their chief function is to allow water vapour and other gases to pass in and out of the plant.

45. **Functions of Leaves.**—The functions of leaves will be more fully considered in Chapter IX. But it may be mentioned here that they act as—

(*a*) Breathing organs;

(*b*) As organs of transpiration;

(*c*) As actual laboratories, in which is built up out of carbon dioxide of the air and the nutrient salts of the soil the organic building material of which the plant body is made.

## PRACTICAL EXERCISES ON CHAPTER IV.

1. Sketch a Rose leaf and mark the stipules, petiole, leaf-blade. Describe the leaf.

2. Sketch the leaf of the Arum Lily, sketching the veins carefully. Describe the leaf.

3. Examine a shoot of Salvia, and describe the arrangement of leaves.

4. Pick leaves of the following plants and describe them with regard to—

(*a*) Their composition ;
(*b*) Incision ;
(*c*) Apices ;
(*d*) Outline;
(*e*) Margin ;

Pepper tree, Acacia, Mimosa, Violet, Sunflower, Iris, and Chrysanthemum.

5. Sketch a leaf of the Sweet Pea, marking the tendrils.

6. Embed a Privet leaf in pith. Cut a transverse section through the midrib. Mount it and examine it under the microscope. Note—

(*a*) The epidermis and stomata ;
(*b*) Palisade cells ;
(*c*) Spongy tissue ;
(*d*) The vascular bundle.

7. Strip the epidermis off a leaf. Mount it and examine it under the microscope. Note the stomata. Make a sketch of the surface view of the epidermis.

## QUESTIONS ON CHAPTER V.

1. Mention the chief differences between the tissues of a typical stem (e.g. Sunflower) and a typical leaf (e.g. Privet)—

(*a*) As regards structure ;
(*b*) As regards function.

2. What are the parts of a leaf? Describe the leaves of an Acacia with reference to—

(*a*) Development ;
(*b*) Shape ;
(*c*) Venation.

3. On what parts of plants do stomata occur? On which parts are the largest and on which the smallest number of them? Show how different plants differ in this respect. Name some plants which are devoid of stomata.

4. Give a sketch of :—

(*a*) An exstipulate simple leaf, with reniform outline, dentate margin, and reticulate venation.

(*b*) A stipulate imparipinnate compound leaf, each leaflet being ovate in outline and having the margin entire.

(*c*) A sessile, exstipulate, lanceolate, simple leaf, with margin entire, and parallel venation.

5. Describe the appearance of a typical leaf as seen in transverse section at right angles to the midrib.

6. Give an account of the various methods of leaf-folding in buds. For each method quote at least one example.

7. Give an account of the most common forms of the venation of leaves.

8. Describe the anatomical structure of a typical leaf, and point out the functions which its various tissues have to perform.

9. Describe (*a*) the external form, (*b*) the internal structure of the green leaf of any plant that you have studied.

## CHAPTER VI.

### THE FLOWER AND INFLORESCENCE.

46. **Definition.**—A flower is a leafy shoot specially modified for the purposes of reproduction. It is to be especially borne in mind that all the parts of the flower are morphologically of the rank of leaves. The facts that the floral members are arranged in spirals or whorls, that the flowers are often borne on a branch arising from the axil of a leaf or bract, that stamens may be transformed into petals all substantiate this view.

The diverse and beautiful forms found among Angiosperms have been developed chiefly owing to the part that insects play in affecting cross-pollination.

47. **Parts of a Flower.**—A typical flower, e.g. Wild Rose, consists of four rings or whorls of organs borne upon the flattened head of the flower stalk or PEDICEL called the RECEPTACLE (also called the THALAMUS). The outside whorl is composed of SEPALS and is called the CALYX (from Greek—*kalyptein*, to cover). The next whorl is made up of PETALS, and is called the COROLLA (from Lat.—*corona*, a crown). The third whorl is made up of STAMENS and is called the ANDROECIUM (Greek—*andreios*, male; *oikos*, a house). The innermost whorl is made up of CARPELS and is called the GYNOECIUM (or

gynaecium), or PISTIL (Greek—*gunaikeion*, the woman's house).

If a flower possesses all four whorls it is spoken of as COMPLETE. If any are missing it is spoken of as INCOMPLETE. If androecium and pistil are present the flower is called PERFECT or hermaphrodite, if either is missing IMPERFECT or unisexual. Imperfect flowers may be STAMINATE (having stamens only) or PISTILLATE (having a pistil only).

48. **The Thalamus.**—The thalamus, or receptacle, may assume various forms. For example, it may be flattened, convex, e.g. Poppy; or hollow and cup-shaped, e.g. Rose. According to its shape and the arrangement of floral members upon it we divide flowers into three classes: (*a*) HYPOGYNOUS flowers; (*b*) PERIGYNOUS flowers; (*c*) EPIGYNOUS flowers.

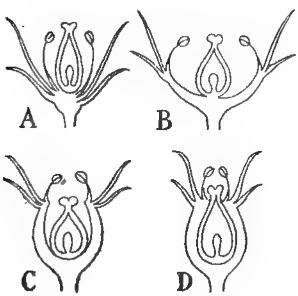



FIG. 46.

A. Hypogynous flower. B, C. Perigynous flowers. D. Epigynous flower.

In a hypogynous flower (fig. 46 A) the gynoecium is situated on the highest part of the thalamus and the other whorls inserted below it. In a perigynous flower (fig. 46 B and C) the thalamus is flattened or cup-shaped, the gynoecium occupying the middle of the disc, and the other whorls being situated round about it. In epigynous flowers (fig. 46 D) the floral axis is concave as in some forms of perigyny, but its margin becomes adherent to the gynoecium, so that the other whorls are inserted on the pistil. In hypogynous and perigynous flowers the gynoecium is said to be SUPERIOR, and the other whorls INFERIOR. In epigynous flowers the gynoecium is inferior, and the other whorls superior.

49. **The Calyx.**—The calyx usually consists of one whorl of from two to five green, leaf-like structures. But there may be two whorls as in the Strawberry, and the sepals may be coloured, e.g. Nasturtium, Salvia. If the sepals are joined, however slightly, the calyx is said to be GAMOSEPALOUS. If free it is said to be POLYSEPALOUS. The calyx assumes various shapes in different Natural Orders, and hence the following terms are used to describe them :—

TUBULAR (like a tube), fig. 47 (I.).

URCEOLATE (or vase-shaped), fig. 47 (III.).

OBOSE (fig. 47 (II.)).

SPURRED (if sepals are prolonged backwards into a spur, e.g. Tropaeolum).

SACCATE (if there are four sepals, two of which form a pouch, e.g. Wallflower (fig. 47 (IV.)).

GALEATE, or hooded (e.g. Monkshood).

CAMPANULATE, or bell-shaped.

INFUNDIBULIFORM, or funnel-shaped.

BILABIATE (if it forms two lips).

If the calyx falls off when the flower opens it is said to be CADUCOUS, e.g. Poppy. If it falls off when flower withers, DECIDUOUS, e.g. Ranunculus, and if it remains until after fruit has ripened PERSISTENT, e.g. Tomato.

Its chief function is to protect the flower while in the bud. But in many cases it takes on other functions. For example, in most Monocotyledons it has the same attractive functions as the corolla, being similar in size and colour. The calyx is then said to be PETALOID. In many members of the Compositae (e.g. Thistle, Cornflower) the calyx has been reduced to a ring of hairs called a PAPPUS, and this helps subsequently in fruit dispersal. In other cases the persistent calyx takes a great share in the formation of the fruit, e.g. Apple, Oak.

50. **The Corolla.**—The corolla is usually much more

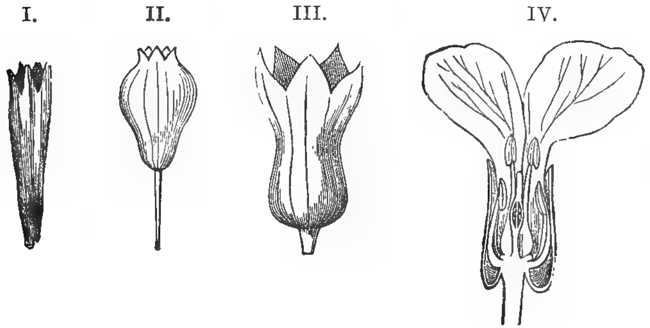



FIG. 47.—Calyces.
I. Tubular. II. Obose. III. Urceolate. IV. Saccate. (From "Thomé's Botany".)

conspicuous and much more delicate in structure than the calyx. It may be GAMOPETALOUS or POLYPETALOUS. Its chief function is to attract insects, for which purpose it is often highly coloured and sweet scented. It may also protect the stamens and carpels. It rarely persists after fertilization.

The following terms are used when describing the petals:—

UNGUICULATE, or clawed, if they are broad above and form a narrow limb below.

LIGULATE, if ligules are formed at junction of claw and limb (if the ligules cohere, as in the Daffodil, a corona is formed).

FIMBRIATED, if fringed with hairs.

I. II. III.

IV. V.

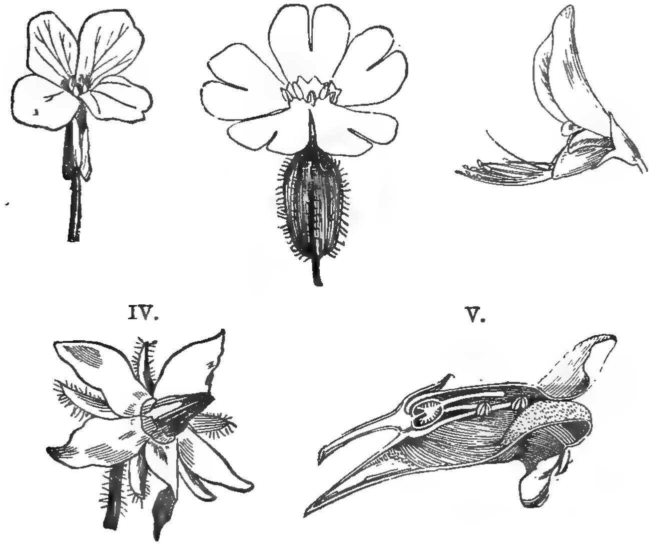


FIG. 48.—Corollas.

I. Cruciform flower of *Lunaria*, with unguiculate petals. II. Caryophyllaceous corolla of *Lychnis vespertina*, with corona. III. Papilionaceous corolla of Erythrina. IV. Rotate corolla of the Borage (*Borago officinalis*). V. Bilabiate personate corolla of *Antirrhinum majus*.

A polypetalous corolla may be CRUCIFORM when there are four unguiculate petals arranged in the form of a cross; ROSACEOUS if it consists of five petals, not clawed, attached perigynously; PAPILIONACEOUS if it consists of five irregular petals as in the Pea; CARYOPHYLLACEOUS if it consists of five regular clawed petals attached hypogynously to the receptacle, e.g. Pink.

A gamopetalous corolla may be TUBULAR, CAMPANULATE, INFUNDIBULIFORM, URCEOLATE, GLOBOSE, BILABIATE (cf. calyx, par. 49); BILABIATE and RINGENT if the two lips gape apart, e.g. Salvia; BILABIATE and PERSONATE if the two lips are closed up, e.g. Snapdragon; GLOVE-SHAPED as in fox-glove; ROTATE if there is a spreading limb and short tube; LIGULATE, or strap-shaped, when the lower part of the corolla forms a tube, and the upper part is flattened out, e.g. Sonchus and ray florets of Sunflower.

If one whorl only is present besides the androecium and gynoecium it is called a calyx whatever its appearance, e.g. Anemone and Clematis. Sometimes appendages of the petals, called ligules, cohere together to form a second structure similar to the corolla. Such a structure is called a *corona*, e.g. Narcissus. If calyx and corolla resemble one another, as in most Monocotyledons, the two whorls are grouped together under the term PERIANTH.

51. **The Androecium.**—The androecium is made up of a number of stamens varying from two to an indefinitely large number.

Each stamen (Figs. 49, 50) consists of two parts—a cylindrical stalk called the FILAMENT supporting a little knob called the ANTHER. The latter is composed of two lobes, each lobe containing a pair of sacs filled with a fine powdery substance called POLLEN. The two lobes are joined by a strip of tissue containing a vascular bundle. This strip is called the CONNECTIVE. If the pollen sacs face the carpels the stamens are said to be INTRORSE, if they face the perianth EXTRORSE. When ripe the anther lobes dehisce, liberating the pollen. The septum between the two pollen sacs usually breaks down so that the contents of both sacs are liberated through the same split in the lobe. The dehiscence is brought about by the contraction of the cells of the inner of the two layers forming the walls of the loculus. This layer is called the ENDOTHECIUM or FIBROUS LAYER. The dehiscence may be longitudinal as in the Gladiolus,

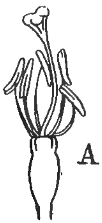



FIG. 49.

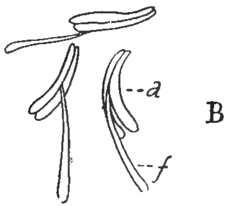



FIG. 50.

A. The androecium and gynoecium of the Cape Crocus. B. Different views of the stamens. *a*. Dorsifixed anther. *f*. Filament.

transverse as in some Labiatae, porous as in Heath, or valvular as in Cassytha.

If a stamen possesses no anther, or produces no pollen, it is called a STAMINODE. If no filament is present the stamens are said to be SESSILE.

The following terms are used in describing the androecium, POLYANDROUS, if stamens are free; ADELPHOUS, if the filaments cohere; MONADELPHOUS, if united to form one bundle, e.g. Broom; DIADELPHOUS, if united to form two bundles, e.g. Pea; POLYADELPHOUS, if united to form many bundles, e.g. Orange; SYNGENESIOUS, if the anthers only cohere, e.g. Sunflower, Potato; TETRADYNAMOUS, if there are four long and two short stamens present, e.g. Wallflower; DIDYNAMOUS, if there are two long and two short stamens, e.g. Foxglove. The stamens are said to be EPIPETALOUS if they adhere to the corolla, e.g. Primrose; GYNANDROUS, if they adhere to the gynoecium, e.g. Orchids. The following terms are used in describing the insertion of the anthers upon the filaments: BASIFIXED or INNATE, if the filament is attached to the base of the anther; ADNATE, if filament seems to run up the back of the anther; DORSIFIXED, if filament is attached to a point in the back of the anther, and latter is fixed; VERSATILE, if filament is similarly attached but anther is free to swing about.

52. **Pollen.**—The fine yellow powder produced by the anthers is called pollen. This is produced by division of the interior cells of the anthers. These form a number of pollen mother cells, each of which divides into four daughter cells. These are the pollen grains. The walls of the mother cells and daughter cells gradually disappear and the grains lie loose in the cavity of the anther lobe. Sometimes the walls do not entirely disappear, so that the grains remain united, e.g. in Mimoseae in fours, while in the Orchids and Asclepiads the whole mass of pollen grains remains joined together forming a POLLINIUM.

53. **The Gynoecium.**—The innermost whorl of the flower is called the GYNOECIUM (or GYNAECIUM) or PISTIL, and consists of one or more structures called CARPELS (fig. 51). If only one carpel is present the gynoecium is said to be MONOCARPELLARY, if more,

POLYCARPELLARY. A typical carpel consists of three parts, the apical portion called the STIGMA, a long slender portion connecting the stigma to the lower part called the STYLE, and a box-like structure at the bottom called the OVARY. Inside the ovary are structures called OVULES, borne on an outgrowth of the margin of the carpel called a PLACENTA.

If the placenta simply projects a little way from the inner wall of the ovary the ovary is said to possess PARIETAL placentation. The polycarpellary gynoecium may consist of a number of separate carpels, quite free from one another, in which case it is said to be APOCARPOUS, or the carpels may be joined together, in which case the gynoecium is said to be SYNCARPOUS. The fusion may not be quite complete. Sometimes the stigmas are free, in other cases the styles as well may be free. In these cases it is easily seen how many carpels are present, but when the fusion is complete it is more difficult. Only by a careful examination of the ovary is it possible to tell the number of carpels present.

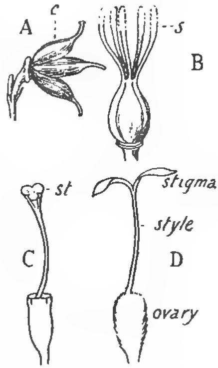



FIG. 51.—Pistils.
A. Polycarpellary pistil of Monkshood. *c*. Carpel. B. Syncarpous pistil of Flax, showing separate styles (*s*). C. Syncarpous pistil of Cape Crocus. *st*. Stigmas. D. Syncarpous pistil of Sunflower.

54. **Placentation.**—When the margins of the carpels fuse to form a unilocular ovary and the placentas are projections of the ovary wall, as described above, the placentation is said to be PARIETAL. The number of

placentas indicates the number of carpels. If the margins of the carpels project further into the ovary so as to divide it into separate compartments or loculi, the placentas meet in the centre to form an axis, and the placentation is said to be AXILE (fig. 52). The number of loculi indicates the number of carpels. If one loculus is present the gynoecium is said to be UNILOCULAR, if two are present BILOCULAR, if more MULTILOCULAR. In some cases the ovary is divided into loculi, not by the projection of the margins of the


FIG. 52.—Cross section of Ovaries showing Placentation.

A. Cape Crocus showing axile placentation. B. Passion Flower showing parietal placentation. C. Pentstemon showing axile placentation.

carpel towards the centre, but by the growth of FALSE SEPTA, or outgrowths, from the surface of other parts of the carpel. This condition must be carefully distinguished from the division of the ovary into loculi by TRUE SEPTA, i.e. by septa formed by outgrowth and fusion of the margins of the carpel. Lastly, if the floral axis projects into the centre of the ovary and the ovules are borne on this projecting axis the placentation is said to be FREE-CENTRAL. The carpels fuse at their margins as in parietal placentation so that only one loculus is formed, but the ovules are borne on a prolongation of the floral axis, not on the margins of the carpels. If a single ovule is inserted on the floor of the ovary the placentation is said to be BASAL.

55. **Aestivation.**—This term is applied to describe the manner in which the sepals and petals are folded in the flower bud (cf. vernation, par. 37). Just as we have valvate, imbricate and contorted vernation of leaves in a bud so we can have valvate, imbricate and contorted aestivation of the calyx or corolla. In addition, the margins of the floral leaves may be folded inwards on themselves. In this case the aestivation is INDUPLICATE. If the corolla or calyx contains five leaves, two internal, two external, and one partly internal, partly external the aestivation is QUINCUNCIAL. VEXILLARY aestivation is characteristic of the corolla of Leguminosae (see fig. 98).

56. **Regular and Irregular Flowers.**—It is important to note the variations in symmetry of a flower, as this often indicates how pollination is brought about. If all the petals and sepals are the same shape and similarly arranged with regard to the centre of the flower, the flower is said to be REGULAR, e.g. the Peach. If the sepals or petals differ in size or shape or arrangement from one another the flower is said to be IRREGULAR, e.g. the Pea.

Regular flowers are radially symmetrical or actinomorphic, i.e. they can be divided into similar halves by two or more planes passing through the axis. Irregular flowers may be ISOBILATERAL, i.e. divisible into similar halves by two planes through the axis at right angles to each other, ZYGOMORPHIC, divisible into similar halves by one plane only, e.g. the Pea, Violet, Salvia;

or ASYMMETRICAL, having no plane of symmetry, e.g. Cactus.

57. **Cohesion and Adhesion.**—When similar parts of a plant are united we use the term COHESION. Thus we speak of the cohesion of sepals in a gamosepalous calyx. But when dissimilar parts are united we use the term ADHESION. Thus we speak of the adhesion of the stamens to the petals, of the calyx to the ovary, etc.

58. **Floral Diagrams and Formulae.**—It is very useful in describing a flower to draw a diagram of the arrangement of its members as they are seen in a cross-section of the opened bud, so arranged that the transverse section of the axis of the inflorescence stands above and that of the bract below. Such a diagram is called a FLORAL DIAGRAM. Cohesion of parts may be indicated by connecting lines, and aestivation of the perianth may be shown on it as well. A diagram representing the vertical section of the flower should also accompany the floral diagram as this gives further information which it is impossible to insert in the floral diagram, e.g. whether flower is hypogynous, epigynous, or perigynous.

Similarly FLORAL FORMULAE enable us to describe very shortly the number of members in each whorl of a flower, and certain facts about their arrangement. In these formulae, the letters K, C, A, and G, stand for calyx, corolla, androecium and gynoecium respectively. The number which follows these letters gives the number of sepals, petals, stamens or carpels. Cohesion is indicated by brackets enclosing the number of parts. A horizontal bracket indicates adhesion between the parts of successive whorls; a horizontal line above the number of carpels means that the ovary is inferior, a line below, that it is superior.

59. **The Inflorescence.**—In Angiosperms the flowers are usually borne in clusters on special branch systems which are termed INFLORESCENCES. Each floral axis

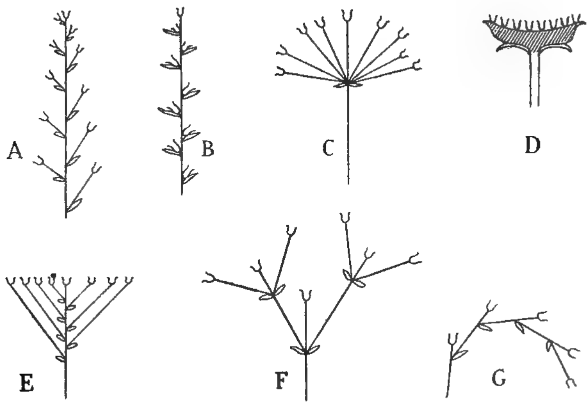



FIG. 53.—Diagrams of Inflorescences.

A to E. Racemose. F, G. Cymose.
A. Raceme. B. Spike. C. Umbel. D. Capitulum. E. Corymb.
F. Dichasium. G. Helicoid Cyme.

arises in the axil of a leaf which in this case is called a BRACT. Leaves borne on the floral axis itself are called BRACTEOLES. When several bracts surround a single flower, e.g. Pink, or an inflorescence, e.g. Sunflower, they form an INVOLUCRE. When a single bract is enlarged and ensheathes a single flower, e.g. Narcissus, or an inflorescence, e.g. Arum, it is called a SPATHE. If bracts are present the flower is said to be BRACTEATE, if absent, EBRACTEATE. If the main vegetative axis of the plant ends in a single flower, e.g. Tulip, the flower is said to be SOLITARY, and TERMINAL. If the flowers are developed singly in the axils of ordinary foliage leaves they are said to be SOLITARY and AXILLARY. Usually, however, the flowers are borne in clusters.

According to the relative development of the main and lateral axis we divide inflorescences into two classes: (1) RACEMOSE or INDEFINITE inflorescences, in which the main axis has indefinite powers of growth and continues to give off lateral branches which bear the flowers; and (2) CYMOSE or DEFINITE inflorescences in which the primary axis ends in a flower and growth is continued by a lateral branch.

60. **Racemose Inflorescences.**—According to the different development of the lateral axis we divide racemose inflorescences into the following kinds:—

(1) *Raceme.*—Stalked flowers borne on an elongated main axis or peduncle (fig. 53 A), e.g. Foxglove.

(2) *Spike.*—Sessile flowers borne on an elongated main axis (fig. 53 B). If the axis is thickened and succulent the spike is called a SPADIX, e.g. Arum Lily. If the spike is deciduous and bears unisexual flowers it is called a CATKIN or AMENTUM, e.g. Willow.

(3) *Umbel.*—Main axis shortened so that flowers (which are stalked) seem to come off from the same level (fig. 53 C), e.g. Cherry.

(4) *Capitulum.*—The main axis shortened and flattened and sessile flowers borne on this head (fig. 53 D) e.g. Sunflower.

(5) *Panicle.*—A compound raceme, the main axis bearing racemes laterally, e.g. Oats.

(6) *Compound Umbel.*—An umbel bearing small umbels in place of the single flowers.

(7) *Corymb.*—The main axis elongated, but the lateral axes of different length so that all the flowers come to one level (fig. 53 E), e.g. Candytuft.

61. **Cymose Inflorescences.**—According to the number of daughter axes given off we distinguish cymose inflorescences into :—

(1) *Uniparous Cyme.*—Each successive axis ends in a flower after producing one daughter axis. If the daughter axes are always produced on the same side we get the HELICOID cyme (fig. 53 G) ; if alternately left and right the SCORPIOID cyme. The successive daughter axes often straighten out and come to be in a straight line resembling racemes. This false axis (resembling the main axis of a raceme) is called a SYMPODIUM. The cyme can easily be distinguished from a raceme by noting the position of the bracts.

(2) *Biparous Cyme.*—Each successive axis ends in a flower after producing two daughter axes (fig. 53 F), e.g. Pink. This type of inflorescence is also called a DICHASIUM, and the branching is known as false DICHOTOMY.

(3) *Multiparous Cyme.*—A whorl of daughter axes is given off before the mother axis ends in a flower. This resembles an umbel somewhat in appearance but can be distinguished from it by the fact that the oldest flower is in the middle.

(4) *Verticillaster.*—Apparent whorls of flowers are given off at each node, but in reality two cymose bunches placed on opposite sides of the stems are

produced. Each bunch is a dichasium of scorpioid cymes, e.g. Dead Nettle.

62. **Mixed Inflorescences.**—In many plants we find a mixture of inflorescences. For example, in the Sunflower, while each inflorescence is indefinite, yet taking all the inflorescences the arrangement is definite, for the terminal one opens first. In the cultivated Geranium cymose clusters are arranged in umbels. In the Lilac we have a raceme of cymes.

## PRACTICAL EXERCISES.

1. Examine the inflorescences of Foxglove, Ornithogalum, Salvia, Sunflower, Crassula, Aloe, Cotyledon, Protea, Wallflower, and state what kind of inflorescence they possess.

Draw sketches of the inflorescence and number the flowers in the order they appear.

2. Describe the following flowers using the following scheme: Oxalis, Pea, Wild Rose, Peach, Apple, Gladiolus, Acacia, Antirrhinum.

*Scheme.*

*Flower.*—Say whether flower is sessile or pedicellate, bracteate or ebracteate, complete or incomplete, hermaphrodite or unisexual (pistillate or staminate,) symmetrical (actinomorphic or zygomorphic) or asymmetrical, heterostylic (dimorphic, trimorphic, etc.), dichogamous (protandrous or protogynous) hypogynous, perigynous, or epigynous, regular or irregular.

*Calyx.*—Say whether flower is poly- or gamo-sepalous, and give number of sepals.

*Corolla.*—Say whether flower is poly- or gamo-petalous and give the number of petals and shape of corolla. Say whether petals are clawed or ligulate, and whether a corona or nectaries are present.

If calyx is petaloid the corolla and calyx may be described together under the term PERIANTH. In this case poly- or gamophyllous should be used instead of poly- or gamo-sepalous, etc.

*Androecium.*—Give the number of stamens. Say whether they are polyandrous, syngenesious or adelphous. Describe the stamens and say whether they are sessile, epipetalous or possess filaments. State whether anthers are introrse or extrorse, adnate, innate, dorsifixed, or versatile.

*Gynoecium.*—Say whether it is mono- or poly-carpellary (apo- or syn-carpous) and give the number of carpels.

Say whether ovary is unilocular or multilocular, superior or inferior. Give the number of ovules and their placentation. Describe style and stigma.

3. Examine and make drawings of the stamens of Foxglove and Aloe, to show : (*a*) general form, (*b*) insertion of anthers, (*c*) mode of dehiscence, (*d*) internal structure.

## QUESTIONS ON CHAPTER VI.

1. Draw a diagram of a longitudinal section through a simple pistil ; insert an anatropous ovule on a central placenta and show how this would be fertilized by a pollen grain.

2. Describe the formation of the pollen grains in an anther. In which natural order of plants is the formation different from the usual one?

3. What is the placenta of plants? Give an account of the more common forms of placentation.

4. Explain the terms hypogynous, perigynous, and epigynous as applied to the corolla, and give some examples drawn from the South African Flora, illustrating these terms.

5. Describe briefly with examples the following forms of inflorescence, and point out the relationship which exists between them : Panicle, raceme, umbel, spike, spadix, capitulum.

6. What is meant by a floral diagram? What is its value? Draw the floral diagram of a flower which has the following formula:—

$$K5\ C5\ A5+5\ G\ \underline{(5)}.$$

7. Give an account with examples of the following terms as applied to the calyx : regular, irregular, saccate, tubular, bilabiate.

8. What parts of a typical flower are supposed to be modified leaves? What evidence can you adduce for this?

9. Name and illustrate three types of flower arrangements ;

name two orders in which examples of the umbel may be found.

10. Distinguish carefully between definite and indefinite inflorescences. Define the following and give one example of each: spike, umbel, capitulum, dichotomous cyme, spadix, verticillaster.

11. Draw the floral diagram of the following flower :—

$$K(5)\ \overbrace{C(5)\ A(5)}\ \overline{G(2)}.$$

## CHAPTER VII.

### THE FRUIT.

63. **Definition.**—After the ovule has been fertilized it develops into a seed. At the same time the ovary is stimulated into further growth, and develops into the fruit. Very often changes occur in other parts of the flower as well as the ovary, and it used to be customary to distinguish between "true fruits" formed from the ovary only, and "false fruits" or pseudocarps formed from the parts of the flower as well as the ovary. This distinction was unsatisfactory, and has therefore been abandoned, and we may best define a fruit as the result of changes produced in the flower by fertilization. The covering of the fruit is known as the PERICARP.

64. **Kinds.**—Fruits may be divided into SIMPLE, COMPOUND (or aggregate) and COLLECTIVE (or multiple). A SIMPLE fruit is formed from a single flower with a syncarpous or monocarpellary ovary, e.g. Pea, Cherry, Apple. A COMPOUND fruit is made up of numerous simple fruits, but is formed from a single flower with an apocarpous ovary, e.g. Strawberry. A COLLECTIVE fruit is not formed from a single flower, but from an inflorescence—it may look like a simple fruit, e.g. Pineapple and Fig, or like a compound one, e.g. Mulberry;

and only by studying its development from the flower can its nature be ascertained.

Simple fruits may again be divided into Dry and Succulent, and dry fruits may be either Dehiscent (i.e. they open to let the seeds out), or Indehiscent (do not open). Succulent fruits are almost all indehiscent.

65. **Dry, Indehiscent Fruits.**—The dry, indehiscent fruits are divided into three groups: Achenes, Nuts, and Schizocarps.

An Achene is a small, dry, indehiscent fruit, containing one seed, and usually formed from one carpel, e.g. Ranunculus. A Cypsela differs from an ordinary Achene in being formed from two carpels. This fruit is found in the Compositae. A special kind of Achene is found in the Gramineae, where the pericarp and testa are united. This is called a Caryopsis.

A Nut is larger than an Achene, has a harder pericarp, and is formed from more than one carpel, e.g. Acorn. A variety of Achene or Nut is the winged, one-seeded, indehiscent fruit called Samara, e.g. Combretum, Dodonaea.

A Schizocarp is a dry, indehiscent fruit formed from several carpels and splitting when ripe into as many parts as there were carpels; each part is called a Mericarp and contains one seed. Schizocarps are found in N.O. Malvaceae, Geraniaceae, Umbelliferae, etc.; and the fruits of Hollyhock (Althea), Nasturtium (Tropæolum) are Schizocarps. The fruit of Ricinus (Castor Oil) is like a Schizocarp, but the three Mericarps afterwards open and set free the seeds.

66. **Dry, Dehiscent Fruits.**—There are several kinds of dry, dehiscent fruits.

The FOLLICLE is formed from one carpel, contains several seeds and dehisces by splitting along the ventral margin, e.g. Asclepias, Crassula, Delphinium—all of which have compound fruits of two or more follicles.

The LEGUME is also formed from one carpel, but dehisces down both ventral and dorsal sutures, and it contains several seeds, e.g. Pisum, Lupin.

The LOMENTUM is a legume which breaks up into one-seeded portions, each containing one seed, e.g. Arachis, Desmodium.

The CAPSULE is a dry, dehiscent fruit formed from more than one carpel. Capsules dehisce in various ways. The commonest method is by splitting: if it splits along the midrib of each carpel, as in Iris, the capsule is LOCULICIDAL; if it splits into carpels, leaving the placenta in the middle, it is SEPTICIDAL, e.g. Rhododendron; if the outer wall of the fruit breaks away leaving the septa standing, it is SEPTIFRAGAL, e.g. Datura (fig. 54). Other capsules dehisce by pores, e.g. Papaver, and sometimes the upper half of the pericarp splits off like a lid, e.g. Portulaca, Anagallis.

The SILIQUA is a special form of capsule found in N.O. Cruciferae. In this, the pericarp breaks into two parts from the base upwards, leaving a false partition, the REPLUM, to the edges of which the seeds are attached. The short, broad Siliquas are known as SILICULAS, e.g. Candy-tuft (Iberis).

67. **Succulent Fruits.**—Succulent fruits are chiefly BERRIES and DRUPES. The BERRY is a succulent fruit with a pericarp of two layers, the epicarp or skin, and mesocarp or pulp. It is formed from two or more

carpels and contains several seeds, e.g. Solanum,

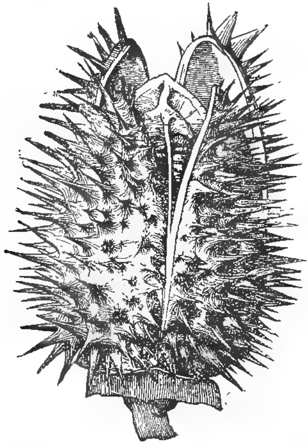


FIG. 54.—Septifragal capsule of Datura.

Tomato. The DRUPE (fig. 55) contains only one seed and has a pericarp of three layers, epicarp, mesocarp,

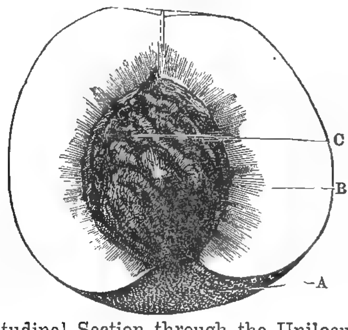



FIG. 55.—Longitudinal Section through the Unilocular Drupe of the Peach.

A. Epicarp. B. Mesocarp. C. Endocarp.

and a hard stony endocarp, e.g. Prunus. It is formed from one carpel.

Other fleshy fruits are the POME, e.g. Apple and Pear, in which the fleshy edible portion is formed from the receptacle, the core being the ovary; the PEPO, a variety of berry with a hard epicarp, e.g. Cucumber, Gourd, Melon, Papaw.

Compound fruits are usually collections of simple fruits, e.g. the Raspberry is a collection of drupelets. The Strawberry consists of a swollen fleshy receptacle bearing numerous Achenes; in the Rose, the Achenes are enclosed in a cup-shaped fleshy receptacle; the Custard-apple (*Anona reticulata*) and Sweet-sop (*A. squamosa*) are both made up of numerous berries sunk in and united with the fleshy receptacle.

68. **Collective Fruits.**—Collective or Multiple fruits are not common.

The Pineapple (Ananas) is formed from an inflorescence, the whole of which becomes a succulent mass, the main axis usually growing beyond and producing green leaves. The Mulberry is also formed from an inflorescence. Each ovary gives rise to an Achene, which is enclosed in fleshy pulp derived from the perianth.

The Fig is derived from an inflorescence which is a peculiar pear-shaped form of capitulum, the flowers being inside. The true fruits are little Achenes, popularly regarded as seeds, and the succulent part is derived from the whole inflorescence and receptacle.

There are several other fruits found cultivated or wild in South Africa, which present features of interest.

The Banana is a berry in which the seeds have not developed, owing to cultivation.

The Cocoa-nut (fig. 56) is a fibrous drupe. The epicarp is hard and green, the mesocarp fibrous, forming the cocoa-nut fibre of commerce, and the endocarp is the hard shell. The edible portion is the endosperm of the seed, the testa being a thin brown covering inside the hard shell. There is a minute embryo at one end, below one of the three little pits at the lower end of the shell.

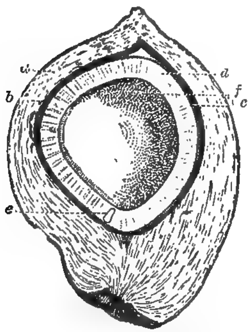


FIG. 56. — Longitudinal Section of Cocoa-nut.

*a*. Epicarp. *b*. Endocarp. *c*. Testa. *d*. Endosperm or albumin. *e*. Embryo. *f*. Cavity in the endosperm which contains the milk.

The Walnut is also a drupe, the epicarp and mesocarp of which peel off as it ripens, the nut we eat is the "stone," its endocarp being hard and woody. The single seed inside has a thin brown testa, and splits readily into two halves, the cotyledons.

The Date is really a berry containing one seed.

The Almond is a drupe, the seed of which is eaten.

The Cape Gooseberry is a berry surrounded by the persistent calyx; other berries found here are the Orange, Naartje, Tree Tomato and Grenadilla.

69. **Dispersal of Seeds.**—Just as the flower was dependent on outside agents for cross-pollination, so the fruit must have help in dispersing its seeds. The chief agencies by which seeds may be dispersed are wind, water, animals, and propulsive mechanisms in the fruit itself.

70. **Dispersal by Wind.**—Some seeds are so small and

light that they are blown away like dust, e.g. Poppy seeds and Orchids. Some fruits have what is known as a Censer-mechanism, i.e. they open only at the top, and the seeds cannot get out until the fruit is blown to and

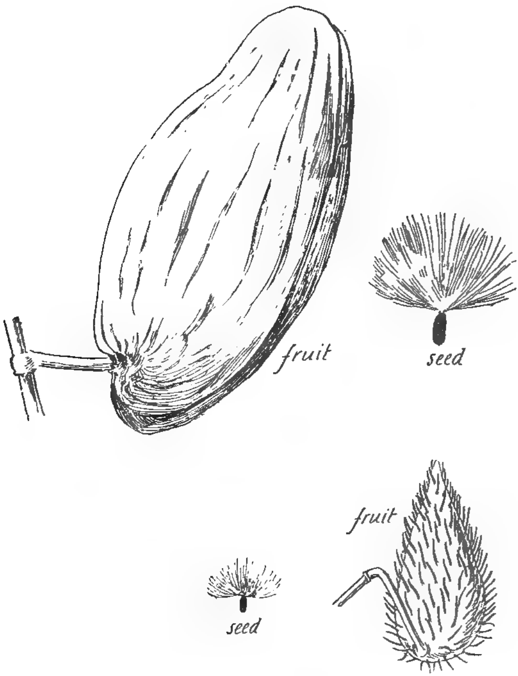



FIG. 57.—Dispersal of Seeds by Wind.
The fruits of two Asclepiads showing the plumed seed.

fro by a strong wind, which will tend to carry the seeds to a good distance, e.g. Snap-dragon. Other plants have winged fruits, e.g. Combretum, Ash, Sycamore, or plumed fruits, e.g. Anemone, Clematis, and many of the Compositae.

Sometimes the plume is derived from the persistent

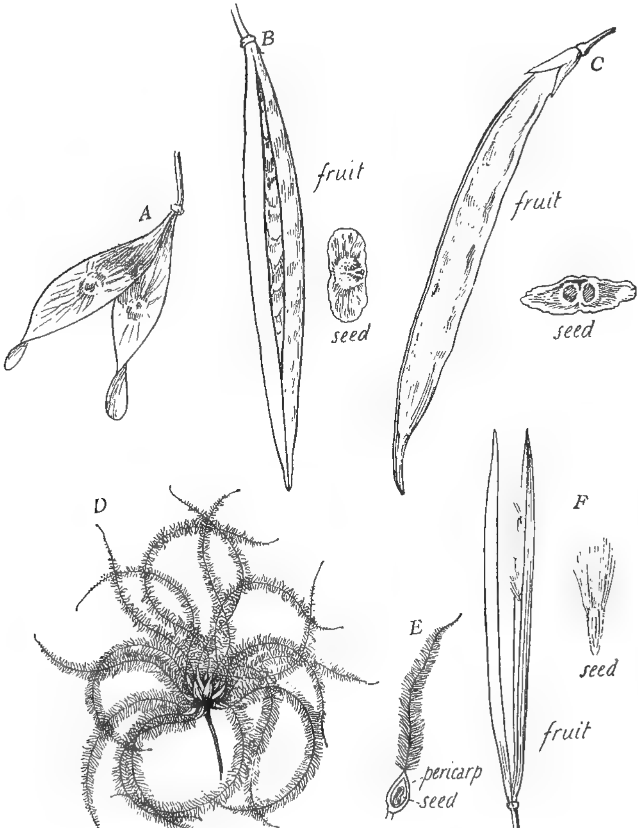



FIG. 58.—Dispersal of Fruit Seeds by Wind.

A. Fruit of Hemelboom. B. Fruit of Tecoma. C. Fruit of Bignonia. D. Fruit of Clematis. E. Achene of Clematis fruit, showing plumed tail. F. Fruit of Oleander.

style, e.g. Anemone, in other cases it is the calyx which forms a pappus of hairs and aids in dispersal.

Winged seeds are found in Bignonia, Tecoma and Pinus, and plumed seeds in Asclepias, Gossypium, Epilobium and Oleander.

71. **Dispersal by Animals.**—Animals and birds either carry the fruit away involuntarily, or eat it and drop the seed. To the latter class belong all the succulent fruits. It will be noticed that these fruits usually develop a bright attractive colour when ripe, but when unripe they are usually green, and therefore not conspicuous. The seeds are all protected by a hard indigestible covering, so that if swallowed they will pass uninjured through the animal's alimentary canal. Most succulent fruits are dispersed by birds, and are found on shrubs and trees, a few only are eaten by other animals. Fruits which are carried away by animals are usually provided with hooks or spikes. To this class belong the various burs, found on the veldt, and there are many other hooked fruits found in South Africa, e.g. Martynia (fig. 59), Bidens (Black Jack), and Medicago. Some of these hooked fruits are very troublesome to wool-growers, for example, Xanthium, which is a proclaimed weed in South Africa, and farmers allowing it to grow on their land are liable to a heavy fine. Harpagophytum (the Grapple plant) is almost equally troublesome, but not so common.

72. **Dispersal by Water.**—Fruits dispersed by water are found chiefly in aquatic plants. They are not common. The fruit of *Luffa cylindrica* has a light, spongy mesocarp and a waterproof epicarp, which enable it to float for long distances on the water without the seeds being injured. This fruit furnishes the well-

known "loofah" or bath-sponge. The Cocoa-nut fruit is also dispersed by floating, hence Cocoa-nut Palms are among the first plants to grow on coral islands. Water-lily seeds have a spongy covering which enables them to float.

73. **Explosive Fruits.**—Explosive fruits are few in number, and do not succeed in sending the seed to any great distance. In some, the propulsion of the seeds

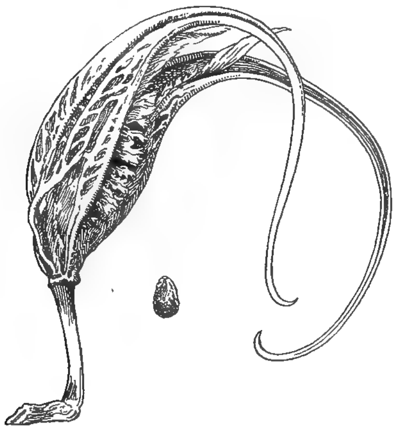


FIG. 59.—*Martynia proboscidea.*

depends on the extreme turgidity in some part of the fruit, e.g. Impatiens (Touch-me-not) and Oxalis (Sorrel). Some of the Leguminosae have pods that burst open suddenly, the two halves becoming twisted. In the Geranium, the styles curl up and jerk out the seeds, and in the Violet and Pansy the capsule splits open and throws out the seeds to some distance. These various methods of dispersal are very important to plants. The wide distribution of seeds gives them a better chance in the struggle for existence, overcrowding is prevented, and the young seedlings get more food, light, and air than they would if all crowded round the parent plant. The study of seed distribution also helps us to understand how plants are scattered over various parts of the earth's surface, how "weeds" arise in cultivated land, and how oceanic islands get their flora.

## SUMMARY.

### A. Classification of Fruits.

1. Simple
   - Dry
     - Dehiscent
       - Follicle
       - Legume
       - Capsule
       - {Siliqua / Silicula}
     - Indehiscent
       - Achene
       - Nut
       - Samara
   - Succulent
     - Drupe
     - Berry
     - Pome
2. Compound.
3. Collective.

### B. Dispersal of Fruits.

1. Wind.
   - (*a*) Light seeds.
   - (*b*) Winged seeds.
   - (*c*) Plumed seeds.
   - (*d*) Winged fruits.
   - (*e*) Plumed fruits.
2. Animals.
   - (*a*) Succulent fruits.
   - (*b*) Hooked fruits.
3. Water.
4. Explosive fruits.

## PRACTICAL WORK.

1. Examine as many as possible of the fruits mentioned. In each case sketch the fruit, showing its method of dehiscence—if dehiscent—and sketch a seed. Find out whether the fruit was formed from an inferior or superior ovary and from how many carpels. Find also whether any other part of the flower besides the ovary has developed into the fruit. In the

case of the indehiscent fruits, vertical and longitudinal sections should be cut and sketched.

2. Collect examples of the various methods of seed dispersal. This can easily be done in May, June and July.

## QUESTIONS ON CHAPTER VII.

1. Select any four plants, belonging to different Natural Orders, whose mechanisms for seed distribution you have studied. Name the plants you select, and the Orders to which they belong; briefly describe the fruits, and explain how the seeds are distributed. Make sketches where possible.

2. Describe the following fruits, giving examples and sketches: Nut, Siliqua, Drupe, Samara, Pome, Berry, Follicle.

3. Write a short essay on the dispersal of seeds and fruits by animals, and specially indicate any adaptive structures in the seed or fruit which ensure such dispersal.

4. How are fruits classified? What agents have caused the evolution of so many different kinds?

5. What is a fruit? Describe the following fruits: Peach, Apple, Orange, Gooseberry, Grape, Strawberry. What is the nature of the edible portion in each case?

6. Compare the three chief methods by which fruits are dispersed, paying special attention to—

(*a*) The efficiency of the method;
(*b*) The economy of the method.

7. Define a fruit botanically, and give the reasons why the following cannot be considered fruits in the strict botanical sense: strawberry, apple, pineapple.

8. Describe in botanical language the following fruits: (1) the fig; (2) the acorn; (3) the pineapple; (4) the cocoa-nut.

9. Mention with examples several mechanical devices which aid in the distribution and sowing of seeds.

## CHAPTER VIII.

### POLLINATION AND FERTILIZATION.

74. **Pollination.**—Flowering plants are often spoken of as seed-plants in contra-distinction to the seedless or non-flowering plants, as only the flowering plant is able to produce seeds.

Seeds are formed from the ovules in the ovary after certain conditions have been fulfilled.

In order that an ovule may develop into a seed the pollen grains must first be transferred from the anther to the stigma. This transference is called POLLINATION. There may be (*a*) Self-Pollination, (*b*) Cross-Pollination. In the first case the pollen is transferred from stamens to stigma of the same flower, in the second case the pollen from one flower is placed on the stigma of another flower.

If Cross-Pollination takes place, it is obvious that some external agent must be employed, since plants are stationary, and cannot themselves transfer the pollen from one flower to another. The chief agents effecting Pollination are wind, insects, birds and water.

75. **Anemophilous Flowers.**—It is usually easy to determine if a plant is wind pollinated (*anemophilous*). Such plants have small inconspicuous flowers. They produce

large quantities of dry powdery pollen, and have large hairy stigmas. Many flowers which are wind pollinated come out before the leaves, so that the pollen grains have free access to the stigmas, e.g. Hazel, Oak; others, e.g. Mealie, have the inflorescence well above the vegetative shoot. Wind-pollinated flowers found in South Africa are the Gramineae, the Coniferae, Casuarina, Quercus, and many others.

76. **Entomophilous Flowers.**—Entomophilous (insect pollinated) and ornithophilous (bird pollinated) flowers are far more numerous. They usually have large, conspicuous and highly coloured corollas, or are arranged in showy inflorescences. Some, e.g. Bougainvillea and Poinsettia have large highly coloured bracts, others, e.g. Mimosa, make themselves attractive to insects by their conspicuous and numerous stamens. Many are sweetly scented, and secrete honey. Often the corolla is modified, and the honey secreted in such a way that an insect cannot reach it without touching either the stamens or the stigma, or both.

Entomophilous flowers have usually sticky stigmas, and do not produce much pollen. Some, which depend on moths, either open at night or emit their scent at night, and are white or pale yellow in colour, e.g. Nicotiana, Oenothera. A special arrangement between flower and insect is found in Yucca and Ficus. In the tropical parts of South Africa are many bird-pollinated flowers, one of the best known being the Kaffir boom (Erythrina).

Some entomophilous flowers instead of secreting honey produce large quantities of pollen. Some of this is taken by insects for food, the rest being used for pollination. The Poppy is a pollen flower.

It may be observed here that insect-pollinated flowers have an advantage over those depending on the wind, inasmuch as their pollen is not wasted, they do not have to produce nearly as much of it, and they can have quite small stigmas. On the other hand, they have to produce a corolla, honey and scent, and should there be a scarcity of insects they run the risk of not getting pollinated at all.

Hydrophilous (water-pollinated) flowers are rare and only occur in a few aquatic plants.

77. **Cross-Pollination.**—It has been found that cross-fertilization produces on the whole stronger and healthier offsprings. Darwin, in his book "Cross and Self Fertilization of Plants" gives an account of experiments which he carried out for a number of years, and he found that, in general, the offspring of cross-fertilized plants were superior in height, weight, and fertility to the offspring of self-fertilized plants. This being so, we should expect to find in the higher plants devices for favouring or ensuring cross-pollination. This is the case.

78. **Contrivances and Conditions Favouring Cross-Pollination.**—(*a*) *Diclinism.*—The simplest method of ensuring cross-pollination is to have stamens and pistil on different flowers (diclinism). If the flowers are on separate plants, they are known as DIOECIOUS, e.g. Willow (Salix), if, on the same plant, they are MONOECIOUS, e.g. Ricinus, Cucumis Begonia and Pumpkin (fig. 60).

(*b*) *Dichogamy.*—Another method of avoiding self-pollination is the phenomenon known as Dichogamy, i.e. stamens and stigma ripen at different times. PRO-

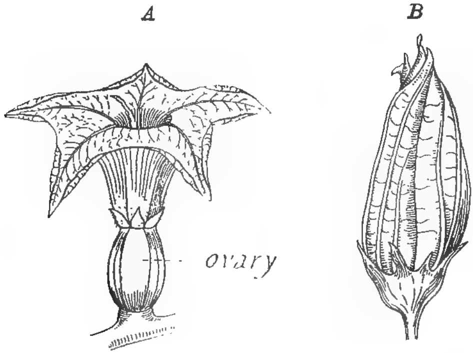



FIG. 60.—Monoecious Flowers.
A. Pistillate flower of Pumpkin. B. Staminate flower of Pumpkin.

TANDROUS flowers have the pollen ripe before the stigma, PROTOGYNOUS flowers have stigma ripe first (fig. 61).

FIG. 61.—Protandrous Flower.
A. Young Carnation flower. Stamens ripe. B. Older Carnation flower. Stigmas ripe.

Protandrous flowers are found in the N.O. Compositae, Labiatae and Umbelliferae, and are much commoner than the protogynous flowers ; examples of the latter are

Arum and Aristolochia. Geranium, Carnation and Sunflower are good examples of protandrous flowers.

(*c*) *Heterostylism.*—A curious phenomenon found in some flowers is that of HETEROSTYLISM. It is well seen in Oxalis. This plant bears three kinds of flowers (TRIMORPHIC), each of which has different lengths of stamens and styles (figs. 62, 63). Complete fertility is only obtained when the pollen from a long stamen is taken to a long-styled flower, or from short to short. The

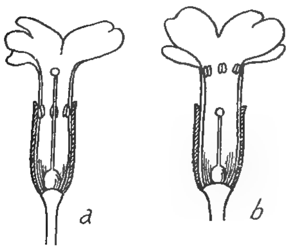



FIG. 62.—Sections of Primrose Flowers, Showing Dimorphic Heterostylism.

*a.* Long-styled Primrose. *b.* Short-styled Primrose.

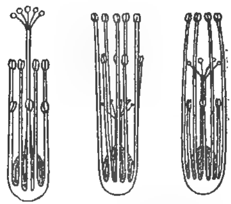


FIG. 63. — Trimorphic Flowers of Oxalis, Showing Stamens and Pistil.

short-styled forms can, of course, be self-pollinated, but this results in few seeds, which are more or less sterile. Further details are given in the description of this flower (see § 152). The Primrose bears DIMORPHIC flowers, i.e. one flower has a long style and stamens half-way down the corolla tube, the other has a short style and stamens at the top of the tube (see fig. 62).

(*d*) *Self-sterility.*—Another condition preventing self-pollination is SELF-STERILITY, i.e. incapability of a flower to be fertilized by its own pollen. This is found in some species of Abutilon and Passiflora. Closely allied to this is the phenomenon of pollen-prepotency. If the stigma of a plant A be pollinated from the stamens of A, and from the stamens of another flower B, the ovules will be fertilized by the pollen of B and not of A, even though the pollen from A was there first.

(*e*) *Special devices.*—Many flowers have special devices for ensuring cross-pollination, which do not come under

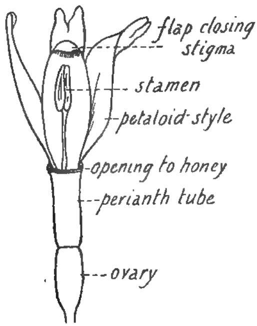



FIG. 64.—Iris Flower with Petals Removed.

any of the above headings. The IRIS (fig. 64) has petaloid styles under which are the three stamens with their extrorse anthers. Just above the stamen is a little flap, the upper surface of which is the stigma. The honey is at the bottom of the perianth tube, and the three inner perianth lobes are striped so as to act as honey guides. Insects entering the flower to get the honey first deposit the pollen brought from another flower on the stigma; then as they go farther in they get a further supply of pollen from the stamens, and when they come out they close the stigma flap, thus preventing self-pollination (fig. 64). Bignonia, the Golden Shower, has a sensitive stigma which closes when touched—thus an insect entering the flower pollinates it, then reaches the stamens and gets fresh pollen. By the time it leaves the flower the stigma is closed, so self-pollination is prevented.

Salvia has an ingenious arrangement. The corolla is bilabiate, and the lower lip forms a convenient resting place for insects. There are only two stamens and these have short filaments, and long connectives. The upper half of each connective bears a half anther, the lower halves, which are much shorter, are united together. The whole arrangement forms a lever, so that when an insect enters the flower and presses against the lower halves of the connectives, the upper lobes bend down and its back gets dusted with pollen. The flower is protandrous and later on the stigma bends down so that it is just touched by an insect entering the flower. The mechanism can most easily be seen in the blue Salvia. If a pencil is inserted in the opening of this flower the stamens will be seen to bend down and deposit pollen on the top of it (figs. 65 and 66).

Most of the Compositae are specially adapted for cross-pollination. The perfect florets have honey at the base of the style. The syngenesious anthers are introrse and the pollen is shed into the anther tube. The flower is protandrous and at this stage the stigmas are closed. The style, which is often hairy, then grows out of the stamen tube, carrying the pollen with it to the top of the flower, where it can be taken by visiting insects. The stigmas then separate, the inner surface only being receptive. They will receive pollen from any insect which has previously visited a younger flower. Finally, in many cases, the stigmas curl round to touch

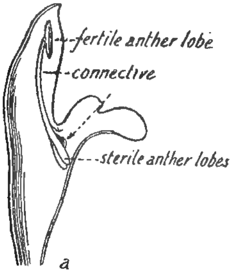



FIG. 65.—Salvia Flower.

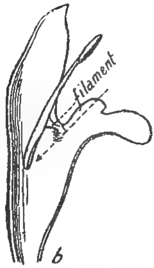



FIG. 66.—Longitudinal Section of Flower of Salvia, Showing the Mechanism of the Stamens.

their own styles and thus they become self-pollinated. Thus every floret is practically certain to set seed. The arrangement can be well seen in the Sunflower and in

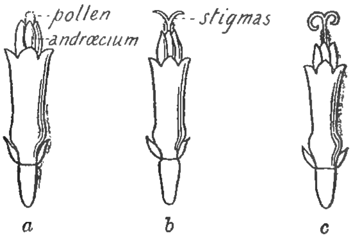



FIG. 67.—Disc Florets of Helianthus (Magnified).
*a.* First stage. *b.* Second stage. *c.* Third stage.

the Cosmos (fig. 67). The Cornflower (Centaurea) is similar, except that, instead of the style lengthening, the stamens, when touched, contract, thus forcing the pollen out of the top of the anther tube.

Many other flowers have interesting arrangements for pollination, e.g. Orchid, Lupin (and other Leguminosae), Violet, Protea, Campanula, Arum, Aristolochia. Some of these are described under their natural orders, but the student should observe as many as possible for himself—noting: (*a*) What insects visit the flower; (*b*) What arrangements the flower has for ensuring cross-pollination.

79. **Self-pollination.**—A few plants are regularly self-pollinated, the commonest of these are Senecio and Capsella; other plants produce two kinds of flowers, the large showy ones, which are cross-pollinated, and small inconspicuous flowers, which do not open and which are self-pollinated. These are called CLEISTOGAMOUS flowers and are found in Viola, Oxalis and other plants. The cleistogamous flowers of Viola look like buds—their stamens contain very little pollen, and are closely pressed to the stigma. The pollen grains germinate inside the anthers. The petals are very minute. The production of these cleistogamous flowers ensures the setting of a fair amount of seed.

80. **Structure of the Ovule.**—The ovule is attached to the ovary by a slender stalk, the FUNICLE. The body of the ovule consists of a mass of parenchymatous tissue, the NUCELLUS, with one large special cell, the EMBRYO-SAC.

Around the nucellus are two skins or INTEGUMENTS, but just opposite the embryo-sac these integuments are separated, and the space between is called the MICROPYLE. The base of the nucellus from which the integuments arise is called the CHALAZA.

When the ovule is fully developed the nucleus of the embryo-sac divides up into two. These move to each end of the embryo-sac, and there each divides into four.

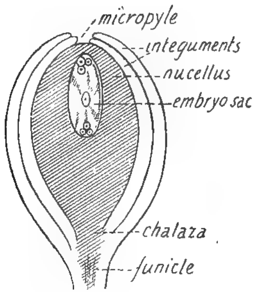



FIG. 68.—Orthotropous Ovule, Showing Contents of Embryo-sac.

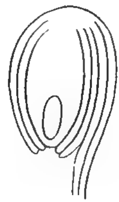


FIG. 69.—Anatropous Ovule.

Then three of the nuclei at the micropylar end of the embryo-sac become surrounded by protoplasm and form

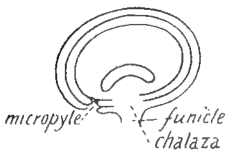



FIG. 70.—Campylotropous Ovule

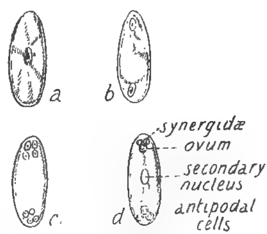



FIG. 71.—Development of Embryo-sac.

*a.* Embryo-sac with nucleus undivided. *b.* Nucleus divided into two. *c.* Each nucleus divided into four. *d.* Appearance of embryo-sac when ready for fertilization.

three cells. The largest is the oosphere, ovum or egg-cell, the two smaller are the Synergidae (helping cells).

Three of the nuclei at the other end also form three cells, the antipodal cells. The fourth nucleus from each end passes to the centre of the embryo-sac. There they fuse and form one nucleus—the SECONDARY NUCLEUS. The ovule is now ready for fertilization.

81. **Forms of Ovule.**—There are several forms of ovule.

(1) The orthotropous ovule (fig. 68) is straight, having the micropyle opposite to the funicle.

(2) The anatropous ovule (fig. 69) is inverted so that the chalaza is at the opposite end to the funicle, and the hilum next the funicle.

(3) The campylotropous ovule (fig. 70) is curved.

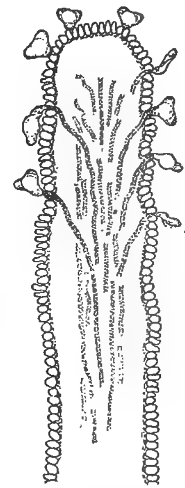


FIG. 72. — Pollen Grains Germinating on the Stigma of the Evening Primrose (Œnothera). (From Darwin's "Elements of Botany".)

82. **Structure of the Pollen Grain.**—A young pollen grain is unicellular, and the cell wall consists of two membranes or coats. The outer coat, the EXINE, is cuticularized, and frequently ornamented with various patterns. The inner coat is the INTINE. After a time, the nucleus divides into two, thus forming two cells. The smaller is the GENERATIVE cell, the larger the VEGETATIVE cell. There are no cell walls between these cells, but the generative cell lies freely in the protoplasm of the vegetative cell.

When the pollen grain reaches the stigma, germination takes place. The generative cell divides into two

Male Cells or Gametes. The vegetative cell bursts through the exine, and grows out into a pollen tube (fig. 72). This pollen tube grows down the style into the ovary, and the two male cells pass down it. At first the pollen grain is nourished by the sticky fluid on the stigma, afterwards by the tissues of the style.

83. **Fertilization.**—When the pollen tube reaches the ovary it is guided towards an ovule, and enters it by the Micropyle. It pierces the apex of the nucellus, and the synergidae cause the apex of the pollen tube to swell and burst. One male cell then fuses with the oosphere. This is fertilization, and the fertilized oosphere is then called an Oospore, and finally develops into the Embyro of the young seed. The other male cell fuses with the secondary nucleus, forming the endosperm nucleus This divides and forms the Endosperm of the seed.

## PRACTICAL WORK.

1. Examine the pollen grains of several flowers under the microscope, and if possible obtain a stigma in which pollen grains are germinating and examine it (Escholtzia is a good flower for this purpose).

2. Put a drop of sugar solution on a slide, place some pollen grains in it—these will then germinate and the process can be observed under the microscope.

3. Cut sections through the ovaries of various flowers. In some of these it will be possible to make out the structure of the ovule.

4. Examine and draw the Male and Female flower of Pumpkin, Begonia, Oak and Willow.

5. Examine and sketch old and young flowers of Geranium, Salvia, Delphinium, Lupin, Oxalis and Primula. Examine also the inflorescence of Helianthus and sketch the florets in the various stages.

6. Obtain some cleistogamic flowers of Violet and examine these.

## QUESTIONS ON CHAPTER VIII.

1. Make a drawing to show the structure of an ovary with its style and stigma, and of an ovule contained in it at the time of fertilization, and indicate the course of the pollen tube. Label the different parts in your drawing; no further description of it need be given.

2. What is the difference between pollination and fertilization? Write brief descriptions of flowers whose structure favours: (*a*) pollination by wind; (*b*) pollination by insects. Name two examples of (*a*) and three examples of (*b*).

3. What is meant by pollination? Distinguish carefully between self-pollination and cross-pollination. Choose any flower you have studied which contains honey and is pollinated by insects, and state: (*a*) Where the honey is formed; (*b*) how insects in obtaining the honey touch the pollen and stigmas; (*c*) the adaptations favouring cross-pollination: (*d*) anything else of interest you know about the pollination of the flowers selected. Make a sketch of the flower as seen in longitudinal section to show the pollination-mechanism. Name the flower you select.

4. Explain the peculiarities of the following kinds of flowers; Trimorphic; cleistogamous; ornithophilous. Mention as many examples of each kind as you know.

5. Describe the structure of an ovule and three typical forms which it may assume. Mention for each form at least one plant in which it occurs. Give, with reference to some familiar example, an account of the changes which an ovule undergoes to form a ripe seed.

6. Give an account of the structure and function of a pollen grain.

7. Explain clearly the biological significance of (*a*) brightly coloured, (*b*) irregular, (*c*) regular, and (*d*) inconspicuous flowers.

8. Of what advantage is cross-pollination to a plant? Describe three mechanisms which you have observed in flowers, which aid in effecting cross-pollination. Name the flowers you choose and give sketches.

# CHAPTER IX.

## PLANT PHYSIOLOGY.

84. **Nutrition of Plants.**—The problem of how and whence plants obtain the necessary materials for life and growth is one which was for a long time a puzzle to investigators. Until 1630 it was commonly believed that they received all their food from the soil, in a state ready for use, i.e. that no further elaboration took place in the plant itself. But in 1630 Van Helmont made the first experiment in plant physiology, with the object of disproving this hypothesis. He thoroughly dried and weighed some soil, and put it in a pot, and in this pot he planted a Willow branch which he had also weighed. He watered it daily with rain water for five years, and at the end of that time he weighed both again, having previously dried the soil. He found that the plant had gained about 160 lb. in weight, whereas the soil had only lost two oz. He concluded that all this gain in weight was due to water alone, i.e. that the substance of the plant is almost entirely formed of water. Other investigators showed that this conclusion was not correct, but many of the facts of plant nutrition were not discovered till much later, and even now there are stages in the process of assimilation which are still not certainly known.

85. **Essential Constituents of Plant Food.**—There are two methods of ascertaining exactly what chemical elements are essential for the nutrition of plants. The first is to analyse chemically a healthy plant and thus discover its composition. The second is to grow the plant in a medium of which the constituents are known and kept under chemical control. By the second method it has been discovered that the following elements are indispensable to the healthy growth of all green plants, Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Phosphorus, Potassium, Calcium, Magnesium, and Iron. When analysed, most plants contain in addition to these, Chlorine, Silicon, Sodium, and some other elements, but only these ten are essential. All except carbon are absorbed from the soil, in the form of various chemical compounds dissolved in water. The method by which carbon is obtained will be considered later.

86. **Water Culture.**—It has long been known that a plant can be grown in water containing salts in which all the above elements, except carbon, are present. That carbon is essential will be proved later; that the other elements are essential can be shown by the method of water culture. Several plants of the same species and size are grown in glass jars, with their roots dipping into a culture solution, and if any of the necessary salts are omitted there is no healthy growth. Hydrogen, and oxygen together form water. Nitrogen is present in various salts called Nitrates, Sulphur in Sulphates, Phosphorus in Phosphates, the remaining elements forming the bases of these salts, e.g. Potassium nitrate, Sodium sulphate, etc.

87. **Experiment 1.**—To see which elements are necessary for healthy growth.

*Apparatus.*—Large glass jars, holding one litre, with corks to fit, black or brown paper, slips of Tradescantia or Pea seedlings, or Mealie seedlings (Tradescantia gives the best results), distilled waters, various salts.

*Method.*—Measure out a litre of distilled water, and weigh out one gramme of potassium nitrate, ½ gramme each of sodium chloride, calcium sulphate, magnesium sulphate and calcium phosphate. Thoroughly clean the jars, and rinse with distilled water, then dissolve the above salts in the litre of distilled water and fill the jar with it. Add a few drops of iron chloride solution. This is the Normal Solution, and contains all the essential elements except carbon. Cut a slip of Tradescantia (Wandering Jew) just below a node, fix it through a slit in the cork, and fix the cork in the bottle. There must be an air space between the cork and the bottle, and the cork must be perfectly dry. Then cover the jar with black or brown paper, and label it. Make up the solutions for the other jars in the same way, but in each one omit one element, e.g. in one use sodium nitrate, instead of potassium nitrate, thus omitting potassium; in another use potassium phosphate or sulphate, instead of the nitrate, thus omitting nitrogen. Choose slips of Tradescantia as nearly as possible the same size as the first, and fix one in each bottle. Label each bottle, saying what element is omitted; one bottle should contain distilled water only, and one should have everything except the iron chloride. Unless the corks are kept perfectly dry, the plants are apt to be attacked by mould; but if the experiment is carefully done, it is possible to see some result at the end of a month, while in two months the differences in the plants are quite striking. If the solutions in the bottles get too low, they should be filled up with distilled water.

*Results.*—At the end of eight or ten weeks, the only plant that has grown well is the one in the Normal Solution; the one without iron has grown tall, but all the new leaves are white; the one in distilled water has hardly grown at all, nor has the one without nitrogen.

*Deductions.*—Iron is necessary for the formation of green colour, and all the other elements are necessary for healthy growth.

88. **Absorption.**—Much of what we know about the absorption of water by roots and its passage through the plant was discovered by Stephen Hales in 1727, but he knew very little about the chemical substances present in the soil which are absorbed with this water. Water occurs in the soil under two conditions, (1) free water, which trickles through the soil if it is properly drained. (2) Capillary water, which adheres to the surface of soil grains, and to plant roots in thin films. It is this capillary water which is absorbed by the roots, and it contains various dissolved substances, such as sodium chloride, calcium carbonate, etc. The ROOT-HAIRS are the organs which absorb this water. They come into close contact with the particles of soil, so that when a seedling is pulled up we always see soil adhering to it wherever the root-hairs occur. The process by which root-hairs are enabled to absorb water is OSMOSIS. Whenever two liquids of different densities are separated

by a membrane they will diffuse through it, the less dense liquid diffusing more quickly than the other. This process is known as Osmosis, and can be demonstrated by a simple experiment.

89. **Experiment 2.**—To show the process of Osmosis.

*Apparatus.*—Thistle funnel, piece of bladder, or other membrane, sugar, water, red ink, beaker, stand.

*Method.*—Tie the membrane tightly over the thistle funnel, and fill it with a solution of sugar and water coloured with red ink. Fix this to a stand, so that it dips into a beaker of pure water, and note the level of the solution in the tube of the thistle funnel. Leave for fifteen minutes, or longer.

*Result.*—The sugar solution rises slowly in the tube (an inch or more in an hour), and in a few hours the water in the beaker is coloured pink and tastes sweet.

*Deduction.*—Both liquids have diffused through the membrane, but the pure water has passed into the thistle funnel more quickly than the sugar solution has passed out (since the level rises), and it can easily be shown that the sugar solution is denser than pure water.

*Note.*—For the membrane use either a piece of bladder which can be obtained from any butcher, or the membrane of an egg. The latter gives quicker results, and can be used with an ordinary piece of glass tubing instead of a thistle funnel. To obtain it, break the top off an egg, empty out the contents, and place the shell in dilute hydrochloric acid for twenty-four hours. The shell will then all dissolve away, and a tough thin membrane will be left.

90. **Osmosis in Roots.**—The membrane represents the cell-wall of each root-hair, the two liquids represent the cell-sap in the root-hair and the water in the soil. But

it must be noted that in this experiment we have nothing to represent the cytoplasm. Hence it does not quite demonstrate what happens in the living plant, where the cytoplasm exercises an influence on the quantity of the various salts absorbed, and also controls the exit of the cell-sap. But just as, in the experiment, the water passed into the thistle funnel more quickly than the solution passed out, so in the root-hairs water passes in more rapidly than out, until the cells are turgid. Apparently the cytoplasm then becomes permeable, and sap is passed into the next cell until it also is turgid, and so on, until the water is forced into the wood-vessels of the root. It thus enters the vessels under pressure and will tend to rise upwards. This gives rise to what is known as "root-pressure".

91. **Experiment 3.**—To show the force of root-pressure.

*Apparatus.*—Glass and rubber tubing, young plant (Broad Bean, Dahlia, Geranium all give good results).

*Method.*—Cut the stem of the plant off close to the soil and quickly fix the rubber and glass tubing to it, and fill the latter with water up to a certain mark (if possible use thermometer tubing with fine bore).

*Result.*—The water rises in the tube.

*Deduction.*—It has been forced up by the root. It is not only in the root-hairs that osmosis takes place, but the water is passed from cell to cell by the same process until it reaches the vessels. Here it is forced upwards, partly by root-pressure, and partly by the force of capillarity which causes water to ascend fine tubes, the finer the tubes the higher being the rise.

92. **Experiment 4.**—To show the force of Capillarity.

*Apparatus.*—Glass tubing of different bores, coloured water, beakers.

*Method.*—See that the tubes are clean and dry and then stand them all in a beaker of water which has been coloured with red ink.

*Observation.*—The liquid rises in the tubes, and ascends highest up the tube with finest bore.

*Deduction.*—Liquids will ascend fine tubes, and if the tube is very fine (called a capillary tube) the liquid will ascend some inches.

Vessels in the root and stem have far smaller diameters than any tube that can be made, hence liquids will ascend fairly high in roots and stems by the force of capillarity alone; but this force would not be sufficient to cause the rise of water in tall trees, etc. · this rise is due partly to capillarity, partly to root-pressure, and partly to other causes.

*Absorption of Food Materials.*—As has been seen, the water in the soil is not pure, but contains various dissolved substances. Roots are unable to take in their food in a solid form, it must be in solution.

93. **Experiment 5.**—To show that roots cannot absorb insoluble substances.

*Apparatus.*—Carmine, eosin, water, seedlings, two bottles.

*Method.*—Fill the two bottles with water, in one put some eosin, in the other some carmine. Both these will colour the water, but the former is dissolved in it, the latter is not, it is only held in suspension. Place a seedling in each bottle with the roots in the coloured water.

*Result.*—In a few hours the stem and leaves of the seedling in eosin solution are coloured red, the other is unchanged.

*Deduction.*—The root has absorbed the soluble eosin, not the insoluble carmine, hence roots can only absorb soluble substances.

94. **Summary.**—We see then that the root absorbs water from the soil, which contains all the necessary salts dissolved in it; that only soluble substances can be so absorbed, that the physical process by which absorption takes place is osmosis; that the food so absorbed is passed on to other parts of the plant, partly by osmosis and partly by capillarity; and that this process of absorption gives rise to the phenomenon of root-pressure.

95. **Insoluble Substances.**—Certain salts in the soil, e.g. calcium carbonate, are insoluble in water. These are acted upon by the acid cell-sap diffused from the root during the process of osmosis and thus rendered soluble.

96. **Experiment 6.**—To show that roots give out acid.

*Apparatus.*—Blue litmus papers, funnel, test tubes, blotting-paper.

*Method.*—Line some test tubes and also a funnel with blotting-paper which must be kept damp. Between the paper and the glass place some strips of litmus paper. Put some seeds against the litmus paper so that when they germinate the roots will touch the paper. Mealie seeds germinate quickly and give good results, so do Sunflowers.

*Result.*—When the roots are 2 or 3 inches long, the litmus papers will be seen to have red marks where the roots have touched them.

*Deduction.*—Since acids turn blue litmus red, the roots must have given out acid. Another experiment which shows the same thing is to grow some seeds in a layer of sand on marble. The marble must be perfectly smooth, and the sand must be kept moist. In a few weeks when the seeds have grown well, if the sand is washed off fine markings will be seen in the marble—these are caused by the acid from the roots dissolving away the marble just where they have touched it.

97. **Transpiration.**—We saw in the experiments on water culture that the solutions were very dilute, i.e. the root absorbs a very large quantity of water in order to obtain a comparatively small amount of salts. Much of this water actually enters into the composition of the plant, some plants containing as much as 90 per cent of water; but a great deal of it is not wanted, and is therefore given off by the leaves. This escape of water vapour from a plant is called TRANSPIRATION, and the current of water which passes from roots to leaves is called the Transpiration current.

98. **Experiments in Transpiration**:—

*Experiment* 7.—To show that leaves give out water vapour.

*Method.*—Fix some long-stalked leaves through a card and seal up the opening. Place the card over a tumbler of water so that the stalks dip into water, and invert a clean dry beaker over the leaves.

*Result.*—In a short time drops of water are seen on the glass.

*Conclusion.*—The leaves have given off water vapour, which has condensed on the glass.

*Experiment* 8.—To see which surface of the leaf gives off moisture most quickly.

*Apparatus.*—Filter papers, cobalt chloride.

*Method.*—Dissolve some cobalt chloride in water till the solution is a fairly deep pink, then soak the filter papers in it, and dry them thoroughly. When quite dry they turn a bright blue colour, but the least drop of moisture will turn them pink again. Place a leaf between two pieces of this cobalt paper and wrap them in a duster so that no moisture from the air may reach them. Two other pieces, without a leaf should be placed in a duster for comparison. Leave for a few minutes (three or four) and then examine.

*Result.*—The paper next the underside of the leaf has turned pink where the leaf touched it, that next the upper side is either unchanged, or only slightly pink.

*Conclusion.*—The under side of the leaf gives out most moisture.

99. **Experiment 9.**—To measure the rate of transpiration:—

*Apparatus.*—Glass bottle, cork to fit, leaves.

*Method.*—Bore a hole in the cork, put the stalks of the leaves through it, fill the bottle with water, push in the cork so that the stalks are in water, and stop up the hole with wax. Since the hole is waxed up no evaporation can take place, and any loss of weight must be almost entirely due to transpiration. Weigh the whole apparatus, and weigh again at the end of an hour, and at the end of twenty-four hours. Hence calculate the percentage loss per hour and per day. Fit up two other bottles in the same way, and in one place a leaf whose lower surface has been covered with vaseline, in the other a leaf in which both surfaces have been covered. Compare the loss per cent in each case with that of the uncovered leaf. It will be found to be considerably less, thus showing that transpiration takes place through the stomata, since when they are blocked by vaseline it almost ceases.

100. **Experiment 10.**—To demonstrate the sucking force exerted by leaves.

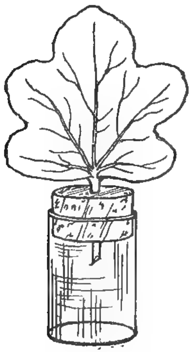


FIG. 73.—Apparatus by which to Measure the Rate of Transpiration.

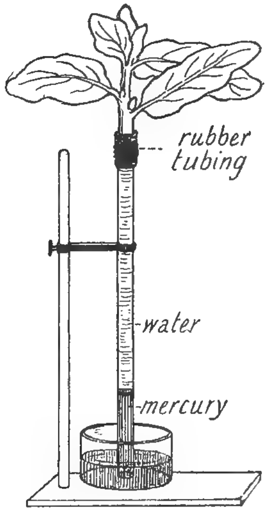



FIG. 74.—Apparatus to Show the Sucking Force Exerted by Leaves.

*Apparatus.*—Glass and rubber tubing, mercury, small dish, stand branch.

*Method.*—Obtain a branch with fresh young leaves and a fairly thick round stem. Cut the end under water, and keeping it under water attach to it a short piece of rubber tubing, and a piece of glass tubing. Tie the rubber tightly with thread or copper wire, and lift the whole apparatus out of the water. If it is airtight the water will all stay in the tube. Fix it to the stand, as in the diagram, with the lower end dipping into a cup of mercury.

*Result.*—In a few minutes the mercury begins to rise up the tube ; it may rise as much as 5 inches in an hour ; this will depend partly on what shoot is used, and partly on the temperature.

Since mercury is thirteen and a half times as heavy as water, this experiment shows that a leafy shoot is able to lift up a considerable weight of water. The transpiration current may also be shown to exist by cutting some leafy shoots and letting them dip into red ink. In a short time the veins will all be coloured red.

101. **Transpiration Current.** — This TRANSPIRATION CURRENT is very important in causing the distribution of mineral substances throughout the plant. The rate of transpiration is regulated by the stomata. They close in darkness, for then less food is needed, and by so doing they also prevent the plant getting too cold, as excessive evaporation lowers the temperature considerably. They also close if transpiration is too active, i.e. if more water is being lost than the roots can absorb. On the whole transpiration is more rapid in sunlight, and in a strong wind, than in shade or still air. This can easily be verified by a modification of Experiment 9. If four bottles are fitted with leaves as described, and weighed, and then one is placed in sunlight, one in the dark, one in the shade, and one in a direct draught, and then weighed again, it will be found that the percentage loss is greatest in Nos. 1 and 4, and least in Nos.

2 and 3, in fact there will be almost no loss in the one placed in the dark.

Another method of showing that sunshine and wind affect transpiration is by using a piece of apparatus called a potometer. A description of this will be found in the Appendix.

Arrangements for reducing the rate of transpiration found in many plants, are discussed later, under the heading Xerophytes.

102. **Carbon Assimilation.**—We have seen that carbon is found in all green plants, but is not absorbed by the roots. If the plants grown by water culture are tested, they will be found to contain a considerable amount of carbon, yet none was supplied in the solution. It is hence obvious that they must obtain it from the air. There is in the air a small quantity of a certain gas called carbon di-oxide, which is a compound of carbon and oxygen. It is produced by the breathing of animals and plants, and by all processes of burning, if the substance burnt contained carbon, e.g. burning coal or wood. It is an invisible gas, but it has the property of turning lime-water milky, hence its presence can be demonstrated by leaving a dish of lime-water exposed to air for some time, when a scum forms on the surface.

The leaves absorb this carbon di-oxide; they break it up into its elements, carbon and oxygen; they keep the carbon and give out the oxygen. The carbon, together with water absorbed by the roots, is made up into certain complex substances, chiefly starch. This process of forming organic compounds from carbon di-oxide and water is known as CARBON ASSIMILATION or PHOTO-

SYNTHESIS. Only the green parts of plants can assimilate, and they can only do it under certain conditions. They must have light, either daylight, or bright electric light, and they must have a certain temperature. Assimilation is not only important for the plants themselves, being their chief method of obtaining carbon, but it is also immensely important to us, as by its means the air is kept pure and fit to breathe. All animals breathe out carbon di-oxide, and if it were not for plants taking it in there would soon be an excess of this gas in the air.

The first visible product of assimilation in plants is starch, hence if we can show that starch has been formed we shall know that assimilation has taken place.

103. **Experiment 11.**—To see if green leaves contain starch.

*Apparatus.*—Iodine solution, alcohol, beakers, leaves.

*Method.*—Boil some leaves to kill them, and then soak them in alcohol or methylated spirits till all the green colour has come out. This may take some time, but nasturtium leaves are fairly quick. Then place the whitened leaves in iodine.

*Result.*—They turn dark purple or black.

*Deduction.*—They must contain starch, since this substance always turns purple with iodine.

104. **Experiment 12.**—To show that assimilation does not take place in the dark.

*Apparatus.*—A plant in a pot, alcohol, iodine, dishes.

*Method* (i.).—Pick a leaf from a potted plant, and test for starch as above, then place the plant in a dark cupboard for forty-eight hours, pick another leaf and test again. Place it in the sunlight for a few hours, then pick a third leaf and test it.

*Results.*—The second leaf shows no purple colour with iodine and therefore contains no starch, the first and third leaves both turn purple.

*Deduction.*—The plant loses its starch in the dark, but makes more when again exposed to the light.

*Method* (ii.).—Pin pieces of silver paper across a leaf on a plant, so as to block out the light from part of the leaf; they must not be pinned tightly enough to exclude air. After two days pick the leaves and test for iodine. It will be found that only the parts of the leaf which had light contain starch, the others contain none.

105. **Experiment 13.**—To see if carbon di-oxide is necessary for starch formation.

*Apparatus.*—Caustic potash, bell-jar, dish, leaves.

*Method.*—Set some leaves with their stalks in a glass of water, stand them beside a dish of caustic potash solution, and cover the whole with a bell-jar. Set the apparatus in a good light, and leave for two days. Fix up another experiment as a control in which the conditions are exactly the same, except for the dish of caustic soda (fig. 75). This substance absorbs carbon di-oxide, hence the leaves under the first jar have none of this gas, those under the second have. At the end of two days boil and decolorize both sets of leaves and test for starch.

*Result.*—Those from the first jar do not contain starch, those from the second do.

*Deduction.*—Carbon di-oxide is necessary for starch-making.

106. **Experiment 14.**—To see if green leaves absorb carbon di-oxide in the sunlight and give out oxygen.

*Apparatus.*—Two bell-jars with corks that tightly fit the holes at the top, two candles, two large dishes of water, beaker, leaves.

*Method.*—Stand a candle in each dish of water and light it. Stand a beaker of water containing some leaves beside the candle in one dish, cover both leaves and candle with the bell-jar, and then cork up the top tightly. Cover the other candle also with a bell-jar and cork it up. Presently both candles will go out and at the same time water will rise in the bell-jars. This is because the candle in burning uses up the oxygen in the jars, and forms carbon di-oxide; and the gases left do not support combustion. So now we have two bell-jars, each containing some carbon di-oxide. Place both dishes with their bell-jars in a bright sunny place, and leave for three or four hours. Great care must be taken to see that the jars are absolutely air-tight, and that no air enters them when they are moved. Then quickly take the stopper out of each jar, and insert a lighted taper.

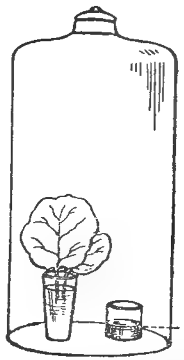


FIG. 75.—Apparatus to Show that Carbon Di-oxide is Necessary for Carbon Assimilation.

*Result.*—The taper burns in the jar which had leaves in it, but goes out in the one that had no leaves.

*Deduction.* — The leaves must have absorbed the carbon di-oxide in the first jar and replaced it by oxygen, otherwise the taper would be extinguished, as it is in the second jar.

107. **Experiment 15.**—To see if water plants give out oxygen.

*Apparatus.*—Slips of Elodea, or some other water weed, funnel, large beaker, test-tube.

*Method.*—Fill the beaker with water, and fix the water weeds under the funnel in it. Fill a test-tube

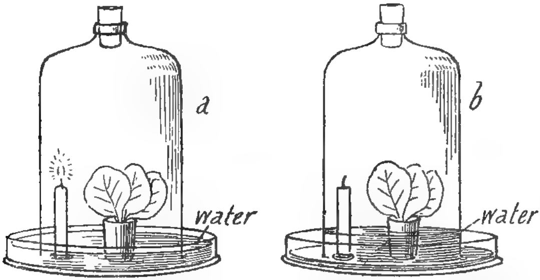



FIG. 76.—Experiment 14.—*a.* When Candle is Burning; *b.* Candle Extinguished. Note the rise in level of the water.

with water, place your thumb on the end and invert it into the beaker of water. Slip it over the top of the funnel (which must be under water), taking care that no water runs out. Place the apparatus in sunlight.

*Observations.*—Bubbles arise from the weeds and go up to the top of the test-tube, gradually displacing the water. When the tube is nearly full of this gas slip it off the funnel, keeping the mouth under water, put your thumb under the end as before, and take it out. Keep the tube closed till you are ready to test the gas.

Test it with a glowing splint; this immediately bursts into flame, showing that the gas is oxygen.

*Deduction.*—Green water plants give off oxygen in the sunlight.

108. **Storage of Reserve Material.**—Most of the starch formed in the leaves by the process of assimilation is used up by the plant in the processes of respiration and growth, but some is stored up in various parts of the plant as reserve material. Starch, being insoluble in water, is acted upon by a ferment called diastase, which transforms it into sugar, and in this form it is conveyed to other parts of the plant.

109. **Reserve Materials.**—These are found in various parts of the plant, in seeds, underground stems, roots, leaves, and fruits. There are various storage forms of food material. Carbohydrates are substances which consist of Carbon, Hydrogen and Oxygen, and starch and cellulose are the two chief forms in which carbohydrate is stored up. Starch is found in the cotyledons of the Bean, and in the endosperm of the Mealie, while the cell-walls of the endosperm tissue of the Date seed are thickened and represent storage of carbohydrate in the form of cellulose. Other forms of carbohydrate are inulin (found in the roots of many Compositae) and sugar (found in the roots of Carrot and Beet, and in the fleshy leaves of the Onion bulb). Oil forms the storage product in many seeds, e.g. Castor-oil, and in others we find aleurone grains, e.g. Sunflower.

110. **Experiment 16.**—Cut thin sections of the cotyledons of Sunflower, and of the endosperm of Castor-oil seed. Mount in water, and examine under the

microscope. The bright globules of oil can be seen clearly, and if a solution of potash is added and the sections gently warmed these globules will become cloudy and dissolve. In the cells of the Sunflower cotyledons, rounded grains can be seen as well as the oil globules. If the section is stained with iodine solution, these grains stain brown or yellow, showing that they are aleurone grains.

111. **Experiment 17.**—Cut sections of the cotyledons of the Bean seed, mount in water, and stain with iodine. The grains in the cells all stain purple, showing that they are starch.

Cullulose stains blue with Schultz's solution. Sugar will give a red precipitate if a few drops of Fehling's solution are added and the liquid heated. Inulin is precipitated by alcohol in the form of very characteristic crystals, called sphaerites, marked by a series of concentric and radiating lines.

112. **Ferments** are substances found in plants and animals, which have the power of inducing chemical changes without themselves being changed.

Diastase, which changes starch into sugar, has already been mentioned, and there are others which act upon proteids, oil, cellulose, etc., and convert them into simpler substances. By means of these ferments, the various insoluble storage materials are converted into forms in which they can diffuse through the organism.

113. **Respiration** or breathing takes place in plants just as it does in animals. Every living thing requires a supply of energy, and this is obtained by respiration. In a machine, fuel is burnt and thus energy is replaced

in the form of heat. In living beings, a similar process takes place, but the rise in temperature is very small, and the process of combustion is a slow one. In plants the organic material obtained by assimilation is consumed, carbon di-oxide being set free, and oxygen being absorbed. Thus respiration is, to a certain extent, antagonistic to assimilation and the two processes may be contrasted.

| | *Respiration.* | *Assimilation.* |
|---|---|---|
| 1. | Oxygen is taken in, and carbon di-oxide is liberated. | Carbon di-oxide is taken in and oxygen is liberated. |
| 2. | Energy is set free. | Energy is stored up. |
| 3. | Takes place in all parts of the plant at all times. | Takes place only in green parts of the plant and only in the sunlight. |

In the daytime assimilation is far more active than respiration, hence in any experiments with green plants it is necessary to place them in darkness, in order to detect their respiration, as in the daylight the carbon di-oxide evolved in respiration is at once re-absorbed by assimilation.

114. **Experiment 18.**—Place some germinating peas on damp cotton-wool in a jar, and cork it up. Set up a similar jar without the peas as a control. Test the air in both jars at the end of twenty-four hours by putting a lighted match in each, and also a little lime-water.

115. **Experiment 19.**—Obtain three large jars with corks, and place a little lime-water in each. Hang a large leaf by a thread from the corks of two of the jars,

and put one of these in a dark cupboard, and the other in the sunlight. The third jar serves as a control. At the end of two or three hours, examine the jars. The lime-water in the jar which has been in the dark will be quite milky, owing to the carbon di-oxide breathed out by the leaf, the other two will be unchanged. Laurel leaves or any thick leaves that do not fade quickly can be used for this experiment.

116. **Experiment 20.**—Obtain a long, narrow-necked flask, and in it place some germinating seeds. Place

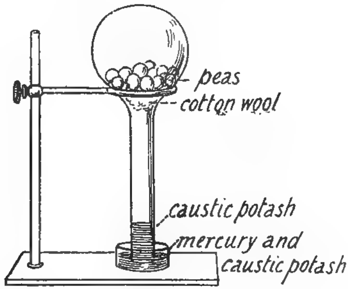



FIG. 77.—Apparatus to Show that Germinating Seeds give out Carbon Di-oxide (Experiment 20).

some damp cotton-wool in the neck of the flask; this prevents the seed falling out, and also keeps them damp. Now invert the flask, and let the neck dip into a dish of caustic soda solution. This absorbs all the $CO_2$ breathed out by the seeds; hence in a short time the solution will rise in the neck of the flask to take the place of the oxygen absorbed by the seeds in it. This experiment can also be performed with opening flower buds, or leaves, but if the leaves are used, the apparatus must be placed in the dark, or the flask covered with dark paper.

117. **Experiment 21.**—Line a beaker with blotting-paper, damp it, and fill it with germinating seeds, packed round the bulb of a thermometer. Place beaker under a bell-jar, the thermometer passing through its cork. Put small dish of caustic potash in bell-jar to absorb any carbon-dioxide given off by seeds. Fix up another similar apparatus, using seeds killed by boiling. After a few hours compare the two thermometers. Rise in temperature of living seeds is due to respiration.

118. **Experiment 22.**—Fill a test-tube with mercury, and invert it in a dish of mercury. Then slip two or three germinating mealie seeds under the test-tube. They will at once rise to the top, being lighter than mercury. In a few hours the mercury will have sunk two or three inches in the tube, showing that some gas has been given out by the seeds. With a bent pipette force a little lime-water up to the top of the test-tube. It at once turns milky, showing that the gas given out by the seeds was carbon di-oxide. This experiment illustrates the phenomenon of intra-molecular respiration; the seeds were able to exhale carbon di-oxide without having any free oxygen; they must have obtained their oxygen from the decomposition of complex substances in the seeds themselves.

119. **Parasites.**—Though the majority of green plants obtain their food from the carbon di-oxide of the air, and from salts in solution in the soil, there are a few exceptions.

Parasites are plants which obtain their food from other plants, and are distinguished as total or partial parasites, according as they obtain all or only some of their food from other plants. The Dodder (Cuscuta) is an example of a total parasite, one species of which is parasitic on Lucerne in this country. The seed germinates late in the spring, when the Lucerne is well established. It sends out a little root in the ground, and a thread-like shoot into the air, this shoot elongates rapidly and circles around until it comes in contact with the stem of a Lucerne plant. It twines round this host plant, and sends suckers or haustoria into the stem. The xylem and phloem of these haustoria fuse with the xylem and phloem in the vascular bundles of the host plant, and thus the Cuscuta draws all its nourishment from the host. The root dies off as soon as the parasite is well established. After a time the Dodder produces clusters of pinkish flowers, but it never has any green leaves, only small reddish-brown scales on its thin red stems. The seeds ripen at the same time as the Lucerne seed, hence, when the Lucerne seed is gathered, the seeds of this parasite are very apt to be gathered with it.

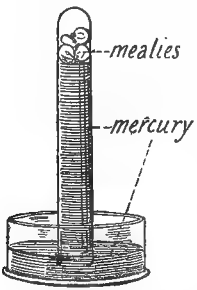


FIG. 78.—Experiment to Show Intra-molecular Respiration.

The mistletoe is a partial parasite; it has green leaves, and is therefore able to assimilate carbon di-oxide from the air, but it takes its supply of water and dissolved salts from the host plant on which it lives. The seeds are dispersed by birds, who eat the berries, and deposit the seeds on the branch of some tree. There it germinates, and the radicle penetrates the bark, and sends out haustoria which fuse with the xylem of the host plant. This plant is a perennial, and each year new "sinkers" are developed, which penetrate the new wood in the host.

Viscum capense and V. rotundifolium live on various South African trees. Loranthus and Striga are partial, Hydnora a total, parasite.

120. **Saprophytes.**—Saprophytes are plants which obtain their food from decaying organic substances.

Many orchids are saprophytes, either partial or total. The roots or rhizomes of such saprophytic plants exhibit a curious formation, known as MYCORRHIZA. The whole root-tip is covered by a fungus sheath, the hyphae of which penetrate into the root-cells, and also spread out in the soil around. This fungus appears to absorb organic food from the decaying vegetable matter in the soil, and convey it to the plant, and the fungus at the same time obtains food from the plant. This is an arrangement known as SYMBIOSIS i.e. a union between two plants, the fungus and the flowering plant, in which each derives benefit from the other. Many plants in the orders Orchidaceae and Ericaceae exhibit this mycorrhiza.

A curious relation between roots and bacteria exists in the order Leguminosae. On the roots of plants of this order are found tubercles, and these are caused by certain bacteria, which penetrate through the root-hairs into the cortex of the root. These bacteria have the power of absorbing free nitrogen from the air of the soil, and passing it on to the host in the form of nitrates, while they themselves obtain carbohydrates from the leguminous plants. This is another example of symbiosis. As a result of this remarkable arrangement, soil in which leguminous plants have been grown is richer in nitrates than it was before. It is also possible now to obtain tubercles from the roots of the leguminous plants and add them to a soil deficient in nitrates; if a leguminous crop is then grown the soil will be enriched.

121. **Carnivorous or Insectivorous Plants** obtain most of their nitrogenous food from the bodies of insects. They are found in swampy places, or in damp tropical forests, or they are epiphytes; hence they do not obtain salts from the soil as easily as other plants. Drosera, the sun-dew, is an insectivorous plant, of which several species are found in this country. The leaves are small, round and covered with sticky, reddish-coloured hairs or glands. These glands secrete an acid fluid, and it is the glistening appearance of this that gives the plant its name. When an insect alights on the leaf, probably in search of honey, it is caught in the sticky secretion. The hairs then bend over, and finally the whole leaf curls up, enclosing the insect. The secreted fluid seems to have the power of digesting the solids in the insect's body, which are thus absorbed by the plant. The leaf then uncurls, and the dried-up remains of the insect blow away. The tentacles will move when touched with any substance, but they will not curl over and pour out their digestive juice unless the substance is organic. A tiny scrap of raw meat, or white of egg will be digested just as the insect was. The so-called PITCHER-PLANTS have their leaves modified for

the purpose of entrapping insects. Nepenthes, Sarracenia, and Cephalotus are Pitcher-plants, in which the

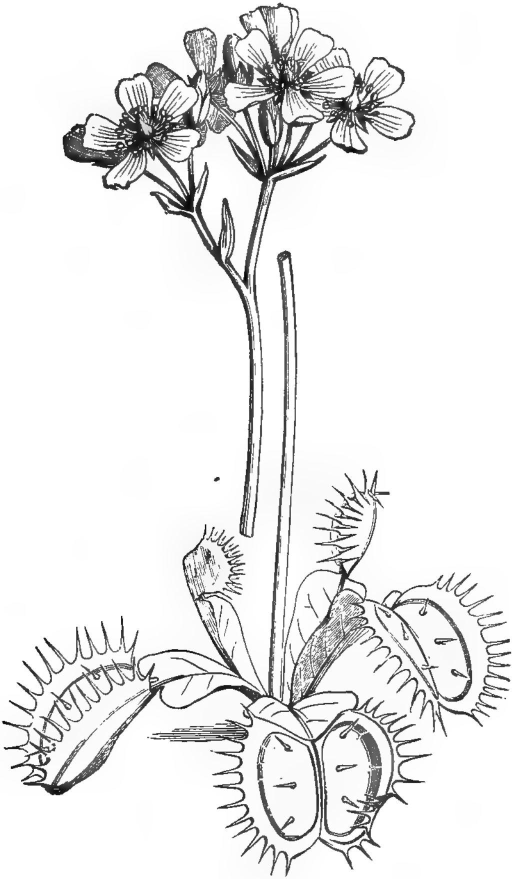


FIG. 79.—Venus's Fly-trap (*Dionæa muscipula*).

whole or part of the leaf is modified to form a trap-like receptacle with a lid, which is brightly coloured, but does not close. On the inner side of the pitcher are downward pointing hairs, and at the bottom is a fluid, and the insects slip down the sides, fall into the liquid, and are drowned, and then digested. Dionæa, Pinguicula, and Utricularia are other insectivorous plants which exhibit different mechanisms for the capture of their prey. Dionæa, which grows in the peat-bogs of North Carolina, captures insects by the sudden closing of the two halves of a leaf. Pinguicula has sensitive leaves, the margins of which close over the captured insect. Utricularia is an aquatic plant, growing in small pools, and small green bladders are found in some of its leaves. In each bladder there is a small valve, which only opens inwards. Minute water animals, snails, etc., can easily pass into this opening, but cannot get out again. They are then absorbed by the plant by means of the digestive juices inside the bladder.

## The Plant and Its Environment.

122. **Irritability.**—Protoplasm has the power of being stimulated by outside influences and of making a certain response to them. This property of protoplasm is known as IRRITABILITY, and is most important to the plant, as by this means it is brought into harmony with its surroundings. The growing parts of plants exhibit this property more than the mature organs, but in some cases the mature organs will show movement in response to a stimulus.

123. **Stimuli.**—A STIMULUS denotes any outside influence which excites a response on the part of the plant. The chief stimuli are light, gravity, moisture and

mechanical contact. It must be clearly understood that a plant will only exhibit such a response to stimulus, if it is in a healthy condition, and if it has all the requisites for healthy growth, i.e. a suitable temperature, moisture, etc.

124. **Light.**—The influence of Light on plants may be considered from two points of view,—(1) its stimulating action, (2) its directive action.

125. **The Paratonic Influence of Light** is the term used to denote the effects produced in plants by variations in intensity of light. The general influence of light in this respect is to retard growth. Plants grow more quickly in the dark. On the other hand, entire absence of light would, in the end, cause the plant to become unhealthy, the stems being white, and the leaves yellow (the etiolated condition).

Movements are induced in some plants by variations in the intensity of light. Of this class are the "Sleep-movements" of many leaves, e.g. Cassia, Oxalis and *Mimosa pudica,* which droop and close up at night. The same effect may be produced by too great illumination. In both cases the use of the movement is to prevent excessive transpiration.

Some flowers show movement induced by variations in the intensity of light. Mesembryanthemum closes its flowers at sunset, so does Portulaca, the Four-o'clock. Others like Oenothera, the Evening Primrose, open at night. This movement is caused by unequal growth in the lower and upper surfaces of the floral leaves.

126. **The Heliotropic Influence of Light.**—This is the name given to the influence of light on the direction of

growth. Heliotropism is, then, the response made by an organ, as regards the direction of its growth to the influence of light. The parts of a plant are said to be POSITIVELY or NEGATIVELY HELIOTROPIC according as they turn towards or away from the light. As a rule, stems grow towards the light, roots away from it, and leaves tend to place themselves at right angles to the incident rays. This is known as DIA-HELIOTROPISM.

127. **Experiment 23.**—Grow a Geranium or Sunflower plant in a window, so that it gets light from one side only. In a short time, it will be found that the stems have all turned towards the light, and the leaves at right angles to it.

128. **Experiment 24.**—Pin a Bean seedling to a cork in a large jar with a little water in it. Cover this jar with black paper, leaving a slit down one side. In a few days the shoot will be growing towards the slit, and the root away from it.

129. **Gravity.**—The response made by plants as regards their direction of growth to the stimulating influence of gravity is known as GEOTROPISM. As before, we speak of positive and negative geotropism. Primary roots are POSITIVELY GEOTROPIC, i.e. they grow towards the centre of the earth; Secondary roots are DIAGEOTROPIC, and stems are NEGATIVELY GEOTROPIC.

130. **Experiment 25.**—Line a test-tube with blotting-paper, fix a Pea or Mealie seedling between the blotting-paper and the glass, and then wet the blotting-paper, and keep it damp. As soon as the radicle and plumule have come out, turn the test-tube upside down. It will

be found that both curve round, so that the radicle again points downwards and the plumule upwards.

131. **Experiment 26.**—Pin a Bean seedling to a cork which has been previously fixed to the side of a dish containing mercury and a little water. The seedling should be pinned with the root horizontal. The root will soon turn and grow right down into the mercury. This shows that it is not the weight of the root which makes it turn down, since the tip forces its way into the mercury, in spite of the great resistance offered by this dense liquid.

132. **Water.**—The direction of growth of roots is influenced by moisture, and they are therefore said to be positively hydrotropic. This property is very useful to them, as it enables them to grow towards the damper parts of the soil.

133. **Experiment 27.**—Get a large box and fill it with dry sand or sawdust. In the middle, place a flower-pot with the hole corked up, or any porous pot. Fill this pot with water. Then plant some seeds which have just germinated in the sand, at various distances from the flower-pot. After a few days pull them up and see if their roots have grown towards the flower-pot, i.e. towards the moisture.

Another method is to obtain a box with a bottom of wire gauze, fill it with damp sawdust, plant seeds in it and hang it up. The roots grow out through the gauze, owing to the influence of gravity, and then turn back again because of their hydrotropism. If, however, the air is very dry, the roots may shrivel up in the air and not turn back, hence the first method is more satisfactory.

134. **Contact.**—Certain organs of a plant are sensitive to contact, e.g. root-tips, tendrils and some stems. If a growing root encounters an obstacle, such as a stone, it will curve away from it, continuing its downward course when it has curved round the stone. This property is of great use to roots penetrating the soil, and can easily be shown experimentally.

135. **Experiment 28.**—Fix a few stones by means of sealing wax to the sides of a glass funnel, then line the funnel with blotting-paper and fill it with sawdust. Place some soaked seeds between the blotting-paper and the glass, above the obstacles. As the seeds germinate, the roots will grow downwards along the sides of the funnel, till they reach the obstacles, when they will curve round them. The stones must be quite small.

136. **Tendrils.**—The tip of a young tendril grows around in a spiral until it comes in contact with some support, it then becomes concave at the point of contact, and if the support is suitable, the stimulus is transmitted to other parts of the tendril and it twines round the support. At the same time the part of the tendril below the point of attachment becomes spirally coiled, thus drawing the stem close up to the support. Since both ends of the tendril are fixed before coiling begins, the spiral has to be reversed at some point; if it is right-handed in the upper part, it will be left-handed below. This coiling of the tendril causes it to act like a spring, and diminishes the effects of shock or strain.

The stigma of Bignonia is sensitive to contact, the two lobes close when touched, and do not open for some time. Leaves of some insectivorous plants also show movement in response to contact.

137. **Adaptations to Environment.**—Every gardener knows how rapid is the growth of weeds in any neglected piece of ground and how difficult they are to exterminate. When he plants out his flowers he has to shade them and water them carefully every day, till they are established, while all around in the same soil the weeds spring up and flourish, and have to be continually rooted up. Why is this? The weeds obviously are better adapted to the existing conditions than the cultivated plants; they are either the natural wild plants of that particular district, or they may be imported plants which find their new surroundings exactly suited to their requirements, as, for instance, the Cosmos, and the Khaki Weed (Tagetes) which are spreading so rapidly through the Transvaal. Now we know that most flowering plants produce a very large number of seeds, and as it is impossible that all these can become mature plants, only the fittest will survive. If all the seedlings were exactly alike, it would be mere chance which of them survived in the struggle for existence. But they are not all alike, they exhibit individual differences, and if any of these "variations" gives them an advantage over the others, they will survive, and the new variation will tend to be transmitted and ultimately to become fixed.

Examine the common weeds found in any garden and notice what special characteristics they have that enable them to gain the upper hand. Some have very deep tap roots, and a spreading rosette of leaves which covers all the ground just around the plant and causes the extinction of any other seedlings; others having quick-growing underground stems. Most of them have self-pollinated flowers, so that they are certain to set seed, and most have excellent methods of seed-dispersal either by wind or by animals.

In the same way, if the plants of any particular district be examined, they will probably show certain characteristics which specially fit them to live in those particular surroundings. From this point of view we may group plants into:—

1. Xerophytes, which are adapted for life in very dry places.

2. Hydrophytes, which live in water or marshes.

3. Mesophytes, which are the ordinary land plants, and

4. Epiphytes, which live on other plants, but do not take any nourishment from them.

138. **Xerophytes.**—These are plants which can live with a very small supply of water, and therefore they are found in places where there is a long dry season, or where the soil is very sandy, so that the water all runs through it. They are also found on rocky ground, where there is again a scanty supply of water; on the sea shore, where the presence of an excess of salt in the soil hinders absorption by the roots; and on high mountains, where the plants are exposed to drying winds. In all these places the plants have to check transpiration without preventing assimilation; a difficult problem, since the same conditions are favourable to both functions. We find that different plants have

adopted different devices to prevent excessive transpiration. Most of them, e.g. Pinus, Eucalyptus, Aloe, have their stomata sunk in pits, instead of being on the surface; their leaves have also a very thick cuticle. Some, like the Silver Tree, have a dense covering of hairs on their leaves, others, e.g., Crassula and Cotyledon, have thick fleshy leaves which store up water. Pinus has needle-shaped leaves which do not expose so much surface for transpiration; in Erica the leaves are small, narrow, and closely crowded. In many species of Acacia the leaves are so finely divided that the leaflets are quite minute, so that again the surface exposed is diminished.

One species of Acacia bears phyllodes, instead of compound leaves, and this makes the flat surface lie in a vertical plane, and so checks transpiration. The same result is obtained in Eucalyptus, by twisting the leaf on its petiole, so that it is edgewise to the mid-day sun. In Euphorbia, the stem is thick, fleshy and green, and the leaves are altered to thorns; in Asparagus, the stems are green and needle-like, and the leaves are scales or thorns. Such leaf-like stems are called cladodes; and they too have vertical assimilating surfaces, thus checking transpiration.

A few plants, like Psamma, and some grasses, roll up their leaves, thus protecting the stomata and checking transpiration. Many Xerophytes are thorny, e.g. Prickly Pear, Aloe. This is probably because growing as they do in places where moisture is scarce, they are very liable to be eaten by animals, and must therefore protect themselves against them.

139. **Hydrophytes or Water Plants** are subject to less extremes of temperature than land-plants, owing to the specific heat of water being so high. There is also more carbon di-oxide in water than in air, as this gas dissolves readily in water. Hence we find that water plants grow very rapidly and branch freely, especially in the tropics, where growth is not hampered by either a cold or a dry season. The leaves of a water plant, if submerged, are either ribbon-shaped or narrow, and arranged in whorls or finely divided. The epidermis contains chlorophyll and has no cuticle, and there are no stomata. The floating leaves are rounded or slightly lobed, bear stomata on their upper surface, and have a waxy cuticle so as to prevent wetting. Some Hydrophytes bear two kinds of leaves, floating and submerged, others have only the floating leaves. The stems have very little mechanical tissue, as the water supports all the weight of the plant; if, however, the plant grows in running water it may be subjected to strong pulling strains due to the current; in this case the vascular bundles are placed centrally, as in the root of a land plant. There is little conducting tissue in stem or root, as the whole plant is able to absorb water. For the same reason there are few or no root-hairs, the root serving merely to fix the plant to the bottom. Air spaces are present in all parts of a water plant. They help it to float, and also convey air to the lower parts growing in deep water or mud where there is little oxygen present for respiration. Most water plants reproduce themselves extensively by vegetative methods, and flower much less freely than land plants; when they

do flower, the flowers are formed above water as in the Water Lily.

140. **Hygrophytes.** — Hygrophytes (moisture-loving) plants grow in marshes, or at the sides of rivers and streams, and they show characteristics intermediate between the truly aquatic plants and those which live on land.

141. **Epiphytes** cling to other plants for support, but are not parasitic upon them. They abound in the tropics where the dense forests shut out the light from the ground beneath, so that small herbaceous plants must either become epiphytes or climbers. The epiphytes, by their position, get plenty of light and air, but it is difficult for them to obtain the necessary water and salts.

They all possess certain characteristics in common. Firstly, they must all have excellent methods of seed dispersal by either wind or birds. Secondly, the seedling must be able to fasten itself to its support as soon as it germinates, and so we find epiphytes have clasping roots which are usually adventitious. Thirdly, these plants have but a small and precarious water supply, hence they show all kinds of xerophytic characters, especially the capacity for water-storage.

Most epiphytes obtain the mineral subtances required for nutrition from decaying organic matter.

142. **Elongation of Root and Stem.**—It will have been noticed when the germination of seeds was being observed, that the radicle and plumule both elongate rapidly after they emerge from the seed. To find out in which part of the root and stem this elongation

takes place the following experiments may be performed.

*Experiment* 29.—Obtain some germinating seeds with radicles about half an inch long. Mealies, Beans, Peas, Sunflowers will all do for this experiment. Get a ruler graduated in millimetres, some indian ink, and a fine pen. Now mark all the radicles with fine lines a millimetre apart, beginning at the tip. Then place the seeds on damp blotting-paper or damp sawdust and leave for twenty-four hours. Then notice the position of the marks. If the experiment is done on a cold day it may be necessary to leave the seedlings for two days. Sketch the seeds (*a*) as they were, (*b*) as they are now. The reason that the part behind the tip increases in length, and not the tip itself is that the cells at the tip behind the root-cap are all meristematic, i.e. they are rapidly dividing and forming new cells, whereas those a little farther back are expanding to their full size. Hence it is in this region that the greatest increase in length is noticeable, though the actual growth takes place just behind the root-cap.

*Experiment* 30.—To observe the elongation of the stem some young seeds should be taken in which the plumule is just out. A Broad Bean or Pea seedling is best for this, as in the mealie the actual growing point of the stem is wrapped around by the sheathing leaves, and hence cannot be marked. Mark the plumule in the same way as the radicle, and proceed as before.

Opening buds can also be used for this experiment, those of the Oak are suitable; the short internodes should be carefully marked, the shoot set in water and left for some days. If the opening buds can be marked while still on the tree and left to open naturally it will be better, but as a rule the shoot will develop after it has been picked, if it is placed in water.

## PRACTICAL WORK.

1. All the experiments described should be performed and the results carefully noted. Note also the time taken, and the particular plant used. The Transpiration experiments succeed best in the early spring, as do those on Root Pressure, but the other experiments can be performed at almost any time in this country.

2. Specimens of Parasites, Saprophytes and Insectivorous Plants should be obtained and carefully studied. Dodder and Mistletoe occur in many parts of South Africa, so does at least one specimen of Drosera; Nepenthes and Sarracenia are fairly easy to cultivate in a hot-house.

3. Xerophytes, Hydrophytes and Epiphytes should be studied in their natural surroundings. Almost any kopje will furnish numerous examples of Xerophytes, the same place should be visited before and after the dry season. The Karoo plants are practically all Xerophytes. Epiphytes are plentiful in Natal, and can be found anywhere where there are fairly dense woods and forests. Hydrophytes should be looked for in both still and running water and their characters compared. Cut sections of the leaves and stems of Xerophytes and Hydrophytes and note how the internal structure differs from that of the typical Mesophyte, such as Sunflower.

## QUESTIONS ON CHAPTER IX.

1. Give an account of the processes of root absorption. By what means are roots able to absorb substances which are insoluble in water?

2. What is a carbohydrate? Mention the chief carbohydrates, stating how they are distinguished from each other. How are oils and fats distinguished from carbohydrates?

3. What conditions are essential in order that a green plant may form starch? Give an account of the experimental evidence on which your answer is based.

4. Explain how you would proceed to make a water-culture. Indicate the effect on a plant of the omission of salts containing Iron and Nitrogen respectively.

5. Describe some experiment by which you could measure the rate of transpiration.

6. What is respiration? How would you show that it takes place in germinating seeds? How must your experiment be modified if green leaves are used instead of seeds, and why?

7. What is meant by "nitrification"? What is its importance in plant life and under what conditions does it occur?

8. What is heliotropism? Give an account of any experiments you have performed to investigate the nature of the heliotropic phenomena in stems and roots.

9. For what different purposes do you consider that a plant requires to be supplied with water? How are some plants able to withstand long-continued drought uninjured? Give examples.

10. Name several different species of plants that you have found growing by the sea-side, and not inland. State exactly where and how each was growing, and mention any characters possessed by each that you think fitted it to its particular circumstances.

11. Write a list of plants you have found growing with their leaves submerged in water. How do such plants obtain the gases they require for respiration and photo-synthesis? Compare the structure of their leaves with that of the leaf of a land plant.

12. Give a short account of the conditions of growth and the nature of the vegetation in one of the following:—

(*a*) A wood;
(*b*) A kopje;
(*c*) A marsh;
(*d*) A wide stretch of open veldt.

13. What is a parasite? Give examples. How is a parasite distinguished from (*a*) an epiphyte, (*b*) a saprophyte?

14. Explain, in detail, how you would test for the presence

of starch in a green leaf. Carefully describe, and sketch where possible, experiments you have performed to prove the following:—

(*a*) That starch is formed by photo-synthesis only in green parts of plants.

(*b*) That it is formed only when these parts are exposed to the light.

(*c*) That the carbon di-oxide of the air is used in this starch-making.

(*d*) That this carbon di-oxide enters the leaves through the stomata.

(*e*) That oxygen is given off during assimilation.

15. (*a*) Draw as exact to life-size as you can a germinating seed, with its root marked so as to find out which part grows in length most rapidly. Draw it again as it would appear twenty-four hours later.

(*b*) Explain how you would show that a leaf loses water chiefly through its stomata.

16. How would you show that the presence of oxygen (or "fresh air") is necessary for the germination of seeds?

17. Describe, in detail, experiments you have carried out to find out the answers to the following questions:—

(*a*) What will happen if you grow a plant in a position where it can get light from one side only?

(*b*) What causes a root to grow downwards and a stem to grow upwards?

(*c*) Which side of an ordinary foliage leaf gives off most water?

(*d*) "Green leaves make starch in the light." What happens in the case of a leaf which is partly green and partly white? (Mention the plant used in carrying out this experiment.)

18. Carbon and nitrogen are known to be essential elements to a plant. Describe experiments to show whether these elements are obtained by the plant from the soil or from the air, giving an exact and detailed description of how the experiments you describe were set up and the results obtained from each.

19. Describe and explain the appearance of a seedling which has been supplied with air and moisture, but has been kept in the dark.

20. Write an essay on "Protective Adaptations against Dryness," illustrating it throughout by reference to your own observations on plants which show such adaptations. Say where you saw each plant you mention ; e.g. on veldt, mountain or sea-shore (where?), in school garden or as a preserved specimen pictured in a book (what book ?) etc.

21. State what you know as to the movement of sap in the stem.

22. Explain fully the functions performed by chlorophyll in a plant.

23. State what you know of the processes referred to in the following sentence: "Experiments have shown that carbon di-oxide is absorbed and that oxygen is given off by all green surfaces of plants during the hours of sunlight".

24. In what form and for what purpose are the following elements appropriated by plants: carbon, calcium, sulphur, nitrogen, oxygen.

25. From what source and in what forms do green plants usually absorb their nitrogenous food? Mention cases in which the nitrogenous food is absorbed from other sources and in other forms.

26. Say what you know about the absorption of liquids by plants. What are the chief organs concerned in the process in the case of the higher plants? Enumerate the chemical elements which are essential to the nutrition of green plants and explain how such plants are enabled to absorb substances which are insoluble in water.

# CHAPTER X.

## CLASSIFICATION.

143. **Systems.**—In classifying plants it is desirable to group them as far as possible in accordance with their natural relationships. There are many difficulties in making a natural system of classification, hence we find that some botanists prefer one system, some another. In Great Britain the system commonly used is that of Bentham and Hooker; on the Continent that of Engler is preferred; the latter system is the one used in this book.

144. **Species, Genus and Natural Orders.**—It will be noticed that each plant has two names, e.g. "prunus persica" is the peach, and "prunus cerasus" is the cherry; the first of these names denotes the genus, the second the species. A species is a group of plants which resemble each other so closely that it is difficult to tell them apart; e.g. peach is the species "persica". Species which resemble each other more or less closely and yet possess distinguishing characteristics are grouped together in one GENUS, e.g. peaches, plums, apricots and cherries all belong to the genus "prunus".

Genera are again grouped into NATURAL ORDERS, and these are grouped into divisions and classes.

145. **Flowering Plants** are divided into two large

classes, Angiosperms and Gymnosperms. The former have their seeds in an ovary, and the latter do not.

Angiosperms are again divided into two large classes, Monocotyledons and Dicotyledons. These two classes are easily distinguished from one another by certain well-marked characteristics.

*Monocotyledons* have parallel veined leaves, the parts of the flower in threes, stem with scattered, closed vascular bundles, and seeds with one cotyledon.

*Dicotyledons* have net-veined leaves, and parts of the flower in twos, fours, or fives (rarely threes), stem with a ring of open bundles or with secondary thickening, and seeds with two cotyledons.

Dicotyledons can again be divided into two SERIES, Archichlamydeae and Sympetalae. The latter series have gamopetalous corollas, the former either no corolla, or a polypetalous one; but occasionally in the Archichlamydeae the corolla is gamopetalous.

The Natural Orders considered in this book may then be grouped as follows:—

146. FLOWERING PLANTS.

- Angiosperms
  - Dicotyledons
    - Archichlamydeae
      - N. O. Proteaceae
      - Cruciferae
      - Crassulaceae
      - Rosaceae
      - Leguminosae
      - Geraniaceae
      - Oxalidaceae
      - Malvaceae
      - Ficoideae or Aizoaceae
    - Sympetalae
      - N. O. Ericaceae
      - Labiatae
      - Solanaceae
      - Scrophulariaceae
      - Compositae
  - Monocotyledons
    - N. O. Liliaceae
    - Amaryllidaceae
    - Iridaceae
- Gymnosperms

Protea (Proteaceae) and Erica (Ericaceae).

147. **N. O. Proteaceae.** *General Characters.*—Trees or shrubs with very diverse foliage. Leaves adapted to resist drought. Natives of Australia and South Africa. Flowers mostly capitate: no corolla, four stamens inserted on sepals, ovary free, fruit an achene, or nut.

*Type.*—Leucospermum (Kreupelhout) (fig. 80). *Plant*, tree or shrub. *Stem*, woody. *Leaves*, simple, exstipulate, entire, net-veined, and hairy. *Inflorescence*, capitulum. *Flower*, irregular, incomplete. *Calyx*, elongate, three of the sepals cohering, the fourth free when flower opens, coloured. *Corolla*, absent. *Androecium*, four sessile anthers adhering to apices of sepals. *Gynoecium*, ovary free, one-celled, superior, style deciduous, stigma thickened.

Fruit, a nut.

*Pollination.*—By insects.

*Other Genera.*—*Protea*, similar to Leucospermum but an involucre present formed of persistent coriaceous imbricate bracts, often coloured or bearded. *Fruit*, a tailed achene (tail formed by the persistent style) covered with stiff hairs. *Leucadendron*, flowers dioecious, involucre formed by the upper leaves, mostly yellow. Female flowers form a cone. *Fruit*, a flat, or winged, nut. *L. argentum* (the Silver Tree), a striking member found in the Cape Peninsula. Brabejum (Wild Almond), found by the side of streams. *Mimetes*, shrubs similar in habit to Leucospermum. *Flowers* reddish or purple in small heads. *Calyx* regular. *Segments* distinct.

148. **N. O. Cruciferae.** *General Characters.*—Flowers, polypetalous hypogynous, parts in twos or fours; cruci-

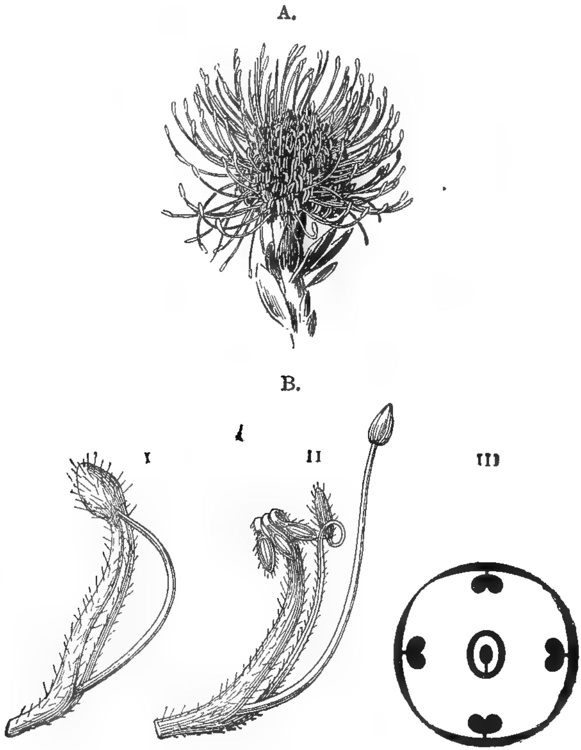



Fig. 80.

A. Flower head of *Leucospermum elliptium.* B. *Leucospermum conocarpum.* I. Flower-bud. II. Flower opened. III. Floral diagram.

form corolla, tetradynamous stamens; gynoecium syncarpous, 2 carpels; ovary 2 celled, placentation parietal; fruit a siliqua or silicula.

*Type.*—Cheiranthus (Wallflower) (figs. 81-87).

*Plant.*—Herb, perennial.

*Stem.*—Herbaceous above, woody below, solid, ribbed, hairy.

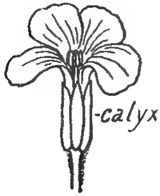



FIG. 81.—Flower.

FIG. 82.—Petal.


FIG. 83.—Androecium.

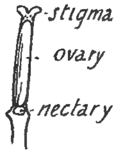



FIG. 84.—Gynoecium.

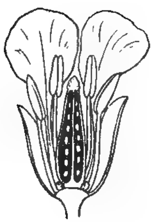


FIG. 85.—Vertical Section through Flower.

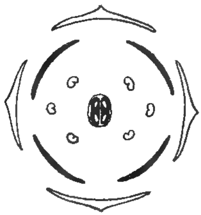


FIG. 86.—Plan or Floral Diagram.

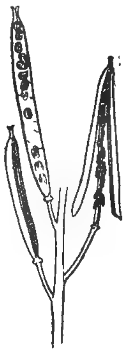


FIG. 87.—Fruit.

FIGS. 81-87.—Cheiranthus (Wallflower).

*Leaves.*—Alternate, cauline, simple, sessile, exstipulate, lanceolate, entire, net-veined, hairy.

*Inflorescence.*—Raceme.

*Flower.*—Actinomorphic, complete.

*Calyx.*—2+2, inferior, polysepalous, the 2 lateral sepals pouched.

*Corolla.*—4, inferior, polypetalous, cruciform—petals clawed.

*Androecium.*—2+4, tetradynamous, inferior, nectaries at base of two short lateral stamens, anthers dorsifixed, introrse.

*Gynoecium.*—Syncarpous 2, superior, ovary bilocular, owing to the development of a false septum between the two parietal placentas. Ovules numerous.

*Fruit.*—A siliqua.

*Pollination.*—The calyx forms a kind of tube holding the petals together and thus the honey is partially concealed. The flowers are attractive to insects, but there is no special device for ensuring cross-pollination, hence self pollination is probably quite frequent.

*Other Genera.*—Heliophila is common in South Africa; it has blue flowers. Brassica is a large genus, extensively cultivated; it includes Cabbage, Turnip and Mustard. Matthiola (the Stock) is cultivated for its flowers. Iberis (Candytuft) has irregular flowers, the two outer petals of each flower being much larger than the other two; it has a silicula for its fruit. Capsella (Shepherd's Purse) is a fairly common weed;—Nasturtium (Watercress), Lepidium (Cress), Cochlearia (Horse Radish), and Raphanus (Radish) are all used as vegetables.

149. **N. O. Crassulaceae.**—*General Characters.*—Plants, usually perennials, with xerophytic characters, e.g. fleshy leaves and stems, tufted growth, close pack-

ing of leaves upon one another, thick cuticle, waxy surface, etc. Leaves are decussate. Inflorescence is usually cymose. Flowers regular and polypetalous.

FIG. 88.—Single Flower of Cotyledon.

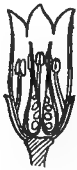


FIG. 89.—Cotyledon, Vert. Section through Bud.

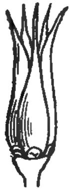
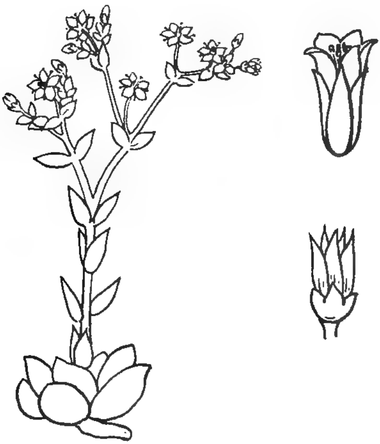


FIG. 90.—Cotyledon Gynoecium of Older Flower.

FIG. 91.—Cotyledon Floral Diagram.



*b*

*c*

*a*

FIG. 92.—Crassula.

*a. Crassula Stachyera* (nat. size). *b.* Flower (enlarged). *c.* Fruit (enlarged).

Floral formula may be written KnCnAn + nGn (see p. 90), where "n" represents any number from 3 to 30. Stamens may equal or double number of petals; usually obdiplostemonous. If only one whorl of stamens, formula is KnCnAo + nGn. Corolla may be gamopetalous. Flowers usually perigynous. Gynoecium is apocarpous, usually a nectary at base of each ovary. Fruit is a group of follicles.

*Type.*—Crassula (figs. 92-93).

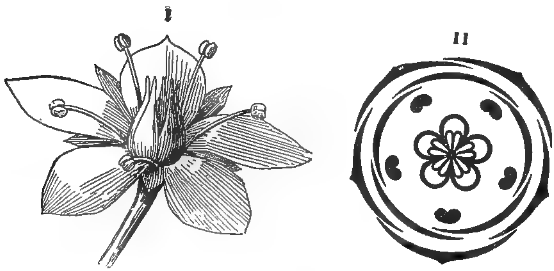



FIG. 93.—*Crassula Centauroides*, Thumb. I. Flower (Xa). II. Diagram of Flower.

*Plant.*—Succulent herb, perennating by means of a rhizome.

*Leaves.*—Decussate, simple, thick and fleshy, connate in some species.

*Inflorescence.*—A dichasium.

*Flower.*—Regular, complete.

*Calyx.*—Polysepalous, 5 sepals, inferior.

*Corolla.*—Polypetalous, 5 petals, perigynous.

*Androecium.*—Polyandrous, 5 stamens.

*Gynoecium.*—Apocarpous, 5 carpels, superior. Ovaries each one-celled, containing numerous ovules with marginal placentation.

*Fruit.*—A collection of 5 follicles.

*Pollination.*—Flowers slightly protandrous, visited by insects for honey. Both cross- and self-pollination may take place.

*Other Genera.*—This order is well represented in South Africa, and the plants belonging to it are easily recognised by their regular flowers, apocarpous pistils, and well-marked xerophytic character. Cotyledon and Bryophyllum are gamopetalous. The former has 10 stamens, the latter's leaves have the peculiar property of developing adventitious buds on their margins, which give rise to new plants, hence it is called "Leaf of Life" or "Kannidood". Kalanchoe has a gamopetalous corolla, and parts in fours. Sedum, with large pink inflorescences, is cultivated in rockeries, and so are Sempervivum and Echeveria. Rochea is a well-known South African genus.

FIG. 94.—Vertical Section through Flower of Peach (Prunus).

150. **N. O. Rosaceae.**—*General Characters.*—Plants are herbs, shrubs or trees. Leaves alternate, usually stipulate. Flowers regular; corolla polypetalous, perigynous. Stamens numerous. Pistil apocarpous or monocarpous.

*Type.*—*Prunus Persica* (Peach) (fig. 94).

*Flower.*—Regular, complete, bracteate.

*Calyx.*—Gamosepalous 5, inferior, cup-shaped and small.

*Corolla.*—Polypetalous, 5 perigynous, pale pink.

*Androecium.*—Free, numerous, perigynous; *Anthers* dorsifixed, introrse; *Filaments* long.

*Gynoecium.*—Monocarpellary superior, stigma terminal, style long—ovary one-celled with one or two pendulous ovules.

*Fruit.*—A drupe.

*Pollination.*—This flower is adapted for pollination by all sorts of insects. There is honey at the base of the calyx tube. Self-pollination is also possible; but apparently does not always take place, since quite a number of flowers fail to form fruit.

*Chief Genera.*—These may conveniently be grouped as follows:—

(1) *Spiraeoideae.*—Carpels 2-5, fruit of 2-5 follicles: Spiraea.

(2) *Pomoideae.*—Carpels 2-5, fruit a pome: Pyrus.

(3) *Rosoideae.*—Carpels numerous.

- (*a*) Fruit a collection of drupelets: Rubus.
- (*b*) Fruit a collection of Achenes on a convex receptacle: Fragaria, Potentilla, Geum.
- (*c*) Fruit a collection of Achenes inside a hard receptacle: Agrimonia (2 carpels), Leucosidea.
- (*d*) Fruit a collection of Achenes inside a fleshy receptacle: Rosa.

(4) *Neuradoideae.*—Carpels 5-10 united to receptacle to form a dry fruit: Neurada.

(5) *Prunoideae.*—Carpels 1, fruit a drupe: Prunus.

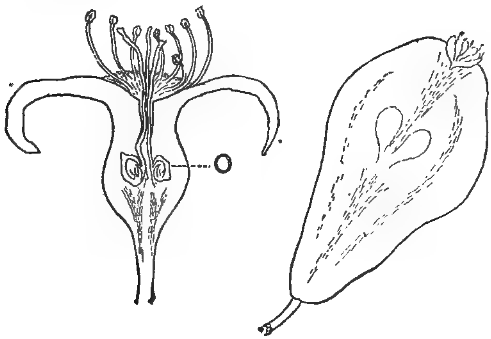
151. **N. O. Leguminosae.** — *General Characters.* — Flowers polypetalous, perigynous; pistil of one carpel; fruit a legume; leaves usually compound, pinnate. This is the second largest order of flowering

plants and is widely distributed. It includes herbs, shrubs, trees and climbing plants. The roots of leguminous plants often have tubercles which are able to assimilate free nitrogen. The order is divided into three well-marked sub-orders.

(1) Mimoseae.

(2) Caesalpineae.

(3) Papilionaceae.




A B

FIG. 95.

A. Young fruit of the Pear. O. The ovary. B. Mature fruit, both longitudinally divided. (From Darwin's "Elements of Botany".)

(1) *Mimoseae.*—Flowers regular, stamens numerous and free.

*Type.*—Acacia (Mimosa or Wattle). This genus has about 400 species, mostly trees. Many are cultivated here for foliage and flowers; some for their bark, which is used for tanning. One species of Acacia (the Karroo Thorn) has two white thorns in the place of the stipules, and several other species are thorny.

*Leaves.*—Alternate, compound, bi-pinnate, stipulate, paripinnate, petiolate, leaflets minute, numerous and net-veined, unicostate (in some species the leaves are altered to phyllodes, q.v.).

*Inflorescence.*—Raceme of capitula.

*Flowers.*—Actinomorphic, complete, minute, scented,

*Calyx.*—Gamosepalous, 5, inferior, pale yellow.

*Corolla.*—Polypetalous, 5, perigynous, yellow.

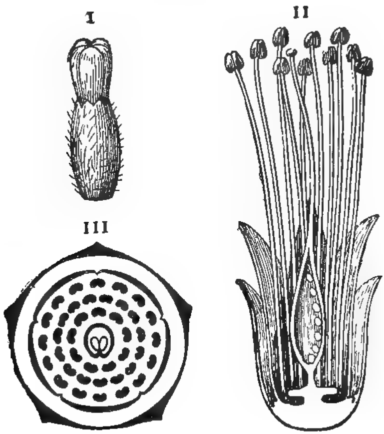



FIG. 96.—*Acacia horrida.*

I. Flower-bud (×3). II. Section through flower (×5). III. Diagram of flower.

*Androecium.*—Numerous, free, perigynous. The stamens have long filaments and hang out of the flower, making the whole inflorescence conspicuous.

*Gynoecium.*—One carpel superior, stigma small, style long, ovary small and round, ovules numerous, placentation marginal (the structure of the ovary can only be made out with a microscope, or after pollination when it is ripening into fruit).

*Fruit.*—A Legume.

(2) *Caesalpineae.*—Flowers zygomorphic, stamens 10 or fewer, free.

Plants in this division are mostly trees with pinnate or even simple leaves and large showy flowers. The best known genera found in South Africa are Poinciana (the Flamboyante tree of Natal), Cassia, Schotia (Boer-boom), and Bauhinia. Several species of Cassia yield the drug Senna.

*Type.*—Cassia (fig. 97).

*Plant.*—A tree.

*Leaves.*—Compound, paripinnate, alternate, stipulate.

*Leaflets.*—Obovate, entire, net-veined, unicostate.

*Inflorescence.*—Racemose.

*Flower.*—Zygomorphic, complete, conspicuous, diameter about 1½ inches.

*Calyx.*—5, polysepalous, inferior.

*Corolla.*—5, polypetalous, perigynous, yellow.

*Androecium.*—10, free. The three lower stamens are longer than the others and project outwards, in some flowers to the right and in others to the left. The 3 upper stamens are reduced to staminodes. Anthers dehisce by pores.

*Gynoecium.*—Monocarpellary, superior.

Ovary one-celled, placentation marginal, ovules numerous.

*Fruit.*—A legume, often with septa between the seeds.

*Pollination.*—This is a "pollen flower" (q.v.) and contains no honey. It seems probable that insects eat the pollen of the short stamens (the 4 upper ones) and carry away on their bodies that of the 3 lower long stamens. Apparently self-pollination may occur, but is unlikely, as the stigma is well above the stamens (see diagram).

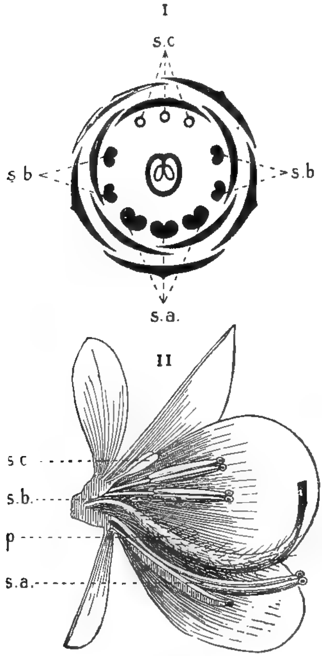



FIG. 97.—*Cassia arachoides.*

I. Diagram of flower. II. Vertical section of flower. *sa*, large stamens; *sb*, small stamens; *sc*, staminodes.

(3) *Papilionaceae.*—Flowers zygomorphic, corolla papilionaceous—stamens 10, monadelphous or diadelphous.

This division is the best known and most easily recognized of the order—it includes herbs, shrubs and trees and climbing plants. Well-known genera are Lathyrus (Sweet Pea, etc.), Pisum (Pea), Lupinus

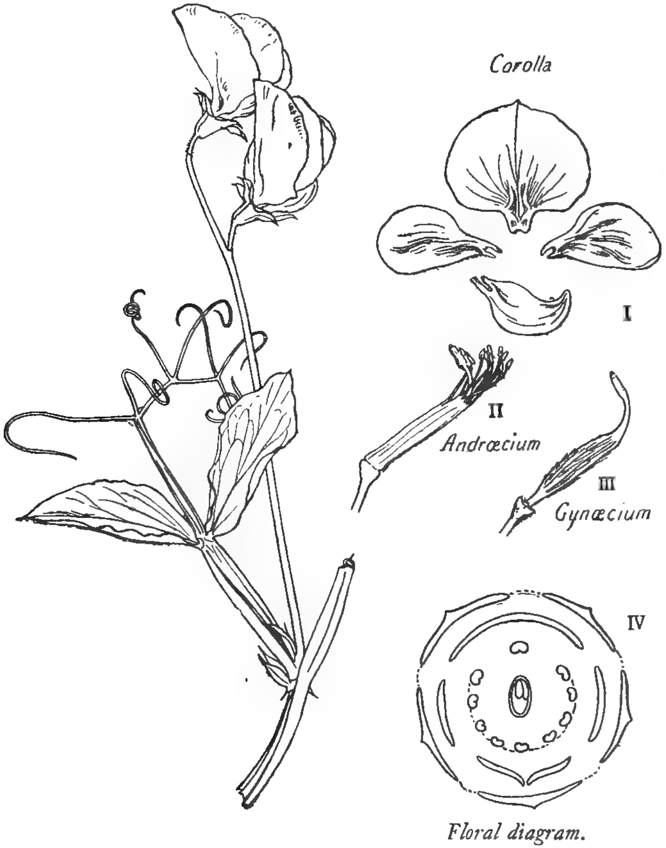



FIG. 98.—Sweet Pea.

(Lupin), Trifolium (Clover), Virgilia (Kerriboom), Crotalaria, Medicago (Lucerne), Indigofera, Sutherlandia and Erythrina (Kaffir-boom).

*Type.*—Lupinus (the Lupin). These are common herbaceous annuals, cultivated for their showy flowers.

*Inflorescence.*—A raceme.

*Flower.*—Zygomorphic, complete, bracteate, pedicellate.

*Calyx.*—Gamosepalous, 5, inferior.

*Corolla.*—Papilionaceous, polypetalous, 5, perigynous. The upper petal is the *Standard*, the two side ones are the *Wings* and the two lower are united to form the *Keel.*

*Androecium* monadelphous, 10 perigynous; *Filaments* united at base, free above, 4 being longer than the other 6; *Anthers* basifixed, 2 lobed, introrse. The anthers of the shorter stamens are larger than the others.

*Gynoecium.*—Monocarpellary, superior. Stigma terminal and small, style curved; ovary long and hairy, one-celled, ovules numerous, placentation marginal.

*Fruit.*—A legume which bursts open when ripe and jerks out the seeds, the 2 halves of the pericarp twisting spirally.

*Pollination.*—The stigma is only receptive when rubbed, so the flower has a good chance of cross-pollination. The pollen is shed into the keel. When insects visit the flower they cling on to the wings; this depresses the keel and the pollen is forced out of the little opening at the tip of the keel by means of the shorter stamens which have swollen filaments and act as a kind of piston. When the insect leaves, the keel springs back to its former position—thus four or five visits may be made to the same flower, and cross-pollination is practically certain.

Note that in many Papilionaceae the same result is brought about by the style having a brush of hairs to sweep out the pollen, e.g. Lathyrus. A few explode when an insect visits them and it is thus dusted with pollen, e.g. Medicago.

152. **N. O. Geraniaceae.** — *General Characters.* — Flowers polypetalous, hypogynous, pentamerous, usually regular; stamens 10, fruit a schizocarp.

*Type.*—Pelargonium (garden geranium).

*Inflorescence.*—A cyme.

*Flower.*—Zygomorphic, complete.

*Calyx.*—Polysepalous, 3 + 2, inferior. The posterior sepal forms a long spur which is adherent to the pedicel and contains honey.

*Corolla.*—Polypetalous, 2 + 3, hypogynous.

*Androecium.*—7 stamens, 3 staminodes, monadelphous, hypogynous, anthers basifixed, introrse. Filaments expanded at base.

*Gynoecium.*—Syncarpous 5, superior, stigma 5-fid. Styles fused round a prolongation of the axis called a carpophore; ovary 5 celled, with 1 or 2 ovules in each cell.

*Fruit.*—A schizocarp. The 5 carpels with their long persistent styles separate from the carpophore and roll up with some force, so that the seeds are shot out.

*Pollination.*—The flower is markedly protandrous and the corolla attracts insects who must touch the anthers before they can reach the honey in the long spur. Only long-tongued insects can reach it. If they then visit an older flower they will deposit this pollen on the stigmas.

*Other Genera.*—Geranium has regular flowers and 10 perfect stamens.

Monsonia has 15 stamens, and so has Sarcocaulon (the Candle-bush).

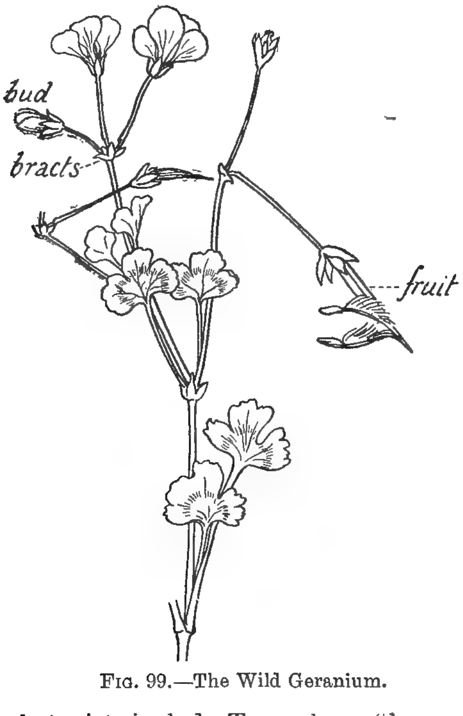



FIG. 99.—The Wild Geranium.

Many botanists include Tropeolum (the garden nasturtium) and Oxalis (the sorrel) in this order.

*Oxalis* has radical trifoliate leaves which in some species exhibit sleep movements. Several species have trimorphic flowers. There are 10 stamens, the filaments being slightly connate at the base. The stamens may be short, medium, or long, two kinds being found in one flower. The styles are free, and of three

Wild Geranium (Geraniaceae) and Oxalis (Oxalidaceae).

lengths corresponding to the stamens, i.e. if one flower has short and long stamens it will have styles of medium length, etc. (see diagram on page 113). Honey is found at the base of the tube formed by the filaments. An insect gets pollen on two parts of his proboscis, and when he enters another flower the pollen will be put on to the stigma of corresponding length. Self-pollination being almost impossible in this flower, reproduction occurs in two other ways. The plant produces cleistogamous flowers as well as the trimorphic ones; it also reproduces itself vegetatively. The fruit is a capsule, the seed has a fleshy aril, and by its sudden inversion it is shot out.

153. **N. O. Malvaceae.**—*General Characters.*—Herbs, shrubs or trees with stipulate leaves. Flowers pentamerous, frequently with an epicalyx. Corolla polypetalous, 5, twisted in bud. Stamens numerous, united into a tube which is joined to the petals. Gynoecium 1 to numerous, ovary many celled, axile placentation. Fruit a capsule or schizocarp.


FIG. 100.—Hibiscus.

*Type.*—Hibiscus.

*Plant.*—A shrub, much cultivated for its showy flowers.

*Leaves.*—Alternate, simple, stipulate, net-veined, serrate, smooth, dark green.

*Flower.*—Complete, regular, large and showy.

*Calyx.*—5, gamosepalous, inferior, cup-shaped with an epicalyx.

*Corolla.*—5, polypetalous, though the stamen tube makes the corolla appear gamopetalous, inferior, petals twisted in bud and crumpled when open.

*Androecium,* numerous, monadelphous, epipetalous; each filament bears only half an anther which is extrorse.

*Gynoecium.*—5, syncarpous, superior, stigmas 5-fid, style long, ovary 5 celled, placentation axile, ovules numerous.

*Fruit.*—A capsule.

*Pollination.*—Flowers protandrous, stigmas above stamens rendering self-pollination almost impossible. The flower is visited by humming-birds for the sake of the honey which is at the base of the stamen tube, and

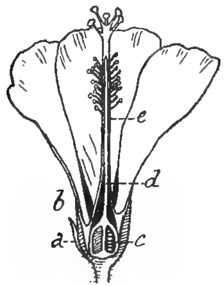



FIG. 101.

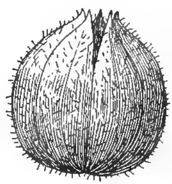


FIG. 102.

Fig. 101. Vertical Section of Hibiscus Flower.
*a.* Epicalyx. *b.* Calyx. *c.* Ovary. *d.* Style. *e.* Androecium.
Fig. 102. Capsule of *Hibiscus urens*.

thus cross-pollination may take place. The species *Rosa sinensis* very seldom sets seeds, but other species do, e.g. *H. sabdeniffa* (the Rozelle), which is cultivated for the sake of its fruits from which jelly is made, and *H. esculentus* (the Okra), the fruits of which when young and green are eaten as vegetables in many countries.

*Other Genera.*—Abutilon (the Japanese Lantern) is an ornamental shrub much cultivated for its pretty flowers. They have no epicalyx. Althea (Hollyhock), found in many gardens, has large showy flowers which tend to become "double" by the stamens turning to petals. Malva, the mallow, is occasionally cultivated in this country. All the above have a schizocarp for fruit.

Gossypium (the Cotton Plant) has an epicalyx of 3 parts only; the fruit is a capsule, the seeds being covered with hairs for wind dispersal; these hairs form the material known as cotton.

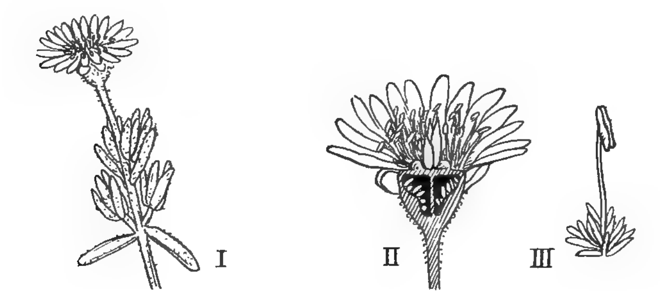



FIG. 103.—Mesembryanthemum.

I. Single flower. II. Vertical section. III. A stamen.

154. **N. O. Ficoideae or Aizoaceae.**—*General Characters.*—Plants are xerophytic herbs with opposite (occasionally alternate) fleshy, exstipulate leaves. Typical floral formula is P 5 or (5); A 5; G (3); ovary 3-celled with numerous ovules in each cell. Dedoublement is very common in the androecium, and in Mesembryanthemum, the outer stamens are represented by petaloid staminodes. The ovary is usually superior with axile placentation, but in Mesembryanthemum it is inferior, and multilocular, with parietal placentation. The fruit is a capsule.

Mesembryanthemum is the most important genus in the order, having over 300 species in South Africa. The succulent leaves are opposite and decussate, and closely packed together; the young leaves stand face to face at the apex and protect the young bud. The flowers are solitary or in dichasial cymes. The corolla is absent, but replaced by the numerous petaloid staminodes. The ovary is inferior, with from 5 to numerous cells, and axile placentae. The fruit, a capsule, only opens in moist air.

*Mesembryanthemum edule* is the Hottentot Fig, the fruit of which is a succulent capsule and edible. *Mesembryanthemum crystallinum*, the ice-plant, has its leaves covered with small glistening hairs, hence its name.

*Mesembryanthemum obcordellum* is a curious plant, the leaves being completely connate, forming a single flat body, and enclosing the flower bud. When ready to flower, the bud forces its way through a slit in the apex of this body, and opens above it, but the ovary remains within.

Some species, e.g. *Mesembryanthemum Hookerii*, and *Mesembryanthemum calcareum*, show protective mimicry, i.e. the leaves are coloured on the surface exactly like the soil on which they grow, so the plant is almost indistinguishable. Others have what is called "window leaves," i.e. the soft green portion of the leaves is underground, the apex only being above the soil; this exposed part is colourless, and protected by a thick epidermis or cuticle; it serves as a window through which light reaches the green part below.

*Pollination.*—The flowers are brightly coloured from pure white to deep red, purple, or yellow and are very brilliant. They seem to be visited by insects for the sake of the pollen and hence cross-pollinated, but self-pollination can easily occur.

*Other Genera.*—Galenia (Kraalbush) is common on the Karoo. Tetragonia is very like the ice-plant, having leaves which glisten in the sun. Aizoon has red flowers and is found in the Cape.

*Vegetative Reproduction.*—Many species of Mesembryanthemum are readily reproduced from slips.

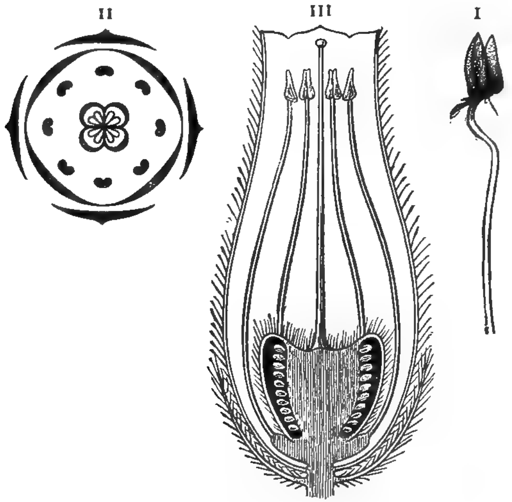



FIG. 104.—*Erica cerinthoides.*

I. Anther. II. Floral Diagram. III. Longitudinal Section of Flower.

155. N. O. **Ericaceae.**—*General Characters.*—Plants, shrubs, or trees. Leaves simple, usually narrow. Flowers regular. Calyx 4-5 partite, persistent. Corolla 4-5 petals, gamopetalous. Stamens usually twice as many as petals, dehiscing by terminal pores. Pollen grains in tetrads. Gynoecium 4-5 carpels, syncarpous, superior. Below the gynoecium is a fleshy disc secreting honey.

*Type.*—Erica (the Heaths).

*Plant*, small shrub.—*Stem*, woody. *Leaves*, exstipulate, evergreen, small, rolled, in whorls. *Inflorescence*, raceme. *Flower*, bracteate, hermaphrodite, regular, hypogynous, complete. *Calyx*, gamosepalous, 4-partite, persistent. *Corolla*, gamopetalous, 4-lobed, globular. *Androecium*, 8 stamens, free, hypogynous. Anthers have horn-like appendages and open by terminal pores. Pollen in tetrads and powdery. *Gynoecium*, syncarpous, 4 carpels. *Ovary*, 4-celled, each cell containing two or more anatropous ovules. *Fruit*, a capsule.

*Pollination.*—Chiefly by bees. A gland below the ovaries secretes honey. When bees visit the flower they touch the hanging stigma first, since it is longer than the stamens, and then the stamens.

*Other Genera.*—Macnabia has the calyx longer than the corolla, a hooked style and white flowers. Eremia has small bell-shaped flowers in terminal umbels; there is one seed only in each cell. Blaeria and Grisebachia have 4 stamens, otherwise they resemble Erica (fig. 104).

156. **N. O. Labiatae.**—*General Characters.*—Leaves, decussate, simple, exstipulate, often hairy Stem, square. Inflorescence, a verticillaster. Flowers, zygomorphic. Calyx, hypogynous, tubular, 5; corolla 2-lipped, upper lip of 2, lower of 3 petals. Stamens, 4 didynamous, or 2 epipetalous. Gynoecium of 2 carpels which form a superior 4-celled ovary, each cell containing 1 ovule. Fruit of 4 nutlets.

*Type.*—*Leonotis* (fig. 105).

*Plant.*—A herb from 2 to 3 feet high.

*Flower.*—Zygomorphic, orange-coloured, complete, 1½ inches long.

*Calyx.*—Gamosepalous, 5, inferior, hairy.

*Corolla.*—Bilabiate, gamopetalous, 5 hypogynous, tube long and narrow.

*Androecium.*—4, didynamous, epipetalous. Anthers dorsifixed, introrse.

*Gynoecium.*—2, syncarpous, superior, stigma 2-fid, style long, ovary 4 celled, placentation axile, 1 ovule in each cell.

*Fruit.*—4 nutlets.

*Pollination.*—There is honey on a disc round the ovary which can only be reached by long-tongued insects owing to the length of the corolla tube. The stigma projects beyond the anthers and is therefore touched first by visiting insects; the 2-lipped corolla with the stamens closely pressed against the upper lip ensures that the insect will touch them on its way to the honey.

*Other Genera.*—Salvia, a large genus of 500 species, many of which are extensively cultivated for their ornamental flowers, has a curious lever-mechanism for pollination (see Chapter VI). One species is the herb known as Sage. Thymus (Thyme), Mentha (Mint, Peppermint), Origanum (Marjoram) are all well-known herbs used for flavouring, etc. Lavandula (the Lavender), Rosmarinus (Rosemary), and Pogostemon (Patchouly) all yield oils used in perfumery.

157. **N. O. Solanaceae.**—*General Characters.*—Plants, herbs and shrubs, some climbers. Flowers solitary or in cymes, usually regular. Calyx 5, persistent. Corolla

5, gamopetalous. Androecium 5, epipetalous. Gynoecium 2, syncarpous, superior. The ovary is placed

I

Fig. 105.—*Leonotis Leonurus.*
I. Flowering branch.

obliquely in the flower, but this is difficult to see. Fruit, a berry or a capsule.

*Type.—Solanum sodomaeum* (Bitter Apple) (fig. 106).

*Plant.*—Herb or small shrub with thorny leaves and stem.

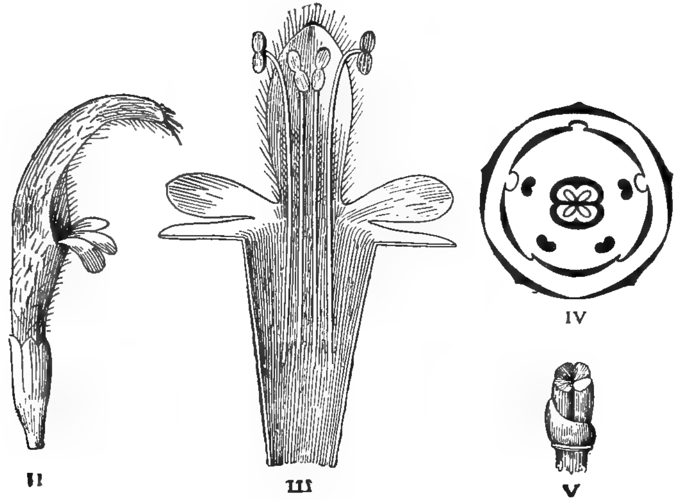



Fig. 105*a*.—*Leonotis Leonurus.*

II. Flower. III. Corolla opened. IV. Diagram of Flower. V. Fruit. (All nat. size.)

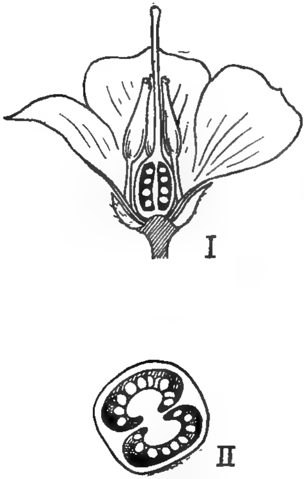



Fig. 106.—Solanum.

I. Vertical Section of Flower of *Solanum sodomaeum.* II. Transverse Section of Ovary of Solanum.

*Inflorescence.*—Solitary or cymose.

*Flower.*—Actinomorphic, complete.

*Calyx.*—5, gamosepalous, inferior, green and thorny.

*Corolla.*—5, gamopetalous, hypogynous, purple.

*Androecium.*—5, free, epipetalous, filaments short, anthers very large, dehiscing by pores.

*Gynoecium.*—2, syncarpous, superior, stigma 2-fid, style long, ovary 2-celled, placentation axile, placentas dumb-bell shaped, ovules numerous.

*Fruit.*—A berry, large and yellow.

*Other Genera and Species.*—*Solanum tuberosum*, is the potato; *Solanum melongena*, the egg plant; and *S. lycopersicum*, the tomato. The well-known Potato Creeper is also a species of Solanum.

Lycium is the Kaffir thorn, often used for hedges. Physalis is the Cape Gooseberry. Capsicum is cultivated for its fruits called chillies or red peppers; it is found wild in Canada and South America. Datura (Stink blaar or Thorn apple) is a very common weed in the Transvaal, with a 4-celled ovary and a 4-celled thorny capsule for fruit. Nicotiana is the Tobacco plant. Petunia, Salpiglossis, and Schizanthus are all cultivated in this country for their flowers.

This order is fairly easily distinguished from all except Scrophulariaceae; the essential difference being the oblique position of the ovary. This, however, is not easily made out and the regularity of the flower with its 5 stamens is the most usual distinction.

158. **N. O. Scrophulariaceae.**—*General Characters.*—Mostly herbs and small shrubs, a few trees and climbing plants; many are parasites. Flowers, gamopetalous,

hypogynous, zygomorphic; stamens, 4, didynamous, or sometimes 2, rarely 5, epipetalous; gynoecium, 2, ovary 2-celled, axile placentation, fruit, a capsule.

*Type.*—Antirrhinum (Snapdragon) (fig. 107).

*Plant.*—Perennial herb.

*Stem.*—Erect, herbaceous, sometimes woody at base, round, solid.

*Leaves.*—Simple, cauline, alternate, petiolate, exstipulate, lanceolate, entire, net-veined.

*Inflorescence.*—A raceme, one bract to each flower.

*Flower.*—Complete, zygomorphic.

*Calyx.*—Gamosepalous, 5, inferior, persistent.

*Corolla.*—Gamopetalous, personate, 5, inferior, brightly coloured.

*Androecium.*—4 didynamous, epipetalous, anthers 2-lobed, introrse.

*Gynoecium.*—Syncarpous 2, stigma slightly 2-fid, style long, ovary superior, 2-celled, ovules numerous and borne on large axile, dumb-bell shaped placentas.

*Fruit.*—Capsule, dehiscing by 3 pores.

*Pollination.*—This flower is adapted for pollination by bumble-bees, but self-pollination may occur. The insect rests on the lower lip of the corolla and in pushing its head in for honey, which is at the base of the ovary, touches first the stigma and then the stamens. Some bees go right into the Snapdragon flower to get out the honey, and others bite through the base of the corolla, thus obtaining honey without pollinating the flower.

*Other Genera.*—Digitalis (the Foxglove) is extensively cultivated here for its flowers, it is wild in Great

Britain. Several species of Linaria occur in South Africa. Pentstemon is cultivated for its flowers and has a staminode in place of the fifth stamen. Veronica has 2 stamens only and 4 petals. Nemesia has a spurred corolla and the upper lip is 4-cleft.—It is peculiar to South Africa but is much cultivated in England. Halleria has a nearly regular corolla (*H. lucida* is the

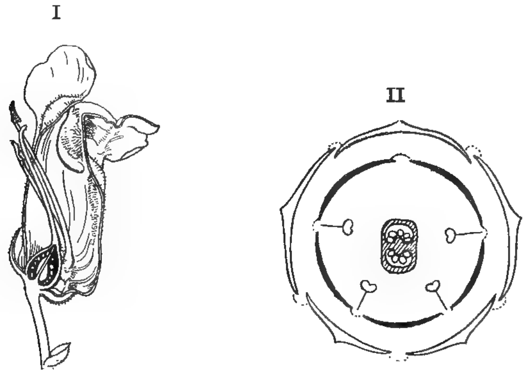



FIG. 107.—Antirrhinum (Snapdragon).

I. Vertical Section of Flower. II. Floral Diagram.

White Olive). Harveya is a parasite with very showy flowers. Striga is a partial parasite.

159. **N. O. Compositae.**—This is the largest order of flowering plants comprising over 11,000 species, more than 10 per cent of the total number of species of Phanerogams. The characters of the Order are so well marked that it is the easiest of any to recognize; on the other hand the determination of the genera is a matter of great difficulty.

The *plants* are herbs, shrubs, or trees and have every variety of vegetative habit.

Sonchus or Sow-Thistle (Compositae)
and Iris (Iridaceaë).

The *inflorescence* is a capitulum, but often the capitula are again grouped in racemes, corymbs, etc. Each capitulum is surrounded by an involucre of bracts. Sometimes the florets are all alike and perfect, they may be all tubular or all ligulate, more commonly, however, there is a distinction into a "*disc*" of regular florets and a "*ray*" of zygomorphic florets. The flower may be perfect or imperfect. The *Calyx* is usually a pappus of hairs, sometimes it is absent or represented by small teeth. The *Corolla* is gamopetalous, of 5 petals, ligulate or tubular, epigynous. *Androecium*, stamens 5, epipetalous. Anthers introrse, syngenesious. *Gynoecium*, syncarpous of 2 carpels. Ovary inferior, 1-celled, containing 1 erect basal ovule. *Fruit* an achene, often crowned with a pappus.

*The Pollination Mechanism* in this order has already been considered (Chap. VI). It is singularly effective, since if cross-pollination fails, self-pollination can always take place, and even those flowers, such as Senecio and Sonchus, which get few insect visitors, can always set seed and still get an occasional chance of cross-pollination.

*The Dispersal of Seeds.*—In most cases the fruit is surmounted by a pappus of hairs which enables it to be blown away by the wind, but occasionally the calyx is hooked and causes the fruit to adhere to animals—e.g. Bidens (Black Jack). In Arctium the bracts are hooked and so the whole head of fruit is carried away. In Xanthium the involucre becomes hard and woody and covered with hooks which enable it to cling to the wool of animals; it has proved so troublesome a weed in this country, quite spoiling the wool of sheep, that it has been found necessary to impose a heavy fine on any farmer who allows it to grow on his land.

This order is generally considered the most highly developed of all, as it is certainly the most successful. Some of the reasons for its success are:—

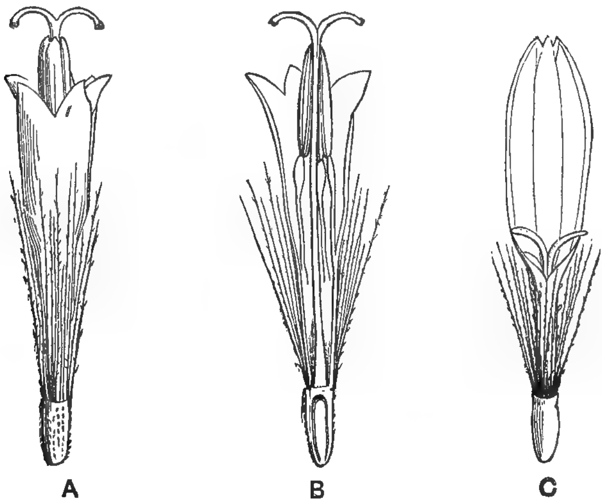



Fig. 108.

A. Tubular floret of a Senecio. B. The same, divided longitudinally. C. Ligulate floret of same.

(1) The massing of the flowers in heads which secures greater conspicuousness and a saving of material in corollas, etc. Also one insect can fertilize many flowers in a short time without having to fly from one to the other.

(2) The very effective pollination arrangements, honey

and pollen being protected, and self-pollination being always possible.

(3) The excellent mechanisms for seed dispersal.

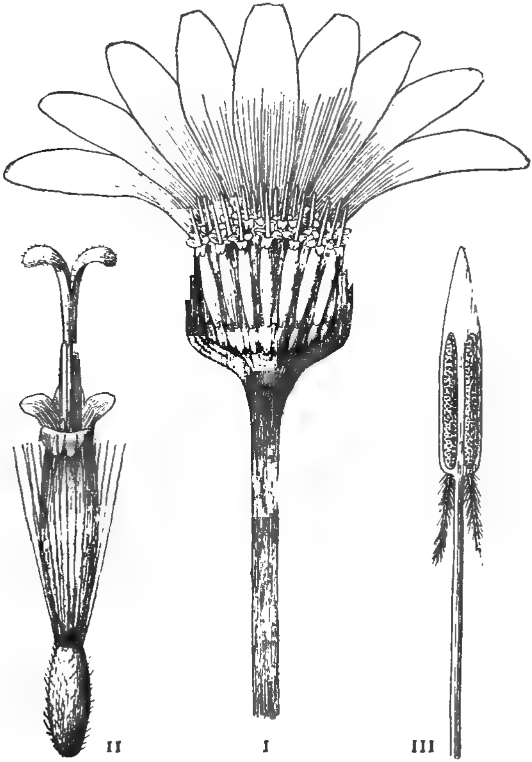



Fig. 109.—*Gerbera asplenifolia.*

I. Section through Capitulum. II. Disc-flower. III. Stamen.

*Chief Genera.*—These are grouped as follows:—

(1) Tubuliflorae.—Some or all florets tubular.

(2) Liguliflorae.—All florets ligulate.

To the Tubuliflorae belong Vernonia, Bellis (the

Daisy), Aster, Helichrysum, Xanthium, Zinnia, Helianthus (Sunflower), Dahlia, Bidens (Black Jack), Chrysanthemum, Senecio (fig. 108), Calendula (Marigold), Centaurea (Cornflower), Gerbera (fig. 109), and many others.

The Liguliflorae are not so numerous, the best known are Sonchus (the Sow-thistle) and Chicorium (Chicory).

160. **N. O. Liliaceae.**—Mostly herbs; a few shrubs or trees are found. The flowers are regular—Perianth 3 + 3, hypogynous, androecium 3 + 3, gynoecium 3, syncarpous superior. Fruit a capsule, or a berry.

*Type.—Aloe.*—Shrubby succulent plants, with thick fleshy leaves arranged in dense rosettes.

*Inflorescence.*—A raceme.

*Flower.*—Regular, complete, bracteate.

*Perianth.*—Gamophyllous, 3 outer and 3 inner petals, pointed at top, flame coloured, hypogynous, honey at the base of the perianth tube.

*Androecium.*—3 + 3 stamens, free, hypogynous; anthers dorsifixed, introrse, 2 lobed, filaments long and white.

*Gynoecium.*—3 carpels—syncarpous, superior, style long, stigma terminal, ovary 3-celled, ovules numerous, axile placentation.

*Fruit.*—A capsule.

*Other Genera Belonging to the Order.*

*Asparagus.*—Some species are thorny shrubs (Wacht een bietje), others, climbing plants. The leaves are reduced to scales or thorns, the stems becoming leaf-like (Cladodes). One species, often called *Smilax*, is much used for table decorations. The real Smilax is another

Ornithogalum (Liliaceae) and Richardia Africana (Aroideae).

genus with dioecious flowers, also belonging to this order.

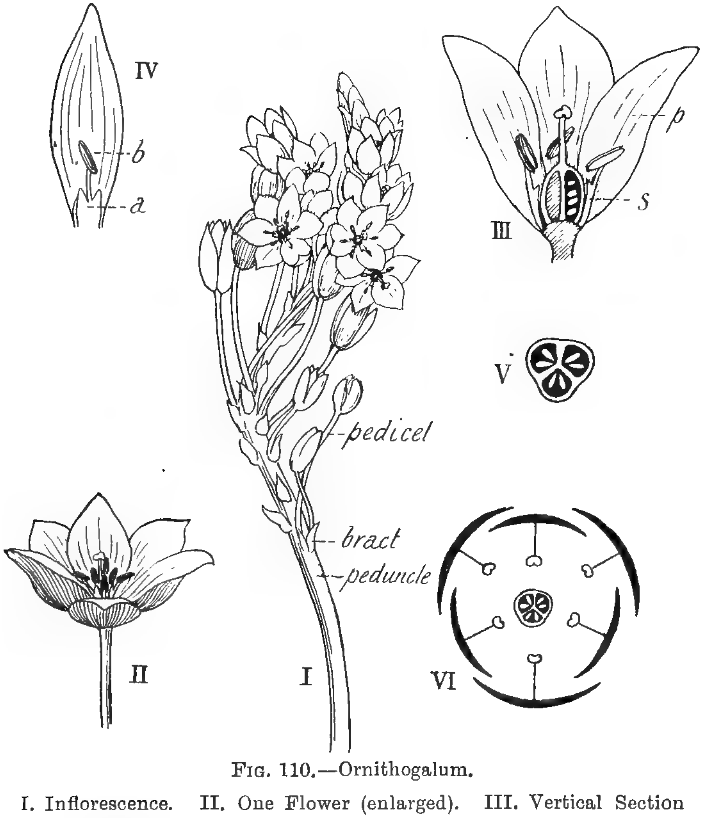



FIG. 110.—Ornithogalum.

I. Inflorescence. II. One Flower (enlarged). III. Vertical Section (*p.* = petal, *s.* = stamen). IV. One Petal with Stamen (*a.* = filament with nectary, *b.* = anther). V. Ovary cut transversely. VI. Floral Diagram.

*Agapanthus.*—This has large umbels of blue or white flowers, and is found wild in Cape Colony and in gardens in the Transvaal.

Other genera are *Ornithogalum* (Chinkering Chee) *Allium* (Onion), Yucca, Bulbine, Eucomis, Gloriosa, Lilium, Tulipa, Dracaena.

Economically this order is of no great importance; the bulb of the onion and young shoots of asparagus are used for food, but many of the plants have very beautiful flowers and are extensively cultivated.

161. **N. O. Amaryllidaceae.**

*General Characteristics*—Plants are herbs. Flowers regular, perianth 3 + 3, androecium 3 + 3, ovary inferior 3-celled. Fruit a capsule, or a berry.

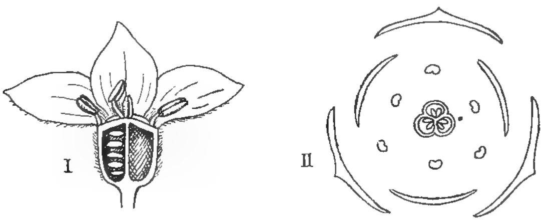



FIG. 111.—Hypoxis.

I. Vertical Section of Flower. II. Floral Diagram.

*Type.*—Hypoxis (fig. 111).

*Inflorescence.*—Flower regular complete. Perianth polyphyllous, 3 + 3 superior; outer segments green on under side, white or yellow upper side.

*Androecium.*—Free 3 + 3 superior, anthers long, basifixed, 2 lobed, introrse. Filaments short.

*Gynoecium.*—Syncarpous, 3, inferior, style very short or absent, stigma large, 3-fid. Ovary 3-celled, axile placentation, numerous ovules.

*Fruit.*—A capsule which dehisces by splitting across.

*Pollination.*—Self- and Cross-pollination. Insects are attracted by the colour; honey is secreted by a sort of disc at the top of the ovary.

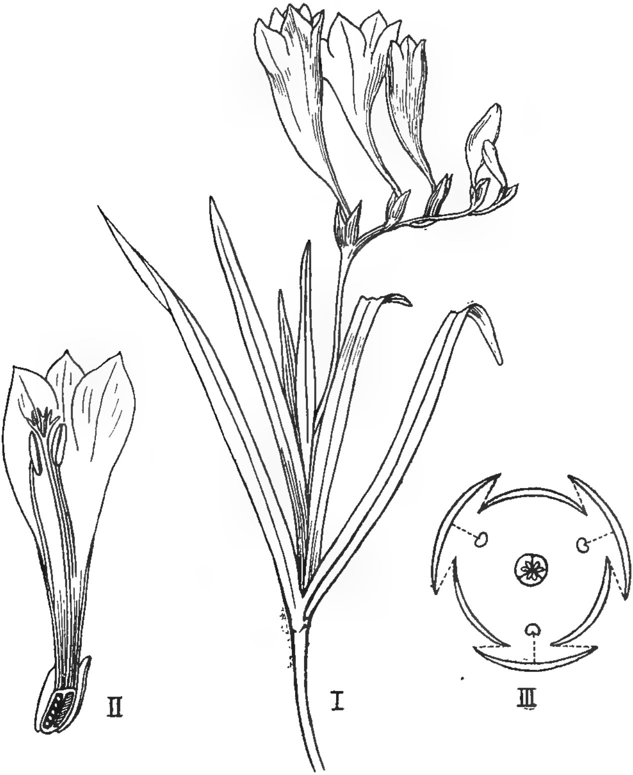



Fig. 112.—Freesia.

I. Flowering Stem. II. Vertical Section. III. Floral Diagram.

*Other Genera.*—Amaryllis (the Belladonna Lily), Haemanthus, Gethyllis (Kukumakranka), Galanthus, (the Snowdrop) Narcissus (Daffodil and Jonquil)

The last two genera are not native to South Africa, but are extensively cultivated.

162. **N. O. Iridaceae.**

*General Characteristics.*—Plants are perennial herbs, with Corms or Rhizomes. Leaves usually equitant, flowers regular or zygomorphic, perianth superior 3 + 3, stamens 3, ovary inferior, 3-celled, fruit a loculicidal capsule.

This order is widely distributed in South Africa.

*Type.*—Freesia (fig. 112).

*Plant.*—Perennial herb.

*Leaves.*—Radical, simple, linear, parallel veined, entire, smooth, green.

*Inflorescence.*—A cyme with two green bracts to each flower.

*Flower.*—Actinomorphic, complete.

*Perianth.*—3 + 3 gamophyllous, superior. The perianth forms a tube spreading at the top.

*Androecium.*—3, epiphyllous, free. Filaments long, anthers dorsifixed and extrorse.

*Gynoecium.*—3 syncarpous, inferior, style long, branching into 6 parts to form the stigma. Ovary 3-celled, placentation axile, ovules numerous. Fruit a capsule.

*Other Genera.*—*Gladiolus* (fig. 113) has many different species and is found all over South Africa. It has an irregular perianth. *Moraea* has no perianth tube and has large petaloid stigmas. *Homeria* (Tulp) is a poisonous weed with very pretty flowers. Romulea, Aristea, Ixia, Watsonia and many other genera are found in the Colony, some in other parts of South Africa. The *Iris*,

Gladiolus and Freesia (Iridaceae).

which gives its name to the order, is extensively cultivated in South Africa though a native of Europe. It


FIG. 113.—Gladiolus.

I. One Flower. II. Vertical Section through Flower.

has a very interesting arrangement for cross pollination (see chap. VI.).

## QUESTIONS ON CHAPTER X.

1. Give an account of the principal characteristics of the leaf, flower, and fruit in either a Mesembryanthemum, or an Acacia, or a Brassica, and draw either the floral diagram, or a longitudinal section through the flower of the one you select.

2. Show by means of a floral diagram of each how you would distinguish a Crassula from a Cotyledon (or Kalanchoe) By what characters would you recognize these two genera as belonging to the order Crassulaceæ?

3. Choose three of the following genera:—

Helianthus ;
Senecio ;
Sonchus ;
Osteospermum.

and tell how they differ or agree in the arrangement of the different kinds of florets (tubular and ligulate, perfect and incomplete, fertile and sterile) on the head, and in their fruit.

What characteristics of the perfect floret are common to all three?

4. Briefly describe:—

(*a*) the type of fruit;

(*b*) The method of securing cross-pollination, found in any three of the following genera or of other members of the same orders:—

(1) Hibiscus;
(2) Pelargonium;
(3) Leucadendron;
(4) Datura;
(5) Disa;
(6) Gladiolus;
(7) Asparagus;
(8) Haemanthus;
(9) Helianthus.

5. Describe the structure of a typical stamen. Mention the chief features of the androecium in each of the following plants:—

Helianthus;
Pisum;
Salvia, or Erica;
Brassica;
Rosa or Protea;
Gladiolus.

6. Give as full an account as you can of the following South African plants, and of the Natural Orders to which each belongs.

Make a floral diagram in each case, state whether they are insect or wind-pollinated, and describe how their seeds are distributed:—

Asparagus;
Gladiolus;
Senecio;
Erica, or Salvia.

7. Give an account of three of the following genera as illustrating the orders to which they belong:—

Arthrosolen (or Struthiola);
Either Erica or Salvia;
Either Solanum or Disa;
Either Leucospermum or Pirus;
Mesembryanthemum.

8. Give an outline of the scheme of classification of flowering plants you have used, and show clearly the principles, on which this method of grouping the orders is based.

9. Give an account of the carpels found in the following genera, paying special attention to

(*a*) Their number;
(*b*) Their position with regard to the other floral members;
(*c*) Whether the ovary is superior or inferior:—

Aloe;
Gladiolus;
Protea, or Rosa;
Erica, or Salvia;
Crassula;
Senecio;
Crotalaria.

10. Give the most important characters of four South African plants belonging to different Natural Orders which you have seen growing from the following:—

Liliaceae;
Iridaceae;
Proteaceae;
Rosaceae;
Ericaceae;
Compositae;
Crassulaceae;
Leguminosae.

Give the names of the genera to which they belong and localities in which you found them. State by what means their flowers are pollinated. How are their seeds distributed? Mention any other facts of interest concerning them.

11. Describe the principal characters of the following:—

(*a*) The inflorescence of Brassica. Give a diagrammatic sketch.

(*b*) The leaf of Oxalis. State what you know of its sleep movements.

(*c*) The gynoecium of Pisum. Sketch the whole gynoecium from the side and the ovary in cross section.

(*d*) The androecium of Hibiscus. Sketch it as seen when the flower is cut in longitudinal section.

(*e*) Leaf of Acacia. Sketch it.

(*f*) Gynoecium of Cotyledon (or of Kalanchoe).

Sketch a single carpel from the side and its ovary in cross section.

(*g*) The corolla of Sonchus. Make sketches.

12. Write an account of the floral structure and methods of pollination met with in N. O. Labiatae.

13. Point out the variations in structure and position of the ovary in the various genera of Rosaceae, and show why they are all assigned to the same order.

14. Name two genera belonging to the order Leguminosae, and explain how, given a plant belonging to one of them, you would

(*a*) recognize it as belonging to this order;

(*b*) find out in which of the two genera it should be placed.

15. Name a genus belonging to either Ericaceae or Solanaceae. Select a plant belonging to the genus and describe its general habit, leaf, and fruit. Draw floral diagams in ground plan and vertical section to show structure of flower.

16. Note any points of interest in the following flowers: Salvia, Sunflower, Oxalis, Gorse, Cornflower, Daffodil.

17. Arrange the following natural orders under their classes and sub-classes: Liliaceae, Proteaceae, Compositae, Crassulaceae, Malvaceae. Give in a few words the reasons for assigning them to their places.

18. What are the principal characters of the N. O. Geraniaceae? Mention the more important S. African genera.

19. Give an account of the more important characters of the N. O.'s Iridaceae, and Liliaceae, and state what you consider to be the principal differences between them.

20. Give an account of the gynoecium in Crassulaceae, Cruciferae, Compositae, Leguminosae, Malvaceae, and state what kinds of fruits are found in these orders.

21. Describe the principal characters of (*a*) the stem, (*b*) the leaves, (*c*) the flower, (*d*) the fruit, of any plant belonging to the N. O. Amaryllidaceae. Name the plant which you describe.

22. In a system of classification what significance is attached to (*a*) the modification of the vegetative characters and (*b*) the cohesion, adhesion, and reduction of the floral parts?

23. Mention five general characters by means of which you could distinguish a monocotyledonous from a dicotyledonous plant.

24. What are the general characters of the Rosaceae? Mention any noteworthy differences exhibited in the floral structure of this order.

# APPENDIX I.

*Herbaria.*—A herbarium is a collection of pressed and dried plants, usually arranged in their various natural orders. Before such a collection can be made some or all of the following must be obtained:—

1. *Portfolios*, for pressing plants as collected; made of two strong pasteboards with encircling straps and handle, and containing sheets of paper.

2. A *collecting* tin or vasculum for bringing plants home; also several small tins for little plants.

3. *Presses* for drying plants made of iron frames filled in with wire netting. The papers lie between the frames, which are provided with strong straps or frames to obtain the necessary pressure. If these presses are unobtainable, heavy books can be used instead.

4. *Drying paper.*—Stout manila paper is best, but blotting paper can be used.

5. *Mounting paper* in large sheets $16\frac{1}{2} \times 10\frac{1}{2}$ inches.

6. *Mercuric Chloride* for poisoning, and *Naphthalin* for keeping away insects.

7. *Alcohol* for preserving specimens for subsequent microscopic examination.

*Collecting.*—The first step in making a herbarium is of course to collect the specimens. This must be done in fine weather; specimens collected in wet weather will seldom dry satisfactorily and are always apt to be attacked by mould.

In this country it is advisable to take a portfolio filled with drying paper when starting on an expedition for collecting plants for the herbarium, and to press the plants as soon as obtained, as so many of the veldt flowers fade very quickly. Some can, however, be brought home in the vasculum, and this should be done whenever possible. If possible the entire plant should be taken, including the root, fruit, and seed. In the case of trees and shrubs collect twigs in various stages, i.e. with buds, leaves, flowers, fruits, and also take a piece of bark.

Each specimen should be numbered when placed in the portfolio or vasculum, and a note should be made of its appearance, method of growth, etc.

Large flower heads such as thistles may be sliced in half before pressing. Conifers and Heaths should be immersed in boiling water before drying, or their leaves will fall off when dried.

Delicate water plants must be arranged on sheets of white paper under water, and must always remain on these sheets while drying.

*Drying.*—The specimens must be spread out on the sheet as naturally as possible. The flowers should be spread out, and where possible a vertical section should be cut and pressed. In the case of composites some florets should be pressed separately as well as the capitulum. The sheets must be piled up without lumps in the middle, and then pressed. The drying papers should be changed frequently. When the plant is thoroughly dry it should be poisoned by immersion in a solution of mercuric chloride in alcohol.

*Mounting.*—When the specimen is thoroughly dried it must be mounted on a sheet of paper, and fastened with little strips of gummed paper. The sheet must then be labelled, the label should give the name of the specimen, its natural order, place and date of collection, and any other feature of interest.

*Preservation in Alcohol.*—Instead of pressing and drying plants, they may be preserved in alcohol or formalin. They should be soaked in methylated spirit for a few days, and then transferred to a fresh bottle of pure alcohol. If this is tightly corked they will keep for a practically unlimited time. Each bottle must of course be labelled.

## MISCELLANEOUS QUESTIONS.

1. Very briefly state how you would prepare a specimen of a flowering plant for your herbarium from the time of collecting in the field to the time of mounting it.

2. Give a brief account of the methods by which plants can reproduce themselves.

3. Describe carefully, giving an example in each case: (*a*) a caryopsis, (*b*) a tap root, (*c*) an apocarpous ovary, (*d*) a phylloclade, (*e*) a compound leaf, (*f*) a siliqua, (*g*) monadelphous stamens, (*h*) syngenesious anthers, (*i*) acrescent calyx, (*j*) a gamopetalous corolla, (*k*) an achene, (*l*) a capsule.

4. Describe carefully and give examples of: (*a*) a runner, (*b*) a spathe, (*c*) a gynandrous stamen, (*d*) a dioecious plant, (*e*) a spine, (*f*) a fibrous root, (*g*) an involucre.

5. What structural peculiarities are found in flowering plants which grow (*a*) in fresh water, (*b*) in very dry situations? Show with regard to one of these classes of plants the advantage of the peculiarities mentioned.

6. What do you understand by the following terms: Annual ring, dichasium, endodermis, parasite, parenchyma, rhizome, stoma?

7. Describe and give examples of: (*a*) endorhizal root growth, (*b*) a capitulum, (*c*) a papilionaceous corolla, (*d*) free central placentation, (*e*) a reniform leaf.

# APPENDIX TO CHAPTER II.

*Turgor of the Cell.*—The cytoplasm is a semi-permeable membrane; that is, it exercises control over the passage of the cell-sap, containing salts in solution, outwards, though it allows the passage of water inwards. As a consequence the cell continues to absorb water until the cell-wall is tightly stretched. A cell in this condition is said to be turgid or in a state of turgor. If such a living turgid cell is treated with a 10 per cent. salt solution, it will be found that the following changes occur. The cell first decreases in size. The cytoplasm contracts away from the cell-wall and rounds itself off into a spherical or oval mass in the middle of the cell. This phenomenon is known as plasmolysis.

The crispness and firmness of herbaceous plants depend on the turgidity of the cells. So long as the cells are turgid, so long will the tissues be firm. But if there is a deficiency in the water supply, so that the cells are no longer turgid, then the tissues become limp and the plant fades. A renewal of the water supply will make the cells turgid again, unless they are dead. It is to be noted that this control over the cell-sap is essentially a property of living protoplasm; when the cells are killed, the control is lost, and the sap will diffuse out of the cells.

*Experimental Work.*—To observe plasmolysis, scrape some hairs off the stem of a cucumber, or some other hairy plant, mount them in water on a slide, and examine under the high power of a microscope. Make out the granular cytoplasm, the nucleus, and the vacuole filled with cell-sap. Irrigate with a 10 per cent. salt solution and watch the cells. (The irrigation is best done by putting a few drops of salt solution on one side of the cover slip and a piece of blotting-paper on the other. The blotting-paper sucks the solution through.) After the cells have been plasmolysed, they can be irrigated with fresh water until they are turgid again. For comparison cut some thin sections of fresh beetroot and treat them in the same way.

Cut some slices of beetroot (fresh and unboiled), measuring about 2 inches by 1 inch by 1 inch. Immerse some of these in a beaker of fresh water, and others in a 10 per cent. salt solution. After a few hours take out both sets of slices. Note that those in the fresh water are hard and stiff, whereas those in the salt water are limp and flaccid. If these latter are transferred to fresh water they will soon become firm again.

Take a small test tube, fill it with a 10 per cent. salt solution and tie a piece of bladder tightly over the top. Now immerse the tube in fresh water and leave for an hour or more. Note that the bladder is now swollen out; that is we have made an imitation of a turgid cell. If this imitation cell is now immersed in a 20 per cent. salt solution it will be seen that the bladder becomes concave instead of convex, i.e. the cell is no longer turgid.



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# APPENDIX II.

*The Potometer.*—This apparatus enables us to calculate the rate of transpiration by observing the rate of absorption by a cut shoot. The special glass tube required can be obtained from any maker of botanical apparatus. It consists of a bent tube communicating with a straight tube, open at both ends. A branch with green leaves is cut under water, then attached to the bent tube by rubber tubing. The branch must be of the same diameter as the tube, and the connection must be made under water. Still keeping the apparatus under water, the straight tube is closed at the upper end by a cork, and at the lower end by another cork, through which a length of thermometer tubing has been passed. The length of the thermometer tubing should be about 18 inches. As all this has been done under water, all the tubes will be full of water, and if the apparatus is airtight they will remain full when it is lifted out. If any water runs out the fastenings are not airtight and the experiment must be begun again. When the apparatus is taken out of the water, the potometer tube with the branch is clamped to a retort stand, so that the branch stands upright. The thermometer tube should be made to dip into a beaker of water.

The rate of absorption will be measured by the rate at which water ascends the tube. To see this the tube is lifted out of the beaker of water, and a piece of blotting-paper is placed at the open end. This draws out a little water and therefore causes a bubble of air to go in. The tube is then put back into the beaker, and the rate at which this air bubble ascends the tube is measured.

If the apparatus is placed first in the sunshine and then in the shade, the effect of sunlight on the rate of transpiration can be observed.

# INDEX OF TERMS.

# INDEX OF PLANTS.

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