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PRACTICAL BOTANY

BY

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PRACTICAL BOTANY.

SECTION I.—MORPHOLOGY

GENERAL STUDY OF THE PARTS OF PLANTS.

Secure a number of annuals. Remove them carefully from the ground without much injury to their roots.

1. Examine each of these plants and note that every one of them consists of the two main portions—

(*a*) the aerial or the above ground part or **the shoot.**

(*b*) and the portion buried in the soil or **the root.**

2. **The shoot**—Observe that in all these plants the shoot is green, that it consists of several branches (except in seedlings) and these consist of a stem or axis bearing the leaves in every case, and in some flowers and fruits in addition. In a full plant note if any portion of the main stem is below ground. Observe the thickness and strength of the main stem.

3. Select a branch from every one of the plants gathered and observe that—

(*a*) the axis or stem bears the leaves either singly, in pairs, or in groups of three or more at the same place

The part of the stem which bears the leaf is termed a **node,** and the part of the stem lying between any two successive nodes is called an **internode.**

(*b*) The internodes and the leaves get smaller and smaller towards the free end of the branch indicating that they arise in acropetal succession.

(*c*) Every branch terminates in a bud which is merely a number of very young leaves in the course of development closely packed.

(*d*) Branches arise in the angles formed by the leaf with the stem, i.e., the **axil**; these branches develop from small lateral vegetative buds situated in the axils of leaves.

4. **The leaf.**—Observe the leaves of all the plants chosen and note—

(*a*) **Parts of the leaf.**

(1) The parts of the leaf, namely, the base, the stalk and the blade.

(2) The form and shape of the blade, the margin and surface also.

(3) The colour of the leaf on both the sides.

(4) The venation of the leaf **parallel or reticulate**, and the general nature of the frame work of the leaf. The frame work of veins is well seen in the "skeleton leaves" of *Ficus religiosa*.

(*b*) **Arrangement of leaves on the stem.**

(1) The leaves are borne by the axes in a definite order and they spring on the axis from the nodes.

(2) They are so arranged on adjacent nodes that a leaf at one node does not stand immediately above the leaf at the node just below it. The advantage of this mode of arrangement is evident.

(3) **Whorled or cyclic.**—In the whorled or cyclic arrangement of leaves two or more leaves are at each node and these leaves alternate with the leaves of adjacent nodes.

(4) If two leaves occur at a node, as in *Morinda tinctoria*, the leaves of a stem form four vertical rows along the stem; if three leaves are borne by the stem, as in *Nerium*, the number of rows will be six.

(5) Each leaf in any one row is separated from the leaf immediately above or below it in the same row by two internodes. If one observes a stem with leaves arranged in a cyclic manner from above the rows can be very clearly seen. The plants *Vinca rosea* and *Nerium* show the rows very well.

(6) **Spiral or alternate.**—At every node there is only one leaf. Select a leaf at random and from it follow the leaves round the stem up the successive nodes, until you reach a leaf standing exactly above the one with which you started. The sixth leaf will be exactly above the first, the seventh exactly above the second and so on. Beginning with the first leaf, if you pass a thread round the stem touching the nodes successively until you reach the sixth

node, it will be seen that the thread makes two spirals. Th difference between any two successive leaves will be $\frac{2}{5}$ 360 degrees, i.e., 144 degrees. The leaf arrangement **phyllotaxis** is **spiral.**

It must be remembered that the spiral arrangeme of leaves is generally distorted by growth, and it is therefor difficult to trace it on a mature shoot It is clearly seen a the apex of a branch where the twisting effects of growth d not occur.

5. **The root.**—Note—

(*a*) that the main root is in continuation of the main stem,

(*b*) that it is pale in colour,

(*c*) that the main or tap-root goes vertically downwards,

(*d*) that it bears branch roots in acropetal succession and these take lateral directions,

(*e*) the root hairs in the younger portions of the roots of plant growing in loose sand or saw dust (especially in seedlings of mustard or other plant).

6. **The flower** —Note—

(*a*) the position of the flowers, axillary or terminal, single or grouped together,

(*b*) the flower-stalk, the **bract**, and the floral leaves, namely, **sepals, petals, stamens** and the **pistil**, and

(*c*) the attachment of the parts of the flower at the end of the flower stalk or the **receptacle.**

7. **The fruit** —Tear or cut open the fruits and note that hey consist of chambers filled with seeds. In some fruits (*Crotalaria, Cleome, Gynandropsis*) there is only one cham ber, while in others there may be more than one. Note th **placentas** and the **pericarp** or fruit wall. The seeds ar found in four lines in *Gynandropsis*, but in *Crotalaria* ther s only a single line of seeds.

FIELD OBSERVATIONS.

1. **Herbs**—

(*a*) Note—(1) the general form of the shoot system of the entire plant,

(2) whether the leaves, flowers and fruits are displayed on the branches effectively to sunlight and air,

(3) the root system as regards the spread and the direction of the growth of the main root and its branches.

(*b*) Construct an accurate outline drawing of the plant you are studying indicating the following points—

(1) the general form of the entire plant and the display of the absorbing root and the leaf surfaces,

(2) the form of the main central axis and the arrangement of lateral members,

(3) the plan of the lateral branches, including the position of the leaves, flowers and fruits, if present.

2. **Trees—**

(*a*) **Form and arrangement of the parts.**

(1) Observe whether the trees are of the erect or of the spreading type, and also whether the branches have any regular arrangement on the stem.

(2) Are the leaves properly disposed over the crown of the tree to secure the maximum amount of sunlight?

(3) Sketch the outline of the whole tree.

(*b*) **The plan and the development of the branches.**

Select a terminal shoot of the tree representing three or four years of growth, and note the following points —(1) leaves and buds, (2) seasonal growth of buds and branches

(*c*) **The plant and the development of the tree as a whole.**

Observe this in young as well as old trees.

THE STRUCTURE OF THE SEED.

(A) EX-ENDOSPERMOUS SEEDS.

1. Examine the seeds of *Dolichos Lablab* and note—

(*a*) their attachment in the fruit,

(*b*) the general outline, the seed-coat, the **raphe**, the spongy white outgrowth, the **hilum** and the **micropyle**. The micropyle lies at one end of the white outgrowth and it can easily be located by squeezing a soaked seed between the fingers, for then water will be seen oozing out from the micropyle.

(*c*) the seed-coat which really consists of two parts, the outer one the **testa** and the inner the **tegmen**,

(*d*) the mass invested by the seed-coat or the **embryo** which consists of two fleshy **cotyledons** (seed-leaves) a the **primary axis** to which these are attached, and

(*e*) the primary axis which is curved; the lower tion outside the cotyledons is called the **radicle** o **hypocotyl**, the upper portion within the cotyledons bein termed the **plumule**.

2. As further examples of ex-endospermous seeds, study the structure of the seeds of *Cicer arietinum*, *Erythri indica*, *Cajanus indicus* and *Cucurbita* or *Cucumis*.

(B) ENDOSPERMOUS SEEDS.

1. As a type of endospermous seed examine the seeds of *Ricinus communis* and note—

(*a*) the polished and marbled hard seed-coat and the white outgrowth at the narrow end, the **caruncle**,

(*b*) the white mass inside the seed-coat and the embryo within this mass. This mass or **endosperm** may easily be cut and then separated into two portions and within each of these lies a cotyledon which is thin and leaflike, and

(*c*) the very short primary axis, which is without differentiation.

2. Study the structure of the following seeds as further examples of endospermous seeds :—

Hibiscus cannabinus, *Phœnix*, Coconut, *Trigonella fœnum-græcum*, *Delonix regia*, and *Vinca*.

Note the variations in the endosperm and in the parts of the embryo.

(C) PERISPERMIC SEEDS.

1. Examine a longitudinal section of the fruit of *Piper* and note—

(*a*) the embryo at one corner lying amidst a small quantity of endosperm, and

(*b*) the portion below, which is much larger than the endosperm, the **perisperm.**

2. Place seeds of *Cardamomum* in water and note the thin **aril** enveloping the seed. Cut the seeds both transversely and longitudinally and note (*a*) the seed-coat

(*b*) the white perisperm, and (*c*) the greyish oily endosperm rrounding the embryo.

3. As further examples of perispermic seeds examine the eds of *Nymphæa*.

(D) SEED-LIKE FRUITS.

1. Examine the so-called seeds of *Mirabilis*. They are really one-seeded fruits. Remove carefully the outer coat (**perianth**) without injuring the parts inside and the brownish body exposed is the fruit. A comparison with the ovary and perianth in a faded flower will make this apparent. Note the style scar. Tear away the brown membrane (seed-coat and pericarp) and note the floury endosperm and the embryo consisting of two cotyledons and the primary axis.

2. *Zea Mays*.—The grain is a single-seeded fruit. Note the general shape of the grain and the embryo lying on one of its sides. Detach the embryo carefully, and observe that it consists of a straight axis and a single thick-folded cotyledon. Also note the attachment of the cotyledon to the axis. The rest of the grain consists of a starchy substance which is the endosperm. One surface of the cotyledon (or the **scutellum**, as it is called in grains) is in close contact with the endosperm. Cut longitudinal and transverse sections and note the above parts.

3. *Carthamus* or *Helianthus*.—The "seeds" used for sowing are really fruits, and this fact can be verified by examining them in position on the receptacle of the head. Each fruit is an achene narrower at the base and broader at the apex. The style scar is clearly seen at the apical end.

Remove the white shining **pericarp** and note the seed enclosed in a delicate **seed-coat**. The embryo consists of the primary axis and two cotyledons. The radicle is towards the base and plumule towards the apex and hence the seed is **anatropous** or inverted.

GERMINATION OF SEEDS.

1. Sow some seeds of *Dolichos Lablab* in the germination box, dry seeds in the left half and soaked seeds in the other half. Place the seeds in as many different directions as possible and also at different depths. Also sow in moist

saw-dust these seeds as well as those of *Cicer arietinum*, a few each day, for about a week.

2. Weigh out fifty air dry seeds of *Dolichos Lablab* and after noting the weight put them in a graduated [redacted] containing water. Note the increase in the volume of water which represents the volume of seeds. Take them out and place them in moist saw-dust.

3. Take four jars and after marking them A, B, C and D, place in A a few soaked seeds of *Cicer arietinum* with some water below, in B a few dry seeds without water, in C dry seeds with some water below, in D some seeds completely immersed in water and leave them in a dark place until required

4. Place inside a lamp chimney a piece of blotting paper rolled up and fill it with saw-dust. Place a few soaked seeds of *Dolichos Lablab* and *Cicer arietinum* in different directions between the glass and the paper and then keep the chimney in a dark place after watering it.

5. Remove from the saw-dust the fifty seeds of *Dolichos Lablab* that were sown during the previous lesson. Find out the weight of the seeds and also determine the volume of water absorbed by the seeds by putting them in a graduated vessel of water. Calculate the amount of water absorbed by a single seed.

6. Examine the four jars A, B, C and D, which were left in the dark place. What do you learn from the experiment?

7. Observe the germinated seedlings in the chimney, prepared in the previous lesson.

STUDY OF SEEDLINGS.

1. From the saw-dust select germinated seeds and the youngest plants of *Dolichos Lablab* and observe —

(*a*) the testa which is swollen and split irregularly somewhere close to the micropyle, and

(*b*) the emergence through the slit in the testa and the rapid growth in length of the hypocotyl.

2. In somewhat older seedlings note—

(*a*) the root at the end of the radicle,

(*b*) the root-hairs and the free tip of the root, and

(*c*) the four longitudinal rows of lateral roots springing from the main root.

3. Observe the elongation of the **hypocotyl**, the formation of the loop, the escape of the cotyledons from the testa, the straightening of the hypocotyl, the emergence of the plumule from the cotyledons, the separation of the cotyledons and the gradual shrivelling of the cotyledons due to the depletion of the reserve material.

4. Study the seedlings of *Cucr arietinum* also in the same way. The cotyledons in this case remain inside the testa and never appear above the ground as in the case of *Dolichos* seedlings. Hence the seeds of *Cucr* are said to be **hypogeal** and those of *Dolichos*, **epigeal**.

5. Study the seedlings of *Ricinus communis*, noting the differences compared with *Dolichos* and *Cucr* seedlings

RESERVE FOOD MATERIALS IN SEEDS.

Starch—1. Place in a watch glass bits of the cotyledons of *Dolichos* and also scrapings from the surface of a cotyledon and pour some quantity of the aqueous solution of iodine. The resulting blue colour indicates the presence of starch. This is the test for starch.

2. Examine under the microscope* very thin slices of the cotyledons of *Dolichos* and note the cells and the starch grains.

Observe the starch grains under high power and note the striations in the grains and the dark spot **(hilum)**.

3. Also examine thin sections of a cotyledon of *Cucr* and of the endosperm of *Zea Mays*, and note the starch grains.

4. Observe the starch grains of potato in thin slices. The starch grains are larger than those of *Dolichos* or *Cucr*. Note that—

(*a*) the stratifications near the hilum are concentric whilst the external layers are eccentric and elliptical,

(*b*) the layers are wider on the side further from the hilum,

---

* Read carefully the instructions regarding the use of the microscope

(*c*) many of them between the hilum and the broader end are incomplete,

(*d*) some grains are **compound grains**, i.e., two grains remaining in contact by their broad ends and covered by several layers common to both

5. Note the corrosion of starch grains in the endosperm of a germinated grain or seedling of *Zea Mays* due to a **ferment.**

6. Place in a test-tube a pinch or two of starch and heat the test-tube. Fine drops of water will condense in the upper part of the tube. Continue to heat until the starch begins to turn black and white fumes are evolved. These fumes are inflammable and acid in reaction. From this we learn that starch consists of C, H and O.

7. Put a pinch of starch into a test-tube of cold water and shake it well It does not dissolve Boil it and it will turn into a paste Add a few drops of iodine solution when it is cold and a blue colour is formed. On boiling this the blue colour disappears but returns on cooling

8. Add to starch paste a few drops of sulphuric acid. Test the solution from time to time for starch At first there will be starch, but later it gradually gets lost and sugar appears instead.

9. Put a pinch of starch in water contained in a test-tube and boil it till you get a clear liquid. Pour this liquid into three test-tubes A, B and C. Add to A a little saliva, to B a small quantity of diastase and leave C alone. Place all these in a water bath at 35° to 40° C. for some time. Take a small quantity from each and add iodine solution and note the result. Next add to a little of Fehling's solution a small quantity from each of these tubes and note the result after heating the Fehling's solution.

Proteid and oil.—1. Mount a section of the endosperm of *Ricinus* seed in castor oil and examine it under a microscope. In the cells of the endosperm small ovate bodies appear and these are the **aleurone grains**. Near the narrow end of the grain is seen a small rounded body (**globoid**). It consists of a double phosphate of lime and magnesia.

When the same sections are mounted in water the aleurone grains appear as oval bodies. Within the grains are seen

the proteid crystals (**crystalloids**). These come out very sharply when examined in alcohol.

2. Note that in these sections the aleurone grains are embedded in a ground substance rich in oil, which is in the form of very minute globules.

3. Cut a few pieces of the endosperm of the same seed and put them in a test-tube containing some water. Add to these pieces a small quantity of Millon's reagent (acid nitrate of mercury) and boil the water. The pieces become brick red. This is the test for proteids.

EXTERNAL MORPHOLOGY OF THE ROOT.

Sow seeds of *Dolichos Lablab*, *Canavalia ensiformis*, *Ricinus communis*, *Zea Mays* and *Andropogon Sorghum* in saw dust or in a seedling observation box and use the seedlings for observation and study.

1. In the seedlings of *Dolichos*, *Canavalia* and *Ricinus* note that—

(*a*) the first root springs from the tip of the radicle and grows in length;

(*b*) the lateral or secondary roots appear on the **main** or **tap-root** in four distinct vertical rows, and in acropetal succession;

(*c*) the lateral roots grow horizontally or obliquely and not vertically downwards;

(*d*) all the roots are connected with the tap-root directly;

(*e*) branches arise from the lateral roots also and they grow in directions different from those taken by the lateral roots.

2. In the seedlings of *Zea Mays* or *Andropogon Sorghum* note that—

(*a*) the first root grows from the tip of a radicle and that other similar roots arise from the axis. Such roots as these, all arising from the axis, are called **adventitious** roots.

(*b*) these adventitious roots do not arise in acropetal succession.

3. Note in all the seedlings—

(*a*) the root tip,

(*b*) the region of the root having root-hairs, and

(*c*) the older portion in which the root-hairs have dried up.

Observe—

(*a*) the root-cap, using the lens if necessary. This may not be easily visible to the naked eye though it could be well seen with a low power lens. In *Arachis* seedlings and in the aerial roots of *Pandanus* and *Ficus benghalensis* the root-cap can be seen even with the naked eye.

(*b*) the root-hairs. These are seen to the best advantage in mustard or radish seedlings.

4. As examples of modified roots study the roots of *Raphanus sativus* (Radish), *Ipomœa batatas* (Sweet potato) *Pandanus*, *Andropogon Sorghum* (Cholam), *Piper betel* (Betel vine), *Vanda Roxburghii* (an epiphytic orchid), and the breathing roots of *Avicennia*.

Observe that—

(*a*) the roots are all adventitious in these plants except in *Raphanus* and *Avicennia*,

(*b*) in the radish the swollen underground part consists of the main stem which is continuous with the tap-root and that the root portion bears two rows of lateral roots,

(*c*) in the case of the sweet potato the whole of the underground swollen part is an adventitious root,

(*d*) in the orchid *Vanda* the roots are all adventitious and completely aerial and that they never get into the soil: sometimes some roots may adhere to the supporting portions in this and in *Piper betel* vines,

(*e*) the aerial roots in *Andropogon Sorghum* and *Pandanus* finally penetrate the soil,

(*f*) the roots of *Avicennia* carry some special roots which grow vertically upwards and stand out well in the air above the soil. These roots are termed **pneumathodes** or **pneumatophores** (breathing roots).

STRUCTURE OF THE CELL.

1. Select a young flower-bud of *Cucurbita*, and mount in water a few hairs found on it, and then examine them under a low power and note :—

(*a*) that a hair consists of a row of cells, and

(*b*) that the cells at the base are broader and shorter and those above are longer and narrower.

Examine any one of the basal cells under a high power and observe—

(*a*) the cell-wall and its contents, the protoplasm,

(*b*) the layer lining the cell-wall and its separation into a part free from granules and another granular,

(*c*) the numerous strands stretched across the cavity on all sides with spaces or cavities (**vacuoles**) ; in some of the cells crystals of calcium oxalate may occur,

(*d*) a denser body in the protoplasm occupying various positions in different cells, the **nucleus**, and

(*e*) that the granules in the strands and the layers of protoplasm just within the hyaline layer against the cell-wall are in constant motion,

(*f*) that the protoplasm in these cells is in active motion in various directions and that in thick strands extending across the vacuole two currents may be seen flowing simultaneously in opposite directions. This kind of streaming movement of protoplasm is termed **circulation.**

The cells of the stamınal hairs of *Cyanotis* and *Tradescantia* also exhibit such movements in their protopalsm.

2. Note the young embryonic cells in the sections provided. (Transverse sections of the ovary of *Lilium*, of the vegetative buds of *Corchorus* and *Nerium* and longitudinal sections of root-tips of the roots of any cereal or grass.

3. Examine the root tips of the seedlings given and note the embryonic cells, the layers of cells of the **root-cap**, the older cells and the **root-hairs.**

4. With a razor take off thin slices from the middle of the upper surface of a leaf of *Vallisneria*, mount them and then examine them under a low power and observe—

(*a*) the elongated cells, oblong in shape and the **chloroplasts** imbedded in the protopalsm, and

(*b*) the motion of the chloroplasts round the cell; these are passively conveyed owing to the fact that the layer of protoplasm in which they are imbedded is in a state of movement round and round the cell (**rotation**).

Under high power observe—

(*a*) the cell wall,

(*b*) the protoplasm and its vacuole,

(*c*) the nucleus, and

(*d*) the movement round and round of the protoplasm and note that the direction of the motion is not the same in all cells, in one cell it may be clockwise and anti-clockwise in the cell next to it.

Rotation of protoplasm may also be seen in the cells of the leaves of *Elodea* and in the cells of the internodes in *Nitella* and *Chara*.

5. Peel off or cut with the razor thin slices from the fleshy scale of the bulb of *Allium* and mount them in water. Examine first under a low power and then under a high power and note the cells and the various parts of the same.

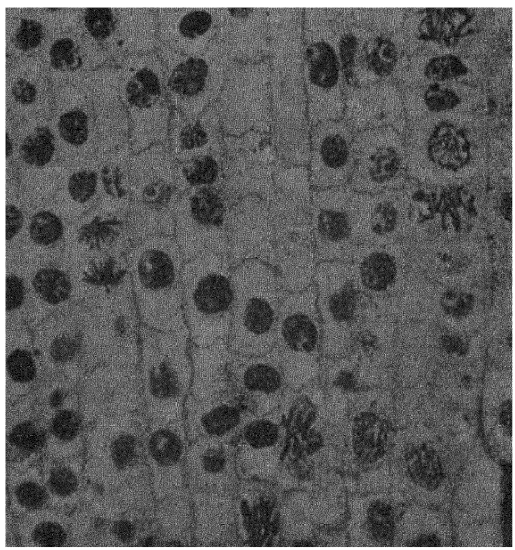


FIG. 1.—Microphotograph of a longitudinal section of the root-tip of *Tradescantia* showing nuclear division in different stages. From a section prepared by Dr. Sampathkumaran. (High power.)

6. Mount slices of *Vallisneria* leaf and of the bulb of *Allium* in iodine solution. Examine under high power and observe the cell and its parts. Note the differences in colour of the various parts. The nucleus will be more deeply brown than the protoplasm.

7. Cell division can be studied with ease in the root-tips of *Tradescantia* or *Allium*, by selecting the roots at the proper time and by fixing them carefully. As satisfactory sections could be obtained only by the use of a microtome, it is advisable to use prepared slides. Different stages of the nuclear division in the root-tip of *Tradescantia* is well seen in Fig. 1, which is a microphotograph of a longitudinal section of the root-tip. (See Fig. 1.)

STUDY OF TISSUES.

1. Examine thin slices cut transversely and longitudinally of the pith portion only of any herbaceous stem, e.g., *Brassica* or *Gynandropsis*. The cells in the transverse section are somewhat rounded Note small spaces at the places where the cells meet (**intercellular spaces**). In the longitudinal section the cells are oblong, elongated transversely, and have more or less square ends. These cells are typical **parenchymatous cells.**

Mount some of these sections in iodine solution and after adding a drop of sulphuric acid (acid two parts and water one part) put on the cover glass. Examine and note the blue or violet colour of the cell-wall. This is the test for **cellulose** cell-wall.

This reaction does not always appear. Spirit material is better than fresh material. Treatment with potash sometimes yields good results. The section must be well impregnated with the iodine solution before transferring it to the acid.

The sections may also be mounted in chlorzinc iodine and the result noted. If chlorzinc iodine is not available, the sections may first be stained in iodine solution (1:1.100 : Iodine : Potassium Iodide : Water) and then transferred to zinc chloride solution (2 1 ·. zinc chloride : water). If staining is not quick add iodine solution again,

2. Examine transverse sections of any fleshy leaf, *Calotropis* or *Portulaca* and observe that the bulk of the section consists of parenchymatous cells.

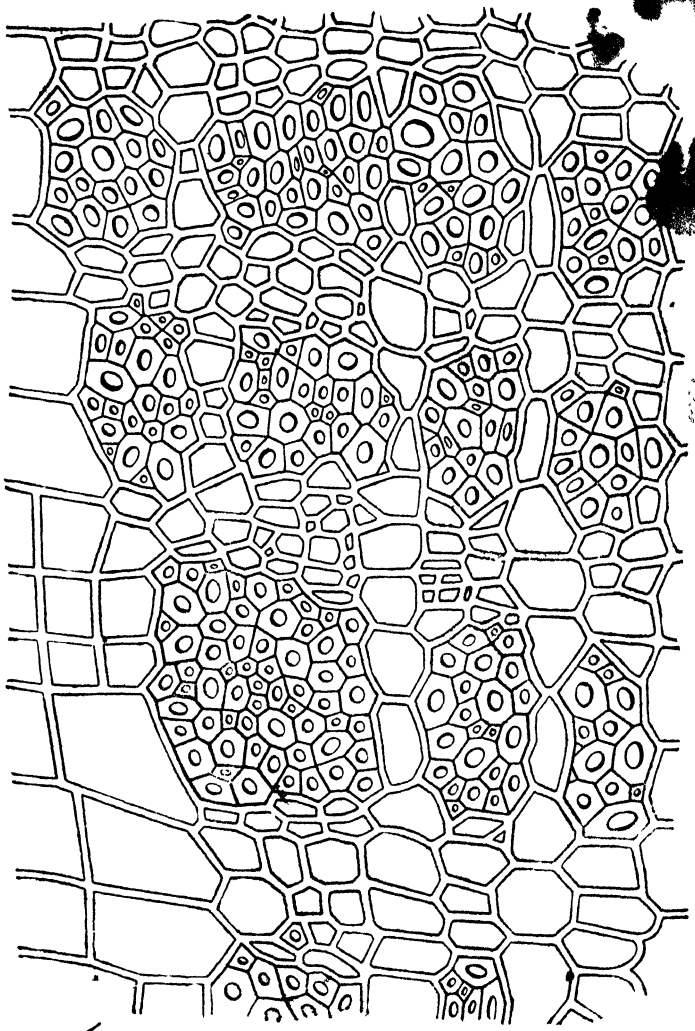


FIG. 2.—Transverse section of sclerenchyma in the stem of *Hibiscus cannabinus*. (Very highly magnified.)

3. Strip the bark from the stem in the material supplied (*Abutilon* or *Sida*) and note the net-work of fibres in it. Tease out a bit of this net-work on a slide and observe the individual fibres under the microscope.

4. Examine transverse sections of these fibres in a section of the stem of *Hibiscus cannabinus* (gogu) and observe the thickness of the walls and the small cavity. These fibres form the tissue termed **sclerenchyma.**

5. Mount some pieces of the fibre in—

(1) aqueous solution of aniline sulphate,

(2) alcoholic solution of phloroglucin acidulated with hydrochloric acid.

(3) aqueous solution of potassium permanganate followed by ammonia.

Observe that the fibres are stained yellow, violet-red and red respectively. This is the test for **lignin** a substance which is the cause of the thickening of the cell-wall.

6. Examine transverse sections of the pith of the stem of *Nerium* and note the **sclerotic** cells. The laminations are well seen. Both simple and branched pits are present. Sections of the endocarp of *Azadirachta* also show sclerotic cells.

7. Examine transverse and longitudinal sections of the stem of *Andropogon Sorghum* in aniline sulphate or phloroglucin. In the transverse section observe —

(*a*) the somewhat rounded cells without any colour forming the bulk of the section (parenchyma), and

(*b*) the yellow or red-stained thick-walled cells, some having very thick walls and very small cavity (fibres) and others with large cavities and thick walls (vessels)

In the longitudinal section note—

(*a*) the parenchymatous cells,

(*b*) the fibres, and

(*c*) the vessels.

Observe that the vessels are not all uniform ; some have rings at distant intervals **(annular vessels)** and others have spirals **(spiral vessels).** There are also vessels with a large number of dots (pits), in the cell-walls. These are **pitted vessels.**

8. Tease out on a slide the vascular strands given a[illegible] examine the vessels.

9. Examine longitudinal and transverse secti[illegible] *Cucurbita* stem after staining them with eosin or [illegible] blue. Note the **sieve tubes** and **sieve plates** [illegible] which alo[illegible] have taken the stain

10. Mount on a slide a transverse section of the stem[illegible] *Helianthus* and observe the cavities lined with small cel[illegible] these are **resin ducts.**

11. Cut longitudinal sections from the peripheral p[illegible] of the root of *Lactuca runcinata* and note the irregul[illegible] work of channels therein. These are **laticiferous vessels.**

12. Examine the glandular hairs in *Petunia*, *Paronia* or any other plant

13. Note the large **oil glands** in the fruit rind of *Citrus*. Cut sections and examine them under the microscope Also observe the same in sections of the leaves of *Citrus* or *Murraya*

CELL INCLUSIONS

1. **Starch grains**—Note these in the parenchymatous cells of the stem of *Nerium* or any other plant.

2. **Chromatophores.**—(*a*) Note the green-coloured bodies in the parenchymatous cells of the leaf of *Ottelia* or any other plant These are known as **chloroplasts** or **chlorophyll grains**

(*b*) Note the red-coloured bodies in the cells of the fruit rind of *Capsicum* and *Withania*. They are called **chromoplasts.**

3. **Calcium oxalate crystals**—Note—

(*a*) Simple crystals in the cells of *Citrus* leaf and *Azadirachta* fruit rind,

(*b*) Clustered crystals in *Thespesia* stem,

(*c*) Needle-shaped crystals **(raphides)** in the cells of the petiole of *Colocasia*, in the cortical cells of *Musa* root and in the stem of *Mirabilis*

4. **Calcium carbonate crystals (cystoliths)**—Examine these in the sections of a *Ficus* leaf

5. **Aleurone grains.**—Note these in the endosperm of *Ricinus*. There are crystals inside the grains, and the substance surrounding it is the protein globulin.

MICROCHEMICAL REACTIONS.

1. **Starch.**—Examine the starch grains found in the cells of transverse section of the stem of *Nerium* or *Aristolochia* [illegible] plant Run in aqueous solution of iodine and note the result.

2. **Sugar.**—Take a little of Fehling's solution and after boiling it add a piece of the fruit of plantain or country pear or bulb scales of onion and continue the boiling. The [illegible] will turn brick red.

3. **Proteids.**—Add Millon's reagent to some slices of the endosperm of castor and these will turn red on heating.

4. **Fats** —Note the oil globules in the sections of the cotyledons of almond or groundnut stained black by Osmic acid.

5. **Cellulose cell-walls.**—These stain blue or violet with sulphuric acid and iodine. Chlorzinc iodine (Schultze's solution) has a similar effect.

6. **Lignified cell-walls.**—Stained bright yellow with aniline sulphate, pink by phloroglucin, and brown with Schultze's solution.

7. **Cuticularised cell-walls** —Stained yellow with Schultze's solution, bright yellow with potash

8 **Calcium oxalate.**—Insoluble in 1 per cent acetic acid but soluble in nitric and sulphuric acids

9. **Calcium carbonate** —Soluble in weak acetic acid with evolution of carbonic acid gas

GENERAL STRUCTURE OF THE ROOT.

1. Mount a young root of *Brassica* or *Setaria* in water and note under the microscope :—

(*a*) the tip of the root with the **root-cap** whose superficial cells are lying loose, isolated or jointed in rows and evidently in the act of becoming shed or peeled off the cap,

(*b*) the **root-hairs** arising from the superficial cells as outgrowths. These are very small near the tip and get longer gradually towards the other side. Observe that the root-hairs consist of thin cell-walls and protoplasm,

(*c*) the transparent outer tissue or **cortex**,

(*d*) the dense inner tissue or **vascular cylinder**

2. Cut thin transverse sections of a young root of *Cicer arietinum* or *Dolichos Lablab* and examine them in chlorzinc iodine or aniline sulphate and observe—

(*a*) the **epidermis** or **piliferous layer** with or without root-hairs,

(*b*) the mass of thin-walled rounded parenchymatous cells forming the cortex, the intercellular spaces, and the cell-inclusions, if any. The cortex is very broad and the major portion of the root consists of this part,

(*c*) the single layer of cells with some thickened radial walls known as **endodermis**,

(*d*) the single layer of cells inside the endodermis consisting of one layer of cells and forming the **pericycle**,

(*e*) the four radiating **primary xylem** bundles, or **protoxylem**, with centripetal development,

(*x*) the four **primary phloem**, bundles, or **protophloem**, alternating with the primary xylem,

(*y*) the parenchyma in the centre of the root.

STRUCTURE OF DICOTYLEDONOUS ROOTS.

1. Examine transverse sections of a root of *Cicer arietinum* or *Dolichos Lablab* a little older than in the previous lesson and observe—

(*a*) the piliferous layer and the root-hairs,

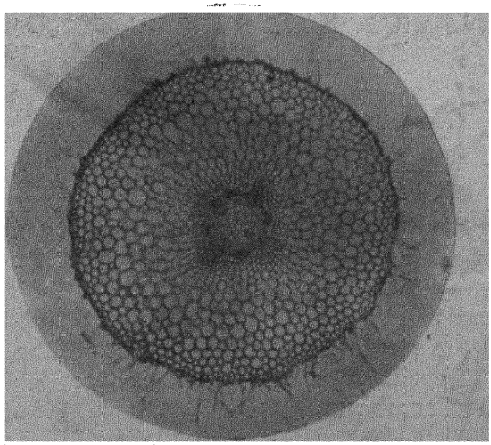


FIG. 3.—Microphotograph of a young root of *Dolichos Lablab* (Low power).

(*b*) the cortex and the endodermis which can be recognized easily by the small dots occurring in the radial walls of the cells. These spots are called Casparian dots,

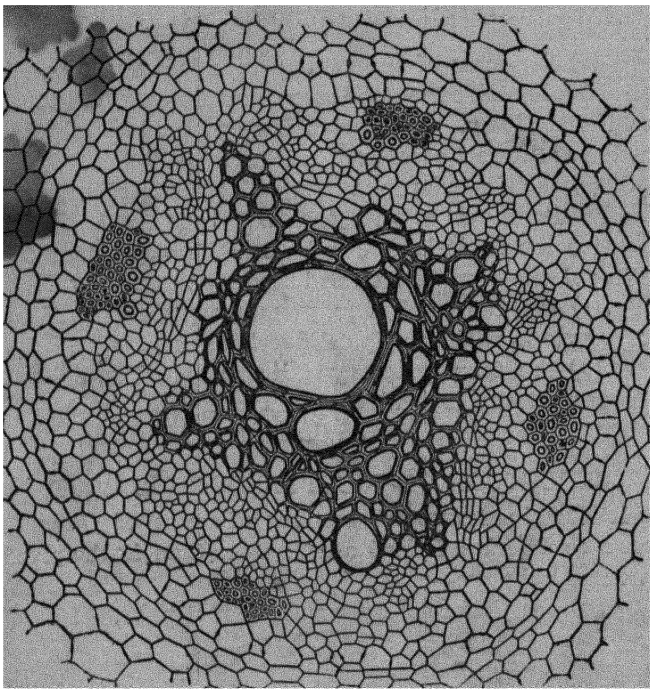


FIG. 4. – Transverse section of a root of *Dolichos Lablab* older than in fig. 3 showing the stelar portion only (High power).

(*c*) the pericycle,

(*d*) the four primary phloem groups, and the four groups of sclerenchyma,

(*e*) the four primary xylem groups, their centripetal development and their meeting in the centre, and

(*f*) the very delicate layer of cells forming a wavy line between the primary xylem and the primary phloem which is known as **cambium.**

2. In sections of *Cicer* or *Dolichos* root older than in the above note the following :—

(*a*) the well formed cambium region,
(*b*) the secondary xylem, and
(*c*) the secondary phloem.

3. Examine transverse sections of the young roots of *Cucurbita*, *Ricinus* and *Raphanus*. Note the number of protoxylem groups in these and mark other differences also.

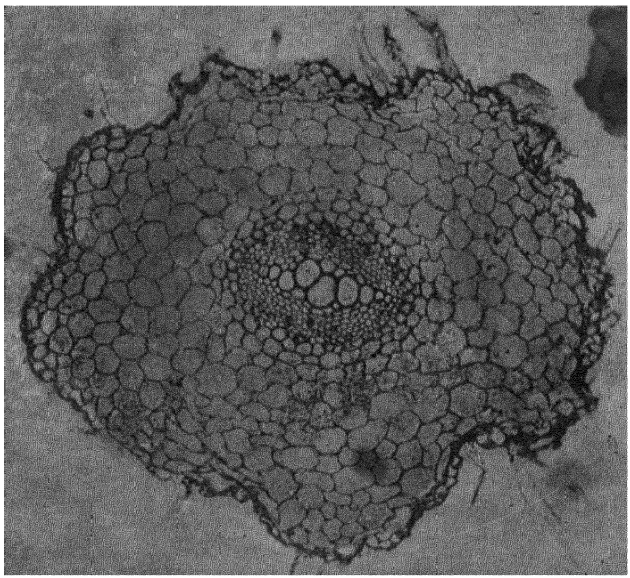


FIG. 5.—Microphotograph of a transverse section of the root of *Raphanus sativus* (Low power).

4. Examine the sections of the old root of *Arachis hypogaea*, *Dolichos* and *Lactuca* and note the protoxylem and the secondary xylem. Observe the cork cells forming the outer portion of the cortex with a cork-cambium at its inner limit, the secondary phloem and the secondary xylem : it must be specially noted that the cortical part including the cork layers originates from the pericycle and hence is of stelar origin. The endodermis, cortex and the piliferous layer are thrown off on the formation of the cork from the pericycle.

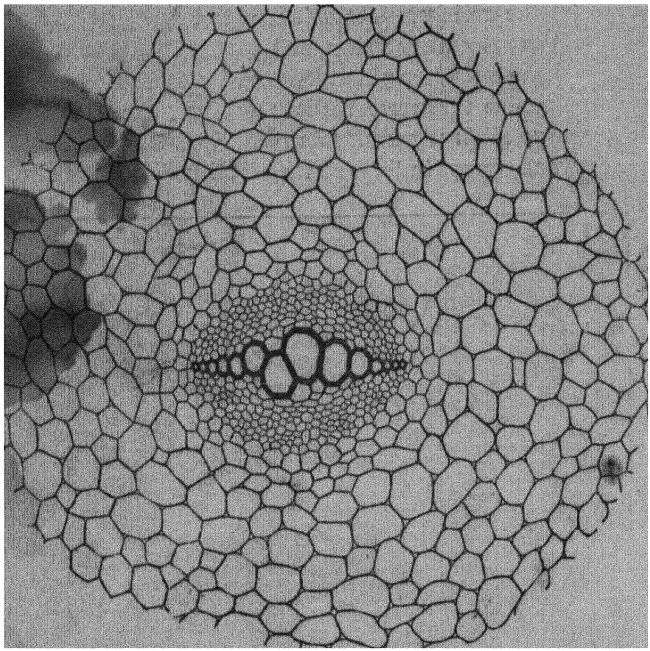


FIG. 6.—Transverse section of a root of *Raphanus sativus*, showing the two protoxylem groups.

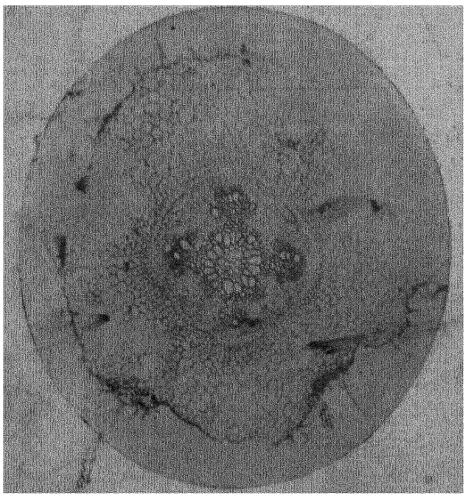


FIG. 7.—Microphotograph of a transverse section of the root of *Dolichos Lablab* showing the formation of cork in the pericycle (Low power).

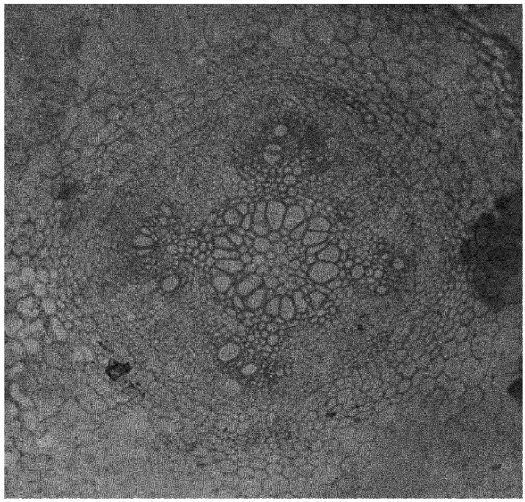


FIG. 8.—Microphotograph of the transverse section of the stele of *Dolichos Lablab* root showing the formation of cork in the pericycle (High power).

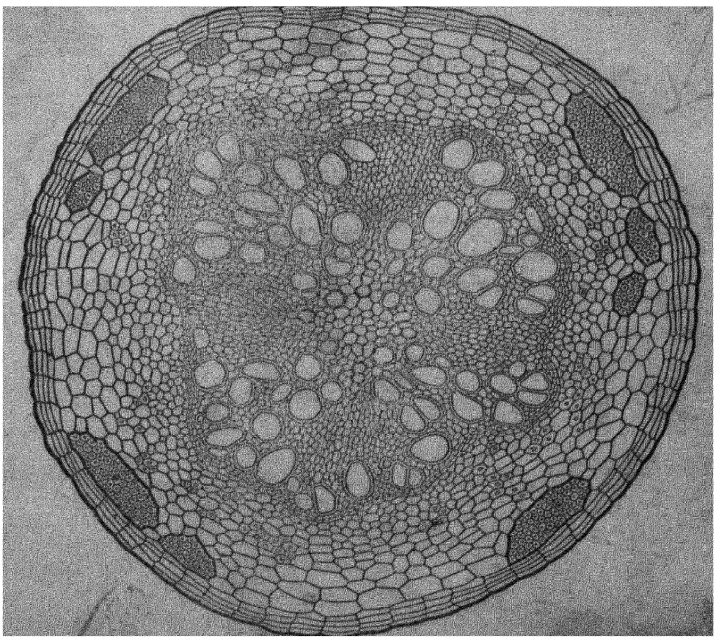


FIG. 9.—Transverse section of an old root of *Arachis hypogaea* in

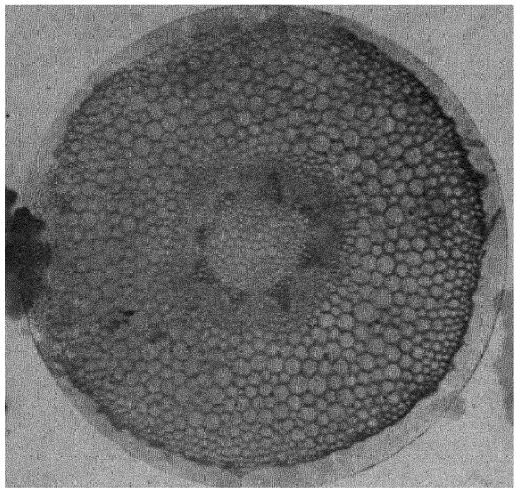


FIG. 10. Microphotograph of a transverse section of a root with eight protoxylem groups (Low power).

STRUCTURE OF MONOCOTYLEDONOUS ROOTS.

1. Take transverse sections of the root of *Colocasia* and examine them.

Note—

(*a*) the comparatively wide cortex surrounding the stele and bounded externally by the piliferous layer, consisting of small cells, some of which have grown out into long root-hairs. The cortical parenchyma consists of regularly arranged rounded cells with plenty of intercellular spaces,

(*b*) the small stele,

(*c*) the endodermis very well marked by the thickening of the inner and lateral walls,

(*d*) the pericycle consisting of a single layer of cells,

(*e*) the protoxylem groups varying in number from 7 to 12 or more,

(*f*) the phloem groups alternating with the xylem groups,

(*g*) central pith.

2. Examine transverse sections of the root of *Allium* and note the parts. Observe in what respects this differs from

the root of C . The protoxylem groups are fewer in number than in *Colocasia*. Note that in the later stage lateral and the inner walls of the endodermal cells b thickened, but the cells lying close to the protoxylem do not become thickened as they serve as passage cells.

3. Prepare transverse sections of the r *Sorghum* and study its structure.

Observe—

(*a*) the root-hairs and the piliferous layer and the layer or layers of thin-walled cells below.

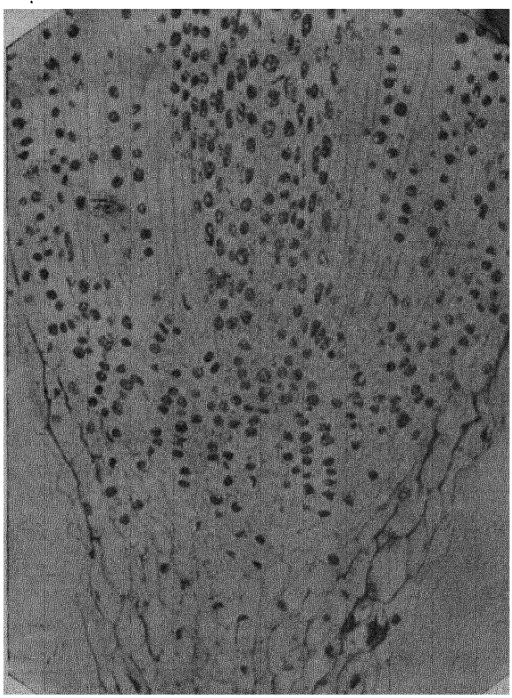


FIG. 11. Micropho d section through the tip of the root of *antia* (High power). From on prepared by Dr. kumaram. (Higher magnifi

(*b*) layers of thick-walled cells beneath forming the exodermis.

(*c*) the broad c of thin-walled cells,

(*d*) the prominent layer of **endodermis** consisting layer of cells with thin walls when young, but in old with walls thickened on three sides, the outer wall thin,

(*e*) **pericycle**, a layer of cells thin-walled in young roots and ... ed in old ones,

(*f*) ... merous xylem groups,

(*g*) ... phloem groups alternating with the xylem, and

(*h*) ... medulla or pith.

4. ... mine transverse sections of *Musa* root and note in ... cts it resembles and in what respects it differs ... oots of monocotyledons already examined. Note ... m and phloem groups found scattered in the region ... e pith.

5. Prepare longitudinal and transverse sections of *Musa* and other roots so as to have some lateral roots and observe how these originate. Note that the lateral roots always arise just at the back of the protoxylem and from the pericycle.

EXTERNAL MORPHOLOGY OF THE STEM

1. Normal erect stem.

(*a*) **Monopodium**.—*Verbena*. The terminal growing point produces internodes and nodes in succession.

(*b*) **Sympodium**.—*Vitis*. The internodes of the axis are not all derived from the same terminal growing point. Compare the flowering branches of *Gossypium* (cotton).

2. **Spines** (or **thorns**).—*Carissa*, *Citrus Bael*, *Zizyphus*. The branches have ceased to grow and have become spines.

3. **Twiner**.—*Dolichos* and *Ipomoea*. Note the direction of the twining.

4. **Tendril climbers**.—*Cucurbita*, *Coccinea*, *Trichosanthes*, *Passiflora* and *Vitis*. Branches have become tendrils. Note the direction of the spirals in the tendrils.

5. **Stolon**.—*Centella*. The stem creeps along the ground and produces adventitious roots at the nodes and the axillary buds develop into short upright shoots. The term **stolon** is used for any basal branch which is disposed to root.

Sometimes the term **runner** is used instead of stolon. Branches of subterranean origin are sometimes known as

suckers The lateral shoots especially when they can be used for propagation often go by the name **offset**

6 **Rhizome.**—*Canna indica* The stem is horizontal and underground Note the scale leaves, nodes, internodes, roots and the aerial branches

7 **Tuber** —*Solanum tuberosum* (potato) Each potato is a swollen branch and remains underground The pits on the surface are the axils and buds are found in these places.

8 **Bulb.** — *Allium cepa* (onion) The stem is very much reduced Note the arrangement of the modified leaves, the axillary buds, the stem and the roots

9 **Corm.** —*Amorphophallus* or *Synanthemis* The stem is condensed into a short fleshy mass Note the buds in the depressions at the top Note the leaf-scars and the roots

10 **Cladode** —*Casuarina* The branches are green and cylindrical and the leaves are reduced to small scales at the nodes

Bouerosia The stem is green and fleshy and leaves are not developed In very young branches small leaves sometimes appear but they also drop off

The pear-shaped segments in *Opuntia* are also cladodes

BUDS AND LEAF-SCARS

1 **Structure and growth of buds** —As examples of buds examine the buds on the branches of *Murraya*, *Nerium*, *Ficus* and *Ardisia crispa* The **axillary buds** are smaller while the **terminal** buds are larger

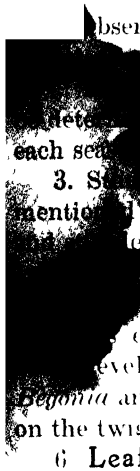
Observe that—

(*a*) the terminal buds in the first two plants mentioned above consist of unfolded young leaves which have the same arrangement as that of leaves on the main stem The arrangement and the general structure can easily be made out by examining the cut surface after bisecting the bud

(*b*) in the other two plants the terminal buds consist of leaves as well as large stipules

2 Study the **scaly buds** (resting buds) in *Rhododendron*, Mango and Mahogany They are covered by a series of

cases and may remain in this condition for a long



bserve the unfolding of these buds and the gradual
of the foliage leaves
of the branch in the case of these plants can
by looking at the scars left by the bud scales
each sca
3. S transverse sections of the buds of the plants
entio above, and note the arrangement of the leaves
es.
ve the growth and the unfolding of the leaves in
ts mentioned above
examples *a* for **adventitious buds** study the
veloping in the leaves of *Bryophyllum*, *Scilla* and
Begonia and (*b*) for **accessory buds**, the buds developing
on the twigs of cotton, *Abutilon* and *Pavonia* plants

6 **Leaf-scars** The leaf-scars vary very much in shape and very often they are quite characteristic of the plant Note the scars in the branches of about a dozen plants available

EXTERNAL MORPHOLOGY OF THE LEAF

1 Examine the cotyledonary leaves of *Mangifera indica* *Dolichos Lablab* and *Hibiscus cannabinus* and note how they differ

2 The first leaves of a plant and those at the base of a branch are frequently small and scaly—**scale-leaves** As examples study *Swietenia mahogany* and *Cicer arietinum*.

3 The leaves below the flowers are frequently small and leaf-like, e g , *Gynandropsis pentaphylla*.

4. The parts of a leaf are the leaf-base, the leaf-stalk or **petiole** and the leaf-blade or **lamina**. Note these in *Abutilon* *Ficus*, *Morinda* and *Nerium*.

5 Examine the stipules in *Cassia auriculata*, *Ficus glomerata*, *Polygonum* and *Phaseolus* and note the peculiarities in them.

6. Study the arrangement of leaves on the axis in the following plants :—

(*a*) **Alternate.**—*Abutilon*, *Withania*, *Anona*, *Delonix elata*.

(*b*) **Opposite.**—*Barleria, Leucas, Tecoma, Morinda*

(*c*) **Whorled.**—*Clerodendron, Nerium, Alstonia.*

7 **Simple and compound leaves.**—Compound are such as have their lamina divided up com separate parts. Simple leaves are not so divide

Simple.—*Thespesia, Hibiscus fœtidus, Jatropha multifida, Thevetia* and *Carica papaya.*

Compound.—*Cassia siamea, Crataeva religiosa, Delonix regia.*

8 Note the arrangement of the leaflets in th ing —

Pinnate —*Cassia siamea, Sadirachta indica*

Palmate —*Gloriosa superba, Crataeva religiosa*

Bipinnate.—*Delonix, Cardiospermum, Melia Azadirachta*

9 Note the shape of the leaf or leaflet in the following :—

Linear or **strap-shaped** *Cynodon, Pandanus, Saccharum*

Oblong *Calotropis, Cassia siamea*

Ovate *Clerodendron, Hibiscus rosa-sinensis*

Cordate *Abutilon, Thespesia*

Sagittate *Colocasia*

Lanceolate *Polygonum, Nerium*

Orbicular *Nelumbium,*

Reniform *Centella*

10 Margin of the leaf —

Entire *Calotropis, Ficus*

Sinuous *Polyalthia, Bauhinia.*

Crenate. *Bryophyllum*

Dentate *Lippia, Hibiscus rosa-sinensis.*

Serrate. *Acalypha.*

Lobed. *Citrullus Colocynthis, Hibiscus cannabinus, Lactuca runcinata, Jatropha multifida.*

11. Apex of the leaf :—

Acuminate, *Dolichos.*

Acute. *Thevetia.*

Obtuse. *Calotropis.*

Mucronate. *Cassia aculeata.*

2. Vernation of leaf —
   Circinnate *Fern.*
   Conduplicate. *Abutilon, Thespesia.*
   Involute. *Canna, Musa*
   Convolute *Nymphaea, Ottelia*
13. Symmetry of leaf —
   Radial symmetry. *Calotropis*
   Bilateral symmetry *Melia, Begonia.*
14. Modifications of leaves —
   Phyllode *Acacia auriculiformis.* The apparent leaves are only petioles flattened and the lamina is not developed.
   Tendrils. *Bignonia* The leaflet is modified into a tendril In *Gloriosa* the tendril is the apex of the leaf prolonged

STRUCTURE OF DICOTYLEDONOUS STEMS.

1. Take transverse sections of a young stem of *Helianthus annuus* and selecting a complete section examine it with a low power lens of the simple dissecting microscope and note (1) the cortex, (2) the vascular bundles and (3) the pith.

Mount thin sections in a drop of glycerine or chlorzinc iodine Observe under a low power of the microscope :—

(*a*) the **epidermis** completely covering the surface forming the outermost layer and consisting of a single layer of cells There may be a few hairs also growing out from this layer Note the chloroplasts in the cells of the epidermis in this case.

(*b*) the several layers of cells with their corners thickened lying next to the epidermis. This kind of tissue is called **collenchyma.**

(*c*) a few layers of thin-walled cells (**parenchyma**) with inter-cellular spaces below the collenchyma.

(*d*) **resin ducts** scattered here and there in the cortical parenchyma

(*e*) a continuous layer of large barrel-shaped cells in close lateral contact and with starch grains in them—the **endodermis.** It is not possible to make out the endodermis in older stems, though it is conspicuous in a very young stem.

The parts (*b*) to (*e*) constitute the **cortex**.

(*f*) the **stele** or central cylinder which occupi[illegible] whole central region of the stem. Of this the most[illegible] nent structural features are —

(i) the **vascular bundles** arrange[illegible]

(ii) the **medulla** or **pith**, and

(iii) the **medullary rays**

2. Examine the same sections under a high [illegible]er and study the structure of the vascular bundles [illegible]. Observe —

(*a*) that each vascular bundle consists of—

(i) the thick-walled tissue of **xylem**, and

(ii) the more delicate smaller celled tissu[illegible] **phloem** and the **cambium**.

(*b*) the pith, a massive tissue forming the centre of the stele

(*c*) the parenchyma separating the vascular bundles laterally from each other and forming the medullary ray tissue, and

(*d*) the **pericycle**, lying between the vascular bundles and the endodermis The part of the pericycle behind the vascular bundles widens out and consists of sclerenchyma while opposite the medullary rays the pericycle is narrower and consists of thin-walled cells.

3 Take very thin transverse sections of a somewhat older stem of *Helianthus* and mount them in glycerine or chlorzinc iodine.

Note —

(*a*) the epidermal layer whose cells are contiguous except where a stoma lies, the thickened outer walls of the cells forming a layer called cuticle, the scanty protoplasm in some cells, and the chloroplasts which are usually absent in the epidermis of many plants.

(*b*) the collenchyma cells in the cortex with walls very much thickened at the angles where the cells meet. The walls are highly refractive and stratified and consist mostly of cellulose The cells contain thin layers of protoplasm and chloroplasts. Note also the larger parenchyma cells with intercellular spaces and the resin passages The endodermis is difficult to make out in this.

(*c*) the walls of the fibres in the pericycle which are and lignified and show differentiation into layers of the most prominent is the bright looking **middle**

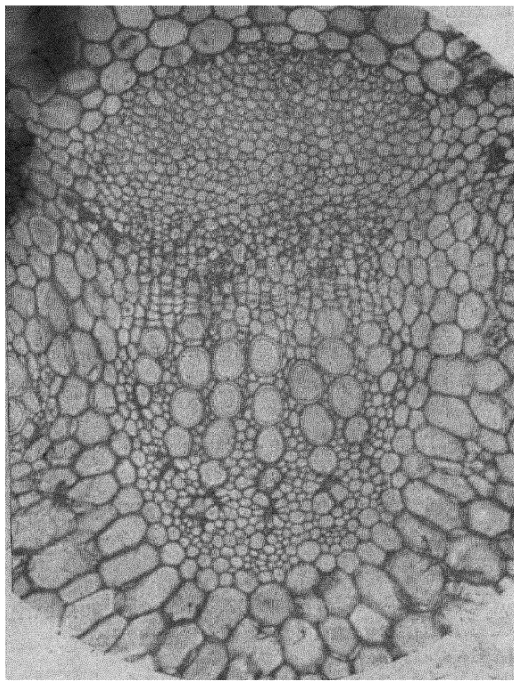


FIG. 12. Microphotograph of a fibro-vascular bundle of a stem of *Helianthus annuus* (High power).

(*d*) in the vascular bundle observe—

(i) the xylem consisting of vessels which are radially arranged and embedded in the tissue composed of **xylem (or wood) fibres** and **xylem (or wood) parenchyma**, the latter being thick-walled lignified cells with protoplasmic contents.

The xylem next to the pith is called **protoxylem** and consists mainly of spiral and annular vessels, mostly crushed and out of shape. The rest of the xylem is sometimes called **metaxylem**.

(ii) the phloem consisting of sieve tubes and phloem parenchyma, and

(iii) the cambium consisting of narrow thin cells arranged in regular tangential rows.

4. Cut radial longitudinal sections and note all the above parts. The sieve tubes being small are difficult to present in the section they can be readily recogni high power. Observe the various vessels of spiral vessels near the pith and pitted vessels ne bium. Note the transitional forms between these

5. Examine sections of a still older stem of *Hel* and study them noting the differences existing betw and the younger stems.

6. Prepare transverse sections of the stem of *Cucurbita* and mount them in glycerine and examine them. Observ first under a low power and note :—

(*a*) the **epidermis** with regular cells, hairs and sto mata,

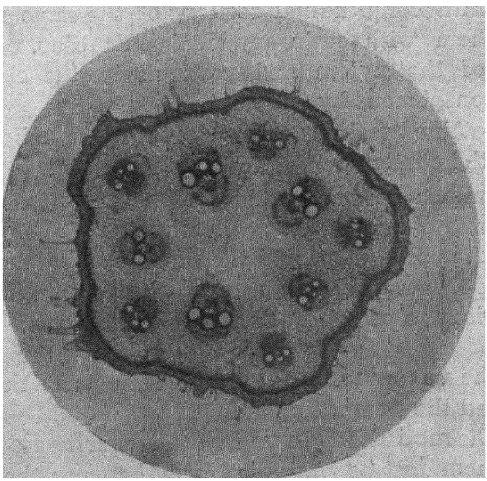


FIG. 13.—Microphotograph of trans ion of a of *Cucurbita* (Low power).

(*b*) the **cortex** broad at the corners and narrow at th furrows, the **collenchyma** and the **endodermis**,

(*c*) the stele bound externally by a continuous band of **...enchyma** which is a part of the broad **pericycle** the ... of which consists of thin-walled parenchyma, and ... two series of **vascular bundles** the outer being ...

...igh power examine one of the bundles of the ...and note the xylem and the two groups of phloem ...outside of it (**bicollateral bundles**). The xylem ...have large cavities and some are filled with ingrowths ...blocking the cavity (**tyloses**).

...ieve tubes in the phloem have large lumen and the ...ates are clearly seen. **Companion cells** are also present. The rest of the phloem consists of small parenchyma-... cells.

The **cambium** consists of thin-walled cells elongated tangentially and narrowed radially, showing very regular arrangement in radial rows. The tangential walls are especially thin indicating repeated and recent division.

7. Examine longitudinal sections of the same stem after staining them with eosin or Hoffman's blue. Note the elements of the xylem and particularly the sieve tubes rendered conspicuous by the stain.

Iodine-stained sections also show the sieve tubes well as it colours the contents.

8. Examine transverse sections of the stem of *Aristolochia bracteata* and observe —

(*a*) the epidermis and the cortex,

(*b*) the sclerenchyma forming a continuous band which together with the parenchyma lying inside forms the **pericycle**,

(*c*) the **vascular bundles** and their parts the **xylem**, **phloem** and the **cambium**, and

(*d*) the **medullary rays** and the **interfascicular cambium** in them just beginning to form, between the cambium of the separate vascular bundles (**fascicular cambium**).

9. Prepare transverse sections of the stem of *Ricinus* or *Hibiscus cannabinus* and examine them. Observe —

(*a*) the **epidermis** which is a continuous layer only interrupted by the **stomata**,

(*b*) the **collenchyma**, the large parenchymatous [redacted] and the **endodermis** forming the **cortex**,

(*c*) the **xylem** and the **phloem** in the stele an[redacted] cially the **cambium** which is here a more or less [redacted] ring.

Examine closely and carefully the cambiu[redacted] vascular bundles. The cells are all arranged in [redacted] and the cell walls are thin and consist mostly of [redacted]

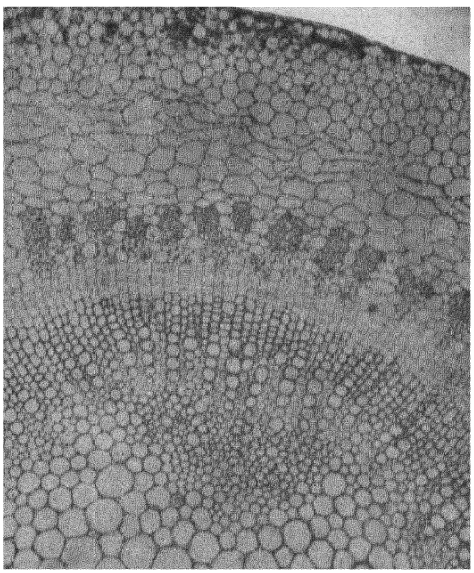
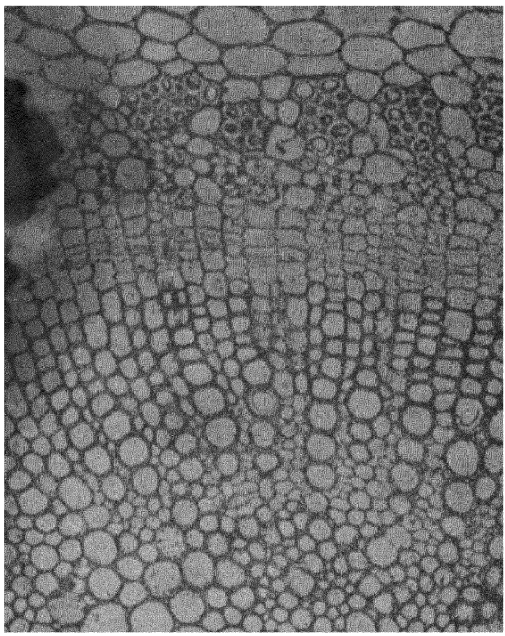


FIG. 14.—Microphotograph of a transverse section of the stem of *Hibiscus cannabinus* (Low power).

The tangential walls are the thinnest and therefore the more recent divisions have been in this direction and have been repeated. In the primary medullary rays some cells are seen radially arranged between the cambium of the bundles. This is interfascicular cambium which completes the ring.



Photograph of a transverse section of the stem of *Hibiscus cannabinus* (High power)

ARBOREOUS TYPE.

10. Take thin transverse sections of an young stem of *Thespesia populnea* and examine them after mounting them in glycerine or chlorzine iodine. Note :—

(*a*) the **epidermis** with cutinised walls and the scales which are scattered,

(*b*) the wide **cortex** consisting of a **collenchymatous** zone below the epidermis, thin-walled parenchyma and **mucilage cells**. The **endodermis** could be made out by the starch grains stained blue with the reagent,

(*c*) that the **stele** consists of the pith and the vascular ring surrounding it, and the **pericycle** is not well defined. Observe the secondary xylem, the secondary phloem and the medullary rays. Also note the small bands of **sclerenchyma** alternating with thin-walled phloem, and

(*d*) the **cork tissue** lying just below the epidermal ayer and the cork-cambium (**phellogen**).

11. Take transverse, longitudinal and radial sections of an older stem of *Thespesia* and observe the various tissues.

12 Cut radial sections of an old stem of *Thespesia*, or *Azadirachta indica* and note —

(*a*) the epidermis, (*b*) the cork cells, (*c*) the cortical cells with large mucilage canals or resin ducts and crystals, (*d*) the phloem consisting of alternate bands of thin-walled tissue and bast fibres, (*e*) the cambium, (*f*) the xylem, (*g*) the medullary rays, and (*h*) the pith.

13. Cut tangenital sections of the same stem first through the phloem and then through the xylem. In the first observe —

(*a*) the medullary rays, (*b*) the fibres disposed in irregular sinuous strands with their walls thick and lignified, and (*c*) the sieve tubes in eosin-stained sections

In the other section note (*a*) the medullary rays varying in height and consisting of one to three or more layers of cells, and (*b*) the elements of the xylem.

AQUATIC TYPE

14 Examine transverse sections of the stem of *Herpestis Monniera* and note —

(*a*) the distinct **epidermis**,

(*b*) the **cortex** consisting of a broad band of parenchyma with large intercellular spaces and the **endodermis** with the radial walls thickened in the middle which is characteristic, and

(*c*) the **stele** consisting of the **pericycle** which is ill-defined, the conspicuous **xylem** which is not very much strengthened by lignification, the **phloem** which has sieve tubes in groups and the not very active **cambium**.

15. Examine transverse sections of the stem of *Hygrophila spinosa* and note in what respects this differs from the stem of *Herpestis*.

STRUCTURE OF CORK AND LENTICEL

Cut transverse sections of the stem of *Jatropha*, *Azadirachta* or *Odina wodier* at different stages and note the formation of cork-cambium and lenticel.

STRUCTURE OF MONOCOTYLEDONOUS STEMS

1. Prepare a cross-section of a stem of *Andropogon Sorghum* or any [illegible] mount it in chlorzinc iodine. The

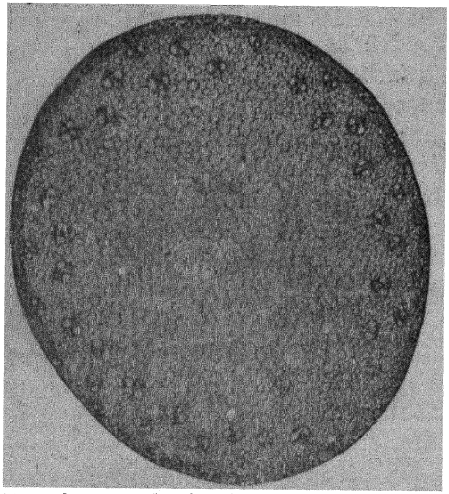


FIG. 16.—Microphotograph of a transverse section of the stem of *Andropogon Schoenanthus* Var. *caesius* (Low power).

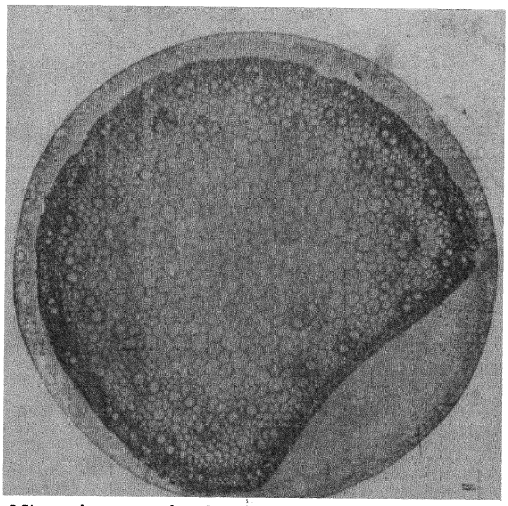


FIG. 17.—Microphotograph of a transverse section of the stem of *Panicum ramosum* (Low power).

various parts stand out clearly even to the naked eye by reason of the colouration. If the glass slide is placed on a white back ground or held against light, the vascular bundles are clearly seen. You will find them scattered irregularly, though they are more crowded together towards the periphery of the stem. Under a very low magnifying lens the parts can be made out more easily. The vascular bundles are found embedded in the **ground tissue (fundamental tissue).**

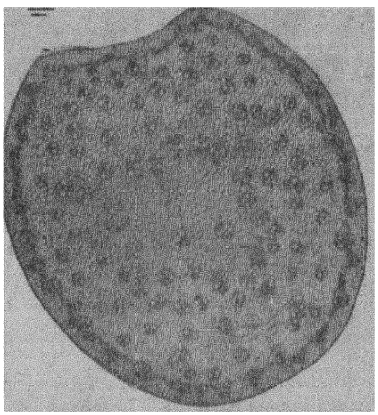


FIG. 18.—Microphotograph of a transverse section of the stem of *Pennisetum cenchroides* (Low power).

2. Examine transverse sections of the stem of *Andropogon Sorghum* and observe under a low power of the compound microscope :—

(*a*) the **epidermis** with thick-walled cells,

(*b*) the **cortex** made up of three or four layers of cells also thick-walled, and

(*c*) the ground tissue of thin-walled **parenchyma** with **vascular bundles** imbedded in them irregularly.

3. Note the various parts under a high power :—

(*a*) the thick-walled epidermal cells of varying sizes with a well developed **cuticle.**

(*b*) the thick-walled cells of the **cortex,**

(*c*) the parenchyma of the ground tissue, and

(*d*) the vascular bundle consisting of **xylem** represented by three or four large vessels arranged like a "V" with the angle towards the centre of the stem; of these the one or two smaller are developed first, and when there are two the outer one is an **annular** and the inner is a **spiral** vessel.

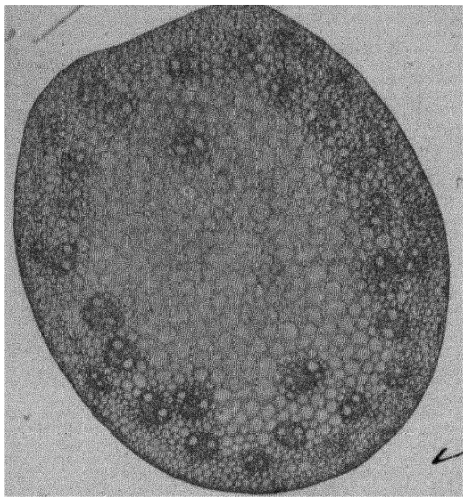


FIG. 19.—Microphotograph of a transverse section of the stem of *Andropogon pertusus*. (Low power).

The remaining two larger ones are **pitted** vessels. The **phloem** consists of sieve tubes and companion cells and may be recognized by the thin cellulose walls. Both the xylem and the phloem are surrounded by a sheath of **sclerenchyma.**

STRUCTURE OF THE LEAF.

1. Examine transverse sections of the petiole of *Helianthus* or any other plant. The general structure resembles that of an young stem; but it differs in the following respects:—

(*a*) the outline is somewhat semilunar, dorsiventrally and not radially symmetrical;

(*b*) the arrangement of the **vascular bundles** is in a **curve**: there are three large bundles and four or five or more smaller ones;

(*c*) the **cambium** of the vascular bundle is not very active and no **interfascicular cambium** is present.

2. Cut sections of the lamina of the same or any other plant and observe :—

(*a*) the upper epidermis and the **cutin** layer,

(*b*) the **palisade parenchyma**,

(*c*) the **spongy parenchyma**,

(*d*) the lower epidermis, and

(*e*) the vascular bundles with the xylem towards the upper and the phloem towards the lower surface.

3. Take a piece of the lamina from a bleached leaf of *Dolichos Lablab* or any other plant and examine it under a low power. Note —

(*a*) the midrib,

(*b*) the lateral veins, and

(*c*) the finer veins of the net-work and their ends.

4. Examine pieces of the epidermis both from above and below of any leaf blade and note the epidermal cells and the **stomata** with their **guard-cells**.

INFLORESCENCE

Study the arrangement of flowers on the floral axis in the following examples —

A. **Racemose, Centripetal** or **Indefinite.**

Racemose. *Crotalaria verrucosa* or *C. juncea.*

Spike. *Achyranthes aspera, Digera arvensis.*

Corymb. *Caesalpinia pulcherrima* and *Cassia sumatrana.*

Umbel. *Calotropis gigantea*

Head. *Tridax procumbens, Helianthus annuus,*

B. **Cymose, Centrifugal** or **Definite.**

Dichotomous type or **Dichasium.** *Nerium odorum Ipomoea carnea, Thevetia neriifolia.*

Monochasium.

Helicoid cyme. *Hamelia patens.*

Scorpioid cyme. *Heliotropium indicum.*

Verticillaster. *Leucas aspera* or *L. linifolia.*

STRUCTURE OF THE FLOWER.

Examine the flowers of *Tribulus terrestris, Dolichos Lablab, Crotalaria verrucosa* or *C. Juncea, Ipomoea sepiaria*

or any other species, *Coccinea indica*, *Achyranthes aspera* and *Crinum asiaticum*

1. *Tribulus terrestris* :—The flowers arise singly from the axils of leaves. The parts of the flower are inserted upon the somewhat enlarged apex of the pedicel or the **floral receptacle**, also called **torus, thalamus.**

Observed that .—

(*a*) the flower is **bisexual** or **hermaphrodite,**

(*b*) the **calyx** consists of five green narrow free **sepals** inserted below the other organs,

(*c*) the **corolla** has five yellow free **petals** alternating with the sepals,

(*d*) the **androeceum** consists of ten stamens which are free and in two whorls ; the stamens of the outer whorl are shorter and alternate with the petals and those of the inner whorl are longer and alternate with the sepals,

(*e*) there are five glands connected with the five shorter stamens,

(*f*) the gynoeceum at the centre of the flower consisting of five carpels united together (**syncarpous ovary**) is inserted on the receptacle above the other floral organs and hence **superior** and that the style is very short not distinct and with five stigmas note that in the small leaved forms the style is distinct,

(*g*) the five cavities of the ovary have numerous superposed **ovules** on axile placentas,

(*h*) the flower is **actinomorphic** or radially **symmetrical.**

2. *Dolichos Lablab* (or *Crotalaria juncea* or C. *verrucosa*).—The flowers of *Dolichos Lablab* are clustered together so as to form a compound raceme, and the pedicels spring from the axils of bracts and there are also two bracteoles placed laterally. In *Crotalaria* the flowers are in racemes, and the bracts and bracteoles are small.

Note that :—

(*a*) the **calyx** is cupular with five teeth and green in colour,

(*b*) the **corolla** has five free petals, one large and posterior (**vexillum** or standard) two lateral (**alae** or **wings**)

and two anterior cohering together to from the **keel** or **carina**; the colour of the petals in Dolichos is white or pinkish, in *Crotalaria juncea* yellow, and in *C. verrucosa* blue,

(*c*) the **androeceum** consists of ten stamens, nine united and one free (diadelphous) in *Dolichos Lablab*, but in *Crotalaria* the stamens are in one bundle (monadelphous) and the anthers are of two forms (dimorphous) alternately short and long,

(*d*) the superior **gynoeceum** has only one carpel and it consists of a long **style**, a **stigma** and an **ovary**. Note the very small ring or **annular disk** at the base of the ovary which secretes honey and this collects at the base of the staminal tube. In the flowers of *Sesbania grandiflora*, the annular disk is very prominent and it secretes honey in abundance. When the flower is open the cavity formed at the base of the androeceum will be full of nectar,

(*e*) the **ovules** on the ventral suture.

3. **Ipomoea**.—The flowers are in cymes and they are bisexual.

Observe that :—

(*a*) the **calyx** consists of five, free, quincuncially imbricating sepals,

(*b*) the **corolla** is monopetalous, tunnel or bell-shaped and five lobed,

(*c*) there are five epipetalous **stamens**, with long filaments and large linear anthers,

(*d*) the **gynoeceum** consists of a two or four-celled ovary with two or one ovule respectively, a long style and a bi-globose **stigma**.

4. *Coccinea indica*.—The plant bears either male flowers or female flowers only on the same plant and hence it is **dioecious**. Flowers are solitary and axillary.

Observe that :—

(*a*) the **calyx** is small, bell-shaped, green and five toothed in both male and female flowers.

(*b*) the **corolla** is white, campanulate and five-lobed in both staminate and pistillate flowers.

(*c*) the **stamens** in the male flower are three, the anthers of two stamens are complete but that of one is half and they

are all united, and that the anther lobes are long and sinuously folded.

(*d*) that the **ovary** in the female flower is **inferior** narrowly fusiform, one-celled with three **parietal placentas** bearing ovules.

5. *Achyranthes aspera.*—The flowers are small and are in long spikes at the ends of branches.

Observe that :—

(*a*) the flowers are deflexed and crowded,

(*b*) the **bract** and the two **bracteoles** are spinescent and persistent,

(*c*) five lanceolate or ovate oblong glabrous perianth lobes green or reddish at the edges with spinescent apex,

(*d*) five **stamens** and the five alternating truncate fimbriate staminodes,

(*e*) the **gynoeceum** in the centre of the flower consists of an ovary with membranous pericarp and a short **style** terminating in a stigma.

6. *Crinum asiaticum* —The flowers are large, showy and are umbellate on a stout scape.

Observe .—

(1) the long bract,

(2) the tubular white perianth with six linear lobes,

(3) the six stamens with versatile anthers, and

(4) the inferior ovary, three celled and with many ovules in each cell.

STUDY OF THE PARTS OF THE FLOWER.

1. Examine the **bract** and the **bracteoles** in the flowers of *Crotalaria juncea*, *C. verrucosa*, *Cassia auriculata* and *Hibiscus rosa-sinensis*.

2. Study the **calyx** in a number of flowers. It consists of sepals. Note the nature of the calyx in the following :—

(1) it is **polysepalous** in *Ipomoea carnea*, *Tribulus terrestris* and in *Cleome viscosa*,

(2) **gamosepalous** in *Datura fastuosa* and *Thespesia populnea*,

(3) the sepals are **caducous** in *Argemone mexicana*,

(4) **persistent** in *Ocimum canum*, and

(5) **accrescent** in *Withania somnifera* and *Physalis minima*,

(6) The sepals are **petaloid** in *Cassia auriculata* and *Caesalpinia pulcherrima*.

3. The **corolla** consists of **petals** and variations occurring in the corolla must be noted by examining a number of flowers.

Note that it is :—

(1) **polypetalous** and **deciduous** in *Tribulus terrestris*, *Gynandropsis pentaphylla* and *Cleome viscosa*,

(2) **papilionaceous** in *Crotalaria juncea*, *Sesbania grandiflora* and *Alysicarpus monilifer*,

(3) **gamopetalous** and **funnel-shaped** in *Datura fastuosa* and *Ipomoea separia* or *I. carnea*,

(4) **tubular** in *Tecoma stans* and *Ruellia prostrata*,

(5) **rotate** or **wheel-shaped** in *Solanum xanthocarpum*,

(6) **salver-shaped** in *Vinca rosea*, and

(7) **ligulate** in *Helianthus annuus* and *Tridax procumbens*.

4. Note the folding of the petals and sepals on their edges in the following :

(1) **contorted** in *Thespesia populnea*,

(2) **imbricate** in *Cassia auriculata* and *Tecoma stans*,

(3) **valvate** in *Calotropis gigantea*,

(4) **quincuncial** in the sepals of *Ipomoea carnea* and *Cassia auriculata*

5. Examine the stamens noting their number, insertion and union of parts. They are —

(1) **indefinite** and **free** in *Argemone mexicana*,

(2) **monadelphous** in *Crotalaria verrucosa* and in *Azadirachta indica*,

(3) **diadelphous** in *Sesbania grandiflora*,

(4) **didynamous** in *Tecoma stans*,

(5) **epipetalous** in *Datura fastuosa* and *Ipomoea separia*,

(6) **gynandrous** in *Aristolochia bracteata*, or other species, and

(7) **syngenesious** (anthers) in *Tridax procumbens* and *Helianthus annuus*.

6. Note the mode and the direction (with regard to the centre of the flower) of the **dehiscence** of **anthers** in the following flowers :—

(1) *Helianthus annuus*—**introrse** dehiscence,

(2) *Argemone mexicana*—**extrorse** dehiscence,

(3) *Berberis tinctoria*—dehiscence by recurved valves (**valvular dehiscence**), and

(4) *Cassia auriculata* and *Solanum xanthocarpum*—dehiscence by **apical pores.**

7. Observe the mode of attachment of the anthers to the filament in some flowers.

The attachment is :—

(1) **adnate** in *Cassia auriculata*,

(2) **basifixed** in *Datura fastuosa*, and

(3) **versatile** in *Crinum asiaticum*.

8. Note the outgrowths called **corona** in :—

(1) the corollas of *Nerium odorum*, *Wrightia tinctoria* and *Passion flower* (**corolline** corona).

(2) the stamens of *Calotropis gigantea* and *Nerium odorum* (**staminal corona**).

9. Examine the gynoecium noting its parts in *Datura stramonium*, *Solanum xanthocarpum*, *Hibiscus micranthus*, *Crotalaria juncea* or *C. verrucosa*, *Argemone mexicana*, *Terminalia catappa* or *Quisqualis indica* and *Portulaca oleracea*.

10. Note the position of the ovary in flowers.

It is :—

(1) **superior** in *Argemone mexicana*,

(2) **inferior** in *Coccinea indica*, *Citrullus Colocynthis* and *Aristolochia bracteata*, and

(3) **half-inferior** in *Punica granatum*.

11. Cut the ovaries of the following and note the parts and the attachment of the ovules :—

(1) *Argemone mexicana*, *Ionidium suffruticosum*.

(2) *Aristolochia bracteata* and *Abutilon indicum*,

(3) *Crotalaria verrucosa*,

(4) *Datura fastuosa* and *Solanum xanthocarpum*.

12. Examine transverse sections of the anthers of *Datura* in different stages and note :—

(1) the anther-wall,

(2) the loculi, and
(3) the pollen grains.

13. Examine under the microscope the pollen grains of different flowers, e.g., those of *Tribulus terrestris*, *Cucurbita maxima*, *Thespesia populnea*, *Tridax procumbens* and the pollinia in the flowers of *Calotropis gigantia*.

14. Note the germination of pollen grains on the stigma in *Tridax procumbens* and in the grass *Cynodon dactylon*.

The germination of the pollen grains and formation of the pollen tubes may be observed by keeping pollen grains in a watch-glass in a solution of cane-sugar or cane-sugar and gelatine (5 to 10 per cent solution). They may also be mounted in one hanging drop and be kept in a moist chamber. For success the sugar solution should be made in spring water and 1·5 per cent of gelatine should be added. The pollen of many of our common flowers germinates readily in the solution, but the strength necessary must be previously determined for each. The strength may vary from 3 per cent to 20 per cent or more.

STRUCTURE OF THE OVARY.

1. **Simple ovary**—Any species of *Crotalaria*. Note the wall or the **pericarp** enclosing a single cavity and the two sutures, the one having the ovules is the **ventral suture** and the other the **dorsal suture**. In this case the ovary consists of a single carpel only and so this is a **monocarpellary** ovary.

2. **Compound ovary**—*Thespesia populnea*. Cut the ovary across and note that it has three to five cavities. Each cavity corresponds to a carpel. This is a **polycarpellary** ovary.

3. **Axile placentation**—*Thespesia populnea*. The ovules are arranged round a central axis.

4. **Parietal placentation**—*Argemone mexicana*, *Carica papaya*. In these there is only one cavity and the ovules are attached to the wall of the ovary in four or five places in rows.

5. **Free central placentation**—*Portulaca oleracea*. The ovary has a single cavity and the ovules are attached to a central axis.

6. Sometimes the ovary is compound but has only a single cavity and a single terminal ovule inside, e.g., *Antigonon*.

STRUCTURE OF THE OVULE.

1. Cut transverse sections of the ovaries of any lily,—*Torrenia asiatica*, *Gossypium herbaceum*, *Stemodia viscosa*

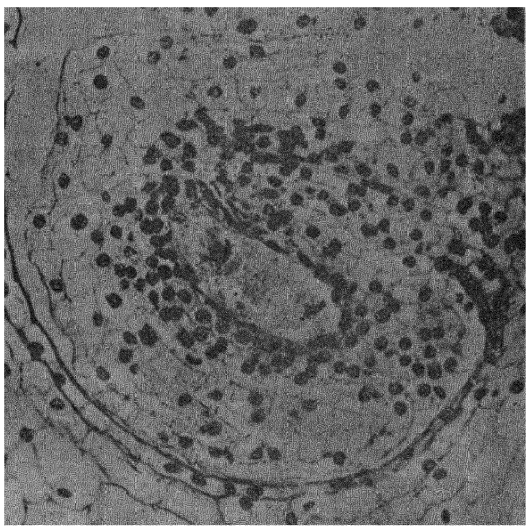


FIG. 20.—Microphotograph of a longitudinal section of the ovule of a lily showing the division of the nucleus in the embryo sac. From a section prepared by Dr. Sampathkumaran (High power).

or *Ionidium suffruticosum*. Note the cavities, pericarp, the placentas and the attachment of the ovules to the placenta. Detach the ovules and observe that they are all attached to the placenta by means of their stalks or **funicles**.

2. Detach a number of ovules by teasing from the ovaries of *Torrenia asiatica* without causing any injury and mount some in a 3 per cent solution of sugar and others in methyl green acidulated with acetic acid, iodine or other stains,

The ovules though very small show the embryo-sac and its contents very well.

Note in the ovules :—

(1) the long **funicle** or the stalk arising from the placenta and ending at the base (**chalazā**) of the inverted ovule; the united portion of the stalk is called **raph**

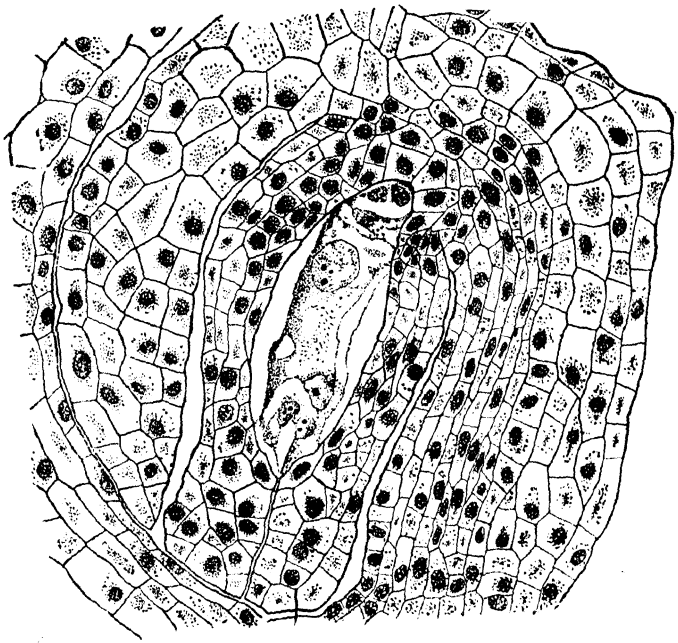


FIG. 21.—Longitudinal section of an ovule of Lily showing the embryo-sac containing the egg-cell, synergids vegetative nucleus and the antipodial cells (High power)

(2) the single integument starting from the chalaza and ending at the apex of the ovule in a fine canal, the **micropyle.**

(3) the **embryo-sac** of which the upper portion protrudes beyond the micropyle and is swollen : the portion of the embroy-sac enclosed by the integument is narrow and slightly swollen and spindle shaped at the base.

(4) note the **antipodal cells** at the base and the **egg-cell** and the **synergids** at the top in the protruding part of the sac.

3. Tease out ovules of *Stemodia viscosa* and note the funicle, integuments, micropyle, the embryo-sac, antipodal cells, egg-cells and the synergids.

4. Cut transverse sections of the ovaries of *Ionidium suffruticosum* and cotton and select sections which have passed through the middle of the ovule.

Observe in the ovules :—

(1) the funicle, chalaza, raphe and the integuments.

(2) the mass of cells lying between the integuments and the embryo-sac, called the **nucellus**, and

(3) the embryo-sac containing the egg-cell, synergids and the antipodal cells.

SYMMETRY OF FLOWERS.

1. Study the insertion and arrangement of the parts of the flower in *Tribulus terrestris* and make a diagram. The plane of symmetry is said to be **radial** or **actinomorphic.**

2. Note the arrangement of parts and the plane of symmetry in *Crotalaria verrucosa*, *Vigna Catiang* or *Dolichos Lablab*—**bilateral** or **zygomorphic** symmetry.

3. Examine the flower buds of *Cassia*, *Caesalpinia* and *Crotalaria* as regards the folding of the sepals and petals and draw diagrams showing the relative position of the floral parts.

4. Examine the parts of the flowers given and draw floral diagrams :—Any species of *Tecoma*, *Abutilon* or *Pavonia* and *Ipomoea*.

UNISEXUAL AND INCOMPLETE FLOWERS.

1. As examples of unisexual flowers study the flowers of *Euphorbia*, *Coccinea* and *Cucumis*.

2. Examine the flowers of *Achyranthes*, *Digera* and *Amarantus* as examples of incomplete flowers.

STUDY OF THE MORPHOLOGY OF THE FRUIT.

1. **Legume.**—Examine the fruits of *Sesbania*, *Poinciana*, and *Clitoria* or any other leguminous plant and note the two sutures and the mode of dehiscence.

2. **Follicle.**—As examples study the fruits of *Calotropis gigantea* and *Sterculia guttata*. The fruits open through one suture only.

3 **Capsule.**—(*a*) *Hibiscus ficulneus*. The dehiscence takes place in the middle of the carpel so as to expose the cavities (**loculicidal dehiscence**).

(*b*) *Aristolochia*. In this case the carpels separate by dehiscence through the septa (**septicidal** dehiscence).

(*c*) *Datura*. The pericarp breaks away from the septa leaving them as a column in the centre (**septifragal** dehiscence).

4. **Schizocarp.**—*Abutilon*. *Ricinus*. *Tribulus*. The fruits break into separate parts called **cocci**, and each coccus may contain one or more seeds.

5. **Pyxis**—*Portulaca oleracea*. The fruit opens transversely by means of a cap-like lid

6. **Achene.**—*Carthamus tinctorius*. *Tridax procumbens*. The fruit contains a single seed almost filling the cavity and the pericarp is leathery and does not fuse with the seed-coat.

7. **Caryopsis.**— *Oryza* (paddy). The grain is a fruit enclosed by the bracts (**glumes**); and the pericarp and the seed-coats have fused into one coat.

8. **Berry.**—*Solanum*. The pericarp is fleshy throughout and numerous seeds are imbedded in it. As further examples study the fruits of Guava, Tomato, *Cephalandra* and *Citrus*.

9. **Drupe.**—*Calophyllum Inophyllum*. *Thevetia neriifolia*. The pericarp is fleshy outside and stony and hard inside. As another example examine the coconut. The pericarp in this case is fibrous outside and stony inside.

10. **Samara (winged fruit).**—As examples study the following fruits noting especially the morphology of the parts adapted for dispersal :—

1. *Pterolobium indicum*.
2. *Hardwickia binata*.
3. *Ailanthus excelsa*.
4. *Holoptelea integrifolia*.
5. *Combretum ovalifolium*.
6. *Gyrocarpus Jacquini*.

11. **Spiny fruits.**—*Tribulus terrestris*

12. **Hooked fruits.**—*Triumfetta pilosa, Pupalia atropurpurea, Tragus racemosus.*

Study the morphology of the hooks in these fruits.

13. **Aggregate fruit.**—*Polyalthia longifolia.* The fruits are one-seeded berries and are developed from a single polycarpellary ovary whose carpels have become free in fruit. As another example examine the fruit of *Michelia.*

14. **Syncarpous fruit**—*Anona squamosa.* The carpels are fleshy and are fused together in one mass forming a berry.

15. **Collective or multiple fruits.**—As examples study the jack fruit (*Artocarpus integrifolia*) and the pine-apple (*Ananas sativus*). In the former the male and female flowers are on different spikes. The succulent edible portion is the perianth and the membranous covering over the seed is the pericarp In *Ananas* the flowers are bisexual and the lower portions of these flowers become fleshy together with the axis.

The fruits of the banyan and the fig are also collective fruits (**syconium**) the cup-like wall being really the axis of the inflorescence hollowed out.

16. **False fruit**—Cashew-nut (*Anacardium occidentale*). The flower stalk becomes fleshy in this case and bears the fruit at the top.

STUDY OF SEEDS.

1. Note the variation in colour and size of the seeds of *Mucuna monosperma, Canavalia ensiformis, Pongamia glabra, Strychnos nux-vomica, Tamarindus indica, Adenanthera pavonina, Mimusops Elengi, Phœnix sylvestris, Thespesia populnea, Abrus precatorius, Balsamodendron Berryi, Abrus precatorius (pink seeds), Canna indica, Albizzia Lebbek, Cucurbita maxima, Cissampelos Pareira, Ipomœa sepiaria, Azima tetracantha, Vernonia cinerea, Cassia auriculata, Mukia scabrella, Pavonia glechomifolia, Calotropis gigantea, Commelina benghalensis, Solanum nigrum, Cleome viscosa, Nerium odorum, Crotalaria verrucosa, Achras Sapota, Tecoma stans, Barleria pilosa, Polygonum indicum var. plebejum, Cardiospermum Halicacabum,*

Argemone mexicana, Hibiscus micranthus, Euphorbia hirta, Aristolochia indica or bracteata, Ricinus communis, Oroxylum indicum, Chenopodium ambrosioides, Amarantus viridis.

2. As examples of seeds adapted for disperal study the following :—

(*a*) **Fleshy seeds**—*Punica granatum, Lycopersicum esculentum.*

(*b*) **Winged seeds**—*Tecoma, Oroxylum indicum, Dolichandrone, Cedrela Toona.*

(*c*) **Comose seeds**—*Calotropis gigantea, Alstonia scholaris, Nerium odorum, Anodendron paniculatum.*

(*d*) **Hairy seeds**—*Hibiscus micranthus, Eriodendron anfractuosum.*

3. **Aril**—This is an extra fleshy or membranous outgrowth covering the seed either partially or wholly and arises from near the micropyle. It is known as **carunele** in *Ricinus* and **strophiole** in *Polygala*. It forms a fleshy covering in *Pithecolobium dulce* and in *Myristica* it appears as a coarse net-work (**mace**).

4. Note the **ruminate endosperm** in the seeds of *Anona, Polyalthia* and *Myristica*.

5. Note the variation in the cotyledons in the seeds of *Hopea, Vateria* and *Artocarpus*.

STUDY OF FAMILIES.

The following families may be studied taking as examples the plants mentioned under each family. They should be described in detail, sketches being made wherever necessary :—

1. Anonaceae—	*Anona squamosa.*
	Polyalthia longifolia.
2. Nymphæaceae—	*Nelumbium speciosum.*
	Nymphæa pubescens.
3. Cruciferae—	*Brassica juncea.*
	Raphanus sativus.
4. Capparideae—	*Cleome viscosa.*
	Gynandropsis pentaphylla.

	Capparis horrida or any other species.
	Cadaba indica.
5. Violaceae—	*Ionidium suffruticosum.*
6. Polygalaceae—	*Polygala chinensis* or any other species available.
7. Portulacaceae—	*Portulaca oleracea.*
8. Malvaceae—	*Hibiscus vitifolius.*
	Pavonia zeylanica.
	Sida veronicæfolia or any other species.
	Abutilon indicum.
9. Sterculiaceae—	*Melochia corchorifolia.*
	Guazuma tomentosa.
10. Tiliaceae—	*Corchorus acutangulus* or any other species.
11. Linaceae—	*Linum usitatissimum.*
	Hugonia Mystax.
12. Geraniaceae—	*Oxalis corniculata.*
	Impatiens any species available.
13. Rutaceae—	*Murraya exotica.*
	Citrus aurantium.
14. Meliaceae—	*Azadirachta indica.*
	Melia Azadirachta.
15. Rhamneae—	*Zizyphus Jujuba* or any other species.
16. Vitaceae—	*Cissus quadrangularis.*
17. Sapindaceæ—	*Sapindus trifoliatus.*
	Cardiospermum Halicacabum.
	Dodonaea viscosa.
18. Anacardiaceæ—	*Mangifera indica.*
	Odina wodier.
	Buchanania latifolia or *B. angustifolia.*
19. Leguminosae—	
i. Papilionaceæ—	*Crotalaria verrucosa* or any other species.
	Tephrosia purpurea or *T. villosa*
	Clitoria Ternatea.

	ii. Caesalpineae—	*Caesalpinia pulcherrima.*
		Cassia auriculata or any other species.
		Tamarindus indica.
	iii. Mimoseae—	*Acacia arabica.*
		Dichrostachys cinerea.
		Neptunia oleracea.
		Albizzia amara.
		Pithecolobium dulce.
20.	Combretaceae—	*Terminalia* any species.
		Quisqualis indica.
21.	Myrtaceae—	*Psidium Guyava.*
		Syzygium Jambolanum.
22.	Cucurbitaceae—	*Cucumis pubescens.*
		Citrullus Colocynthis.
		Coccinea indica
23.	Aizoaceae—	*Trianthema Portulacastrum* or any other species.
24.	Umbelliferae—	*Centella asiatica.*
		Coriandrum sativum.
25.	Rubiaceae—	*Morinda tinctoria.*
		Oldenlandia any species.
		Spermacoce hispida
26.	Compositae—	*Vernonia cinerea.*
		Blumea wightiana or any species.
		Tridax procumbens.
		Vicoa auriculata.
27.	Sapotaceae—	*Bassia longifolia.*
		Mimusops Elengi.
28.	Apocynaceae—	*Vinca pusilla* or *rosea.*
		Nerium odorum.
		Wrightia tinctoria
29.	Asclepiadaceae—	*Calotropis gigantea.*
		Daemia extensa.
		Leptadenia reticulata.
		Pergularia minor.
30.	Boraginaceae—	*Trichodesma indicum.*
		Heliotropium ovalifolium or any species.

31. Convolvulaceae— *Ipomoea sepiaria.*
Evolvulus alsinoides.
Lettsomia elliptica
32. Solanaceae— *Solanum xanthocarpum.*
Solanum nigrum.
Capsicum annuum
33. Scrophularineae— *Stemodia viscosa.*
Herpestis Monniera.
Bonnaya veronicaefolia.
34. Pedalinaceae— *Pedalium Murex.*
Sesamum indicum or *S. prostratum.*
35. Acanthaceae— *Ruellia prostrata.*
Rungia repens.
Hygrophila spinosa.
36. Labiatae— *Leucas aspera.*
Anisomeles malabarica.
Ocimum canum or *O. sanctum.*
37. Amarantaceae— *Achyranthes aspera.*
Amarantus viridis or *A. spinosus*
Celosia argentea
38. Euphorbiaceae— *Euphorbia hirta.*
Phyllanthus maderaspatensis.
Acalypha indica.
39. Urticaceae— *Artocarpus integrifolia*
Ficus benghalensis or any other species.
40. Orchideae— *Eulophia virens.*
Vanda Roxburghii.
Habenaria viridiflora or *H. platyphylla.*
41. Scitamineae— *Musa paradisiaca.*
Zingiber officinalis.
Canna indica or any other species.
42 Amaryllideae— *Crinum asiaticum.*
43 Liliaceae— *Allium sativum.*
A. cepa.
Gloriosa superba.
44. Commelinaceae— *Commelina benghalensis.*

	Cyanotis axillaris or *C. cucullata.*
	Aneilema any species.
45. Palmeae—	*Cocos nucifera.*
	Borassus flabellifer.
46. Aroideae—	*Colocasia antiquorum.*
	Amorphophallus campanulatus.
47. Cyperaceae—	*Cyperus rotundus* or *C bulbosus.*
	Fimbristylis miliacea or any species.
48. Gramineae—	*Panicum javanicum* or *P. ramosum.*
	Cynodon dactylon.
	Eleusine aegyptiaca.
	Andropogon pumilus.
	Chloris barbata.

SECTION II.—PHYSIOLOGY.

WATER AND SAND CULTURE.

1. **Water culture.**—Take nine uniform glass jars of about two litres capacity each, and clean them carefully with nitric acid and water and again with a strong solution of mercuric chloride. Wash thoroughly with tap water and finally with distilled water, preferably boiled water. Fit each jar with a cork or wooden cover having one hole in the middle and a slit running to the edge, and also provided with another hole through which passes a long bent glass tube. Select a seedling of *Dolichos Lablab* or any other plant of about two or three inches height which has been growing in saw dust for a few days, clean the roots of saw dust and wipe off the moisture at the collar. Insert the seedling through the slit of the cover and fix it by means of dry sterilized cotton wool, or dry asbestos passed through the flame of a spirit lamp. Fill the jar with one of the solutions prepared according to the formulas given below and keep the cover at the top so as to immerse the roots, but without damping the cover or the wool. In the case of seedlings with hypogeal cotyledons the reserve material should not be allowed to dip in water but must be sufficiently above it. Aerate the jar by means of the aspirator and the bent glass tube and leave it in a large wooden box, or cover the jar with a dark paper so as to shut off the light.

Watch the progress of the plants every day and compare their behaviour in the several solutions. Aerate the jars every day once or twice for about fifteen minutes each time, without much disturbance to the roots. At the end of every week change the plants to pure distilled water for a day and then to fresh culture solutions of the respective formulæ. The experiment is to last for six weeks and must be watched with proper care.

Test the solution in the culture jars occasionally and, if you find it alkaline, correct it by adding a little of 5 per cent

phosphoric acid. If the solution decreases due to evaporation make it up by adding distilled water.

Normal Solution (Crone).

Potassium nitrate	1·0 gm.
Ferrous phosphate	·5 „
Calcium sulphate	·25 „
Magnesium sulphate	·25 „
Distilled water	1 to 2 lit.

Minus Calcium.

Potassium nitrate	1·0 gm.
Ferrous phosphate	·5 „
Magnesium sulphate	·5 „
Distilled water	1 to 2 lit.

Minus Potassium.

Calcium nitrate	1·0 gm.
Ferrous phosphate	·5 „
Calcium sulphate	·25 „
Magnesium sulphate	·25 „
Distilled water	1 to 2 lit.

Minus Phosphates.

Potassium nitrate	1·0 gm.
Ferric chloride	1 or 2 drops of a watery solution.
Calcium sulphate	·25 gm.
Magnesium sulphate	·25 „
Distilled water	1 to 2 lit.

Minus Sulphur.

Potassium nitrate	1·0 gm.
Ferrous phosphate	·5 „
Calcium phosphate	·25 „
Magnesium carbonate	·25 „
Distilled water.	1 to 2 lit.

Minus Magnesium.

Potassium nitrate	1·0 gm.
Ferrous phosphate	·5 „
Calcium sulphate	·5 „
Distilled water	1 to 2 lit.

Minus Nitrates.

Potassium chloride	1·0 gm.
Ferrous phosphate	·5 „
Calcium sulphate	·25 „
Magnesium sulphate	·25 „
Distilled water	1 to 2 lit.

Minus Iron.

Potassium nitrate	1·0 gm.
Calcium phosphate	·5 „
Calcium sulphate	·25 „
Magnesium sulphate	·25 „
Distilled water	1 to 2 lit.

2. **Sand culture.**—Obtain sand called silver sand or prepare it by pounding pure quartz crystals (Silica, SiO_2). Clean the sand well by washing it several times with dilute sulphuric acid or hydrochloric acid, and then rinse it repeatedly with tap water and finally with distilled water. Prepare three small new flower pots for sowing by filling them with sand cleaned as above. Sow soaked seeds of *Dolichos Lablab* in these pots and water them with distilled water only for about a week, and afterwards water, one pot with Crone's normal solution, another with solution without nitrate. Add a small quantity of [redacted] third and water it with distilled water or solution. For control, sow some seeds in two pots containing ordinary garden soil. Water [redacted] with distilled and tap water respectively.

Watch the progress of the plants daily for about a month.

3. Mix with prepared and cleaned sand an ounce or two of garden soil and fill one pot with this mixture of sand and earth and another with sterile (burnt) sand only. Sow *Dolichos* or other plant in both these pots and water them with culture solution lacking in nitrates. The plant growing in the first pot will grow well and that in sterile sand only not so well. Bacterial nodules will be present in the first and not in the second.

THE WATER CONTENT OF PLANTS AND ASH ANALYSIS.

1. Cut into convenient pieces the plant or its parts you wish to use. Weigh the pieces putting them in a porcelain basin in the fresh state at first, and later again after the material is completely dry. The difference represents the amount of water present. The percentage of water present is very high in succulent plants. For example, in aloe it was 94·6, agave 83·45, euphorbia 86·5 and opuntia 88·5. In the case of woody or wiry plants the amount of water may be as low as 40 to 50 per cent.

2. The dry matter left over consists of organic matter composed of carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus and ash containing mineral matter. The presence of C, H, N may be demonstrated as shown below—

(*a*) Heat in a strong test-tube or a small porcelain basin a bit of the oven-dried dry wood or leaves for some time and it chars thus showing the presence of **carbon.** Or heat some dry leaves or pieces of twigs with copper oxide and pass the gas evolved through lime water, and it becomes milky thereby showing the presence of carbon dioxide containing **carbon,**

(*b*) If some dry leaves or small chips of twigs with copper oxide are heated in a test-tube moisture condenses on the cool sides of the test-tube. From this we infer the presence of **hydrogen.**

(*c*) In a test-tube or crucible heat some dry leaves with soda lime, and ammonia gas is given off, thus showing the presence of **nitrogen.**

3. **Ash analysis.**—The elements to be tested for in the analysis of the ash of plants are calcium, potassium, magnesium, phosphorus and sulphur. Put in a flask some quantity of ash, moisten it with a small quantity of nitric acid and then add hydrochloric acid and digest it for half an hour or so in a water or sand bath. Filter this liquid. If there is any residue on the filter paper it is **silica.**

(*a*) Take a small quantity of the filtrate in a test-tube and add to it barium chloride solution. A white precipitate (barium sulphate) is formed. This indicates the presence of **sulphur.**

(*b*) To a small portion of the filtrate contained in a strong test-tube add strong nitric acid and then two or three times its bulk of ammonium molybdate and heat it. A yellow precipitate is formed and this indicates the presence of **phosphorus.**

(*c*) On adding to the filtrate ammonium chloride, ammonia and ammonium oxalate a white precipitate is formed. This shows the presence of **calcium.**

(*d*) Filter the above liquid and to the filtrate add sodium phosphate and leave it for a while after shaking ; a white precipitate occurs showing the presence of **magnesium.**

(*e*) The presence of **sodium** is inferred from the yellow flame observed when a clean platinum wire dipped in hydrochloric acid and the ash is held over a colourless flame.

(*f*) On looking through a blue or cobalt glass the yellow flame, the flame appears reddish violet and this shows the presence of **potassium.**

(*g*) To the filtrate add potassium ferrocyanide and a dark blue precipitate appears. This indicates the presence of **iron.**

PHOTOSYNTHESIS.

1. **Chlorophyll.**—Gather some leaves of *Dolichos Lablab* or any other plant and boil them in water for a minute or two. Then place the leaves in a loosely stoppered sample tube containing about 20 c.c. of alcohol and keep the tube in a water bath at 60 or 70° C, until the leaves are fully bleached. Instead of boiling the leaves, they may be left in alcohol for several hours or a day. The alcohol abstracts the green colour from the leaves.

(*a*) Pour into a clear test-tube some quantity of this green extract of chlorophyll, and examine it in both transmitted and reflected light. The extract will appear bright green by transmitted light and red in reflected light. If the test-tube containing the extract of chlorophyll is placed against a black back-ground and the light concentrated on the test-tube by means of a biconvex lens the red colour becomes very conspicuous.

(*b*) Pour into each of the three test-tubes marked A, B and C some quantity of the alcoholic extract of chlorophyll,

and expose A to direct sunlight, B to diffuse light and keep C in darkness. Note the effect of strong sunlight, diffuse daylight and of darkness on the colour of the extract. The solution turns brown very soon in A and slowly in B and in C it undergoes no change.

(*c*) Take in a test-tube a quantity of chlorophyll extract and add a few drops of distilled water to it ; then add a little benzol ; shake it and allow it to settle. The benzol being lighter floats above the alcohol and it will be bright greenish blue, while the alcohol will be yellow.

2. Examine the chlorophyll extract contained in a test-tube or in a flat parallel-sided bottle through a spectroscope. A dark band will be seen in the red end of the spectrum.

If a spectroscope is not available, secure an optical lantern and to its lens fasten a card with a vertical slit and obtain a continuous spectrum on the screen by using a prism. By interposing between the slit and the prism a test tube containing the chlorophyll extract, the dark bands can be seen in the spectrum, especially at the red end.

3. **Presence of starch in leaves.**—Pick leaves from two or three different plants which have been exposed to light for a sufficiently long time. Bleach them in the usual way, and steep them in water until they soften. Then place them in an aqueous solution of iodine. If the leaves contain starch they turn blue or almost black. By the use of benzol iodine may be removed from the cell-wall and the protoplasm without affecting the starch grains. Then the blue colour shows up very well.

4. **Disappearance of starch from green tissue in darkness.**—Place a few plants of *Dolichos Lablab* growing in flower pots for two nights in darkness. Test the leaves of this plant for starch and there will be none.

5. **Condition necessary for starch formation.**—

(*a*) **Light.**—In one of the *Dolichos Lablab* plants stencil four of the starch-freed leaflets by means of the light screens and using stencils with some designs and expose them to good diffused day-light. Remove the leaflets after one, two, three and four hours, and test them for starch after bleaching them in the usual way.

The differences in the depth of the colour indicate the difference in the amount of starch formed.

The time required for the appearance of the starch may be easily determined by exposing to light starch-free leaves and examining them at intervals of ten minutes. Traces of starch are seen after ten minutes exposure if the light is good and the leaf vigorous. Filaments of spirogyra freed from starch by keeping them in dark, show starch after an exposure of five minutes to light. For the test chloral-hydrate-iodine should be used.

(*b*) **Carbon dioxide.**—Fit up an young *Dolichos* plant by means of cork to a bottle filled with Crone's normal solution and after it has been growing in it for a day or two in darkness place it on a slab in a dish containing a strong solution of caustic potash Keep this in a larger dish containing a layer of mercury and water and cover it with a bell-jar having a tubulure at the top. Fit the tubulure with a one-holed rubber cork through which passes a bent glass tube which is connected with an U-tube filled with pieces of pumice stone soaked in caustic potash. Expose the apparatus to light and test the leaves for starch at the end of the day. Also set up a similar control experiment without caustic potash solution and test the leaves for starch.

6. **Etiolation.**—Compare the seedlings of *Dolichos Lablab* in the two pots—

A. Grown in darkness for eight days.

B. In light for the same period.

7. **Evolution of Oxygen during photosynthesis.**—Fill a narrow glass jar or a test-tube with water and support it inverted over a large glass jar, also filled with water and previously charged with carbon dioxide which has been prepared separately in Woulff's bottle, by the action of dilute hydrochloric acid on marble or chalk. Place a few vigorous shoots of *Vallisneria*, *Hydrilla* or *Ottelia* in the larger jar and just thrust the cut ends of these into the narrow jar so that they may project a little into the jar or test-tube and keep the apparatus in good diffused sunlight for some hours. Note the evolution of bubbles and when sufficient gas has been collected invert the narrow jar by

closing its mouth with a ground glass and introduce a red hot splinter into it. The flaming of the splinter shows that the gas evolved is oxygen.

8. **The Phosphorus method.**—Take a glass tube about eight inches long and one inch diameter open at both ends and fit it with a good rubber cork at one end. Fix a wire on the inside of another cork and attach a piece of phosphorus to it under water. Introduce two or three vigorous leaves of *Vallisneria* or bits of *Hydrilla* branches into the tube filled with water and partially replace the water by hydrogen and carbon dioxide prepared separately, the former gas by means of a Kipp's apparatus using pure zinc and sulphuric acid. Fix the cork carrying the phosphorus to the other end of the tube and keep the apparatus into the dark for two or three hours till the white fumes subside and then expose it to sunlight. The oxygen evolved will ignite the phosphorus and white fumes will appear.

9. **Effect of light of different intensities on photosynthesis.**—Fit up an apparatus similar to the one arranged as above to show evolution of oxygen by assimilating plants. Introduce a *Vallisneria* or *Ottelia* leaf keeping the cut end half way up the jar. Select a branch which gives a fairly rapid and constant stream of bubbles of oxygen from its cut end and note the rate of evolution of the bubbles (1) in sunlight, (2) in shade and (3) in dim light by counting the number of bubbles evolved per minute.

10. **Effect of different coloured lights on the photosynthesis of plants.**—Take two large wide mouthed glass jars and partly fill one of them with a solution of potassium bichromate and the other with ammoniacal copper sulphate solution. Into each lower a narrower jar placing in the latter some weight so as to sink it in the solution. Introduce a healthy *Vallisneria* or *Ottelia* leaf into another small glass jar keeping the cut end below water and place this in the second jar. Cover the arrangement with a dark card-board and leave it exposed to light. Compare the rate of evolution of bubbles in the two different lights, viz., orange and blue. Under the orange colour the bubbles come out as

under diffused white light, but under the blue colour they are very slow or they do not come out.

11. **Is carbon dioxide necessary for the assimilation of plants.**—Fill a flask about three-fourths with water which has been boiled and cooled so as to drive out all the carbon dioxide contained in it. Place a small quantity of *Vallisneria* or any other aquatic plant and fit the flask with a perforated rubber stopper through which passes one end of a bent glass tube whose other end is connected with an U-tube containing fragments of pumice stones soaked in potash solution. Set up a similar control experiment with water containing carbon dioxide. Expose both the apparatus to sunlight and watch the result.

RESPIRATION.

1. **Evolution of carbon dioxide in respiration—Ganong' method.**—Fit a wide mouthed bottle with a cork having two holes. Push the tube of a thistle funnel through one of the holes, until it nearly reaches the bottom of the jar and cork its wide mouth. Insert into the other hole a short glass tube connecting it by rubber tubing carrying a clip with a J-shaped tube the shorter end of which is drawn to a fine point. On the bottom of the bottle place a wet blotting paper and a few *Dolichos* or *Cicer* seeds that have been allowed to germinate until the roots are about one quarter of an inch long. Dip the J-tube to the bottom of a large test tube filled with lime or baryta water and clip the rubber tubing. Also set up a similar control apparatus without seeds. After a few hours loosen the clip uncork the thistle tube and pour water into it, so as to drive the gas out of the jar through the J-tube from the fine opening of which it will escape into the re-agent causing a precipitate.

2. **Sach's method.**—Place some quantity of germinating seeds in a glass jar fitted with an India rubber cork pierced by two holes and fitted with glass tubes. Connect the tube on the right side with an aspirator interposing a jar or washing bottle (Drechsel's) containing baryta water. The left side must also be connected with a similar bottle containing baryta water and this with a flask having a strong solution of KOH and a tube fitted to its mouth containing

pumice stones soaked in the same solution. When water is allowed to flow from the aspirator air deprived of CO_2 which passes through all the jars and flask to occupy the aspirator bottle. The baryta water in the jar to the left of the seedlings will remain clear whereas that interposed between the aspirator and the seedlings becomes turbid and milky.

Set up another similar apparatus using pellets of paper or seeds boiled instead of seedlings as control.

3. **Absorption of carbon dioxide by potash.**—Take a conical filtering flask having a lateral opening. Place some quantity of germinating seeds of *Dolichos* or *Cicer* on a wet piece of blotting paper inside the flask and introduce a test tube half filled with a strong solution of KOH. Close the mouth with a sound rubber stopper and attach a glass tube to the lateral opening by means of a piece of a rubber tubing and wire ties. Place a beaker containing coloured water (or mercury) so as to dip the glass tube into it and warm the flask a little by the hand so that when the air cools again the water may be sucked a little way up the tube to a point which may serve as the zero for observation. The CO_2 produced by the germinating seeds will be absorbed by the KOH and the coloured water (or mercury) will rise into the tube in a few minutes or within an hour.

Also have a control apparatus with killed seeds or pellets of paper and note the absence of rise of the coloured water in the tube.

N B.—Instead of seedlings young vigorous shoots may also be used in the above experiments

4. **Oxygen necessary for the germination of seeds.**—Take three tubes (U shaped or retort like) and three jars. Place six soaked seeds of *Dolichos* or *Cicer* in one arm (or in the bulb) and invert the tube after inserting a cork with a wad of cotton wool soaked in water to keep the seeds moist. In the case of retort-like tubes no cork is necessary. Fill the jars to about half (*a*) with water (*b*) with solution of KOH (*c*) with pyrogallic acid solution in potash and place the open ends of the tubes in the jars. Examine the seeds after two days and note the result. (See fig. 22.)

5. **Quantitative study of the exchange of gases in respiration.**—By the use of the two tubes fitted in a wooden frame the quantity of CO_2 can be determined volumetrically. The narrow part of the tube is graduated and each division represents 0·2 c.c. Hang the tubes on the wooden support so that the lower ends dip into water contained in the vessels. Put some moist glass wool and about 20 seedlings of *Cicer* or *Dolichos Lablab* inside the

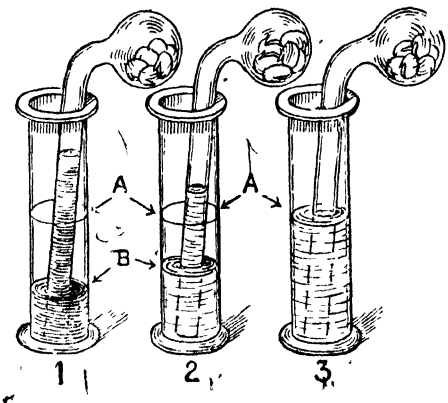


FIG. 22.—Apparatus to show that oxygen is necessary for germination.
Retort-like tube with (1) pyrogallic acid, (2) caustic potash and (3) water.

broader portion of the tubes. Inside one of these hang a small test tube filled with KOH solution. Suck up water to a certain height in both the tubes close the stop cocks and leave the apparatus aside. After some hours or the next day observe the change in the column of water in the two tubes. In a day there may be a rise of about 30 to 40 c.c. of water and this represents the CO_2 given off by the seedlings.

6. **Intra-molecular respiration.**—In water previously boiled and cooled soak a few seeds of *Cicer* for a few hours. Peel off the seed coat carefully without injuring the embryo. Fill a test-tube with mercury and invert it in a small dish of mercury by closing its mouth and clamp it to a stand. Pass three or four peeled *Cicer* seeds into the test-tube without admitting air and by means of a bent tube introduce

some quantity of boiled water into the test tube to keep the seeds moist. Observe the tube for one or two days and note that it is about half or one-third full of gas. Pass into the test-tube some more water and a solid piece of KOH. After sometime the mercury will rise to the top of the test tube due to the absorption of carbon dioxide by the caustic potash. Instead of KOH baryta water may also be used and the tube lifted above mercury when the former solution will rise into the tube and form a precipitate due to the presence of carbon dioxide.

1. **Passage of air through stomata.**—Fill a small bottle or jar about 300 c.c. capacity with water almost fully and fit up an India rubber cork having two holes. Insert the petiole of a *Colocasia* leaf through one hole keeping the cut end below the level of water. In the other hole fit up a bent glass tube so that the end of the tube is not very much below the cork. Suck the air through the tube and note what happens.

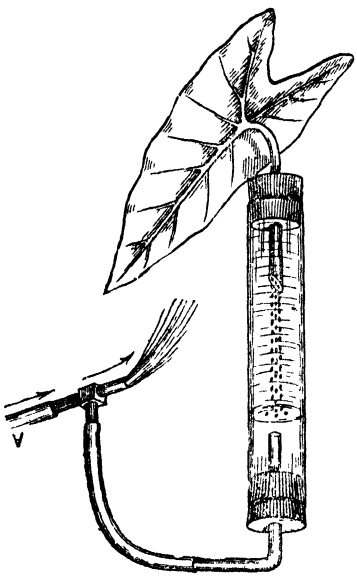
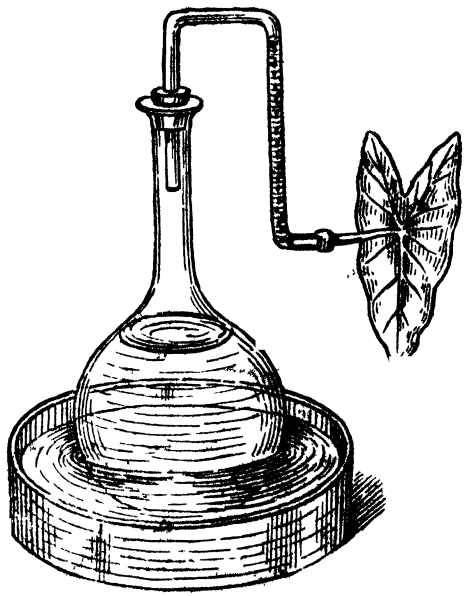


FIG. 23 —Apparatus to show the passage of air through the stomata of a leaf

2. Insert the petiole of a *Colocasia* leaf at one end of a cylindrical straight glass tube of about a foot long and one inch in diameter fitted with single-holed rubber-stoppers to both the ends, after filling the tube with water to about 9 inches. Insert a bent tube into the upper cork (see fig. 23) and suck the air and note the result. Instead of sucking the air, the tube may be connected with a suction tube attached to a water tap and worked.

3. Take a large bottle having a tubulure at the bottom and close the tubulure with a tight fitting rubber cork after passing the petiole of a *Colocasia* leaf through it. Fill the jar with water leaving only a small quantity of air at the top. Bung the neck with a rubber cork having one hole and insert a three-way glass tube so as to have the inner end above water. Connect the outer end of the tube with mercury pump by means of a rubber tubing and rarefy the air from the bottle. Note the bubbles of air rising from the petiole of the leaf when the air is so rarified.

4. Fill a flask (500 c.c.) with 300 c.c. of water and close the mouth with a rubber-stopper having a hole. Insert a



r -Apparatus to show the passage of air through the stomata of a leaf.

twice bent tube after fixing a leaf in its free end and filling the larger end with water to about three-fourths of its height. Heat the flask until the water just begins to boil. Then cool the flask. At once a stream of bubbles will be seen to rise

through the water in the bent tube. If the lower surface of the leaf is vaselined no bubbles arise.

TRANSPIRATION.

1. Fit up a potted plant of *Dolichos Lablab* into an aluminium shell and close the pot with a rubber sheet as shown in the figure. (See fig. 25.) Seal the overlapping edges with rubber solution so as to prevent evaporation and tighten it in the groove by means of the metal band and screw. Weigh the shell in the balance and note the loss of water at intervals of one hour (1) in shade and (2) in sunlight and also from day to day for a few days and note the result.

2. Fill in a U tube with unequal arms with water, fix a rubber cork into the shorter arm and insert a shoot of *Tecoma* or

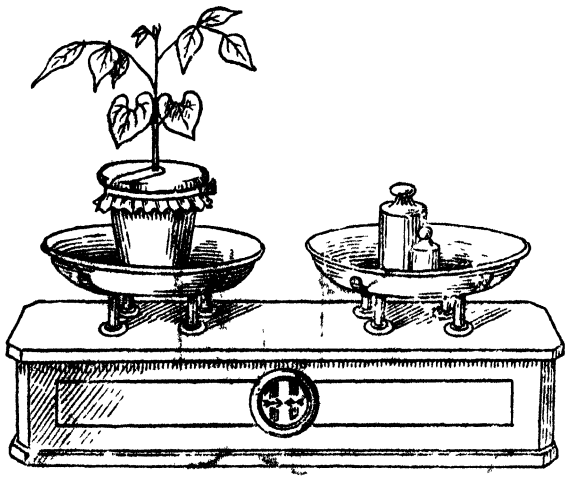


FIG. 25.—Apparatus to determine the amount of water transpired by a plant.

Helia into it. Fill the longer arm of the tube with water and fix into it a rubber cork fitted with a twice bent glass tube which is filled with water. Add a drop of oil into the free end of the tube and place the apparatus in a glass vessel. Transfer the whole arrangement to a balance and determine at intervals the loss of water suffered by the shoot.

3. Take a glass vessel (Calcium chloride tower) having a tubulure at the bottom and fit a graduated glass tube into it. Fill the vessel with water and add a few drops of oil into the graduated tube. Pass a shoot of *Tecoma* through a rubber cork having one hole and fix it into the neck. By means of the balance estimate the loss of water for every half hour due to transpiration and compare it with the amount of water absorbed. (See fig 26.)

4. Fill a funnel with Plaster of Paris made into a somewhat thick liquid by means of distilled water. Connect it by rubber tubing with a long glass tube filled with water and

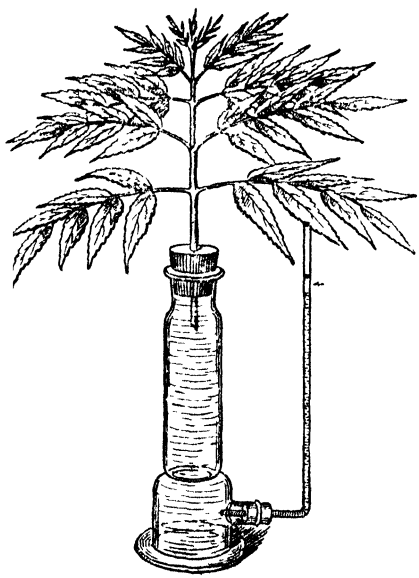


FIG. 26 Apparatus to determine the amount of water lost by a twig by transpiration.

keep the end of the tube under mercury. After some time mercury will rise into the tube owing to the evaporation of water from the funnel.

5. Tie a piece of parchment to the mouth of a thistle funnel making it airtight. Fill the funnel with water and closing the end of the tube with the finger invert it and open under

mercury. Note the gradual rise of mercury as a result of suction due to evaporation of water through the parchment.

6. Connect a vigorous shoot of *Tecoma* or *Melia* about 2 feet long with a glass tube and make it airtight. Fill the tube with water and closing the end with the finger dip it under mercury and withdraw your finger leaving open the end under mercury. As the water is used up in transpiration mercury enters the tube. (See fig. 27)

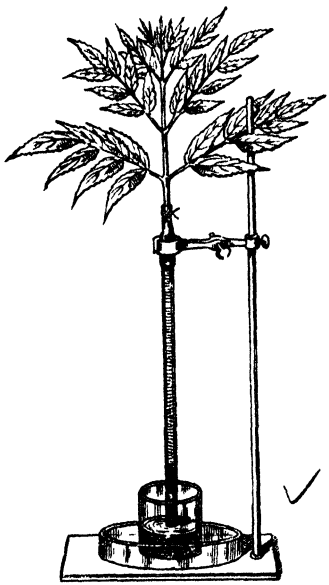


FIG. 27.—Apparatus to show the suction power of transpiration

7. Allow a few branches of *Tecoma* and *Melia* to become flaccid. Insert the lower end of the cut shoot into the shorter arm of a bent glass tube, fill it with water and then pour mercury into the longer arm In a few minutes the shoot will become turgid owing to the pressure exerted by the mercury on water.

8. **Potometer** (Darwin and Acton)—Fit up a perforated cork to the lower end of the potometer tube, insert a capilary tube into it and fill the whole with water. Fix a branch of *Tecoma* to the open end of the bent tube and close the other with a cork. Support the apparatus with a stand and leave the end of the capillary tube to just dip into water after admitting a bubble of air into it. The rise of the bubble serves as an index of the rate of absorption.

9. Fix branches of *Tecoma* or *Melia* or *Mirabilis* in the other models of potometers (Ganong's, Farmer's and McDougal's models) placed before you and calculate the rate of absorption of water in sunlight, shade, darkness and windy places.

10. Place the shoots of *Tecoma*, *Melia* and *Murabilis* in eosine and safranine solution. Examine the shoots at intervals of 10 or 15 minutes and note the height to which eosine or safranine has arisen. Note also the path of ascent of the coloured solution.

Instead of shoots seedlings of *Dolichos Lablab* or other plants may be used.

TURGIDITY.

1. **Osmosis.**—Tie a piece of parchment to the mouth of a thistle funnel and fill it with a solution of sodium chloride. Keep the end of the tube in distilled water contained in a beaker and after some time test the water with silver nitrate. A white precipitate will be formed showing the diffusion of the chloride through the parchment.

2. **Osmotic strength of cell-sap.**—Place in distilled water strips of the hypocotyl of *Ricinus* or other seedlings split longitudinally, and after sometime these curve outwards, i.e., with the epidermis on the concave side. If these strips are placed in 5 per cent solution of common salt or potassium nitrate they straighten or become curled with the epidermis on the convex side. A solution of a lower strength will certainly keep the strip straight and this strength should be considered as equivalent to the osmotic force of the cell-sap.

3. **Plasmolysis.**—Examine the parenchymatous cells of the leaf of *Ottelia*, filaments of *Spirogyra* or tissues with coloured sap under the microscope and note the protoplasmic layer. Irrigate with a 5 per cent solution of potassium nitrate or common salt and watch the separation of the protoplasm from the cell-wall (**plasmolysis**). Again run in pure water and note the return to normal condition. Also use solutions of different concentrations of sodium chloride, grape sugar and cane sugar and determine the strengths of these solutions necessary to induce plasmolysis.

ROOT PRESSURE.

1. Cut across the stem of a vigorous pot plant at about two inches from the soil and tie a piece of rubber tubing about 10 c.m. long over the stump. Insert a capillary glass tube after filling the tube with water coloured red with

eosine and tie firmly. Support the capillary tube horizontally by means of a cleft stick or stand. Pinch the rubber tubing slightly so as to press some fluid out at the open end of the capillary tube, and absorb it with blotting paper. On releasing the rubber tubing air will be drawn into the glass tube. Use this bubble of air as an index and watch the advance of the coloured water.

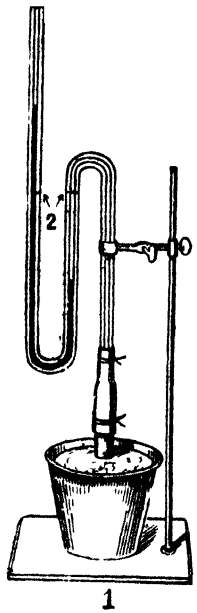


Fig. 28.—Apparatus to show root-pressure
1. Flower pot containing the plant.
2. Manometer tube.

2. Instead of the capillary glass tube, a manometer supplied by Bausch and Lomb Optical Instrument Company may be used. This will enable one to measure the root pressure roughly.

3. If a manometer is not available the piece of apparatus suggested by Darwin and Acton may be used. Connect a T-tube whose one arm is bent at the end so as to be parallel to the other arm with the rubber tubing connected with the root on one side and with the rubber stopper of the bottle containing mercury on the other side. A narrow manometer tube is inserted through the rubber stopper so as to reach the bottom of the bottle. The T-tube and the bottle should be filled with water and the top of the T-tube should be closed.

GROWTH.

1. **Growing region of root.**—Select two or three seedlings of *Cicer* or *Dolichos* with roots grown to about one inch long and mark the roots with waterproof ink at very short intervals. Keep the seedlings on a wet blotting paper between two glass plates and leave the arrangement to rest against one edge of a tray containing some water. After a

day or two examine the roots and note where the lengthening has occurred.

2. Tie a cork on the side of a glass jar containing water and pin a seedling of *Canavalia* or *Dolichos* to it with the root grown to about an inch long. Give enough water supply by means of a strip of blotting paper dipping in the jar. Adjust the scale-pan against the growing root so as to allow it to press into a sealed glass tube set in the cork which is fixed to the pan. Observe the next day and note the pressure with which the pan has been depressed.

3. **Growth rate of stem.**—By means of a fine thread attach the tip of the growing stem of the potted plant to the shorter end of a light lever whose long arm is about 20 inches long. Fix the lever to a stand and keep a scale against a pointer. Since the lever arm to the right is ten times as long as the other, the growth of the stem will be magnified ten times on the scale. Compare the rate of growth at night with that during the day.

HELIOTROPISM AND GEOTROPISM.

1. **Experiments with the Klinostat.**—Fix the young seedlings to corks resting on a jar containing water so as to immerse the roots. Keep one in a fixed position and place the other on the disc of a klinostat revolving on the vertical axis. Give strong one-sided light and observe the position of leaf, stem and root.

2. Keep one of the potted plant on its side and attach the other firmly to the klinostat revolving horizontally. Note that the curvature takes place in one case but not in the other.

3. Pin a few seedlings of *Cicer* to the two corks in corresponding position and fix them to the two bars one of which is fixed to the frame and the other is freely moveable on pivots. Attach the frame to the klinostat and underneath the frame keep a dish of water in order to wet the seedlings at every turn. Note the direction of growth of the root and the shoot after three or four days.

1. **Experiments with the centrifugal apparatus.**—Select six germinating seeds of *Cicer* with roots grown to about an inch long and pin them in different directions to

the corks of the water wheel and on the sides not struck by the stream of water. Keep the apparatus in a sink and attach it to the tap by means of a rubber tube and allow the wheel to revolve rapidly (2 or 3 times a second). In the course of a day the roots will be seen to bend away from the centre of the wheel and growing straight-away in the direction of the radius and the shoot will point towards the centre of the wheel.

2. Pin seedlings carefully to another apparatus of the same kind and place it on its side so that the wheel may revolve horizontally. Note the direction taken by the stem and the root after a day or two.

3. **Experiments with twining plants.**—Rotate horizontally on the klinostat a potted twining plant of *Ipomoeas* which has made a few coils on the support. After a day or so note that the youngest turns unwind and straighten themselves out.

4. Tie a fine thread to the growing tip of a twining plant which has already coiled a few internodes round the support and pass the thread over a lightly running pulley placed vertically over the plant. Hang a small weight (one gram) to the free end of the thread just sufficient to support the stem. Observe the next morning that the terminal portion would have formed a few coils which will ultimately straighten owing to geotropism.

SECTION III.—CRYPTOGAMS.

SELAGINELLA.

A. General external characters.—

These plants are pretty plants grown in green houses. Note the general habit of the plants, which vary according to the species.

Observe that:—

(1) the **profuse branching** of the slender wiry **stems** which occurs in one plane in an apparently **dichotomous** manner but really **monopodial**;

(2) the alternate pairs of small simple single veined **leaves** arranged in **four rows**; note that each pair consists of a small **dorsal leaf** and a larger **ventral leaf**.

(3) the long wiry and stiff cylindrical organs (**rhizophores**) arising at the forking of the stems and growing vertically downwards and producing roots in profusion after penetrating the soil;

(4) the terminal portions of branches **(cones)** having four rows of leaves all alike in size and shape and bearing sporangia (**sporophylls**).

(5) two kinds of **sporangia**.—The **megasporangia** found in the axils of the leaves confined to the base of the cone (**megasporophylls**) and the **microsporangia** found in the axils of the leaves of the upper portion of the cone **microsporophylls**);

(6) the lobed **megasporangia** with four large **megaspores** and the **microsporangia** with numerous much smaller microspores.

B. Internal structure.—

1. **Stem.**—Examine the transverse sections of the stem and note—

(1) the **epidermis** with cuticle;

(2) the **cortex** consisting of an outer compact portion with thick walled lignified cells towards the epidermis and an inner portion of thin walled cells:

(3) the **stele** usually surrounded by an **air space** bridged over by **trabeculae** representing **endodermis** consisting of rows of cells; in some species the air-space may not be very prominent:

(4) the **pericycle** and the **phloem** surrounding the solid central **xylem**;

2. Examine some longitudinal sections of the stem and note that the xylem consists mostly of **scalariform tracheids**.

3. **Structure of leaf.**—Detach carefully leaves from the stem and examine one under the microscope and note—

(1) the single **vascular bundle**, the small outgrowth or **ligule** at the base of the leaf on the upper side, (2) the single large chloroplasts in the cells and (3) the stomata on the lower epidermis near the middle.

4. **Structure of sporangia and spores.**—Examine the entire cone under low power and observe the position of the **megasporangia** and **microsporangia**. Detach the sporangia and isolate the **megaspores** and **microspores**, either by teasing or by pressure, and then note the shape and size of these spores. Observe the thick coat and markings and the three radiating lines in the megaspore.

ADIANTUM OR MAIDEN-HAIR FERN.

The Sporophyte.

A. General external characters.—

The maiden-hair fern is easy to obtain as it is grown in almost every green house. Select a well-grown plant and wash out the soil from the rhizome and the roots.

Observe that -

(*a*) the **rhizome** is creeping and horizontal, and is covered by the leaves, the old bases of leaves, roots and scale-hairs **(ramenta)**; the very young parts of the rhizome are so completely invested by the ramenta that the actual surface of the rhizome could not be seen;

(*b*) the leaves or fronds of the current year are all **pinnately compound** and that each leaf consists of a main leaf stalk and secondary ones, all black shining with numerous **cuneate** pinnæ or **leaflets**,

Note the quite characteristic forked venation and the lobing of the leaflets. The veins branch quite regularly in a dichotomous manner.

(*c*) The young leaves are crowded together near the apex of the rhizome and they are in all stages of development ; the youngest are mere coils without any stalk and the younger have very short stalks. The apex of the rhizome with its young leaves are thickly clothed with the ramenta. The **coiled** condition or the **circinate vernation** is characteristic of the leaves of ferns.

(*d*) **buds** occur at the base of some of the leaves and these are not axillary ;

(*e*) the roots are numerous, brownish **black in colour,** monopodially branching and in acropetal succession ;

(*f*) the **sori** or groups of sporangia are found at the back of the leaflets of mature leaves. The folded flaps of the leaflets at their apices have the groups of sporangia.

B. Internal structure.—

Cut transverse sections of the rhizome and note that the major part of it consists of ground tissue in which are

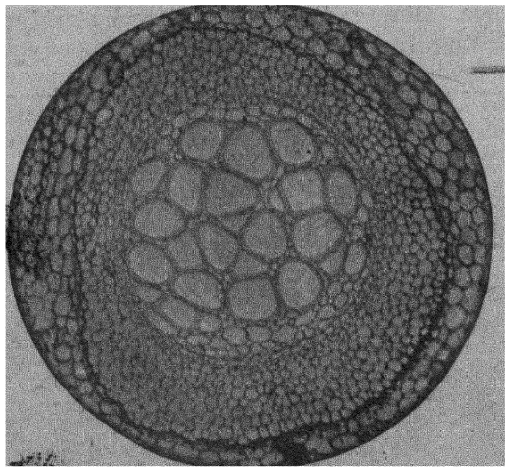


FIG. [illegible].—Microphotograph of a transverse section of a stele in the rhizome of a fern plant.

imbedded a number of vascular strands. These strands may be made out with a low power lens. Each of these

vascular strands correspond to a stele and so the rhizome is **polystelic.**

2. Prepare transverse sections of the rhizome or of the leaf-stalk. Select a thin section and examine it under the microscope.

Under a low power observe :—

(*a*) the epidermis with thickened brownish outer walls ;

(*b*) the ramenta ;

(*c*) sclerenchyma ;

(*d*) outer ground tissue ;

(*e*) the vascular strands or steles ; and

(*f*) the central ground tissue.

3. Study under high power a single vascular strand. (See fig. 29). It consists of :—

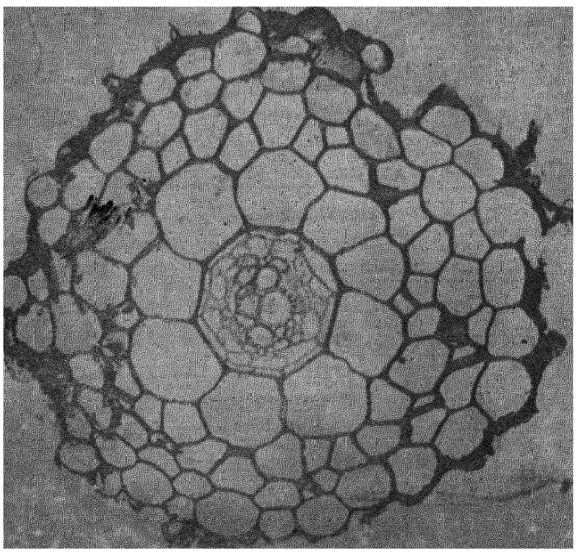


FIG. 30. Microphotograph of a transverse section of the root of *Adiantum.*

(*a*) a sharply marked **endodermis** made up of a single layer of cells with brownish walls surrounding the stele,

(*b*) the **pericycle** surrounding the vascular elements of the stele,

(*c*) the **phloem** next to the pericycle, and

(*d*) the central **xylem.**

4. Examine a longitudinal section of the leaf-stalk and note the parts of the xylem and the phloem. The xylem consists of scalariform tracheids and small tracheids, and the phloem consists mostly of sieve tubes with sieve plates on lateral walls and parenchyma.

5. Study the structure of a root in a transverse section (see fig. 30). A transverse section shows:—

(*a*) the **piliferous layer** with or without root-hairs according to the age of the root,

(*b*) a few large cells constituting the **cortex**,

(*c*) the **endodermis** consisting of a few cells surrounding the stele,

(*d*) the **pericycle** consisting of a single layer of cells,

(*e*) the two strands of phloem, and

(*f*) the diarch xylem.

6. Examine sections of leaves and note in them—

(*a*) the upper epidermis with chloroplasts,

(*b*) the **mesophyll** consisting of star shaped cells with chloroplasts inside and with air spaces amongst the cells outside,

(*c*) vascular bundles, and

(*d*) the lower epidermis and the stomata in them.

7. **Sporangia and spores.**—Cut vertical sections of the folded flaps of the leaflets in which the sporangia are developed. On examining these sections sporangia in different stages of development may be seen. Instead of taking sections the sporangia may be teased out and examined.

Select mature sporangia and observe that—

(*a*) the **sporangium** consists of a stalk composed of a row of cells and the **spore-case** or capsule containing spores,

(*b*) the **spore-case** is lenticular in shape and possesses a wall one cell thick all flat and thin walled, except those forming the **ring** or **annulus** round the edge whose inner and lateral walls are thickened : the annulus extends from the

stalk on one side over the edge to half way down on the other side of the capsule,

(*c*) the spores are inside the spore-case and that they have cutinised thick walls.

Mount some intact ripe sporangia in water and cover them with a coverslip. Place a drop of strong glycerine near the edge of the cover glass and draw it in by means of a bit of filter paper at the opposite side. While doing so observe the dehiscence of the sporangium under the microscope.

The Gametophyte or the Prothallus.

Fern prothallia may be obtained from ferneries where they will be abundant on the flower pots or on the ground. They may also be raised from spores by sowing them on sterilised bits of tile or brick kept sloping in a vessel of water. Prothallia make their appearance in about four or five weeks.

1. Secure a well developed prothallus and study its external features.

Note—

(*a*) its flattened form, obcordate outline and the notched anterior end in which the growing point lies,

(*b*) the green colour,

(*c*) the smooth upper surface and the lower surface bearing fine rhizoids.

2. Examine a prothallus under the microscope and observe :—

(*a*) its thin marginal portions consisting of polygonal thin walled cells containing chloroplasts in addition to protoplasm, nucleus and cell-sap.

(*b*) the cushion formed of several layers of cells,

(*c*) the rhizoids or unicellular prolongations on the lower surface which fix it to the substratum,

(*d*) the growing point in the notch at the anterior side,

(*e*) antheridia on the cushion on the hinder side and laterally amidst rhizoids, and

(*f*) archegonia near the growing point on the cushion.

3. The development of the antheridia and antherozoids and of the sporophyte from the archegonia can be studied by selecting prothallia of different ages. Old prothallia show

the sporophyte still attached to them. The parts of a very young sporophyte still connected with prothallus are clearly shown in fig. 31.

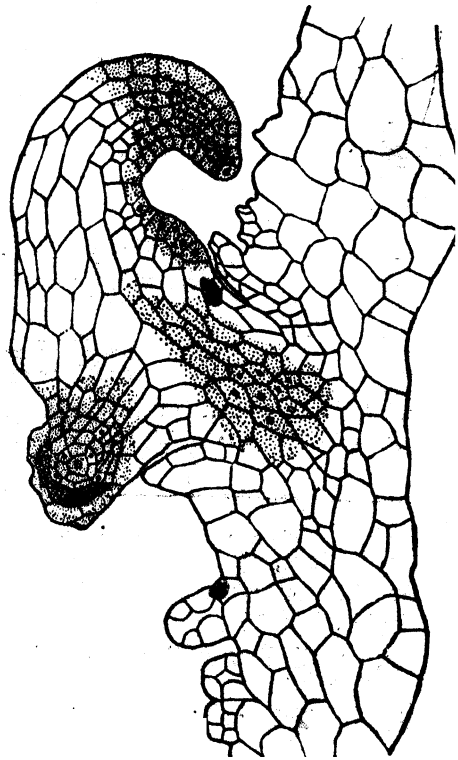


FIG. 31.—Section through a protnallus and a young sporophyte. From a section prepared by Dr. M. A Sampathkumaran.

MARSILIA OR WATER-FERN

1. Secure plants of either *Marsilia minuta or M. coromandelica*. Both these species flourish in wet places such as ditches, corners of paddy fields and margins of ponds. Note the general habit of the plant and its vegetative parts, namely, the slender creeping stems, leaves, roots and sporocarps,

2. Select a well developed plant and observe the mode of branching. The branches do not arise regularly from the axils of leaves.

3. Cut transverse sections of the stem and selecting a section that is entire note under low power :—

(*a*) the stele,

(*b*) the cortex with air spaces and trabeculæ separating the air spaces, and also the diaphragm stretching across the air cavities in some cavities, and

the endodermis.

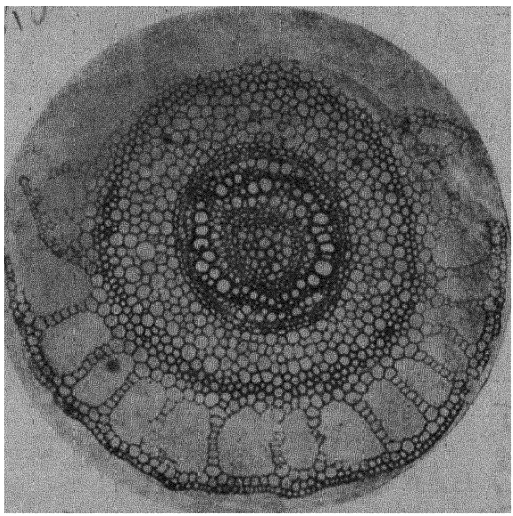


Fig. 32. Microphotograph of a transverse section of a stem of *Marsilia*. (Low power.)

4. Prepare a thin section and under high power observe :—

(*a*) the two layers of the cells forming the peripheral part of the cortex,

(*b*) the air spaces separated by the trabeculæ of one layer of cells,

(*c*) the compact inner portion of the cortex having no air spaces,

the endodermis—both the inner and the outer, and

(*c*) the stele consisting of xylem surrounded by the phloem.

5. Examine a transverse section of the stalk of the leaf and note :—

(*a*) the cortex containing air cavities,

(*b*) the endodermis, and

(*c*) the stele consisting of xylem surrounded by the phloem.

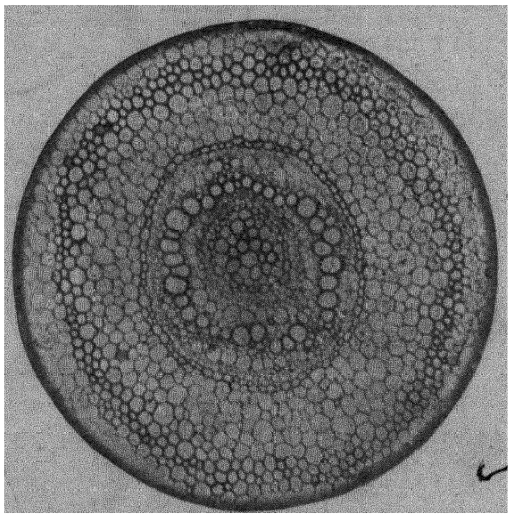


FIG. 33. Microphotograph of a transverse section of a stem of *Marsilia*, showing the central portion. (High power)

6. In a leaf note its long stalk and the two bilobed opposite leaves simulating four leaflets. Note the characteristic venation in the cuneate leaflets.

7. The sporocarps occur at the base of the stalk. They are somewhat bean-shaped and very firm and hard when ripe.

Cut the sporocarp both lengthwise and breadthwise at right angles to the plane of the sporocarp and note the chambers and the sori in them.

8. Place in water a few sporocarps and watch them. In about fifteen to twenty minutes they burst and a gelatinous stalk bearing sporangia gradually comes out. Fully ripened sporangia alone should be used.

Even old sporocarps preserved on herbarium sheets or in spirit show activity. Before placing in water the sporocarps should be scraped at the sides and faces to a slight extent, otherwise they do not burst.

9. Tease out the spores from the sporangia and note the difference in the sporangia and the spores. The larger spores are the **megaspores** and they are found singly in the megasporangia. The **microspores** are smaller and numerous in each microsporangia.

10. Leave the gelatinous stalk bearing the sporangia in water for a day or two and examine the spores. They would have germinated. In the megaspore the prothallus will be seen as a green mass protruding out and in its proximity a large number of sperm-cells will be found in the gelatinous mass above the green prothallus. Numerous rhizoids may also be seen at the sides of the prothallus

LYCOPODIUM.

1. Secure specimens of *Lycopodium cernuum*. Observe and note the general habit and plan of the plant body. Compare the plan with that of true ferns and *Selaginella*. Are these characters concerned with the stem or leaves which distinguish Lycopods from the other Pteridophyta already studied ?

2. Note—

(*a*) the shoot system consisting of much branched stems that are tough, flexible and creeping ; some branches are creeping while others are ascending,

(*b*) the roots on the lower side of the stem springing from the point of branching and also from other parts and their dichotomous branching,

(*c*) the very small narrow leaves crowding and covering the creeping and erect branches, and

(*d*) the **cones** at the ends of some of the erect branches.

3. In the cones observe that :—

(*a*) the leaves bear sporangia in their axils,—one sporangium in the axil of each leaf (**sporophyll**),

(*b*) the ripe sporangia open by slits, and

(*c*) the spores are all small and of one kind (**homosporous**).

4. Examine the spores under high power and note —

(*a*) that the spores are round and tetrahedral in shape,

(*b*) covered with very minute projections externally, and

(*c*) that the spores cannot be wetted by water.

The prothallia are buried in the ground completely or partially. They remain in an active growing condition for a year or more. The sexual organs archegonia and antheridia are borne by them.

BRYOPHYTA.

Pogonatum or Funaria.

As examples of mosses, species of *Pogonatum* or *Funaria* may be examined.

1. Secure some plants of *Pogonatum* and observe in well-grown specimens —

(*a*) the erect unbranched stem attaining a considerable length,

(*b*) the leaves covering the whole of the stem, and

(*c*) the dense mat of rhizoids.

It must be remembered that the leaves and stems of a moss plant cannot be compared with the leaves and stems of the flowering plant. The moss plant is the gametophyte and the flowering plant is the sporophyte.

2. Mount a leaf and examine it under a low power.

Note—

(*a*) the general shape of the leaf,

(*b*) the two portions of the leaf, namely, the basal sheathing portion of the leaf and the upper free portion,

(*c*) the serrated margin, and the somewhat thickened middle portion of the narrow linear or linear lanceolate upper free portion of the leaf, and

(*d*) the basal portion which is thin, membranous and consists of one layer of cells only.

3. Take transverse sections of the stem and note in a thin section under the low power the following :—

(*a*) the peripheral region consisting of thick-walled cells, with brownish cell-walls,

(*b*) the central mass of yellow-walled cells, and

(*c*) the central portion consisting of a few layers of small cells with brown walls and protoplasm surrounding the central mass of cells that are slightly larger and free from any contents and hence empty.

4. Select plants bearing antheridia. Such plants are made out by the cup-like rosettes of leaves at the apex. Detach the starlike apical portion of the stem and dissect it and note :—

(*a*) the **perigonial leaves**,

(*b*) the **paraphyses**, either simple narrow filaments or spathulate,

(*c*) the club-shaped antheridia rising from the axils of the perigonial leaves, and

(*d*) the short stalk and the club-shaped body of the **antheridium** consisting of a wall of one layer of cells enclosing mother-cells of sperm cells or sperm cells themselves according to the stage of development

5. Choose some plants bearing **archegonia** and by teasing the apical portion of the plant several archegonia may be detached. Select one and note in it :—

(*a*) the neck,

(*b*) the ventral portion,

(*c*) the canal cells, and

(*d*) the **ovum** or the **egg-cell**.

The plants bearing archegonia in *Pogonatum* are not so common and easy to detect as the antheridia bearing plants. They occur only in spring and summer and so they have to be collected then and preserved.

6. The **sporogonium** or the **spore capsule** may be seen at the apex of plants. Select some plants in which the sporogonia are not very ripe and note :—

(*a*) the erect stalk or **seta** bearing the spore case or **theca**.

(*b*) the hood or the **calyptra** covering the **theca**,

(*c*) the **lid** or **operculum** closing the mouth of the theca,

(*d*) the membrane stretched across the mouth of the theca and closing it (**epiphragm**) and the 32 teeth forming the **peristome** attached to the membrane, and

(*e*) the **spores** inside the theca.

In case Pogonatum is not available *Funaria hygrometrica* may be substituted as this is a widely distributed common species. This moss can easily be recognized by the calyptra which is oblique and tipped with a process and the seta bent at the top just below the sporogonium.

1. Select a well-grown plant and detach the leaves from it and note that they are sessile, oval and with entire margins and that each leaf has a midrib in the centre and single layered on either side.

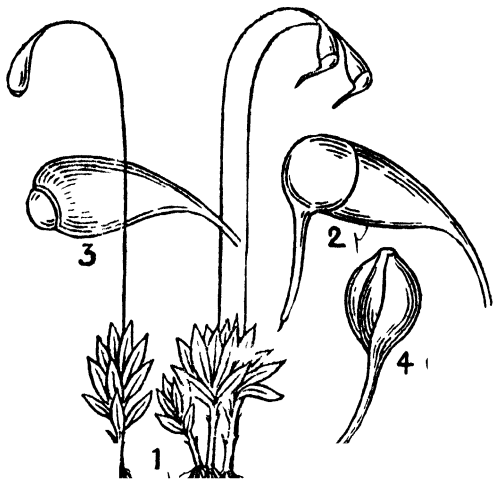


Fig. *Funaria hygrometrica*. 1 Full plant, 2, the sporogonium with its hood, 3, sporogonium with the hood removed 4, hood or calyptra.

2. Choosing some plants having the starlike "male flower" at the apex, tease out and note, the paraphyses, leaves and the **antheridia.**

3. To examine the archegonia tips of shoots which look like buds should be obtained. By teasing these archegonia will be detached and they may easily be examined and the parts made out.

4. Select plants bearing archegonia and note :—

(*a*) the stalk or seta bent at the top,

(*b*) the theca or the sporangium, pyriform and oblique,

(*c*) the **calyptra** or the hood which is short and oblique with a slender process on one side, covering only a portion of the capsule,

(*d*) the oblique lid and the mouth,

(*e*) the **peristome** consisting of two series of triangular teeth, sixteen in each series,

(*f*) the small disc of tissue connecting the teeth in the centre, and

(*g*) the **annulus** which is reddish.

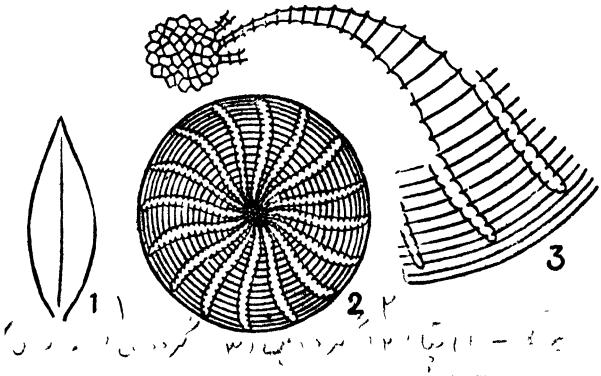


FIG. 35.—*Funaria hygrometrica* 1. Leaf. 2 Peristome 3. A portion of the peristome showing the teeth (All magnified)

LIVERWORTS.

Marchantia polymorpha

In fresh specimens of this plant observe the general habit, the way in which the thallus grows and elongates and the repeated forking of the branches.

1. Examine a portion of the fresh thallus and note.—

(*a*) the dorsiventral character and the flattened form of the thallus,

(*b*) the difference in colour between the dorsal and the ventral surfaces,

(*c*) the prostrate position and the wavy margin,

(*d*) the dull green upper surface showing several diamond shaped areas with a distinct pore (**stoma**) appearing as a small dot in the centre of each of these areas,

(*e*) the growing apex in the terminal depression and the midrib marked in older portions by a shallow groove, and,

(*f*) the small circular cups with crenate margins containing **gemmæ**.

2. To study the appearance and structure of the lower surface, the thallus should be washed well without injuring any part. Take a bit of the thallus and after washing it examine it and note :—

(*a*) the numerous rhizoids springing mainly from the midrib, and

(*b*) the scale-like structures called **amphigastria.** These may be easily and clearly seen near the apex of the thallus.

3 Cut vertical sections and selecting a thin one which is entire note —

(*a*) the superficial layer consisting of one layer of small cells,

(*b*) the pores or **stoma** in the superficial layer consisting of tiers of small cells surrounding the central cavity and the air cavities,

(*c*) the rows of oval cells containing chloroplasts springing from the floors of the air cavities : it is these air cavities that appear as diamond shaped areas in surface view,

(*d*) the vertical plates of cells by which the superficial layer is attached to the subjacent layers of cells,

(*e*) numerous layers of cells with sparsely scattered chloroplasts or without them, and

(*f*) the outermost layer of cells forming the ventral surface, bearing **rhizoids** and **amphigastria**.

4. Sexual organs are not commonly found on plants on which cupules are numerous. Gemmæ are formed during autumn and spring while the sexual organs occur only in summer. Plants in the sexual stage are easily recognized as these organs are borne by vertical branches. These branches bear either antheridia alone (**antheridiophore**) or archegonia alone (**archegoniophore**) and both kinds of branches never appear on the same plant.

Secure plants having branches bearing terminal disks with crenate margins. These are **antheridiophores** having antheridia sunk in the disks on their upper surfaces.

Cut sections through the terminal disk, examine the sections and observe :—

(*a*) the air cavities similar to the cavities seen on the dorsal side of the prostrate thallus as diamond shaped areas,

(*b*) the cavities which are flask-shaped in each of which is seen an antheridium occupying the whole cavity,

(*c*) the wall of the antheridium consisting of one single layer of cells, and

(*d*) the sperm mother cells or the sperms (according to the stage of development) within the antheridia.

Branches bearing the archegonia look like a terminal star at the free ends of the slender stalks. These star shaped bodies vary in diameter from $\frac{1}{4}$ to $\frac{1}{2}$ an inch. In each of these bodies there are nine radiating arms.

Cut sections both horizontally and vertically and by examining these sections observe :—

(*a*) the archegonia in young ones and the sporocarps in old ones, and

(*b*) the general structure of the limbs.

5. Detach from mature female receptacles a few sporogonia (or sporophytes) and note in them —

(*a*) the **perigynium** or the loose covering,

(*b*) the **sporogonium** and its **calyptra**,

(*c*) the massive conical **seta** or stalk, and

(*d*) spores and **elaters** inside the sporogonium or capsule

ALGÆ

Pleurococcus.

As an example of Algæ of the simplest structure, we may study *Pleurococcus*, which forms green patches on walls, bricks, flower-pots and barks of trees.

1. Scrape a little of the green powder from a wall or the bark of a tree, and mount it on a slide in a drop of water, and then examine it under a low power of the microscope.

Note that the powdery stuff consists of cells, some isolated and free and others aggregated in groups. The colonies of cells occur as the result of active cell division and the aggregation of cells is only temporary. As division and growth continue the cells get separated.

2. Examine an isolated free cell under a high power and note :—

(*a*) the well defined **cell-wall**,

(*b*) the lobed and perforated **chloroplast**,

(*c*) the **protoplasm**, and

(*d*) the **nucleus**.

On mounting these cells in iodine or chlorzinc iodine their parts become clearly visible.

Chlamydomonas.

Sometimes the green colour of water in ponds, puddles and ditches is due to the presence of the plant *Chlamydomonas* in large numbers.

1. Mount on a slide a drop of water containing *Chlamydomonas* and examine it under a low power of the microscope. Note :—

(*a*) the small green bodies running in all directions in water,

(*b*) the differences in the rate of motion of these bodies, and

(*c*) the few stationary spores

2. Select an individual plant of *Chlamydomonas* at rest and note under a high power :—

(*a*) the **single cell** composing the individual and its pear shape,

(*b*) the **cell-wall**,

(*c*) the two **cilia** at the pointed end,

(*d*) the **bell-shaped chloroplast** open towards the anterior pointed end or the beak,

(*e*) the **pyrenoid** embedded in the chloroplast at the broad end of the cell,

(*f*) the nucleus lying in the protoplasm within the chloroplast at the broad end of the cell,

(*g*) **vacuole** at the beak, and

(*h*) the **eye-spot**, a red dot of pigment lying on one side just behind the vacuole.

3. Sometimes Chlamydomonads may be found in their resting or "palmelloid condition." That is to say, the plant comes to rest, loses its cilia and eye-spots, and the cell-wall swells and becomes mucilaginous. Within this mucilage the

cell begins to divide very actively and the cells remain aggregated together. These cells escape and become motile, on the occurrence of favourable conditions.

4. This plant varies in its mode of reproduction, according to the species. It is asexual or sexual according to its nutritive conditions. When the supply of food material is abundant asexual reproduction is the rule, and under starvation conditions sexual reproduction occurs.

(*a*) If these plants are placed in culture solutions such as Knop's or Crone's and allowed to grow, we not unfrequently find a large cell containing four ovoid cells. The contents of the cell become divided into four ovoid cells by cell division. These four inner cells sooner or later begin to move within the large cell and they finally escape as complete chlamydomonads, in all respects like the parent. This is the usual asexual mode of reproduction.

(*b*) In some species the contents become divided into a number (32 or 64) of small equal sized **biciliate zoogametes**. These zoogametes fuse in pairs and the resulting zygote acquires a thick coat and rests for a time. The zygote germinates and the protoplasm becomes subdivided into 4 or 8 individual cells, and each of these develops walls and cilia and become independent individuals. As a general rule the gametes that fuse together come from different individuals.

(*c*) The **zoogametes** that are formed in certain species are of two sizes, some smaller (**microgametes**) others larger (**megagametes**). Fusion takes place between the mega- and micro-gametes.

When chlamydomonads found growing in culture solutions are transferred to distilled water, zoogametes are formed.

Spirogyra.

Filaments of *spirogyra* commonly occur as freely floating masses of bright green colour in low-lying waters of tanks, ponds, puddles and running streams. The filaments are slimy to the touch and unbranched.

1. Mount in water on a slide filaments of this plant and examine them under a low power. Note that the filaments are simple and unbranched, rounded at the extremeties, and

partitioned off into a number of relatively short cells by transverse septa ; that the filaments are not all alike some being thick and others thin ; that spirally coiled green bands are found in each cell in all the filaments, but they vary in size and number according to the species.

2. Select filaments that are thick, mount them and examine them under a low-power and observe :—

(*a*) the individual **cells**,

(*b*) the **spiral** green bands of **chloroplasts**,

(*c*) the longitudinal **cell-wall** and the transverse walls or **septa** dividing the filament into a row of cylindrical cells,

(*d*) the **protoplasm**,

(*e*) the **nucleus**.

3. Examine a single cell of a filament under a high power of the microscope and note :—

(*a*) the thick outer longitudinal **cell-wall**,

(*b*) the disc-like **septa** or transverse walls which are continuous with the outer wall.

(*c*) the thin continuous **film** of fine grained **protoplasm** lying within the cell-wall,

(*d*) the **spiral** bands of **chloroplasts** imbedded in the primordial utricle,

(*e*) The **serrated edges** of the bands of chloroplasts and the refractive bodies (**pyrenoids**) found in the middle of the band at regular intervals,

(*f*) the large central **vacuole** containing the colourless cell-sap, and

(*g*) the strongly refractive **nucleus** lying in the centre of the cell and surrounded by a layer of protoplasm from which proceed fine radiating protoplasmic threads.

In the filaments in which the green spiral bands are close together, the nucleus of the cell is not easily seen, but in those in which the spirals are farther apart the nucleus is visible. If the filaments are mounted, after bleaching them in alcohol, in iodine or chlorzine iodine the nucleus becomes very conspicuous.

4. *Spirogyra* reproduces itself both vegetatively and sexually. The filaments break into segments and these segments develop into filaments by cell division, and this is the asexual method.

5. For the study of the sexual mode of reproduction or **conjugation** as it is called, obtain filaments in different stages of conjugation and examine them. Observe the different stages mentioned below :—

(*a*) The cells of filaments opposite one another put out rounded **projections** or **processes**, which meet ;

(*b*) the wall at the point of junction is absorbed, so that the two opposed cells become contiguous by a transverse **conjugation tube** ;

(*c*) meanwhile the contents of the two cells become rounded off, one **(male)** doing so earlier than the other **(female)** ,

(*d*) the protoplasm of the male filament passes through the central canal and coalesces with the protoplasm in the female filament to form the **zygote** ;

(*e*) the zygote surrounds itself with a thick stratified cell-wall which is smooth, or shows various markings of the surface according to the species.

Botrydium

Botrydium is of cosmopolitan distribution. It grows on damp clayey soil.

1. Get, if possible, fresh specimens and with a lens note that an individual plant consists of a green balloon-shaped aerial portion and of a colourless underground part consisting of dichotomously branching rhizoids. The whole plant is really a single multi-nucleated cell. The protoplasm contains numerous chloroplasts in the part exposed to light.

2. Mount an individual plant freed from mud on a slide and note the **cell-wall, protoplasm** and the **chloroplasts** imbedded in it. The nuclei can be made out only with difficulty by staining them either with iodine or other nuclear stains.

3. Reproduction is generally by means of **zoospores** produced in large numbers by the division of the contents. These escape by an opening at the summit. Each zoospore has a single **cilium** and contains two **chloroplasts**.

Sometimes the protoplasm recedes into the underground rhizoids and gets divided into a number of **resting spores**

The contents of a rhizoid may also get to the end of the tube and these become transformed into one single large resting spore covered by a thick, cell-wall and mucilage. Such specimens were collected by Mr. M. O. Parthasaradhi Ayyangar of Madras. Occasionally budding occurs in the balloon-shaped aerial part and the budded part developes into an individual and gets separated from the parent.

Ulothrix.

One of the commonest filamentous algæ occurring mixed with other algæ is the *Ulothrix*. These are found attached to leaves and stems of other aquatic plants or to filaments of other algæ or even to stones. This is, however, not so commonly met with as *spirogyra*.

1. Mount specimens of *Ulothrix* on a slide and note —

(*a*) the rows of short **cells** forming the simple unbranched filament,

(*b*) **the protoplasm**, and

(*c*) the band-shaped **chloroplast.**

2 The process of reproduction may be observed in *Ulothrix* when it is brought into culture Both asexual and sexual reproduction occur in this plant.

The protoplasm in a cell becomes transformed into one or two **zoospores** with four cilia. These escape through a lateral opening formed by the absorption of the cell-wall. After moving about for sometime the zoospore comes to rest, germinates and developes into a filament. This is the asexual mode of reproduction.

The contents of a cell instead of developing into one or two zoospores break up into a large number of **biciliated zoospores**, which are incapable of developing into *Ulothrix* filaments by themselves. They fuse in pairs and the fused mass is capable of giving rise to a filament. Hence these small zoospores are of the nature of gametes (**zoogametes**). The fused mass is a **zygote.** This is the sexual method of reproduction and the zoogametes are both alike (**isogamous**).

Oedogonium.

Several species of *Oedogonium* occur in ponds, puddles and in running water. All the species are alike in the

vegetative part of the filament, which is simple and unbranched. There are differences in the distribution of the sexual organs and in their life history.

1. Mount some filaments of *Oedogonium* in water and examine them under a low power and note :—

(*a*) the unbranched long filaments, of uneven thickness, terminated at the apex either by a rounded cone or by an attenuated process, and the irregularly lobed disc of attachment at the base of the filament,

(*b*) the septa dividing the filament into a series of cells with green coloured contents, and

(*c*) the transverse striæ or septa occurring close together at the upper ends of some cells—the socalled "**caps.**"

2. Examine the cells of the filament under a high power and note :—

(*a*) the colourless **protoplasm.**

(*b*) the parietal **reticulated protoplast** with large **pyrenoids** and starch grains.

(*c*) the **nucleus,**

(*d*) the **vacuole,**

(*e*) the **cell-wall,** and the transverse septa and the "**caps.**"

3. If specimens are examined in the morning formation of the zoospores may be seen. On keeping plants in Knop's or other culture solution (weak—0·1 or 0·2 per cent) in a cold place and raising the temperature of water to 15° or 16° C, zoospores appear in a day or two.

The protoplasm in a cell contracts and escapes as a motile pear-shaped **zoospore,** through the slit formed by the rupture of the transverse wall of the cell. The anterior end of the zoospore is surrounded by a fringe of cilia.

4. The sexual organs are easy to see in this plant. The female **gametes** or the **oogonia** occur as rounded bodies in spherically enlarged cells of the filament. In some species oogonia only occur in a filament, while in others oogonia as well as the male gametes (**antherozoids**) are formed in the same filament.

The male gametes or antherozoids are formed in cells that are smaller and shorter than those of the ordinary vegetative filament. The contents of each of these cells

(**antheridia**) become divided into two parts, which without further division become transformed into two motile bodies or **antherozoids**, similar in form to the zoospores but smaller.

The oogonia may occur singly or in rows of two or more in the same filament.

5. In some species of *Oedogonium* what are called "dwarf male plants" occur on or near the oogonia bearing cells. Antherozoids are formed in these dwarf males and they escape and fuse with the oogonia.

The dwarf male plants develop from **androspores** which are intermediate in size between zoospores and the ordinary antherozoids. The androspore swims about and then settles down in a place by it clear ciliated end and then changes into dwarf male plants The androspores are formed in short cells appearing in female filaments either singly or in chains.

FUNGI.

Rhizopus Nig

Place under a bell-glass in a moist chamber pieces of moistened bread. After two or three days a white flocculent mass with a cob-webby appearance forms on the pieces of bread. This fluffy mass is the vegetative portion or the mycelium of a fungus. In all probability more than one fungus may appear, but the first to appear is the fungus *Rhizopus nigricans*. This plant can easily be made out by the out growth from the **mycelium** of erect **sporangiophores**, each bearing at its tip a small black head. If the bread is kept under the bell-glass for a long period, the *Rhizopus* fungus is succeeded usually by the bluish green *Penicillium* with short conidiophores, like miniature paint brushes, and then by *Eurrotium* (*Aspergillus*) which is rather like *Penicillium* but with larger and longer **conidiophores** bearing globular cluster of chains of **conidia**.

1. Take a small piece of bread on which *Rhizopus* is growing and examine it with a lens. Note that the cob-webby mass or the mycelium really consists of fine cylindrical threads or **hyphæ**, running in all directions, some penetrating the substance of the bread, others creeping

horizontally and a few growing erect and terminating in black heads.

2. Pick up some portion of the mycelium, rather carefully, without damaging the hyphæ and tease it out gently on a slide in water and cover it Observe first under a low power and then under a high power the following characteristics of the mycelium :—

(*a*) Some of the hyphae of the mycelium creep along on the surface horizontally, and these are somewhat thick and without any transverse walls.

(*b*) From these primary filaments branches arise and these grow into the substance of the bread and ramify through it in all directions. These hyphæ also are unseptate and they are thinner than the primary hypha. These thinner branches penetrating the substratum branch repeatedly and become finer as branching proceeds. In fact the whole of the mycelium consists of unseptate hyphæ, and hence **coenocytic.**

(*c*) The erect hyphæ are also thick like the creeping primary ones and are **sporangiophores.**

3. Mount a bit of the mycelium of fresh *Rhizopus* in water on a slide, and after noting that the protoplasm is in close contact with the cell-wall run in salt solution. This will cause plasmolysis of the protoplasmic lining, thus making it visible. If iodine solution is run in the protoplasm stains brown

To make out the numerous nuclei the mycelium should first be fixed and then stained with Delafield's hæmatoxylin.

4. Cut off a number of erect branches with sporangia in different stages of development and mount them carefully in alcohol with least damage. Note—

(*a*) the cylindrical **sporangiophores**, each terminated by

(*b*) the somewhat rounded **sporangium,**

(*c*) clear space or the **columella** within the sporangium.

By examining a number of sporangia in different stages of development observe the points mentioned below :—

(*a*) The free ends of the erect hyphæ becomes swollen and a cross-wall is formed below the swelling cutting off the swollen portion (sporangium) from the rest of the hyphae.

(*b*) the enlarging of the sporangium and the bulging of the cross-wall into the cavity forming the columella.

(*c*) the formation of spores, and the mucilage inside the cell-wall of sporangia, which when mature have radiating crystals of calcium oxalate.

Select a mature sporangium and mount it carefully in alcohol Run in water and observe the sporangium under the microscope. As the water gains access to the sporangia, they burst suddenly and the wall breaks up into fragments and the spores are set free. The bursting is due to the swelling up of the mucilage by the absorption of water. The dense contents of the sporangia consist of spores and mucilage. The columella is seen as a clear space

5. *Rhizopus nigricans* also reproduces itself by means of sexual reproduction, but it does so only rarely. When it occurs it is as detailed below.

When the hyphæ of two mycelia having quite distinct origins growing in the same medium come into close proximity to each other, short club shaped branches arise sometimes on the adjacent hyphæ and grow towards each other. When their ends come into contact, a transverse cross-wall develops in each, cutting off the protoplasm from the rest of the branch. At the point of contact the wall dissolves and the protoplasm at the ends fuses. In the dilated ends of the hyphæ there are many nuclei before fusion, and these nuclei fuse in pairs from the opposite branches

The mycelia growing from spores originating from the same sporangium will not unite, but fusion occurs between two distinct strains cultivated together.

Penicillium Glaucum.

This mould is easily recognized by its blue green colour. When young the mycelia appear as white patches, and as they grow become first pale blue and then dull green, the change of colour starting at the centre of the patch and spreading to the outside.

1. From a growth of *Penicillium* on moist bread isolate a portion of the mycelium and mount it in a drop of alcohol,

add a drop of water and cover. Note that the mycelium consists of : —

(*a*) horizontal and creeping hyphæ,

(*b*) submerged hyphæ growing into and penetrating the bread in all directions,

(*c*) erect hyphæ developing into conidiophores.

2. Examine under a high power and make out the following features of the mycelium.

(*a*) The mycelium consists of separate hyphæ.

(*b*) The conidiophores are non-septate, and each of these bears at its free end a cluster of conidia, some of which will have become detached and will be seen in the water.

(*c*) The hyphæ of the whole mycelium are uniform in thickness.

(*d*) The conidiophore is an unbranched shaft bearing five or six cylindrical segments. These support other branches which give rise to lateral branches, which in their turn may again branch. All the branches thus formed finally arrange themselves parallel to one another and vertical to the mycelium. On the terminal segments of this branch system bottle-shaped segments (**sterigmata**) are formed. From the tip of each **sterigma** a minute globule or **conidium** is formed. Another one forms pushing up the first. By a repetition of this process chains of conidia are formed from the tips of sterigmata. The older conidia forming the outer end of the chain have a blue colouration in their walls which confers the characteristic blue colour to the mould when seen with the naked eye.

3. *Penicillium* resorts at times to sexual reproduction. Two short branches arise from the mycelium and these coil round one another spirally. From this coil short branches (**ascogenous hyphæ**) grow out in every direction. The hyphæ supporting the spiral coil also give rise to numerous hyphæ which grow up over the ascogenous hyphæ and form a compact cover. The walls of the outer layers become thickened and dark yellow in colour and form a hard resistant coating or rind. After several weeks **asci** arise from ascogenous hyphæ. Each ascus bears eight **ascospores.** The ripe **ascocarp** bursts and ascospores are set free. The development of the ascocarp takes about six months' time.

Agaricus.

1. Obtain some specimens or fresh mushrooms and observe that each one consists of a white stalk which is short and usually quite solid and a cap which is dry and cottony above. On the underside of the cap are seen closely-set gills radiating from the stalk to the rim of the cap.

If the **mushrooms** or the **spore-producing** organs of the fungus are carefully dug out, it will be seen that they arise from mycelia permeating the soil.

2. Get mushrooms of different sizes and observe the following points in them —

(*a*) Young mushrooms arise as small button-like masses from the underground mycelium.

(*b*) When quite young these consist of uniform solid tissue.

(*c*) The button-like mass gets differentiated into the cap and the stalk later.

(*d*) The gills and gill-chamber come into existence gradually.

(*e*) The tissue forming the floor of the gill-chamber gets ruptured, and the gills get exposed.

(*f*) Simultaneously with the formation of the gills the stalk grows and elongates carrying the cap up into the air.

3. Cut across the stalk of a matured mushroom, just below the cap, and lay the cap with the gills downward on a sheet of white paper. After a few hours, note that the spores fall out in the usual way and collect in ridge like heaps, forming lines corresponding to the gills. If the paper is smeared with gum and then used, a permanent "spore print" of the mushroom may be obtained.

4. Cut sections of the stalk and the cap from material hardened and preserved in spirit. Note (*a*) in the stalks that the tissue consists of branched septate hyphæ closely interwoven and that the peripheral portion is more compactly packed than the central; (*b*) in the gills cut across tangentially that the main tissue is similar to that of the stalk, that the tissue in the middle of the gills is somewhat loose, that some hyphæ grow erect at right angles to the surface of the gill on both sides and swell at their tips and form **basidia**

bearing four very short branches and each of these branches or **sterigma** carrying a **basidiospore** and that some hyphæ remain as paraphyses.

Puccinia Purpurea.

Examine rusted plants of cholam (*Andropogon Sorghum*) showing red or purple spots on their leaves and stems. With a lens note that these spots are cracks or slits from which an orange powder is shed or can easily be scraped.

1. Scrape off some of the "rust" and note the numerous **uredospores**, each consisting of an ovoid cell with a thick outer-coat (covered with fine spines when mature). The inner layer is thin and the contents of the spore are coloured with drops of orange or yellow oily matter

2 Examine transverse sections of stem or leaf bearing patches of these spores and note —

(*a*) the patch between two of the vascular bundles below the epidermis.

(*b*) the group of **uredospores**, each spore with a slender stalk, an outgrowth from the underlying mycelium.

(*c*) the broken remnants of the epidermis of the leaf of the host plant.

(*d*) the mycelium of the fungus consisting of slender threads traversing the soft parenchyma of the leaf and forming a dense layer just below the patch. The hyphæ do not affect the sclerenchyma and the xylem of the vascular bundles.

3. Examine the "rust" patches formed later on on the stems and leaf-sheaths and blades. Instead of being reddish purple, the patches appear darkish red. This change in colour is due to the appearance of spores of a different kind.

Cut section through these patches and examine them. Note that the spores are two-celled, thick walled and spindle-shaped. These spores are called **teleutospores.**

Mixed up with teleutospores a few uredospores also may occur.

The teleutospores germinate on a flowering plant and affect their leaves. These spores do not at all directly attack the cholam host. On germination basidia are formed and these produce basidiospores.

The intermediate host plant on which *P. purpurea* flourishes in the absence of cholam plant has not been definitely made out. The species of *Puccinia* affecting the wheat plants has as its intermediate host the *Berberis* plant. This fact has been established beyond doubt.

4 If plants of the species *Blepharis mollugnifolia* or *B. boerhaavi folia* are examined red or brown spots are often seen on their leaves. Examine these patches with a lens and note that these appear as swellings, some closed, others especially older ones, open and appearing as cups.

5. Cut sections of the leaf through these spots or **aecidia** and note :—

(*a*) The mycelium of *Puccinia* consisting of hyphæ ramifying through the intercellular spaces in the mesophyll tissue of the leaf.

(*b*) The **aecidium** containing closely packed parallel chains of **aecidispores** and

(*c*) the wall of the **aecidium.**

9 The **fine adjustment**, a screw at the top of the arm or on its sides below the coarse adjustment. This is used for more accurate focussing, especially with the higher power objectives. When this screw is turned the movement is very slight.

Adjustment and the use of the microscope for work—Place the microscope on a table opposite a window with the pillar of the microscope next to you. Turn the plane surface of the mirror so that the light from the sky is reflected through the diaphragm in the stage up the tube of the microscope Light reflected from white clouds is the best Direct sunlight should never be used for microscopic work

See that the low power objective is in proper position at the lower end of the tube. Insert the eye-piece at the upper end Look through the tube and rotate the eye-piece and if any specks are seen to rotate with it, they are on the lenses of the eye-piece These specks must be removed with a clean soft cloth or silk If the field is dim and does not rotate when the eye-piece is turned, the dimness is due to the presence of grease or dirt on the front lens of the objective This dirt also should be cleaned with a cloth.

The object to be examined is placed on the stage so that it is just above the hole in the stage Lower the body-tube by means of the rack and pinion until it is about one centimetre above the object. Look into the eye-piece and adjust the mirror until the eye-piece is filled with light. Close the diaphragm until its opening is about quarter of an inch across or less and turn the coarse adjustment up until the object comes into view Now use the fine adjustment till the object appears with the greatest clearness.

Observations should be made always with the lowest possible power sufficient for clear vision and afterwards a higher power may be used, if necessary For the low power use the flat mirror and a large hole in the diaphragm and with the high power the concave mirror and a small hole in the diaphragm In focussing use the coarse adjustment at first, and the fine adjustment should be used only after the focus has been obtained with the coarse focussing In using the high power very great care is necessary, since, the objective when in focus is very close to the object The object to be examined with a high-power should always be covered with a cover-glass

Accustom yourself to use both the eyes While observing through the microscope keep both eyes open. This will lessen the fatigue.

When the high power is used special attention should be paid to the fine adjustment, to the manipulation of the mirror and the hole of the diaphragm to obtain satisfactory results. While using the high power it is advisable to keep one's finger on the fine adjustment and to move it continuously backwards and forwards

The objectives are very delicate things and so they must be handled with care. Never unscrew the lenses, especially those of the high power objectives. The black coating inside the tube should not be interfered with.

APPENDIX III.

MAKING PREPARATIONS.

Preservation of material.—Fresh material should always be used for examination with the microscope. Specimens that are small and do not require to be sectioned may be simply mounted on a slide in water for observation. But it is often convenient to keep specimens for a time and the best liquid for this purpose is methylated alcohol. Material preserved in alcohol is best for section cutting since the alcohol drives out the air bubbles and renders the tissue more readily to cut. It must be remembered that alcohol dissolves out chlorophyll, oils, resins, etc. Another very good preservative liquid is 50 per cent spirit, 50 per cent water and 5 per cent formaline.

Fixing and hardening.—Although methylated alcohol is a good preservative this reagent causes plasmolysis of the cells. So if we wish to see the tissues and cells in something like their living condition, it is necessary to use reagents which will kill the protoplasm as rapidly as possible and fix it and other contents of cells in as nearly as possible the natural condition. For detailed information on fixing, etc., see Chamberlain's Methods in Plant Histology, Strasburgher's Hand-book of Histology or any other standard work on Plant Histology.

The following fluids are best suited for fixing and hardening :—

(1) Absolute alcohol or strong methylated spirit.
(2) Formaline 4 per cent solution.
(3) Chromic acid ½ to 1 per cent solution (water 300 c.c., chromic acid 2 grains and 3 c.c. of glacial acetic acid).

Specimens fixed in chromic acid should be washed in running water until no more yellow colour is present. Then it should be passed through graduated strengths of alcohol and finally preserved in strong alcohol (about 95 per cent alcohol).

Section cutting.—For a complete study of a solid body such as the root, stem, ovule of a plant it is necessary to cut sections in three directions at right angles to each other.

The best way to study the structure of a solid mass such as a cylindrical stem would be to cut :—

(1) **Transverse** sections, in planes at right angles to the long axis.

(2) **Radial longitudinal** sections, in longitudinal planes passing through the organic axis.

(3) **Tangential longitudinal** sections, in longitudinal planes but not passing through the organic axis

The sections must always be cut accurately in the plane intended, otherwise the difficulty of making out the structure will be enormously increased

For section cutting a razor of good quality with a keen edge is essential If the edge is not good it should be stropped to a keen edge The obtaining of good sections is dependent upon the keen edge of the razor and the proper direction of the section. The specimen to be cut should of course be in a good condition of preservation

While cutting sections it is necessary to keep both the razor and the material well wetted with 50 per cent alcohol. Water may sometimes be used, but it has a tendency to run into drops instead of spreading over the blade Always have at hand alcohol in a dish to dip both razor and material into while cutting the sections.

In cutting sections hold the specimen between the thumb and the forefinger of your left hand and grasp the razor tightly with the right hand The blade of the razor should be held so as to be horizontal with its edge directed towards you Note the position of the left hand, the right hand, the position and the movement of the razor while the demonstrator is cutting sections and do similarly

Mounting.—Take a slide and clean it with a cloth and see that its surface is polished and quite clean After cleaning a slide never touch its surface with your fingers Take hold of a clean slide by its edges with the thumb and forefinger of your left hand and lay it on a clean black or white background

On the centre of this slide place a drop of the mounting fluid-water, dilute glycerine or chlorzinc iodine as the case may be, and p[illegible]h it the specimen or the section you wish to examine Then [illegible]over-glass which is quite clean and clear by its edges between [illegible]gers and bring it down upon the drop in a tilted position so that one edge of it is first wetted by the medium. Then support the cover-slip with a mounted needle at the other end and gently lower it by gradually withdrawing the needle

The mounting fluid used should be just enough to fill the space between the cover-slip and the slide and extend to the margin of the cover-glass If too much has been used the excess must be removed by means of bits of blotting-paper or filter-paper

The slides and the cover-glass should be perfectly dry and clean, and should show a bright polished surface Their surfaces should never be touched with the fingers.

Great care should be taken to see that no air bubbles are present in the medium surrounding the object

It should be remembered that alcohol, water, and their solutions will evaporate, while glycerine and chlorzinc iodine do not.

Reagents and their use.—Always examine the specimen in water first, before applying special reagents. The reagents in common use

are iodine, aniline sulphate and chlorzinc iodine. These may be used as mounting media. If, however, these or other reagents have to be applied to sections mounted in water or alcohol, place a drop of the reagent close to one edge of the cover-slip, taking care that it does not get on to the upper side of the cover-glass, and then place a small torn piece of blotting-paper at the opposite edge of the slip so as to draw in the reagent. If by irrigation the reagent does not reach the section apply the reagent directly by raising the cover-slip and mount as usual.

APPENDIX IV.

LIST OF REAGENTS GENERALLY USED.

Acetic acid —An aqueous solution of 1 to 5 per cent

(1) dissolves calcium carbonate with evolution of bubbles of carbon dioxide gas,

(2) brings out clearly the nuclei of cells when used in conjunction with methyl green,

(3) used in the preparations of fixatives.

Alcohol —This is largely used as a preservative, hardening and fixing agent For dehydration absolute alcohol should be used. Strong alcohol (95 p c) or methylated spirit is used for preserving

Aniline sulphate —A saturated solution in water, acidulated with a few drops of sulphuric acid is used The walls of lignified tissues turn yellow when this solution comes in contact with them Other tissues are not affected

Benzol.—This is used as a solvent of the dark green colouring matter of the chloroplast, also a solvent of latex, wax, etc.

Chloral hydrate —It is used together with iodine for finding out the starch grains within the chloroplasts In 5 parts of water 8 parts of chloral hydrate is dissolved and a few crystals of iodine are added.

Chromic acid —For fixing a very weak solution of this acid is used. Usually ½ to 1 per cent aqueous solution is used.

Chlorzinc iodine (Schultze's solution) —This reagent may be prepared as follows, if it could not be purchased ready made

(*a*) Take 110 grams of zinc and dissolve it in 300 c c. of pure hydrochloric acid and evaporate it to 150 c c. (s.p gr about 1 8)

(*b*) Dissolve 12 grams of potassium iodide in as little water as possible add 15 grams of iodine. Mix (*a*) and (*b*), and filter if necessary through asbestos The solution should have dark-red sherry brown colour.

Eosin.—A dilute aqueous solution of eosin is a good general stain for protoplasmic cell contents and cellulose cell-walls. It is used to demonstrate the structure of the sieve tubes.

Fehling's solution —This is used as a test for grape-sugar. It is prepared as follows

(*a*) Dissolve 35 grams of copper sulphate in 200 c.c. of water.

(*b*) Dissolve 70 grams of Rochelle salt (potassic-sodic-tartrate) in

Use equal parts of (*a*), (*b*) and water. Keep the solutions (*a*) and (*b*) in separate bottles.

Glycerine — A most generally used medium for mounting and for this it is diluted with an equal volume of distilled water

Haematoxylin (Delafield's)—This is the best of the general stains. It may be purchased ready made It may be made as follows —

Add 4 c c. of saturated alcoholic solution of haematoxylin to 150 c.c. of a saturated aqueous solution of ammonia alum After exposing this to light for a week or more, filter and mix the filtrate with 25 c c. of glycerine and 25 c c of methylated spirit. After some time filter and keep in a stoppered bottle.

Hoffman's Blue—This is used as 50 p c alcoholic solution to stain the cell contents and the contents of sieve tubes. The solution must be acidulated with a few drops of acetic acid.

Iodine—It is one of the most useful reagents. An aqueous solution is generally used Dissolve a small quantity of potassium iodide in distilled water and add a crystal of iodine If the solution is deep in colour it should be diluted with distilled water to the colour of sherry

Millon's reagent—One c c. of mercury is dissolved in 9 c.c of strong nitric acid and 10 c c. of water is added This stains proteins brick-red, heating hastens the reaction

Phloroglucin.—A small quantity is dissolved in strong spirit, and strong hydrochloric acid is gradually added till precipitation begins Under this reagent lignified walls turn bright red in colour

Potash—A dilute aqueous soution of about 1 to 5 p c. is used as a clearing agent.

Safranin.—A good general stain. A saturated solution in alcohol diluted with an equal volume of water is made and then the liquid is used

PREFACE.

THIS small book is intended to serve as a practical guide to general botany. The laboratory exercises are largely based upon the matter contained in my "Manual of Elementary Botany for India." These exercises have been in use with successive sets of students for over ten years and have been found to meet their requirements.

The importance of the study of botany as a disciplinary as well as an informational subject is now widely recognized. As to the method of teaching botany there is a diversity of opinion. Some hold the view that the student should be merely led in the laboratory to discover everything for himself. This view, no doubt, is an ideal one and the student is certain to gain knowledge and power by such work. But in our schools and colleges the time available for a science course is not much, and as such this go-as-you-please pace implied in this method is impossible. Further the students, who are of varying capacity and limited resource, if compelled to discover things for themselves, the result will be mere confusion and incoherent knowledge. To obtain satisfactory results it is necessary to help them by giving them clear instructions and guidance as to what they should do.

In this book full and fairly definite instructions are given, and it is expected that each teacher will make additions or eliminations according to his requirements.

The physiological experiments described in this book have all been found to work satisfactorily year after year by my colleagues in teaching, M.R.Ry. P. S. Livanna Rao, M.A., and M.R.Ry. S. N. Chandrasekhara Ayyar, M.A. Though these experiments take time, they should not be omitted. Time spent on them is not a waste of time, it is really time well spent.

MADURANTAKAM,
September 1923.

K. RANGACHARI.