MINISTRY OF EDUCATION, EGYPT.

A Laboratory Notebook of Elementary Botany

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PART I.—MORPHOLOGY.

INTRODUCTION.

The following course of elementary botany has been designed in order to give the student a general idea of the principles of the science, rather than a comprehensive survey of the whole vegetable kingdom. In a short course of this nature it is impossible to include examples of every group, and therefore those types have been selected with which it is most important that the student should become acquainted.

In order to derive full advantage from the course, the following elementary rules of laboratory procedure must be observed:—

Use of Microscope.—Always see that the eye-piece and objectives are clean. Lenses can usually be cleaned by breathing on them and then wiping them with a clean cloth, preferably of silk. If any balsam has got on to the objective, the attention of the demonstrator should be called to it.

When examining an object always use the low power first. When focussing with the high power use the fine adjustment only and be very careful to avoid touching the cover glass with the objective.

Use the plane mirror with the low power and the concave with the high.

Microscope Preparations.—Always clean slides and cover-glasses before use.

When covering an object, hold the cover-glass by the edges, in order to avoid leaving finger-marks on it. Lower it gently on to the drop of liquid to avoid the inclusion of air-bubbles. Be very careful not to use too much liquid for mounting objects, as in this case it will run on to the top of the cover-glass and obscure vision. If this happens make a new preparation.

Drawing.—Make your drawings in the spaces provided for them. Do not make rough drawings on other paper and later on transfer them into this book; above all only draw what you see, not what you imagine to be present, and do not make copies of diagrams from text-books. Always use a sharp pencil. Label every structure shown in your drawings and insert the scales to which they are made.

1. Draw a side view indicating the following parts: foot; body; tube and draw-tube; stage; sub-stage with diaphragm and mirror, one side plane, the other concave; coarse and fine adjustments; eye-piece; low and high power objectives; nose-piece.

2. Paper.—Tear off a small piece of paper and mount it for microscopic examination by placing it on a slide, adding a drop of water and covering it with a cover-glass. This is called a " fresh preparation." Examine it under both low and high powers and draw what you see. The black circles which may be present in this and the following preparations are air-bubbles.

3. Cotton.—Make a similar fresh preparation of cotton-wool. Draw what you see under both powers.

4. Moss.—Examine a moss-leaf under both powers. Notice how the leaf is divided into separate compartments called " cells." Draw what you see.

5. Diatoms.—Examine a drop of water containing diatoms which are plants composed of one cell only. Draw examples of them under the high power.

6. Animal Cells.—Scrape the inside of your cheek with the back of your nail and make a fresh preparation of the material obtained. Make drawings under the high power showing the epithelial cells with nuclei.

7. External Features.—Make a drawing of the bean plant, showing: primary root; root-cap; secondary roots; hypocotyl; stem; branches; buds; leaves; vestigeal tendrils; stipules; flowers. Examine the specimen of a pea plant showing well developed tendrils, and draw one of its leaves.

8. External Features.—Cut off a piece of stem with attached leaf and bud in axil of leaf. Make a drawing to show: stem with ribs; stipules; bud; petiole; leaflets; tendrils; reticulate venation.

9. Flower.—Draw a side view of an open flower showing: flower stalk, or pedicel; calyx, consisting of 5 united sepals; corolla, consisting of 2 anterior petals or keel, 2 lateral petals or wings, one posterior petal or standard.

10. Flower.—With a razor make a median longitudinal section of the flower and draw: flower stalk; thalamus; calyx; corolla; androecium, composed of ten stamens, nine anterior united; gynœcium, with one carpel, consisting of stigma, style, and ovary, the latter containing ovules.

11. Flower.—Draw a transverse section through the base of a flower bud. Examine with a hand-lens and make a drawing to show: calyx tube; corolla of five petals, two anterior united; ten stamens, nine anterior united; unilocular ovary; ovules; placenta.

12. Stamen.—Isolate one of the stamens, put it on a dry slide, and examine it under the low power. Draw: filament; connective; two anthers; pollen. Examine and draw the latter under the high power.

13. Fruit.—Pull off the petals of a faded flower to see the developing fruit. Draw a median longitudinal section of the latter.

14. Fruit.—Draw a ripe pod opened to show the contained seeds.

15. Seed.—Draw an external view of a seed showing: testa; hilum; micropyle. (The latter may be seen more clearly by squeezing a soaked seed, when water exudes through the opening.) Then remove the testa and one cotyledon, and draw the remaining cotyledon with attached embryo showing: plumule; hypocotyl; radicle.

16. Seedling.—Draw a bean after it has begun to germinate, showing: split testa; cotyledons; plumule; hypocotyl; radicle; primary and secondary roots; root-hairs.

17. Seedling.—Draw an older bean seedling after the appearance of the foliage leaves, showing: leaves; stem; hypocotyl; remains of seed; primary root; secondary roots.

18. Histology of Root.—Draw the prepared section of a root under the low power, showing: cortex; stele, consisting of pericycle, xylem, protoxylem, phloem, cambium and pith. In the demonstration of a young root notice, in the cortex, the piliferous layer and root-hairs, ground tissue and endodermis,

19. Histology of Root.—Draw a sector of the section under the high power to show the detailed structure of each tissue.

[illegible] Histology of Stem. [illegible] pith. [illegible]

12. Histology of Root. Draw a section [illegible]
he detailed structure of each tissue.

20. Growing Point of Root.—Draw a longitudinal section through the tip of a root, under both powers, to show: root-cap; dermatogen; periblem; plerome.

21. Origin of Lateral Roots.—Sketch the demonstration slide of a transverse section, showing the origin of a lateral root from the pericycle.

22. Histology of Stem.—Draw the prepared transverse section of a young stem, showing: epidermis; cortex; endodermis; pericycle fibres; vascular bundles; medullary rays; pith.

23. Histology of Stem.—Draw a sector of the same section under the high power, showing: epidermis; collenchyma; cortical cells; endodermis; pericycle or bast fibres; phloem; cambium; xylem consisting of vessels and parenchyma; medullary rays; pith.

24. Histology of Stem.—With a razor cut thin transverse sections of a piece of the stem of a bean, with secondary thickening. While cutting keep the blade of the razor moist with water and float the sections into a watch-glass containing water. Mount the best of them on a slide and examine under the low power. Make a sketch showing the relative positions of the following: epidermis; cortex, containing isolated vascular bundles; pericycle, with pericycle fibres opposite each vascular bundle; vascular bundles, each consisting of phloem, cambium, and xylem; medullary rays; interfascicular cambium with secondary xylem and phloem; pith; air passages between cells of pith and of cortex.

25. Histology of Stem.—Draw the prepared longitudinal section under the high power, showing: epidermis; collenchyma; cortex; endodermis; pericycle fibres; phloem with sieve-tubes and parenchyma; cambium; pitted and spiral vessels of xylem; pith.

26. Growing Point of Stem.—Draw the prepared longitudinal section under both powers, showing: dermatogen; periblem; plerome; origin of vascular bundles from plerome; young leaves; origin of branches.

27. Histology of Leaf.—Draw the prepared transverse section under the high power, showing : cuticle ; upper epidermis with few stomata ; gland hairs ; palisade and spongy parenchyma with chloroplasts ; inter-cellular air spaces ; vascular bundles ; lower epidermis with many stomata.

28. Stomata.—Strip off a bit of the lower epidermis from the leaf of a bean plant. Mount it in water on a slide and examine under the high power. Draw a small part of the epidermis, showing : epidermal cells ; stomata, bounded by guard cells containing chloroplasts.

BACTERIA.

29. Bacteria.—Examine under the high power a drop of water in which grass has been allowed to soak for a week, and also a drop of liquid from putrfying meat. Draw the various forms of bacteria you see: cocci; bacilli; bacteria; vibrios; spirilla; colonial forms.

SACCHAROMYCES.

30. Yeast.—Make a fresh preparation of baker's yeast; draw it under the high power, showing: cells surrounded by cell-wall, containing protoplasm with vacuole; buds; chains of buds.

Examine and draw the demonstration specimen of a yeast cell under the $\frac{1}{12}$ inch objective, stained to show the nucleus.

31. Vegetative Stage.—Place on a dry slide a portion of the mycelium of a white mould growing on damp bread. Draw branching hyphæ before putting on the cover-glass. Then add a drop of water, cover, and draw the cell-wall and protoplasm.

32. Asexual Reproduction.—Draw an unripe colourless sporangium and a ripe dark-coloured sporangium under the high power, showing : aerial hypha ; sporangium. Gently press the cover-glass to burst the sporangia and make a drawing to show the contained spores embedded in mucilage, and columella.

33. Sexual Reproduction.—Draw conjugating hyphæ under the high power, showing gametes and zygotes.

34. Vegetative Stage.—Draw a piece of a filament under the low power, showing: cells, arranged end to end; cell-walls; spiral chloroplasts. Then draw one cell under the high power, showing: cell-wall; protoplasm; chloroplasts containing pyrenoids; nucleus with protoplasmic strands crossing large vacuole.

35. Growth.—Find a cell in which the nucleus has divided and draw it under the high power, showing the commencement of new cell-wall.

36. Sexual Reproduction.—Examine the supplied material under the low power and find successive stages in conjugation. Make drawings to show: lateral outgrowths; conjugation tubes; passage of cell contents; zygotes.

34. Vegetative Stages.—Draw a piece of a filament under the low power showing lly arranged and to end cell-walls; spiral chloroplasts. Then draw one cell under e high power, showing: cell-wall; protoplasm; chloroplasts containing pyrenoids; [illegible] of protoplasm; [illegible] crossing large vacuole.

35. Growth.—Find a cell in which the nucleus has divided and draw it under the high power showing the commencement of new cell-wall.

36. Sexual Reproduction.—Examine the supplied material under the low po and find stages in conjugation. Make drawings to show: [illegible] conjugation tubes; passage of cell contents; zygotes.

37. Vegetative Stage.—Draw part of the thallus under the low power, showing: colourless rhizoids and green filaments. Draw part of the filament under the high power, showing: cell-wall; protoplasm; chloroplasts; mode of branching.

38. Asexual Reproduction.—Find a swollen end of a filament cut off by a cell-wall. Draw this zoosporangium containing a single developing zoospore. Afterwards draw a free swimming zoospore, showing: central region with chloroplasts; clear outer region with nuclei; cilia.

39. Sexual Reproduction.—Draw under the high power part of a filament bearing reproductive branches, to show: antheridium, cut off by cell-wall; spermatozoids; oogonium, cut off by cell-wall; ovum. Afterwards find and draw a fertilized ovum with thick cell-wall.

40. Examine and sketch the demonstration specimens of marine algæ.

41. External Features.—Draw under the hand lens a moss-plant with sporogonium, showing: rhizoids; stem; leaves; sporogonium, with seta, theca, and calyptra.

42. Leaf.—Mount a leaf in water and draw it under the low power, showing: midrib; lamina; cells. Then draw a few cells under the high power to show contained chloroplasts.

43. Stem.—Draw a transverse section of the stem under the high power to show: conducting strand; thin-walled cortex; thick-walled cortex; epidermis, and in some slides, rhizoids and sections of leaves.

11. [illegible] [illegible].—Have ready the [illegible] [illegible] with [illegible] [illegible] [illegible] [illegible] [illegible] spongy tissue with [illegible] [illegible].

46. Leaf.—Mount a leaf in water and draw it under the low power, [illegible] [illegible] cells. Then draw a few cells under the high power to show [illegible] chloroplasts.

48. Stem.—Draw a transverse section of the stem under the low power to show [illegible] conducting strand; thin-walled cortex; thick-walled [illegible] [illegible] rhizoids and sections of leaves.

44. Sexual Reproduction.—Cut off the apex of a moss plant without sporogonium; put it in a drop of water on a slide and carefully separate the leaves with the aid of needles. Then examine under the low power and draw: antheridia; archegonia; paraphyses.

Draw an archegonium under the high power to show: stalk; venter; neck; canal cells; ovum; also draw an antheridium to show the wall and contained spermatozoids.

45. Asexual Reproduction.—Draw a longitudinal section through a capsule under the low power, showing: seta; apophysis; stomata; air-space; spore-sac; spores; columella; annulus; peristome; operculum.

46. Germinating Spores.—Draw under the high power a germinating spore, showing: ruptured spore-case; cells of protonema; rhizoids; buds.

16. Asexual Reproduction. Draw a sporangium and its stalk, showing a [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] gelatinous [illegible]; protoplasm.

18. Germinating Spores. Draw under the high power a germinating spore showing: mycelium; protoplasm; cells of [illegible]; filaments; ends.

47. Sporophyte : External Features.—Draw the fern plant, showing : rhizome ; adventitious roots ; leaves ; buds.

48. Sporophyte: Internal Structure.—Draw a transverse section of the stem, under the low power, showing: epidermis; adventitious roots in some sections; parenchymatous tissue with numerous starch grains; vascular bundles, each surrounded by endodermis, and made up of pericycle, phloem, and xylem, consisting of tracheids and xylem parenchyma. Then draw a vascular bundle under the high power.

49. Sporophyte: Internal Structure.—Draw part of a longitudinal section of the stem under the high power, showing: epidermis; parenchyma; endodermis; pericycle; sieve-tubes of phloem; scalariform vessels of xylem, and xylem parenchyma.

50. Asexual Reproduction.—Draw the under surface of a fertile leaf, showing sori, covered by indusia.

51. Asexual Reproduction.—Strip off a young sorus and examine the inner surface of the indusium under the low power. Draw a sporangium under the high power showing: capsule; annulus; stalk; stomium; contained spores.

52. Gametophyte.—With the aid of a hand lens draw an enlarged view of the under surface of a prothallus, showing: rhizoids; cushion; antheridia; archegonia.

53. Sexual Reproduction.—Mount a prothallus and draw under the high power: antheridia with contained spermatozoids; archegonia with venter, neck, canal cells, and ovum.

54. Sexual Reproduction.—Sketch the demonstration specimen of a young sporophyte attached to a prothallus, showing: foot; stem; leaf; primary root.

55. External Features.—Draw the terminal part of a shoot of the pine, showing: stem; branches; terminal buds; scale-leaves; foliage leaves or needles; dwarf shoots.

56. Structure of Stem.—Draw a segment of the stem of a young pine tree, showing : bark ; cork ; resin canals ; phloem ; cambium ; wood ; annual rings, with spring and autumn wood ; medullary rays ; pith. Estimate the age of the stem.

57. Histology of Stem.—Draw under the low power a transverse section of a young stem, showing : epidermis ; scale-leaf bases ; cortex ; resin-canals ; phloem ; cambium ; xylem ; medullary rays ; pith. Then draw a sector under the high power showing, in addition : sieve-tubes and phloem parenchyma ; bordered pits on radial walls of tracheides ; secretory cells of resin-canals.

56. **Structure of Stem.** Draw a section of the [illegible] of a young [illegible] tree showing: bark; cork; resin canals; phloem; cambium; wood; annual rings, with spring and autumn wood; medullary rays; pith. Estimate the age of the stem.

57. **Histology of Stem.** Draw under the low power a transverse section of a young stem, showing: epidermis; scale-leaf bases; cortex; resin-canals; phloem; cambium; xylem; medullary rays; pith. Then draw a sector under the high power showing, in addition, sieve tubes and phloem parenchyma; bordered pits on radial walls of tracheides; secretory cells of resin-canals.

58. Histology of Stem.—Draw a transverse section of an older stem under the low power to show the annual rings; and under the high power to show spring and autumn tracheides and cork.

59. Histology of Stem.—Draw a longitudinal section of the stem under the high power to show: epidermis; cork; cortex; resin-canals; sieve-tubes; phloem parenchyma; cambium; tracheids with bordered pits; medullary rays in both cross and longitudinal sections; pith.

60. Male Flower.—With a knife cut a median longitudinal section of a male flower and draw : axis ; stamens ; pollen-sacs. Isolate one of the stamens and draw a magnified view of the under surface. Shake out a little pollen on to a dry slide and draw it under the high power.

61. Female Flower.—Draw a similar section of a female flower, showing : axis ; carpellary scales ; placenta ; ovules. Isolate one of the scales and draw both surfaces.

60. Male Flower.—[illegible] a longitudinal section of a male flower showing axis, stamens, pollen sacs. Isolate one of the stamens and draw it enlarged from the under surface. Mount a little pollen [illegible] and examine [illegible] high power.

61. Female Flower.—Draw a similar section of a female flower, showing axis, carpellary scales, bracts, ovules. Isolate one of the scales and draw both surfaces.

62. **Fruit.**—Draw a ripe pine cone.

63. **Fruit.**—Isolate a scale from a ripe cone and draw the upper surface to show: placenta; seeds with wings. Then draw the under surface to show carpellary scale and placenta.

64. **Seed.**—Draw a seed after it has become free from the cone. Then make a longitudinal section and draw: testa; endosperm; embryo, with cotyledons and radicle.

65. External Features.—Draw a maize plant, showing: adventitious and aerial roots; stem, with nodes and internodes; leaves with sheathing leaf-bases; parallel venation; male and female inflorescences.

66. Male Inflorescence.—Draw the panicle of a flowering maize plant indicating main rachis with branches; sessile and stalked spikelets.

67. Male Flower.—Isolate a spikelet, carefully separate the bracts to show the enclosed staminate flowers. Examine with a hand lens and make a sketch to show the arrangement of the parts.

68. Female Inflorescence.—Remove the sheathing leafy bracts from a female inflorescence and make a drawing to show: spike or ear; flowers, each with a long style.

69. Female Flower.—Isolate and draw a female flower under the hand lens, showing: bracts; ovary; style; stigma.

70. Fruits.—Draw an ear. Then make a longitudinal section through the light area of a soaked fruit containing a germinating seed and draw it under a hand lens, showing : pericarp+testa, with remains of style ; endosperm ; scutellum ; aleurone layer ; embryo, consisting of radicle, young rootlet, hypocotyl and plumule.

71. Seedling.—Draw a germinating seed, showing : rootlets with root-hairs; sheath of plumule enclosing first foliage leaf.

72. Histology of Stem.—Cut a transverse section of the stem and draw it under the low power, showing: epidermis; parenchymatous ground tissue with thick-walled outer layer; vascular bundles. Draw a vascular bundle under the high power, showing: sclerenchyma; phloem with sieve-tubes and companion cells; xylem with vessels, parenchyma and intercellular passage.

72 a. Histology of Stem.—Cut a longitudinal section of the stem and draw it under the high power showing: epidermis; ground tissue, consisting of outer thick-walled and inner thin-walled parenchyma; vascular bundle consisting of xylem with pitted and spiral vessels, phloem with sieve-tubes and sieve-plates and protophloem.

73. Histology of Root.—Draw a transverse section of the root under both powers, showing: piliferous layer with root hairs; exodermis; cortex with thick-walled outer and thin-walled inner cells; endodermis; central cylinder, consisting of pericycle, phloem and xylem with vessels and parenchyma.

74. Origin of Lateral Root.—Draw a prepared transverse section of a root showing the origin of a lateral root from the pericycle.

75. **Tap Roots.**—Examine and **draw** the various examples supplied

76. Adventitious Roots.—Examine and draw the following types :—
(*a*) Tuberous roots of sweet potato.
(*b*) Aerial roots of Banyan tree.
(*c*) Root tendrils of ivy.
(*d*) Haustoria of Cuscuta.

77. Surface Modifications.—Examine and draw the following:—
(*a*) Stem of rose, showing prickles.
(*b*) Stem of sunflower, showing hairs.

78. Climbing Stems.—Examine and draw the following:—
(*a*) Vine, showing stem-tendrils, with scale leaves.
(*b*) Convolvulus, showing twining stem.

79. Runners.—Draw a Lippia plant, showing a runner with scale-leaves and adventitious roots.

80. Sucker.—Draw a mint plant, showing suckers with scale-leaves and adventitious roots.

81. Rhizome.—Draw an Asparagus plant, showing the rhizome, with scale-leaves, buds, and adventitious roots.

82. Corm.—Draw a median longitudinal section of the corm of Colocasia, showing: corm of present year, last year, and rudiment of next year; scale-leaves; buds; adventitious roots.

83. Tuber.—Draw a potato, showing: scale-leaves; buds. Cut a section through one of the buds and draw it under a hand lens. Examine the demonstration specimen of a potato that has begun to sprout.

84. Phylloclades.—Examine and draw the following :—

(*a*) Stem of Asparagus, showing needle-like phylloclades.
(*b*) Duck-weed plant (Lemna), showing floating phylloclades with adventitious roots.
(*c*) Muehlenbeckia, with flat green stem bearing vestigeal leaves when young.
(*d*) Spinous phylloclade.
(*e*) Opuntia with fleshy phylloclade.

85. Spines.—Examine and draw the stems showing spines with lateral buds. Notice the origin of the spines in the axils of leaves.

86. Systems of Branching.—Examine and draw :—

(*a*) Thallus of Selaginella showing dichotomous form of branching.
(*b*) Plant showing racemose form of branching.
(*c*) Plant showing cymose form of branching.

87. Summer Buds.—Examine and draw a branch, showing terminal and axillary summer buds. Cut a section of one to show the growing point, protected by overlapping young leaves.

88. Winter Buds.—Examine and draw a branch of an apple tree, showing winter buds enveloped by scale-leaves. Note scars of scale leaves of previous winters. Cut a median section through a bud and draw an enlarged view.

89. Adventitious Buds.—Draw the potato plant, showing adventitious buds.

90. Bulbils.—Draw the bulb of a garlic plant, showing bulbils arising in the axils of the leaves of the bulb. Draw a median longitudinal section of an isolated bulbil.

91. Cotyledons.—Examine the following seedlings, making drawings to show the nature of the cotyledons.

(*a*) Vicia, with fleshy cotyledons below ground.
(*b*) Phaseolus, with fleshy green cotyledons above ground.
(*c*) Raphanus, with non-fleshy green cotyledons above ground.

92. Scale-leaves.—Draw the scale-leaves on the rhizome of the bamboo.

93. Bracts.—Draw the specimens provided, showing green, scaly, and coloured bract.

94. Main Types of Foliage Leaves.—Draw the specimens provided, illustrating the following types: sessile and stalked; simple and compound; stipulate and exstipulate; sheathing leaf base; perfoliate; auriculate and ligulate; peltate; pinnate and palmate.

95. Stipules.—Draw examples of normal (berseem), leaf-like (pea), spiny (Acacia), and tendriliform stipules.

96. Phyllotaxis.—Draw examples illustrating alternate, opposite, verticillate, superposed, and decussate arrangements of leaves on stem.

97. Special Modifications.—Draw the following examples of modified leaves: fleshy leaves and bulbs ; tendrils ; spines ; floating leaves ; insectivorous leaves.

98. Typical Raceme and Corymb.—Draw the examples provided, showing elongated axis and stalked flowers.

99. Spike and Spadix.—Draw examples, showing : elongated axis and sessile flowers.

100. Umbel.—Draw example showing stalked flowers arising from one point on the axis.

101. Capitulum.—Draw a median section to show the sessile flowers arising from enlarged axis. Indicate the disc florets, ray florets, and involucre.

102. Cyme.—Draw the example provided.

103. Floral Symmetry.—Draw examples of actinomorphic, zygomorphic, and asymmetrical flowers.

104. Insertion of Floral Leaves.—Cut median longitudinal sections of the hypogynous, perigynous, and epigynous flowers provided, and make drawings to illustrate the relative positions of thalamus, calyx, corolla, androecium, and gynoecium.

105. Calyx.—Draw examples of polysepalous and gamosepalous flowers and of flowers with rudimentary sepals (*e.g.* pappus).

106. Corolla.—Draw examples of the following :—

(*a*) Polypetalous and gamopetalous flowers.
(*b*) Single whorls and double whorls.
(*c*) Receptacle for nectar.
(*d*) Rudimentary petals.

107. Stamens.—Draw a typical stamen showing filament, connective and anthers.

108. Stamens.—Draw examples of hypogynous, perigynous, epigynous and epipetalous stamens.

109. Stamens.—Draw the prepared transverse section through an anther, showing: connective with vascular bundle; two anther lobes; four pollen-sacs; pollen.

110. Pollen.—Draw examples of pollen-grains from various plants.

111. Monocarpellary Pistil.—Remove the perianth and stamens from the flower and draw the carpel, showing stigma, style, and ovary, with ventral suture. Then cut a transverse section of the ovary and make a drawing to show: placenta; ovules; ventral suture.

112. Polycarpellary Pistil.—Remove the perianth and stamens from the flowers and draw examples of apocarpous and syncarpous pistils. Cut transverse sections of the latter and draw examples of unilocular and multilocular ovaries.

113. Wind-Pollination.—Examine and draw the flowers provided, illustrating the adaptation to pollination by the wind. Note the feathery stigmas, abundant pollen, loose attachment of stamens, absence of nectar and of conspicuous colours.

114. Self-pollination.—Draw the example of a self-pollinated flower, noting the simultaneous ripening of androecium and gynoecium.

115. Insect-Pollination.—Draw the following types of flowers pollinated by insects :—

(*a*) Unisexual (vegetable marrow).
(*b*) Hermaphrodite (labiate flower).
(*c*) Protandrous (composite flower).
(*d*) Protogynous (apricot).

116. Ovule.—Draw under the low power the prepared section of an ovary, showing: wall of ovary; suture; placentas; ovule with funicle; integuments; nucellus; embryo-sac.

Draw the embryo-sac under the high power, showing: ovum; synergidæ; secondary nucleus; antipodal cells.

117. Pollination.—Draw a longitudinal section through the stigma of a pollinated flower, showing: tissue of style; pollen-grains; pollen-tubes.

118. Draw successive stages of cell-division.

(*a*) Resting stage, showing: cytoplasm, nucleus, chromatin, nuclear membrane, nucleoli; centrosome.

(*b*) Early division stage, showing: dissolution of nuclear membrane; formation of spindle between two daughter centrosomes; spireme.

(*c*) Later division stage, showing: chromosomes arranged on spindle.

(*d*) Succeeding stage, showing: chromosomes divided and moving apart.

(*e*) Final stage, showing: formation of daughter nuclei; division of cytoplasm; new cell-wall.

119. Simple Dry Fruits.—Draw an external view and section of the following, indicating pericarp, testa, and seeds :—

(*a*) ACHENEAL FRUITS :—

Achene.
Nut.
Caryopsis.
Cypsela.
Samara.

Simple Dry Fruits.

(*b*) Capsular Fruits :—

Legume.
Siliqua.
Silicula.
Capsule.

Simple Dry Fruits.

(*c*) SCHIZOCARPIC FRUITS.

120. Simple Succulent Fruits.—Draw an external view and section of the following:

(*a*) DRUPES, indicating epicarp, mesocarp, and stony endocarp.

Simple Succulent Fruits.

(*b*) BERRIES; indicating epicarp, mesocarp, and membraneous endocarp.

(*c*) POME of apple, showing thalamus and pericarp containing seeds.

121. Aggregate Fruits.--Draw a strawberry, showing achenes on fleshy thalamus.

122. Composite Fruits.—Draw an external view and longitudinal section of a fig, showing fleshy capitulum, bracts, achenes; also of a mulberry, with fleshy perianths.

CRUCIFERÆ.—Herbs with racemose inflorescences, usually without bracts or bracteoles. Flowers actinomorphic. Floral formula K 2 + 2, C 2 + 2, A 2 + 4, G (2). Corolla cruciform. Two outer stamens short, four inner ones long. Bilocular ovary with false septum and parietal placentation. Fruit a siliqua or silicula.

123. Flower.—Draw the example provided, showing the calyx and cruciform corolla. Then carefully remove the perianth and draw a side view of the andrœcium and gynœcium. Notice the nectaries at the base of the stamens. Cut a transverse section through the ovary and then make a floral diagram of the flower.

124. Fruit.—Draw the fruits provided, showing the dehiscent capsule with false septum and contained seeds.

ROSACEÆ.—Herbs, shrubs, or trees with alternate stipulate leaves. Flowers actinomorphic. Floral formula K 5, C 5. Stamens usually numerous. Carpels free, one to numerous. Thalamus often takes part in the formation of fruit.

125. Flower.—Draw an external view and a longitudinal section of the example provided. Then construct a floral diagram.

126. Fruit.—Draw the fruits of the rose, showing receptacle and achenes. (See para. 120 for drupe and pome.)

[illegible]

126. Flower.—Draw an external view and a longitudinal section of [illegible]. Then construct a floral diagram.

128. Fruit.—Draw the fruits of the rose, showing [illegible] and achenes. [illegible] page 126 for [illegible]

LEGUMINOSÆ.—Trees, shrubs, and herbs. Leaves alternate, stipulate, generally compound. Inflorescence racemose. Flowers actinomorphic or more often zygomorphic. Floral formula K (5), C 5, A 10, G 1. The stamens are sometimes indefinite. Fruit a legume or lomentum.

127. Leaves.—Draw a leaf of an Acacia, showing the stipulate, compound, and pinnate form.

128. Flowers.—Draw the flowers of Acacia and Cassia, showing different types of leguminous flowers. (The bean is an additional example.) Draw a median longitudinal section of each and then construct floral diagrams.

129. Fruit.—Draw an example of a lomentum. (See para. 119 (b) for legume.)

MALVACEÆ.—Herbs or shrubs. Leaves palmately lobed, alternate, stipulate. Flowers solitary or in cymes, actinomorphic. Flowers with an epicalyx, hypogynous, usually pentamerous; stamens usually ∞ united; ovary (1-∞), usually (5), multilocular with axile placentation. Fruit a schizocarp or capsule.

130. Leaf.—Draw the example provided.

131. Flower.—Draw an external view and longitudinal section of the flower and construct a floral diagram of it.

132. Fruit.—Draw the capsule of a cotton plant and the example of a schizocarp.

SOLANACEÆ.—Herbs or shrubs, with alternate exstipulate leaves. Flowers hypogynous, generally actinomorphic. Floral formula K 5, C (5), A 5, G (2). Calyx persistent. Stamens epipetalous. Carpels obliquely placed. Fruit a capsule or berry.

133. Flower.—Draw an external view of the flower of Datura and of the potato plant. Cut open the perianth and make a drawing to show the insertion of the stamens and position of gynœcium. Then construct floral diagrams of the two flowers.

134. Fruit.—Draw the berry of a tomato plant. (See para. 119 (b) for capsule of Datura.)

COMPOSITÆ.—Herbs, rarely shrubs or trees. Inflorescence a capitulum. Floral formula K 0, C (5), A (5), G (2). Calyx sometimes forming a pappus. Carpels with two stigmas, unilocular ovary and single ovule Fruit a cypsela.

135. Inflorescence.—Draw examples of the three types of capitula :—
(*a*) Composed entirely of tubular florets.
(*b*) Entirely of ray florets.
(*c*) Of both types.

136. Flower.—Isolate and draw examples of disc and ray florets. Cut open the corolla of the former and make a drawing to show the arrangement of the andrœcium and gynœcium. Construct a floral diagram.

137. Fruit.—Draw the examples provided, showing presence or absence of pappus.

[illegible]

135. Inflorescence.—Draw examples of the three types of capitula:—
(a) Composed entirely of tubular florets.
(b) Entirely of ray florets.
(c) Of both types.

136. Flower.—Isolate and draw examples of disc and ray florets. Cut open the rolla of the former and make a drawing to show the arrangement of the androecium d gynoecium. Construct a floral diagram.

137. Fruit.—Draw the examples provided, showing presence or absence of pappus.

LILIACEÆ.—Herbs, rarely shrubs or trees. Flowers actinomorphic, hypogynous, perianth usually petaloid. Floral formula P 3 + 3, A 3 + 3, G (3). Stamens arising from perianth. Ovary trilocular, with axile placentation. Fruit a capsule or berry.

138. Flower.—Draw an external view and median longitudinal section of a lily. Then construct a floral diagram of it.

139. Fruit.—Draw the examples provided of capsule and berry.

[illegible]LLIACEÆ.—[illegible]

[illegible]. Flower.—[illegible]

109. Fruit.—Draw the examples provided of capsule and berry.

PALMÆ.—Palms. Leaves large, alternate, and divided. Inflorescence racemose. Flowers unisexual, hypogynous. Floral formulæ P 3 + 3, A 3 + 3, or P 3 + 3, G (3). Fruit a berry or drupe.

140. External Features.—Sketch a date-palm, showing the shape of the leaves and position of the inflorescence.

141. Flower.—Isolate and draw examples of male and female flowers, and then construct floral diagrams of them.

142. Fruit.—Cut open and draw the berries provided. Also examine the demonstration specimen of a drupe (coconut).

GRAMINEÆ.—Grasses. Stems hollow and cylindrical, leaves alternate, with ligule and sheathing base. Inflorescence racemose, consisting of spikelets. Flowers hypogynous, with perianth reduced or absent; stamens three; ovary monocarpellary, with single ovule. Fruit a caryopsis.

143. Spikelet.—Isolate a spikelet and make a drawing to show: glumes; fertile flowers, each with inferior and superior palea, three stamens and two feathery stigmas; sterile flowers.

144. Flower.—Remove the lower palea from an isolated flower and make a drawing to show: superior palea; three stamens; ovary, with two stigmas; two lodicules.

145. Fruit.—Draw the ripe ears of barley and wheat respectively and afterwards draw a single caryopsis.

PART II.—PHYSIOLOGY.

NUTRITION.

1. Different modes of nutrition.—Examples of green plants, saprophytes, carnivorous plants and parasites.

2. Elements necessary for the nutrition of a plant.—Water cultures of seedlings:—

(*a*) In a solution containing K, Na, Ca, Mg, Fe, nitrate, sulphate, phosphate and chloride;
(*b*) In a solution similar to (*a*) but lacking nitrate;
(*c*) In distilled water.

ROOT ABSORPTION.

3. The microscopic structure of a typical living plant cell.—Note the cellulose cell-wall, living protoplasm, and cell-sap in vacuole.

4. Root-hairs.

(*a*) Root-hairs seen with the naked eye.
(*b*) A root-hair highly magnified. Note that it is just an elongated living cell.

5. Osmosis. Egg-membranes containing a sugar solution immersed (1) in distilled water, (2) in a sugar solution of the same concentration as that inside the membrane, and (3) in a sugar solution more concentrated than that inside the membrane.

6. Osmosis. Dried raisins placed (1) in distilled water, and (2) in a sugar solution.

7. **Absorption of dissolved substances by the plant.**—The selective diffusion of different dissolved substances into the living cell illustrated by cells placed (*a*) in an aniline dye and (*b*) in methylene blue.

8. **Nature of living protoplasmic membrane.**—Cells of beetroot, seen under the microscope, (1) living and (2) killed by the addition of alcohol.

9. **Nature of living protoplasmic membrane.**—Cubes of beetroot, immersed in water in beakers, (1) living and (2) killed by heat.

10. Entrance of carbon dioxide into the leaf.—Typical stomata seen under the microscope, in surface view and in section.

11. Passage of carbon dioxide inside the leaf to the cells where it is absorbed.

(*a*) Air-spaces between cells seen in a section under the microscope.

(*b*) Continuous connection of the air-spaces shown by sucking air through a leaf.

12. Path of water and dissolved substances absorbed by the root.

(*a*) A transverse section of a cut stem, the lower end of which has been immersed in a coloured solution. Note in which tissue the colour has ascended.

(*b*) Rich distribution of xylem vessels seen in a leaf which has been cleared in chloral hydrate.

(*c*) A specimen of mistletoe, a partial parasite which obtains its water and dissolved salts by a junction of its xylem with that of its host.

13. Demonstration of root-pressure.

14. Capillarity.

(*a*) Ascent of a coloured solution in capillary glass tubes. Compare the heights reached in broader and in narrower tubes.

(*b*) Ascent of a coloured solution in the vascular bundles of a maize leaf.

15. Demonstration of the fact that water is given off by a plant.

16. Effect of loss of water by transpiration in a case where it cannot be replaced from the root : rapid withering of a cut leaf.

17. Proof that most water is given off from regions where stomata are most abundant : cobalt chloride paper attached to the upper and lower surfaces of a leaf.

18. Loss of weight in a plant owing to transpiration.

19. Demonstration of the transpiration current.

WATER-ECONOMY.

20. Examples of xerophytes, showing the following modifications :—

(*a*) Reduction of transpiring areas ;
(*b*) Hairy surface ;
(*c*) Waxy surface ;
(*d*) Water-storage tissues.

21. Stomata of xerophytes.

(*a*) Section of xerophytic leaf showing thick cuticle and sunk-in stomata, to be compared with :—
(*b*) Section through normal stomata, and
(*c*) Section through stomata of a hydrophyte.

22. Demonstration of the formation of starch in photosynthesis and of the necessity of chlorophyll for the process.

23. The necessity of light for the formation of starch in photosynthesis.

24. The necessity of stomata for the formation of starch.

25. The necessity of light for the output of oxygen.

26. The necessity of carbon dioxide for the output of oxygen.

27. The intake of carbon dioxide by an aquatic plant in the light.

(*a*) Demonstration of the colours assumed by an indicator in tap-water and in water saturated with carbon dioxide.

(*b*) Aquatic plants are seen in two glass tubes of water each containing the indicator and carbon dioxide in solution. One tube is exposed to sunlight and the other kept in darkness.

28. Formation of starch inside chloroplasts in the light.—Chloroplasts of leaves which have been fixed and stained with iodine.

(*a*) From a plant which had been exposed to sunlight.
(*b*) From a plant which had been kept in darkness.

29. Formation of starch around pyrenoids of Spirogyra chloroplasts in the light.—Filaments fixed and stained with iodine after having been (*a*) exposed to daylight, and (*b*) kept in darkness.

30. The absorption-spectrum of chlorophyll.

31. Demonstration showing which light rays are effective in photosynthesis. Rapid bubbling of oxygen from an aquatic plant in white light slowed by interposing an orange glass and nearly stopped by a green glass. Examine the absorption-spectra of the orange and green glasses.

32. Red photosynthetic pigment in marine algæ.

33. Leaf containing a red non-photosynthetic pigment.—The presence of chlorophyll in addition is shown by its solution in alcohol.

34. Necessity of light for the formation of chlorophyll.

(*a*) Seedlings grown in light.
(*b*) Seedlings grown in darkness.
(*c*) Seedlings grown in darkness and exposed to light a short time before the demonstration.

35. Destruction of chlorophyll by intense light.—Solutions of chlorophyll before and after having been exposed to direct sunlight. (Note that the chlorophyll is exposed to the sun's rays behind a screen formed by a solution of alum. This stops the heat-rays.)

36. (Protective movement of chloroplasts in response to intense illumination.—Cells seen under the high power after having been (*a*) exposed to direct sunlight, (*b*) kept in the shade.

MOVEMENT OF PRODUCTS OF ASSIMILATION.

37. Rate of removal of starch from leaves.—Pieces of a leaf stained in iodine at regular intervals after the plant has been placed in darkness.

38. Path of products of assimilation.—Growth of adventitious roots immediately above a circular incision in a willow twig made in such a manner as to sever the phloem.

STORAGE.

39. Carbohydrate storage.

(*a*) Various forms of starch-grains seen under the microscope.
(*b*) Storage of starch by conjugating cells of Spirogyra.

40. Fat storage.—Oil-globules in a seed.

41. Protein storage.—Aleurone grains in a seed.

ENZYME ACTION.

42. Action of the diastase of germinating seeds on starch.

To a dilute solution of starch containing iodine is added :—

(*a*) Liquid obtained by grinding germinating seeds in water and filtering ;
(*b*) Liquid obtained by grinding non-germinating seeds in water and filtering.

43. (N) Action of the diastase of germinating seeds in causing the appearance of sugar in the seeds.

(*a*) Fehling's solution is not reduced by starch but is reduced by maltose.
(*b*) The liquid obtained by grinding dry seeds in water does not reduce Fehling's solution while the liquid from sprouting seeds reduces it.

44. The tissue which produces the enzyme.—Section through maize endosperm seen under the microscope to show the aleurone layer where diastase is formed.

NUTRITION OF PLANTS WITHOUT CHLOROPHYLL.

45. Saprophyte.—Mould growing saprophytically.

46. Parasite.—Mould killing seedlings.

47. Parasite.—Dodder growing on berseem.

48. Parasite.—Orobanche :—

(*a*) Living plant seen attached to its host.

(*b*) Connection of root of parasite with root of host seen under the microscope.

(*c*) Section through the point of junction of parasite and host seen under microscope to show the connection of the vascular bundles.

49. Symbiotes.—Mycorhiza of Pinus :—

(*a*) Roots seen with the naked eye, showing terminal swellings due to the presence of a mycorhiza.

(*b*) Root cleared in chloral hydrate seen under a low magnification to show the fungal hyphæ.

NUTRITION OF PLANTS WITHOUT CHLOROPHYLL.

50. Symbiotes.—Root-tubercles of berseem.

(*a*) Roots seen with the naked eye showing the tubercles.

(*b*) Section of a tubercle fixed and stained with iodine examined under the 1/12 inch oil-immersion objective to see the nitrogen-fixing bacteria and the store of starch.

RESPIRATION.

51. Necessity of oxygen for growth.—Pollen-tubes grown in a sugar solution beneath a cover-slip. Only those pollen-grains grow which are within reach of the oxygen diffusing in from the edges of the cover-slip.

52. Production of carbon dioxide in respiration.—Germinating seeds were placed in two stoppered bottles on the previous evening.

(*a*) A burning match is introduced into the first bottle.

(*b*) Carbon dioxide is poured from the second bottle on to the surface of clear lime-water with which it is then shaken up.

53. Carbon dioxide produced in respiration used up by a green plant in sunlight for photosynthesis.—Two stoppered glass jars each containing leaves and some lime-water: (*a*) kept in darkness; (*b*) in sunlight.

54. Demonstration of the heat produced by the respiration of germinating seeds.

RESPIRATION.

55. Lenticels, through which the respiratory gas exchange of stems takes place.

(*a*) Seen with the naked eye.
(*b*) Microscopic section.

FERMENTATION.

56. Action of invertase secreted by yeast.—Saccharose is added to each of three test-tubes containing :—

(*a*) Filtrate from a suspension of yeast in water.
(*b*) Distilled water.

The test-tubes are placed in the incubator at 32° C. for 10 minutes and then Fehling's solution is added to each and the contents heated.

57. Action of zymase of yeast.

(*a*) Production of carbon dioxide from glucose shown by passing the gas through lime-water.

(*b*) Production of alcohol from glucose demonstrated by its smell and by the iodoform test.

(*c*) Production of heat in fermentation.

58. Aerobic and anaerobic bacteria.—Slope and stab cultures.

SECRETION AND EXCRETION.

59. Mucilage.

(*a*) Inside water-storage tissue ;

(*b*) On the surface of cress seeds, seen both dry and wet.

60. Gum.—Secretory gland-hairs of a leaf seen under the microscope.

61. Etherial oil in Citrus plants.

(*a*) Oil-glands of lemon leaves seen with the naked eye.
(*b*) Leaves crushed and smelt.
(*c*) Section of orange epicarp showing oil-glands under the microscope.

62. Etherial oil in Eucalyptus leaves.

(*a*) Leaves smelt before and after crushing.
(*b*) Oil-glands seen under the microscope in section.

63. Wax secreted on the surface of xerophilous leaves.

64. Latex.

65. Poison.

- (*a*) Nettle plant seen with the naked eye.
- (*b*) Section of nettle leaf under the microscope showing poison gland-hairs with and without a broken tip.

66. Calcium oxalate.

(*a*) Various forms of crystals in plant cells.
(*b*) Comparison of the quantities of crystals present in young and old leaves.

67. Water.

(*a*) Exuded drops seen with the naked eye on various plants.
(*b*) Part of a cleared leaf under the microscope showing a water-secreting gland with xylem vessels leading to it.

68. Nectar secreted by the nectaries of a flower.

69. Change from meristemmatic to vacuolated cells behind the growing-point seen under the microscope.

70. Region of elongation.—Roots of germinating beans were marked on the previous evening with equally-spaced ink lines. The greatest distance apart of these lines now indicates the region of maximum growth.

71. Effect of heat on growth. Compare the amount of growth of seedlings kept at different temperatures.

69. Change from meristematic to elongated cells. [illegible] [illegible] [illegible] [illegible]

70. Regions of elongation. Rows of [illegible] lines were marked on the [illegible] growing [illegible] [illegible]. The [illegible] different [illegible] of these [illegible] indicate the region of maximum growth.

71. Effect of heat on growth. Compare the amount of growth of seedlings kept at different temperatures.

72. Effect of light on growth.

(*a*) Seedlings grown in light and in darkness.
(*b*) Adventitious roots formed only on the shaded side of an ivy stem.

73. Influence of the whole plant on the growth of parts.—When the terminal bud of a stem is removed a lateral bud develops to form a new growing-point.

74. Regeneration.

(*a*) An isolated piece of willow stem showing the development of the lateral buds and of adventitious roots at the lower extremity.
(*b*) Regeneration of the whole plant from an isolated leaf of Begonia.

75. Graft.—A branch of one variety grafted on to the stem of another.

76. Wound callus.—New growth closing a wound.

77. Gall.

(*a*) Gall caused by an insect. Note the hole through which the adult insect emerged.
(*b*) Specimen of the insect (Hymenoptera).

78. Turgor.

(*a*) Young seedlings droop owing to loss of turgor when immersed in a salt solution having a higher osmotic pressure than that of their cell-sap.
(*b*) Older seedlings do not droop under the same circumstances owing to the presence of rigid supporting tissue.

79. Plasmolysis.—Living cells seen under the microscope: (*a*) in water, and (*b*) in a solution of higher osmotic pressure than that of the cell-sap.

80. Disposition of supporting tissue.

(*a*) Comparison of longitudinal and transverse sections of stem and root to show relative positions of supporting tissue
(*b*) Section of a leaf to show girder structure of supporting tissue.

78. Turgid.

(a) Young seedlings kept turgid in water. (b) [illegible] when immersed in a solution having a higher osmotic pressure than that of their cell sap.
(c) Older seedlings do not droop under the same treatment owing to the presence of rigid supporting tissue.

79. Plasmolysis.—Living cells seen under the microscope: (a) in water, and (b) in a solution of higher osmotic pressure than that of the cell sap.

80. Disposition of supporting tissue.

(a) Comparison of longitudinal and transverse sections of stem and root to show relative positions of supporting tissue.
(b) Section of a leaf to show girder structure of supporting tissue.

81. Mutual tension of tissues.—The pith removed from a piece of young stem is seen to be longer than the cortex.

82. Arrangements of supporting tissue in leaves to prevent tearing by the wind.

83. Double spiral spring of tendrils.

PASSIVE MOVEMENTS.

84. Fruits and seeds showing arrangements for transport by wind, water and animals.

AUTONOMIC MOVEMENTS.

85. Swimming movements of (*a*) algæ and (*b*) bacteria. Compare the latter with Brownian movement.

86. Rotation of protoplasm in a cell.

87. Sleep movements.

(*a*) Composite flowers with the ray-floret petals in day and night positions.
(*b*) Leguminous leaves with the petioles and leaflets in day and night positions.

88. Leaf movements due to degree of illumination.

(*a*) Oxalis leaflets horizontal in the shade and folded downwards in direct sunlight.
(*b*) Rapid closing of leaflets of Mimosa pudica in darkness, or in bright light.

89. Pulvini, by which leaf movements are effected.

90. Curvature of tendrils, due to a mechanical stimulus.

TROPISTIC MOVEMENTS.

91. Positive phototropism of (*a*) stems; (*b*) flower-stalks; and (*c*) oat seedling leaves, in lateral illumination.

92. Positive phototropism of a fungus (Pilobolus).

93. Diaphototropism of leaves in lateral illumination.

94. Variable phototropism of an alga.—Vaucheria positively phototropic in weak light and negatively phototropic in strong light.

95. Negative phototaxis of algal swarm spores.

(*a*) Seen under the microscope swimming away from the window side of a drop of water;

(*b*) Seen with the naked eye to be settling down on the side of a glass jar away from the window.

96. Positive geotropism of seedling roots which were placed horizontally in darkness two days previously. The distance apart of ink marks which were equally spaced before the curvature began shows that (*a*) the curvature occurs in the growing region only and (*b*) the curvature is effected by the convex side growing more than normally.

97. Negative geotropism of stems.—The plant was placed on its side in darkness two days ago. Ink marks show the position and nature of the curvature, as in No. 96.

98. Diageotropism of leaves seen by placing a plant on its side in the dark.

99. Diageotropism of lateral roots.

100. Touch stimulus.—Tactile sense organs of a movable staminal filament.

101. Touch stimulus.—Section of pulvinus of Mimosa pudica showing a tactile hair.

102. Gravity stimulus.—Section of a pulvinus stained with iodine to show the starch-grains lying on the lower side of each statocyst cell.

CONDUCTION OF STIMULI.

103. Light stimulus.—Oat seedlings laterally illuminated, some with opaque caps on the tips of the leaf-sheaths and others without such caps. Positive phototropic curvature is shown only by those seedlings without caps, although the region of curvature is seen to be below the region covered by the caps of the other seedlings.

104. Touch stimulus.—Note the effect of touching the leaf of Mimosa pudica: successive folding of the leaflets from the leaf-tip downwards, followed by a downward movement of the petiole and lastly movements of the other leaves.

105. Gravity stimulus.—The root of a seedling was caused to curve geotropically to a right angle by placing it horizontally. The root was then fixed and stained in iodine. It can now be seen under the microscope that the region of curvature is at some distance from the statocysts.