IRVING'S CATECHISM OF BOTANY

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WITH AN APPENDIX

ON

THE FORMATION OF AN HERBARIUM.

Rewritten by

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TABLE OF CONTENTS.

PREFACE.

THE Publishers of Irving's Catechisms, being aware that the treatment of Botany as contained in the said Catechism of Botany had grown considerably antiquated, requested me to revise it. In compliance with this request, I have entirely rewritten the Catechism with the exception of the Appendix.

It has been my aim to make the Catechism of Botany as concise, but also as comprehensive as possible. It is to be used only with the aid of a teacher, that will explain and enlarge the answers given.

Thus it is hoped, that the young boys and girls, who study it, may learn from it, what questions to ask about plants and get an idea of the answers, which the science of Botany is at present in a position to give.

ST. JOHN'S UNIVERSITY,
Collegeville, Minn., July, 1905.

CHAPTER I.

INTRODUCTION.

How pleasing the task to trace a Heavenly Power,
In each sweet form, that decks the blooming flower,
And climb the heights of yonder starry road,
And rise through nature, up to nature's God.

Q. 1. What is botany?

A. Botany is the science of plants.

Q. 2. How may botany be divided?

A. Botany may be divided into (1) morphological botany; (2) physiological botany; (3) ecological botany; (4) economic botany (5) palaeontological botany.

Q. 3. Of what does morphological botany treat?

A. Morphological botany or plant morphology treats of the organs, tissues, development and classification of plants.

Q. 4. Of what does physiological botany treat?

A. Physiological botany or plant physiology treats of the vital functions of plants.

Q. 5. Of what does ecological botany treat?

A. Ecological botany treats of plants in their relations to one another and to their surroundings.

Q. 6. Of what does economic botony treat?

A. Economic botany treats of plants in their relation to man.

Q. 7. Of what does palaeontological botany treat?

A. Palaeontological botany treats of fossil plants.

CHAPTER II.

BIOLOGY.

Q. 8. What is Biology?

A. Biology is the science of life, or rather, of living beings.

Q. 9. How is it divided?

A. It is divided into zoology, the science of animals, and botany, the science of plants.

Q. 10. Why is biology divided thus?

A. Because the subject matter of biology, namely living beings, are by nature separated into two grand groups, called respectively, the animal kingdom, and the vegetable kingdom.

Q. 11. Therefore what is the subject matter of botany?

A. The subject matter of botany is the vegetable kingdom which comprises all plants.

Q. 12. What is a plant?

A. A plant is a living being, with a material organization, belonging to the vegetable kingdom.

NOTE.—The above definition is given as a matter of convenience. The term "living being" in contradistinction to lifeless matter; the term "with material organization" in contradistinction to spirit; "belonging to the vegetable kingdom" to distinguish the plant from the animal, and to show that the distinction between plant and animal life must be taken from the whole kingdom rather than from any one individual or group of individuals. There are other definitions of plant, *e. g.* A plant is a non-sentient organism where "organism" stands for "living being, with material organization." Another definition: A plant is a living being with material organization, having vegetative life. These definitions are philosophically and theoretically quite correct, but practically not a bit better than the one given, since they also throw the question back upon the other question, viz: "How is vegetable life distinguished from sentient life? *i. e.* How does plant life differ from animal life? The distinction between these two is theoretically quite simple, sentient life involving "consciousness," while vegetable life does not. But the difficulty of distinguishing between "consciousness and "non-consciousness" is no less and no greater in the crucial cases than the difficulty of distinguishing between animal and plant life.—Scientists have been unable so far to establish an absolute and at the same time easily applicable criterion. It is generally admitted that the element of consciousness is necessary and sufficient to establish the animal nature of a material living being; it is therefore an absolute and final criterion. But on account of the difficulty of its application in doubtful cases, other more easily applicable criteria have been established, none of which, however is absolute. The principal ones of these will be given in the next question.

Q. 13. How are plants distinguished from animals?

A. Plants may be distinguished from animals (1) in structure (2) nutrition (3) products (4) in habits.

Q. 14 How do plants differ from animals in structure?

A. Plants ordinarily have cell-walls of cellulose, while animals have not. Exceptions: (1) slime-moulds, diatoms among plants; Tunicates have cellulose in mantles. (2) plants have no sense organs, no locomotive organs, while animals have them. Exceptions: unicellular flagellate plants and animals; apparently also the hairs on each half of the leaf of the Venus fly trap (*Dionaea muscipula*), etc.

Q. 15. How do plants differ from animals in nutrition?

A. Generally speaking, plants can subsist on mineral food alone, whilst animals cannot. Except: Exceptions among plants are the whole class of Fungi, all parasitic plants properly so-called, and partially also the insectivorous plants.

Q. 16. How do plants differ from animals as regards products?

A. Plants produce starch, sugar and proteids from mineral substances and set free oxygen during photosynthesis, but this applies only to plants with chlorophyl, while it is claimed that some infusoria produce starch.

Q. 17. How do plants differ from animals in habits?

A. Plants, as a rule, are stationary, animals mobile; Exceptions: lower algae, as desmids, diatoms, also bacteria and the spermatozoids of most cryptogams, while among animals, the corals, sponges, etc., are in their adult stage quite stationary.

Q. 18. Which are the principal organisms of which it is doubtful whether they are plants or animals?

A. The principal ones are the slime-moulds, which by botanists are called myxomycetes *i. e.*, slime-moulds, but by zoologists they are called mycetozoa, *i. e.* fungus animals; besides these many of the ciliated and flagellated, unicellar organisms are claimed by both botanists and zoologists.

Q. 19. What are the grand divisions of the vegetable kingdom?

A. The two grand groups or divisions of the vegetable kingdom are: (1) Flowering Plants, called also Phaenogams or Phanerogams and non-flowering plants or Cryptogams.

Following is a synopsis of the classification of the vegetable kingdom from Engler and Prantl's. "*Die Natürliechen Planzenfamilien*" II Teil 1.abt. p. 1.

I DIVISION.

Mycetozoa — They are also called; in the same work, Myxomycetes, or Myxothallophytes.

1st Class: Acrasiei.
2nd Class: Myxogasteres.
3rd Class: Phytomyxini.
English: Slime moulds. *e. g.* "Flower-of-tan."

II DIVISION.

Thallophytes.

SUB-DIVISIONS.

1st. Schizophytes.
2nd. Algae.
3rd. Fungi; including Lichens, Seaweeds, Pondscum, Bacteria, Mushrooms, Mildew, Molds, Rust, Smut, etc.

III DIVISION.

Embryophyta zoidiogama, formerly called Archegoniatae.

SUB-DIVISIONS.

1st. Bryophyta.
2nd. Pteridophyta.

CLASSES OF BRYOPH.

1st. Hepaticae.
2nd. Musci foliosi.

CLASSES OF PTERIDOPHYTA.

1st. Filicinae.
2nd. Equisetinae.
3rd. Sphenophyllinae.
4th. Lycopodinae.

IV DIVISION.

Embryophyta siphonogama, formerly called also: Phanerogams, Anthophyta, Spermaphyta.

SUB-DIVISIONS.

1st. Gymnospermae.
2nd. Angiospermae.

CLASSES OF GYMNOSPERMAE.

1st. Cycadinae.
2nd. Cordaitinae.
3rd. Coniferinae.
4th. Gnetales.

CLASSES OF ANGIOSPERMAE.

1st. Monocotyledoneae.
2nd. Dicotyledoneae.

CHAPTER III.

GENERAL MORPHOLOGY.

Q. 20. What is plant morphology?

A. Plant morphology is the study of the resemblances and differences of outer form and internal structure of individual plants and their several parts, without regard to function.

Q. 21. What is the method of morphology?

A. The method of morphology is one of comparison; at least principally, since its main task is to trace the homologies existing in the vegetable kingdom.

Q. 22. What is meant by homology?

A. By homology, in botany, is meant similarity or identity of origin and structure. And two parts, of the same or of different plants, which have homology, are said to be the homologous, and the one is said to be the homologue of the other.

Q. 23. From what other terms must we carefully distinguish these?

A. We must carefully distinguish, between homology and analogy, homologous and analogous, homologue and analogue.

Q. 24. What is analogy?

A. Analogy, in botany, is similarity or identity of function in two different parts, without regard to structure; and parts which have analogy are said to be analogous and also the one is called the analogue of the other.

Q. 25. Give examples of homologues aud analogues.

A. The green foliage leaves and the coloured floral leaves of the rose are homologues of each other, but not analogues; also the stem of the rose and the potato tuber are homologues, both being stems, but they are not analogues, having different functions.;—the branches of myrsiphylum and true leaves are analogues of each other.

Q. 26. How far does the morphology of plant extend?

A. The morphology of a plant, to be complete, must extend over the whole life-history of the plant.

Q. 27. What is meant by the life-history of a plant?

A. By life-history of a plant is meant an account of all the different successive stages, through which the plant may pass: that is, the tracing of the plant from one particular stage, taken as the starting point, through all the different forms which it assumes in the course of its development, back to the stage at which the start was made.

Q. 28. What is the most important fact to be considered in connection with the life-history of plants.

A. The most important fact to be considered in connection with the life-history of plants is the almost universal occurrence in them of polymorphism.

Q. 29. What is polymorphism?

A. Polymorphism of a plant is its power to assume two or more essentially different forms of individual existence.

Q. 30. How many different forms does a plant in general, pass through?

A. A plant, in general, passes through two forms of individual existence, and hence, ordinarily it is dimorphic.

NOTE—Exceptions are found among algae and fungi, some having only one form, others having more than two forms, under which they appear. These will be considered under the special morphology of these plants.

Q. 31. How are the two forms of dimorphic plants distinguished?

A. The two forms of a dimorphic plant, are also designated stages or phases of the plant; one of them is asexual and is called the sporophyte, the other is sexual and is called the gametophyte.

Q. 32. Define sporophyte and gametophyte?

A. A sporophyte is that phase of a plant which produces only spores in contradistinction to gametes, which are produced by the gametophyte of the same plant, and are the reason why it is called gametophyte.

Q. 33. Define spores and gametes.

A. Spores and gametes agree in this, that both are single reproductive cells given off by the parent plant; but they differ essentially in this, that every single spore is by its nature capable of giving rise to a new phase of the plant, but that the gametes are not capable of doing this; the latter must unite in pairs, *i. e.*, two gametes must coalesce completely so as to form but one cell, which is capable of giving rise to a new phase of the plant.

Q. 34. What are these two ways of reproduction, called?

A. Reproduction by spores is called asexual reproduction, and reproduction by means of gametes is called sexual reproduction; and since these ways of reproduction, as a rule, regularly alternate with each other, they are together known as alternation of generations.

Q. 35. Why is the reproduction by means of gametes called sexual reproduction?

A. It is called sexual reproduction, because it resembles or rather is essentially the same as sexual reproduction in the animal world.

Q. 36. What are two principal ways of sexual reproduction occurring in plants?

A. The two ways are; (1) the gametes which unite are essentially alike or morphologically indisguishable and in this case the process is called conjugation and the resulting product is called the zygospore; (2) the gametes are unlike, and in this case the process is called fertilization and the product is called oospore.

Q. 37. Why must we distinguish carefully between sporophyte and gametophyte?

A. Because morphology requires that only corresponding parts be compared with one another in order to discover the homologies existing in different plants. Obviously, therefore, sporophyte must be compared with sporophyte, gametophyte with gametophyte. And since that, which is ordinarily called the "plant," may be either the sporophyte, as, for instance, in all flowering plants and ferns, or the gametophyte, as, for instance, in mosses and many lower plants, it is clear that the beginner in botany must early have his attention drawn to this important fact.

CHAPTER IV.

THE PLANT BODY.

Q. 38. Of what does a plant's body consist?

A. A plant's body consists of one or more cells.

Q. 39. What is a plant cell?

A. A plant cell is the unit of plant life and structure; it is essentially composed of nucleated protoplasm and its products; the latter are of great variety, the commonest one being the cellwall, which the protoplasm secretes; and it is from the appearance of this cellwall, that the unit of plant life has received its name.

Q. 40. What is protoplasm?

A. Protoplasm is the physical basis of animal and plant life; *i. e.* animal and plant life is not found outside of protoplasm.

Q. 41. Upon what does the shape and form of the plant's body depend?

A. The form of the plant's body depends upon the formative activity of the plant's protoplasm.

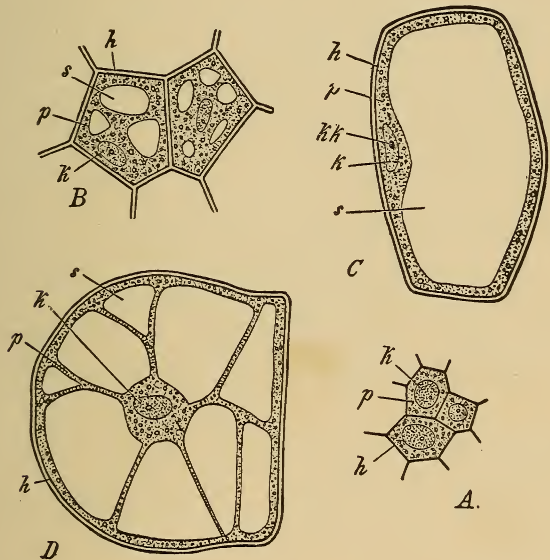

FIG. 1.

PLANT-CELLS IN DIFFERENT STAGES.

A-young cells with very thin walls and densely filled with protoplasm; (x 300;) *B*-same kind of cells but older; cell-walls have become thicker, and the protoplasm has become vacuolated (300 dia.;) *C*-cell still older, protoplasm forms a layer on cell-wall, while the vacuoles have united to form one large central vacuole; the nucleus in protoplasm near cell-walls (100 dia.;) *D*-cell of about same age as *C*, but differing in having the nucleus in central mass of protoplasm. which is connected with the parietal protoplasm by a number of strands. *A* and *C* are from the young ovary of Symphoricarpus racemosus; *C* and *D* from the fruit of the same plant. *H*-cell-wall; *P*-protoplasm; *K*-nucleus; *KK*-nucleolus; *S*-vacuole.

Q. 42. How many fundamentally different forms of the plant body are there?

A. There are only two; (1) thallus; (2) the plant's body is differentiated into stem and root.

Q. 43. What is a thallus?

A. A thallus is a form of plant body, which is either not segmented at all, or segmented into similar parts only.

NOTE—These two forms of the plant body afford a criterion for dividing the whole vegetable kingdom into two Grand Divisions: Thallophytes, *i. e.*, plants whose body is a thallus, including all plants from the lowest unicellar forms up to, but excluding the mosses; cormophytes, including all plants from the mosses upwards.

Q. 44. What is meant by branching?

A. In morphology, by branching is meant division or segmentation into morphologically similar parts or segments; while by its opposite, differentiation, is meant division or segmentation into dissimilar parts.

NOTE—Since the thallophytes divide only into similar parts, namely branches, they need not be considered in the following questions, which refer only to the differentiated segments of cormophytes.

Q. 45. What are the typical parts, into which a cormophyte is divided?

A. The typical parts into which a cormophyte is divided, are root, stem and leaf.

Q. 46. What distinction must be drawn with regard to the segmentation of a cormophyte?

A. We must distinguish between primary and secondary and higher orders of division in the cormophyte.

Q. 47. What is the primary division in a cormophyte?

A. The primary division in a cormophyte is its differentiation into stem and root.

Q. 48. What are the secondary divisions?

A. The secondary divisions are the leaves and branches of the stem, and the secondary roots.

Q. 49. What are the divisions of higher order?

A. Divisions of a higher order are those which arise from those of secondary origin.

Q. 50. What are the principal forms of stems?

A. The principal forms of stems are; (1) culm, or haulm, (2) trunk, vine, caudex, or (3) scape and (4) bulb, corm, rhizome or tuber, stolon or runner.

Q. 51. What is a node?

A. A node is that point of a stem where one or more leaves originate.

Q. 52. What is an internode?

A. An internode is the part of a stem between two successive nodes.

Q. 53. Define culm or haulm.

A. A culm is a form of stem with elongated internodes and a jointed appearance at the nodes, *e. g.* grasses, sedges, etc.

Q. 54. Define a scape.

A. A leafless stem or part of a stem rising from a subterranean part of the plant and bearing only flowers, *e. g.*, dandelion.

Q. 55. What is a bulb?

A. A bulb is a form of stem with very short internodes and fleshy leaves, resembling a bud, *e. g.*, onion, narcissus, etc.

Q. 56. What is a corm?

A. The swollen fleshy base of a stem, differing from the bulb in being solid, *e. g.*, jack-in-the-pulpit, cyclamen, etc.

Q. 57. What is a rhizome?

A. A creeping subterranean stem, usually bearing scale-like leaves and roots at the nodes and becoming erect at the apex, *e. g.*, solomon's seal, water lily, etc.

Q. 58. What is a tuber?

A. A thickened, subterranean branch or part of a stem, *e. g.*, potatoes, etc.

Q. 59. What is a stolon or runner?

A. A basal branch of the stem disposed to root where it touches ground; *e. g.*, runner of strawberry, etc.

Q. 60. What is a trunk?

A. A large, solid form of stem as found in trees.

Q. 61. What is a vine?

A. A vine is an elongated, slender, trailing or twining form of stem; *e. g.*, grape, virginia creeper, etc.

Q. 62. What is a caudex?

A. A caudex is that form of stem which is found in perennial herbs, usually only that part which is persistent above ground.

Q. 63. What is the typical arrangement of branches on the stem?

A. Branches spring only from the axils of leaves; hence, their arrangement on the stem is necessarily the same as that of leaves.

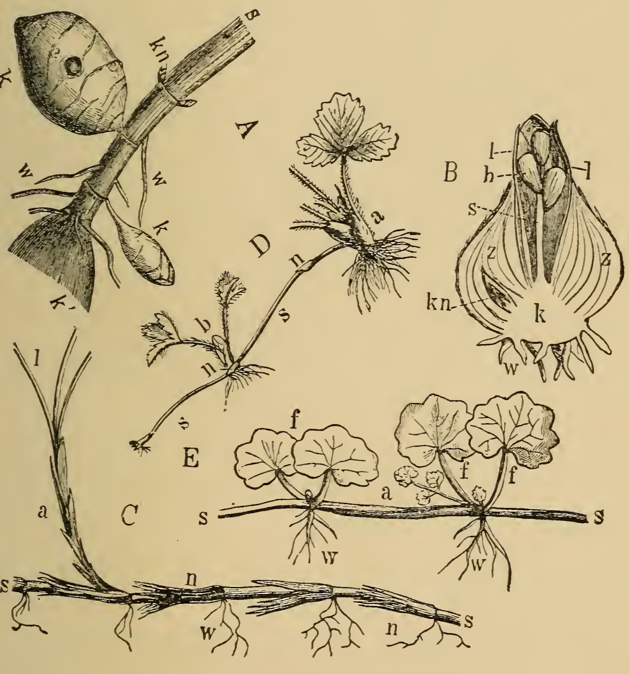

FIG. 2.

Various forms of stems: *A*-Tuberous; *B*-bulbous; *C*-rootstock or rhizome; *D*-runner or stolon of strawberry; *E*-creeping stem of Ground Ivy, (Nepeta Glechoma) the internodes are twisted in order to bring the leaves in one plane. Figure *A*: *s* stems; *kn* leaf bud; *k* tuber; *k* last year's tuber from which the stem grows; *w* roots. *B*: *k* stem; *z* scale-leaves; *s* scape; *b* buds; *l* foliage leaves; *w* roots. *C*: *n* scale-leaves; *a* stem; *l* foliage leaves. *D*: *s* stolon; *n* scale-leaves; *b* bud. *E*: *s* stem; *f* foliage leaves; *a* twisted internode; *w* root.

CHAPTER V.

LEAVES.

Q. 64. What is a leaf?

A. A leaf is a primary lateral out-growth of the stem.

Q. 65. Of what parts does a typical leaf consist?

A. A typical leaf consists of (1) base or foot, (2) petiole or stalk, (3) blade or lamina.

Q. 66. How may leaves differ?

A. Leaves may differ from each other (1) by the presence or absence of the petiole or blade, (2) by divisions of either petiole or blade; (3) in venation; (4) in outline of blade; (5) in appendages to any of their parts.

Q. 67. Name and describe the chief kinds of leaves with regard to these differences.

I. A leaf having a petiole is called stalked or petiolate, while a leaf without petiole is called sessile; a leaf which has no proper blade may be; (1) acicular or needle-shaped as in pines, or; (2), tendril-like as in some vetches; or, (3), cylindrical as in the onion; or (4), prismatic as in the stonecrop, etc.

II. With regard to presence of divisions or their absence: a leaf without divisions of stalk or blade, is called a simple leaf, while leaves having completely divided leaf-blades only, or, divided leaf-blades and also divided petioles are called compound. Compound leaves are either pinnately, or palmately compound according as the separate divisions of the leaf-blade, called leaflets, are arranged on the sides of an elongated axis, as for instance, the pinnately compound leaf of the sumac; or when the leaflets all appear to arise from one point as the palmately compound leaf of clover. When the leaflets of the first division of a compound leaf are themselves similarly divided, the leaf is said to be twice pinnately compound or palmately compound; these divisions may extend still further, so that the leaf may be three times or four times compound; *e. g.*, the leaf of the meadow-rue is thrice ternately compound. These higher divisions however, are often simply called decompound.

FIG. 3.—Netted venation of leaf of Willow (salix caprea); *m* midrib; *n* lateral secondary ribs; *v* anastomosing veinlets. (nat. size.)

III. The venation of a leaf may be either reticulate or parallel, pinnate or palmate. A leaf is said to be reticulate or net-veined when its veins appear to form a net work; but it is parallel veined, when the veins appear to run parallel to each other. It is pinnate veined, when the secondary veins arise from a distinct axial vein, termed midrib, and palmate-veined when the veins arise from the insertion of the petiole.

IV. The blades of leaves may differ

in shape, in margin, in apex and base. The general shape of the leaf blade may be linear, ellip-

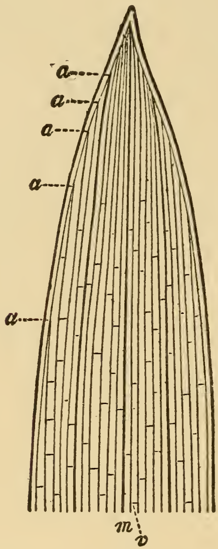

FIG. 4.—Parallel venation of grass leaf; veins anastomosing along margin at *a, a, a, a, a*; *v* veinlet. (x4)

FIG. 5.—Pinnate venation of young fern leaf, the veins do not anastomose; *m* midrib; *ss* secondary lateral veins; *n* smaller lateral veins.

tical, oval, cordate, lanceolate, peltate, etc. The margin or border of the blade may be entire, lobed, cleft, dentate, serrate, laciniate, divided, etc. The apex of the leaf blade may be acute, emarginate, obtuse, mucronate, cuspidate, etc. The base may be acute, obtuse, cordate, clasping, auriculate, perfoliate, connate, etc.

V. Among the appendages of the leaf the most important are the stipules, which are outgrowths from the base or foot of the petiole; they may be foliaceous membranous, spiny, ocreate, etc. Other appendages or outgrowths from the leaf are hair, or spines, or scales.

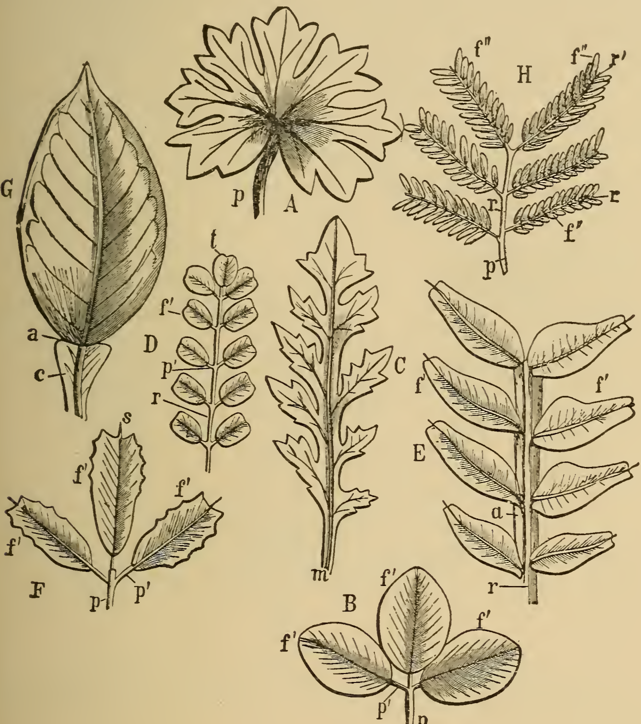

FIG. 6.—*Various forms of leaves:* *A* palmate lobed leaf of Geranium, p petiole; Palmate compound leaf of clover, *p* petiole, p' petiolule, *f* leaflet. *C* pinnate, dissected leaf of shepherd's purse (capsella bursa pastoris) *m* midrib. *D* Pinnate, compound leaf of Hippocrepis comosa, *r* midrib or phyllopodium, p' petiolule, f' leaflet, *t* terminal leaflet. *E* Pinnate, compound leaf of Pistacia Lentiscus without terminal leaflet, *r* midrib or axis, *a* wing of axis, *f* leaflet. *F* Pinnate compound leaf distinguished from *B* because petiolules *p'* do not rise from one point *f* leaflet, *s* mucro, spiny projection of midrib. *G* leaf of the orange must be considered compound on account of joint, *a* between leaf and petiole; *c* wing of petiole. H twice-pinnate compound leaf of Acacia, *p* petiole or principal axis, *r'* secondary axis *f''* leaflets.

Q. 68. How are leaves modified or transformed?

A. Leaves are modified in accordance with their function.

Q. 69. Mention some of the principal modifications or transformations.

A. Some of the principal modifications of leaves are, floral or perianth leaves, stamens, carpels, spines, tendrils, pitchers, scales and bracts.

NOTE—The floral leaves and bracts will be considered under the flower. Specially transformed leaves also occur, as for instance, in onion bulb or cabbage heads for storage of starch.

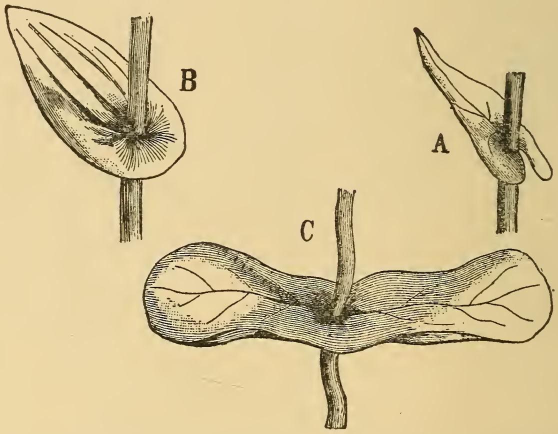

FIG. 7.—*A* auriculate clasping leaf of Thlaspi perfoliatum. *B* perfoliate leaf of Bupleurum rotundifolium. *C* Connate perfoliate leaves of Honeysuckle (Lonicera Craprifolium.)

Q. 70. What are tendrils?

A. Tendrils are elongated, thread-like modifications of branches or leaves adapted to twine around suitable objects and to serve the plant which produces them as a means of mechanical support.

Q. 71. What are pitchers or pitcher-leaves?

A. Pitchers, such as those of Saracenia purpuria or

Nepenthes, are leaves transformed into insect traps. The same may be said of the leaves of the Venus fly-trap and of Sundew.

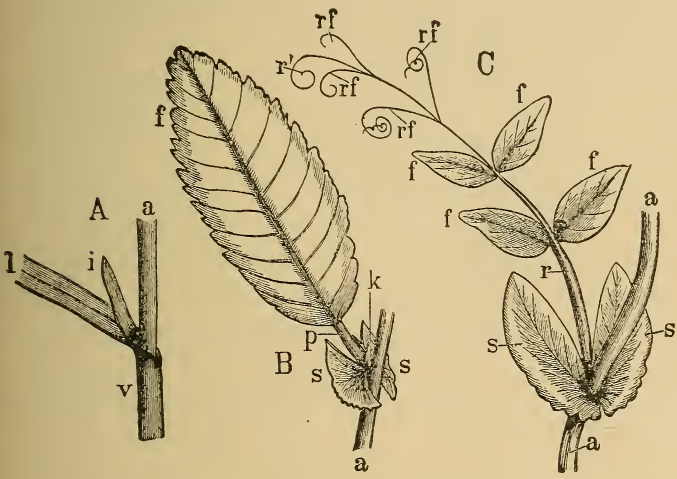

FIG. 8.—Base of leaf of grass, (Poatrivialis) *v* sheath, *i* ligule, *l* blade. *a* stem. *B* willow leaf, (salix caprea) *a* stem, *s* stipules, *p* petiole, *f* blade, *k* bud, *C* leaf of Pea (Pisuna arvense) *a* stem, *s* stipules, *r* axis, *f* leaflet, *rf* tendrils-transformed leaflets.

Q. 72. What are scales?

A. Scales, such as are found on buds or underground stems are transformed or rudimentary leaves.

Q. 73. What are bracts?

A. Bracts are leaves modified with regard to or by reason of the flower, but not included among true floral leaves.

Q. 74. How are leaves arranged on the stem?

A. Leaves are outgrowths from the nodes of the stems; and they occur either singly or in groups at each node. When they occur singly their arrrangement is called alternate, when in groups it is called verticillate or whorled. The simplest group consists of two at a node; this is called opposite arrangement, all groups greater than this are whorls.

Q. 75. How are leaves arranged vertically on the stem?

A. The vertical arrangement of successive leaves always is a spiral, whether the leaves are whorled or alternate; moreover, they are arranged in a definite number of vertical lines parallel to the axis of their stem, which are called ranks or orthostichies.

Q. 76. What is the relation of the spirals and the ranks to each other?

A. The relation of the spirals and ranks of the leaves can be very briefly expressed by the series, ($\frac{0}{1}$), $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, $\frac{21}{55}$; it will be noticed that the numerators of the different fractions are formed by adding the two preceding numerators, the same rule holding also for the denominators. Now as to the meaning of the fractions: the numerator expresses the number of turns the spiral makes around the stem in passing from any leaf in a definite rank or orthostichy along the successive leaves, back to the next leaf in the same rank, above or below that from which the start was made. The denominator expresses the number of leaves successively passed through in making the turn or turns.

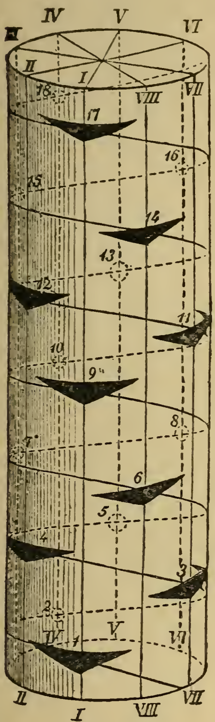

FIG. 9.—*Diagram of leaf arrangement of alternate leaves:* The leaves are arranged or inserted in eight vertical rows called ranks or orthostichies, marked in the figure by Roman numbers I, II, etc.; the leaves are marked according to their succession 1, 2, 3, etc., and are connected by a spiral line, which is called the genetic; it makes three turns between two successive leaves of same rank and passes through eight leaves: hence the divergence is 3/8.

Q. 77. Give examples of some of the above arrangements of leaves.

A. The leaf arrangement or phyllotaxy of the elm and hornbean is expressed by the fraction $\frac{1}{2}$; also that of all grasses; that of all sedges and of the alder is $\frac{1}{3}$, the $\frac{2}{5}$ arrangement is the most common occurring in the cherry, poplar and many other trees and shrubs; $\frac{3}{8}$ is found in the orange, theholly aud common plantain; both $\frac{3}{8}$ and $\frac{5}{13}$ occur in the acicular leaves of firs and spruces; $\frac{8}{21}$ and $\frac{13}{34}$ occur in pine-cones and heads of compositae.

NOTE—There are leaves which form exceptions to the above rules, *e. g.*, the alga. Polysiphonia has a $\frac{1}{4}$ leaf arrangement.

Q. 78. How are the two sides or surfaces of a leaf distinguished?

A. The side which faces the stem or upwards is called the ventral side, while the other which faces away from the stem or downwards is called the dorsal side of the leaf.

CHAPTER VI.

THE ROOT.

Q. 79. What is the plant root?

A. When the plant body is differentiated into dissimilar parts, one group of the parts forms the stem or ascending axis with its members while the other forms the root or descending axis with its members.

Q. 80. What are the principal kinds of roots?

A. The principal kinds of roots are the *primary* and *secondary* roots.

Q. 81. What is a primary root?

A. The primary root is the first root of a seedling.

Q. 82. What are secondary roots?

A. Secondary roots are branches of the primary root.

Q. 83. What other kinds of roots may be met with?

A. Adventitious or aërial roots.

Q. 84. What are adventitious roots?

A. Adventitious roots are secondary roots arising from the stem or any of its parts different from lower end where the primary root arises; adventitious members in general are such as have an abnormal origin.

Q. 85. What are aërial roots?

A. Aërial roots are secondary roots arising from a part of the stem above ground and serving as holdfasts for it; *e. g.*, the aërial roots of ivy, poison ivy.

Q. 86. How are roots properly so-called, modified?

A. Underground roots may be modified for the purpose of storing starch etc., in them, when they are thick and fleshy, and are called taproots; *e. g.*, beet, turnip, etc., or they may be adapted to attack the roots of other plants for the purpose of taking sap from them, when they are called parasitic; *e. g.*, gerardia, bastard toadflax, etc.

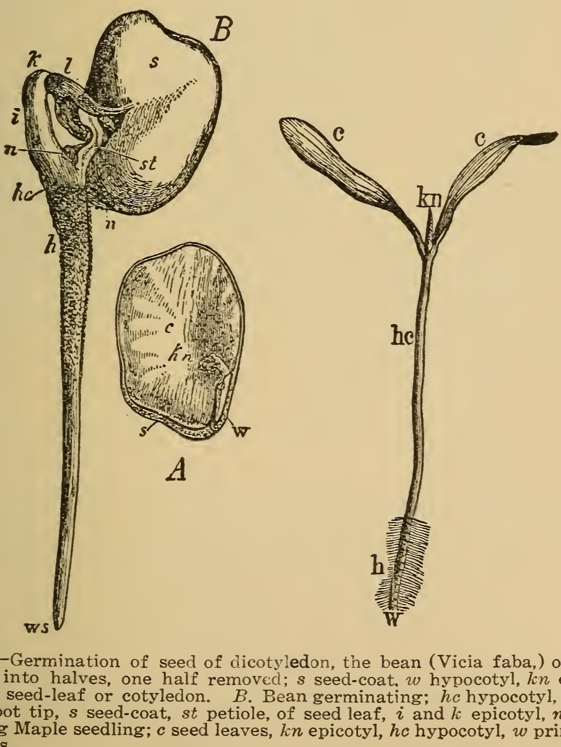

FIG. 10.—Germination of seed of dicotyledon, the bean (Vicia faba,) on left. *A.* Seed split into halves, one half removed; *s* seed-coat, *w* hypocotyl, *kn* epicotyl or plumule, *c* seed-leaf or cotyledon. *B.* Bean germinating; *hc* hypocotyl, *h* primary root, *ws* root tip, *s* seed-coat, *st* petiole, of seed leaf, *i* and *k* epicotyl, *n* bud. On righ, young Maple seedling; *c* seed leaves, *kn* epicotyl, *hc* hypocotyl, *w* primary root, *h* root hairs.

Q. 87. What are the principal forms of roots?

A. Roots are either fibrous, *i. e.*, thread-like, or tuberous, *e. g.*, dahlia, or nodulose, *i. e.*, swollen at the nodes.

Q. 88. What appendages do roots ordinarily develope?

A. Roots ordinarily do not develope leaves and never reproductive organs; but they do ordinarily develope hair-like appendages called root-hairs.

CHAPTER VII.

FLOWERS.

Q. 89. What is a flower?

A. A flower is a portion of the stem or its branches in the higher plants, modified for the purpose of producing spores, *i. e.*, reproductive cells.

Q. 90. What is a complete flower?

A. A complete flower is one that has pistils, stamens, corolla and calix.

Q. 91. What is a pistil?

A. A pistil is a modified leaf, called a sporophyll, *i. e.*, a leaf bearing spores; it is made up of three parts when complete: (1) ovary, (2) style, (3) stigma.

Q. 92. What is the ovary?

A. The ovary is a simple or compound chamber formed by the walls of the sporophyll and containing the ovules or rudimentary seeds. The specialized part of the ovarian chamber on which the ovules are born is the placenta; the ovules are morphologically sporangia, bearing each a single spore which for its size is called the macrospore, it is also known as egg-cell or embryo-sac.

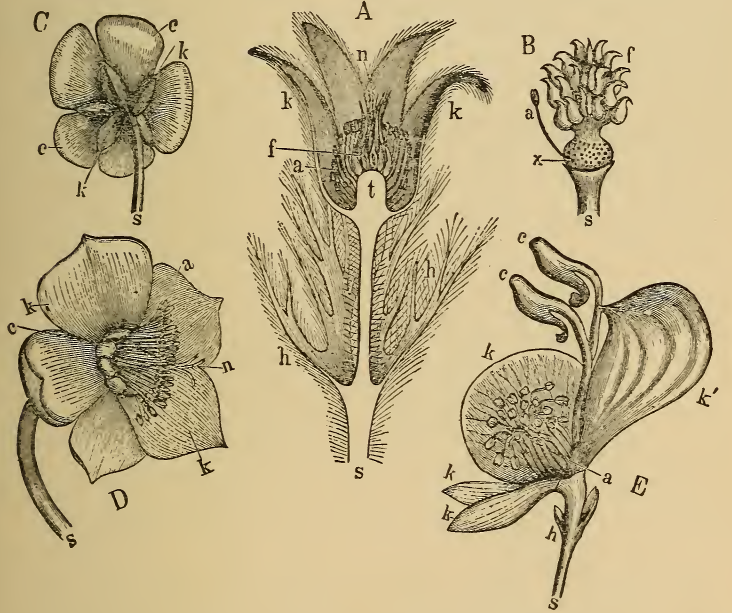

FIG. 11.—Flowers of Ranunculaceae; *s* peduncle, *k* sepals, *c* petals, *a* stamens *f* pistil. *A.* Pasque flower (Anemone pulsatilla) cut through middle of axis, *h* bracts, *t* torus or receptacle *B.* Pistils of Crowfoot, *a* one stamen left on receptacle, *n* the dots marking the points of insertion of the other stamens which were removed. *C.* Complete flower from below. *D.* Flower of Hellebore. *E.* Flower of Monks-hood. *h* bractlets, *k'* transformed sepal or hood, *c* transformed petals.

Q. 93. What is the style?

A. The style is an elongation of the apex of the ovary bearing on its upper end a glandular surface called the stigma.

Q. 94. What place in the flower does the pistil occupy?

A. The pistil occupies the innermost place in the flower.

Q. 95. What is a stamen?

A. A stamen is a modified leaf, called also a microsporophyll, because it bears microspores which are generally known as pollen. The stamen generally consists of two parts: a thread-like stalk called filament bearing the pollen-sacs or pouches, which are known as anthers.

Q. 96. What is the corolla?

A. The essential organs of the flower; namely, pistils and stamens are generally surrounded by two sets or circles of modified leaves; the inner set or circle is called the corolla, the outer the calix and both together are called perianth. The leaves of each set being either separate or grown together; the separate leaves of the inner set or corolla, are called petals those of the outer set or calix are called sepals.

Q. 97. How may flowers differ among each other?

A. Flowers differ among each other,: (1) by the presence or absence of some of their parts; (2) in the number of the respective parts; (3) in position and cohesion, or adhesion of the parts; (4) in various shapes of the parts.

Thus—I: the corolla may be absent, and then the flower is apetalous, or both the corolla and the calix, then the flower is naked or achlamydeous; when only one of the two is absent, it is always the corolla. When the stamens are wanting, the flower is pistillate and conversely, when the pistils are wanting, the flower is staminate, and when both are wanting it is neutral.

II. The difference in the number of the respective parts gives rise to the different plans of the flower. The principal kinds are the plan of three, *i. e.*, the different floral parts as sepals, petals, stamens and pistils are three in number, or a multiple of three; this plan is typical of the monocotyledons; the plan of four or five, when the parts number four or five or multiples of these numbers; both these plans are typical of the dicotyledons.

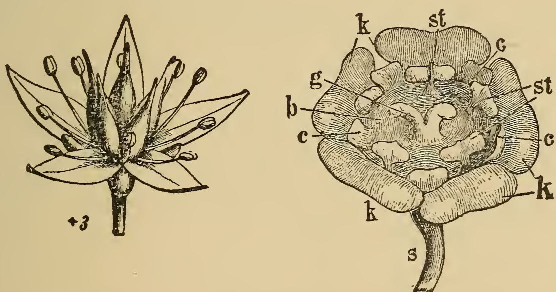

FIG. 12. On left flower of stonecrop; parts all separated from each other; on right, flower of gooseberry, showing cohesion and adhesion of the sepals, petals, stamens and pistils; *k* calyx, *c* corolla (petals), *st* stamen, *b* disk, *g* style.

III. The principal differences of flowers, arising from the relative position or insertion of its parts, are those that are founded on the relation of the position of the pistil and of the other parts. (See figure 12.)

By cohesion is meant the growing together of parts of the same set, while by adhesion is meant the growing together of parts of different sets. The former gives rise to compound pistils, monadelphous stamens mono or sym-petalous corolla, etc., while the latter gives rise to apparent differences of position.

When all the parts of a set are similar to each other they are called regular; when this is true in all the respective sets, the whole flower is regular. If one or more of the sets have one or more dissimilar parts the whole flower is irregular. The commonest irregularities are transformation of the corolla or calix or parts thereof into a nectary, *i. e.*, a gland producing a sweet, liquid, popularly called honey, but botanically known as nectar.

Q. 98. What is meant by inflorescence?

A. Inflorescence signifies the arrangement of flowers on the stem.

Q 99. What is the arrangement of flowers?

A. Since flowers are the homologues of branches, their arrangement is the same as that of branches, *i. e.*, axillary or ternimal, or both.

Q. 100. What is axillary inflorescence?

A. Axillary inflorescence obtains when the flowers arise from the axils of leaves and is also called indeterminate or acropetal, and is further known as the racemose type.

Q. 101. What constitutes a terminal inflorescence?

A. An inflorescence is terminal when all its separate flowers terminate branches, and hence it is called determinate and is further known as the cymose type.

Q. 102. Name some of the principal inflorescences of the racemose type.

A. Raceme, corymb, umbel, spike, head, spadix, catkin or ament, and panicle.

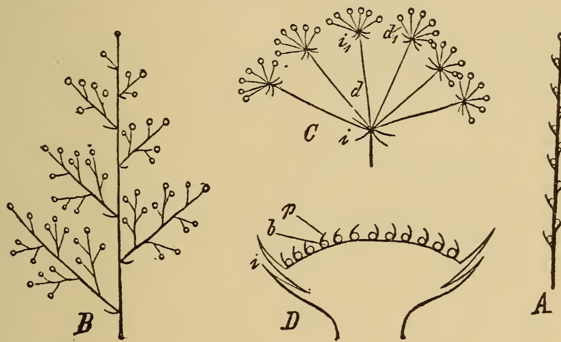

FIG. 13.—*Diagrams of racemose inflorescences:* *A.* Spike. *B.* Compound raceme. *C.* Compound umbel; *i* involucre, *i* involucel, *d* ray, *d1* secondary ray. *D.* Head, *i* involucre, *p* bract, *b* flower.

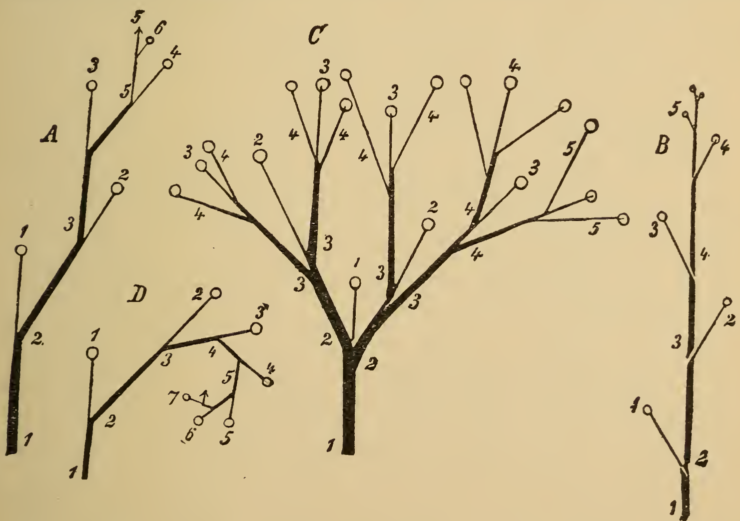

FIG. 14 —*Diagrams of cymose inflorescences:* The numbers indicate the order of succession of the flowers; No. 1 being first to open, No. 2 second, etc. *A* and *B* scorpioid, *C* dichasial, *D* helicoid cyme.

Q. 103. Name the principal cymose inflorescences.
A. Cyme, fascicle and cymule.

Q. 104. Instead of a definition mention a common or a well known example of each.

A. Example of raceme *e. g.*, forget-me-not, pepper-grass, of corymb, the hawthorn genus; umbel, the whole parsley family; spike, the common plantain; head, clover, dandelion, aster, spadix, jack-in-the-pulpit, calla lily, catkin, or ament, flowers of willow, poplar, hazel; panicle, oats, buckeye. Examples of cyme, elder, wild cranberry, fascicle, day flower, spiderwort; cymule, chickweed, pearlwort.

CHAPTER VIII.

THE FRUIT.

Q. 105. What is meant botanically by fruit?
A. The fruit is, in a strict sense, the ripened pistil. But often, after fertilization, parts adjacent to the pistil develope in a special way and in combination with the pistil and thus become parts or appendages of the fruit.

Q. 106. What is the seed?
A. The seed is the ripened ovule.

Q. 107. What does the seed contain?
A. The seed contains the young plant or embryo with or without nourishment for it, in the shape of starch, oil, etc.

Q. 108. What is therefore the relation of seed, embryo, and fruit?

A. The fruit contains a seed or seeds, the seeds contain the embryos; the fruit serves as a protection to the seed and very often as a means for the dispersal of the latter; the seeds serve as a protection to the embryo and generally also supply nourishment for its germination.

Q. 109. How may fruits be classified?

A. Fruits may be classified into simple and compound; true and spurious; dry and fleshy.

Q. 110. Define these.

A. A simple fruit is a single ripened pistil; a compound fruit consists of several ripened pistils. A true fruit consists of the ripened pistils only; a spurious fruit consists of the ripened pistil along with other parts intimately united to it. A dry fruit is one having no flesh or pulp; a fleshy fruit is one that is more or less juicy throughout.

Q. 111. Mention some of the fleshy fruits.

A. The principal fleshy fruits are the berry, the drupe, the pepo or gourd-fruit. The pome or apple is also fleshy but not a true fruit, since the fleshy part is the greatly developed calix; a berry is fleshy throughout as gooseberry, cranberry, grape, tomato; but not the strawberry, the fleshy part being the greatly increased receptacle or summit of the floral axis.

Q. 112. What are the two principal kinds of dry fruits?

A. The dry fruits are distinguished into dehiscent and indehiscent fruits. A dehiscent fruit is one which when ripe opens to let out the seeds; an indehiscent fruit is one that remains closed.

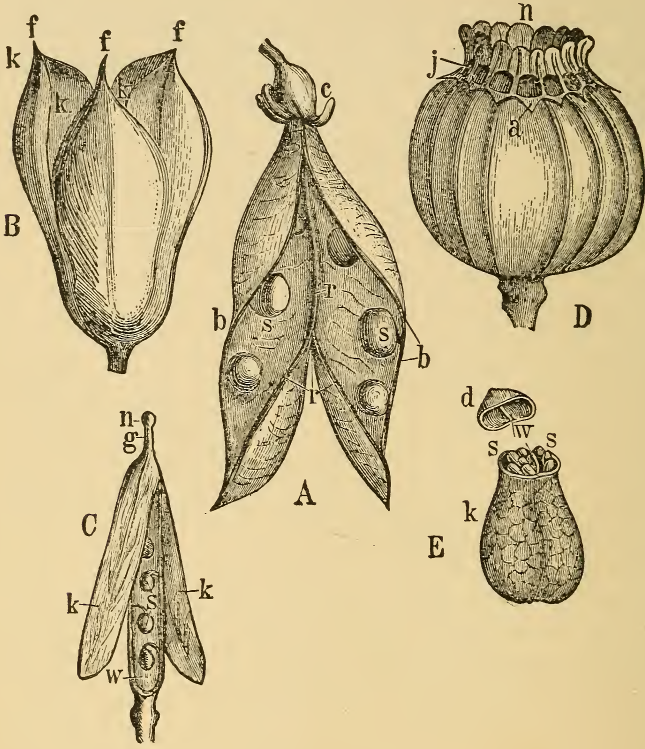

FIG. 15.—Dry dehiscent fruit. *A.* Pod or legume of pea; *r* dorsal suture, *b* ventral suture, *c* calyx remnants, *s* seeds. *B.* Septicidal capsule of Colchicum autumnale; *f* separate carpel. *C.* Silique as found in mustard family, *k* valves, *s* septum or partition, *s* seed. *D.* Fruit of the Poppy (Papaver somniferum) *n* stigma, *j* pores, *a* valves covering pores. *E.* Pyxis of Henbane; *d* lid, *s* seeds, *w* partition.

Q. 113. Mention the principal dehiscent fruits.

A. The dehiscent fruits are compound capsules, such as the fruit of the blueflag, follicle or simple pod splitting along one side only; legume splitting along both sides, *e. g.*, beans and peas; the silique the two sides of which split away from a central partition; the pyxis, a pod the top of which comes off as the lid from a dish, and the cone, the fruit peculiar to pines and most gymnosperms.

Q. 114. Mention the principal indehiscent fruits.

A. They are the akene, as the fruit of buttercup, crowfoot, sunflower, dandelion, etc., the caryopsis or grain, as corn, wheat, etc., the samara or winged fruit, *e. g.*, maple, ash, elm, boxelder, etc.

CHAPTER IX.

THE SEED.

Q. 115. What is the most important part of the seed?

A. The most important part of the seed is the embryo or young plant contained in it.

Q. 116. Describe the embryo?

A. The embryo is generally so far developed in the seed, that the following parts can be made out: (1) cotyledon or seed leaf, (2) radicle, caulicle or hypocotyl which is the descending axis of the embryo and developes the primary root; (3) the plumule or epicotyl, the ascending axis, the stem, bearing scales or rudimentary leaves.

Q. 117. How many cotyledons or seed leaves has the embryo?

A. The embryo has two cotyledons in the dicotyledonous plants, one in the monocotyledons, and several in most gymnosperms.

Q. 118. How is the nourishment for the embryo usually stored in the seed?

A. The nourishment for the embryo, is usually stored in the form of starch or oil or proteid matter in one of the following ways: (1) in the greatly enlarged, thick cotyledons, as in beans, acorns and most dicoty ledons; (2) it surrounds the embryo, *i. e.* the embryo is embedded in the nourishment, which in this case is called endosperm, as in wheat, corn and most monocoty ledons.

CHAPTER X.

TISSUES.

Q. 119. What is meant by tissue in botany?

A. Multicellular plants consist of many similar or dissimilar cells; layers or systems of similar cells are called tissues.

Q. 120. How may different kinds of tissues be distinguished?

A. In two ways, (1) with regard to their power of growth and division or multiplication; (2) with regard to form of cellwall, contents and their chemical constituents.

Q. 121. How many kinds do we distinguish according to the first of these ways?

A. Respecting capacity for division or growth, two kinds of tissues are to be distinguished: (1) meristem or embryonic tissue still capable of growing; (2) adult or permanent tissue incapable of further growth.

Q. 122. How many kinds of tissue are to be distinguished with regard to form and constituents?

A. The following kinds are distinguished by form of cell wall or constituents; (1) parenchyma, (2) prosenchyma, (3) collenchyma, (4) sclerenchyma, (5) cuticularized parenchyma, (6) tracheal or vascular, (7) sieve tissue (8) glandular tissue.

Q. 123. How are these different tissues to be grouped?

A. They are to be grouped into (1) such as are derived from parenchyma, (2) such as are derived from prosenchyma (3) such as are specialized cells from their very origin.

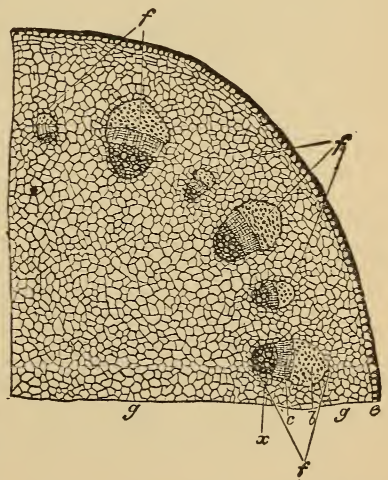

FIG. 16. Cross-section of petiole Hellebore (20 dia.); *e* epidermis, *g* parenchyma, *f* fibrovascular bundle, *x* xylem or wood, *c* bast, *b* sclrenchyma.

Q. 124. What is parenchyma?

A. Parenchyma or fundamental tissue consists of thin walled cells which are more or less isodiametric, *i. e.*, whose diameter is approximately constant, no matter in what plane it is taken.

Q. 125. What is prosenchyma?

A. Prosenchyma is a tissue composed of elongated thinwalled cells, which are, as it were, spliced together at the ends; in this way they differ from parenchyma whose constituent cells meet more or less at right angles.

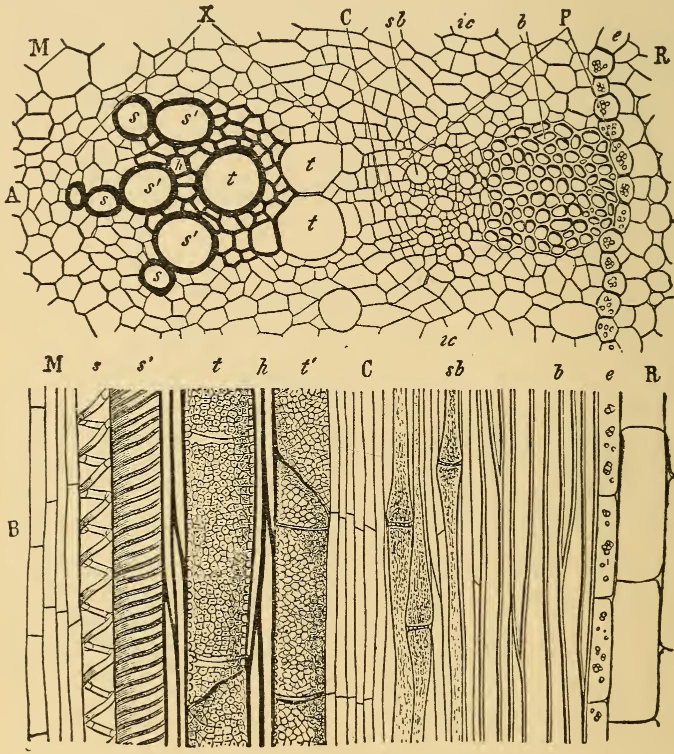

FIG. 17.—Upper figure *A* a cross-section, the lower *B* a longitudinal section of fibro-vascular bundle of sunflower; *m* parenchyma, *x* wood, *c* cambium, *p* bast, *r* cortex, *s* and *s'* spiral ducts, *t* and *t'* pitted ducts, *h* wood-fibre, *sb* sieve tube, *b* bast fibres, *e* endodermis (150 diameters).

Q. 126. What is collenchyma?

A. Collenchyma is parenchymatous tissue, the cell-walls being thickened at adjoining corners. The substance constituting this thickening is capable of becoming glue or gelatine and hence the name.

Q. 127. What is sclerenchyma?

A. Sclerenchyma is prosenchyma with very much thickened walls, as occurring especially in bast fibres.

Q. 129. What is tracheal or vascular tissue?

A. Tracheal or vascular tissue consists generally of prosenchyma, with lignified and variously thickned and bordered or perforated walls; it is distinguished into two principal kinds: 1. Tracheids, closed tracheal cells, the wall between the successive cells persists. 2. Tracheae, the walls between the successive cells are absorbed and the cells are usually also of a larger diameter; from their appearance and function they are also called ducts or vessels.

Q. 130. What is sieve tissue?

A. Sieve tissue consists of elongated cells or tubes communicating through specialized openings, called from their appearance, sieve-plates.

Q. 131. What is glandular tissue?

A. Glandular tissue consists of cells specialized for the purpose of secreting or excreting certain substances, as for instance, aromatic oil, nectar, latex or milk, etc.

CHAPTER XI.

THE PLANT CELL.

Q. 132. How does the typical plant cell differ from the typical animal cell?

A. The typical plant cell differs from the typical animal cell, in this, that it surrounds itself by a cell-wall which at first is always composed of the chemical substance cellulose, while the animal cell is lined by a protoplasmic membrane.

NOTE.—There are exceptions in both kindgoms, nevertheless this difference in the separate cells is responsible for most of the difference of appearance and general behavior between plants and animals.

Q. 133. How do cells come into existence?

A. So far as is known, both plant and animal cells arise only by division of pre-existing cells. Cell-division is always preceded by the division of the nucleus.

Q. 134. In how many ways does nuclear-division take place?

A. In two ways: 1. Direct or amitotic. 2. Indirect or mitotic.

Q. 135. What is direct nuclear-division?

A. Direct nuclear-division or amitosis takes place in the following manner: the nucleus of the parent cell constricts, without apparent change, in the configuration of the chromatin; the constriction in the middle of the nucleus advances until finally it is separated into halves.

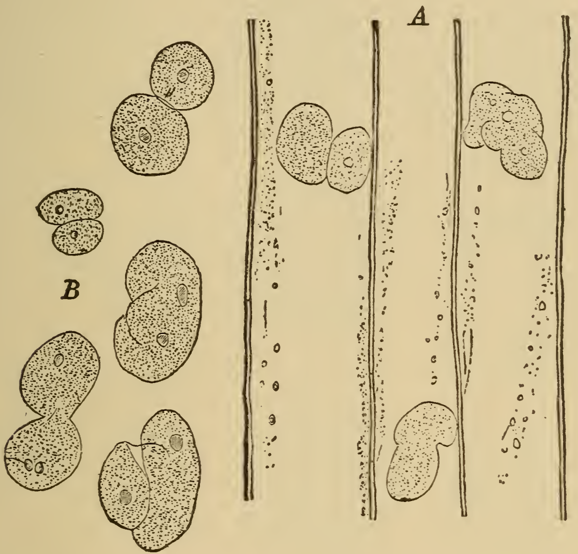

FIG 18. (540 dia.) Direct division of nucles: *a* fresh, *b* after staining with acetic methyl-green in cells of old internodes of common spiderwort.

Q. 136. What is indirect nuclear-division?

A. Indirect nuclear-division, called also mitosis or karyokinesis, is so designated on account of a series of complicated changes, which accompany it. The nucleus appears transformed into a bipolar spindle of arched fibres, in the equatorial plane of which the chromatin gathers in the shape of a thread or spirem; this thread breaks into a definite number of parts called daughter-chromosomes, which split lengthwise and move along the spindle fibres to the opposite spindle-poles; there they fuse into a new nucleus, and then a cell-wall is secreted at the equatorial plate of the spindle, thus separating the two new cells.

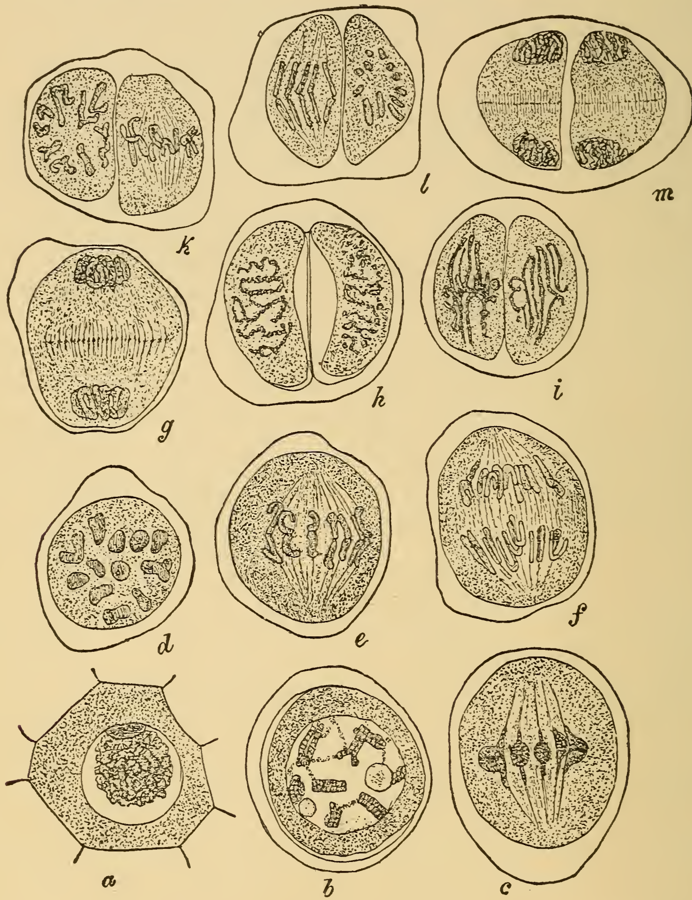

FIG. 19. Indirect cell-division or mitosis or karyokinesis, in pollen mother-cell of Fritillaria persica (800 dia.) *a* chromatin contracted in nuclear cavity, on its upper surface lies the nucleolus; *b* polar view of *c* bi-polar spindle, chromatin gathered in equatorial plate of spindle, *d* polar view, *e* equatorial plate or the chromosomes composing it split into halves, *f* chromosomes sliding along the spindle fibres to opposite poles of spindle, *g* formation of daughter nucles at poles, the spindal still visible, *h* spirem stage of daughter nuclei, *i* spindal formation, *k* equatorial plate stage, *l* halving of chromosomoes, *m* formation of grand-daughter nuclei.

Q. 137. What is the relative importance and frequency of occurrence of these two modes of nuclear-division?

A. Mitosis or indirect nuclear-division is, by far, the most common mode of nuclear-formation, the direct mode being extremely rare; moreover, as the latter occurs only in old tissues, it is now generally considered as a last feeble effort of the cell to grow, though only mitosis is followed by cell-division?

CHAPTER XII.

REPRODUCTION.

Q. 138. How many different modes of reproduction occur among plants?

A. The following: 1. Sexual reproduction. 2. Asexual reproduction. The latter is again of two kinds, namely Rejuvenescence and vegetative reproduction.

Q. 139. What is vegetative reproduction?

A. Vegetative reproduction, which should rather be called propagation, consists in this that a part or member of the parent plant-body is separated from it, and then develops as an independent plant.

Q. 140. What are the principal ways in which vegetative reproduction or propagation may take place?

A. They are the following: 1. By specialized branches or parts of stem as bulbs, bulbils, rhizomes, tubers, runners, stolons, which naturally propagate the plant; also but more rarely by specialized roots, as, for instance, those of the Jerusalem artichoke, Dahlia, etc. 2. Any node of the stem, branch or even leaf may, theoretically at least, be made to propagate the plant, and as is well known this is the florist's and gardener's favorite method, especially when they wish to preserve the peculiar qualities, which any particular plant has. 2. Propagation by means of gemmae, which occurs especially in plants that have no true stem, therefore, from the Byrophytes downward. Since the gemmae vary from highly specialized bodies, multicellular in structure, down to nuciellular gemmae, this method gradually leads over to rejuvesence or spore-reproduction.

Q. 141. What is meant by rejuvescence?

A. By rejuvescence is meant a peculiar change which the protoplasm of a cell may under definite circumstances undergo. This peculiar change of the protoplasm of a cell make take place in such a manner that the whole protoplasm of one cell contracts to form one or more spores, *i. e.*, cells capable of giving rise directly to another individual plant like the one from which the spores were derived; or it may give rise to cells which must each unite to other homologous cells in order to give rise to a new individual. The first of these methods is called spore reproduction, the second sexual reproduction; so that it appears that rejuvescence is a phenomenon that appears in spore formation and in gamete-formation only, and therefore is a special phenomenon of reproduction.

Q. 142. What is the principal difference between spore reproduction and sexual reproduction?

A. The principal difference consists in this that spores are able to reproduce the plant each for itself, while the sexual reproduction requires that two morphologically similar spore-cells, called in this connection gametes, must unite and fuse in order to produce a new individual. This latter fact, *i. e.*, the necessity of union of two gametes seems to be due to the reduction of the number of chromosomes to one-half the number that is found in the nucleus of the sporophyte.

CHAPTER XIII.

DEVELOPMENT.

Q. 143. What is growth?

A. Growth is change of form with or without increase of mass. It is brought about by protoplasm that is still in its embryonic condition. When protoplasm reaches the adult condition it ceases to grow.

Q. 144. In what directions may growth take place?

A. Growth may take place in one direction only, in which case the result is a thread of greater or less length; or growth may occur in two directions, when the result is a flat expanded body known as a thallus, or finally, growth occurs in three dimensions and the result is a solid, at first globular, but on account of unequal growth, it soon becomes more or less cylindrical.

Q. 145. What is normally associated with growth?
A. Cell-division is normally associated with growth.

Q. 146. Is growth localized or does it take place uniformly throughout the growing part!
A. In many of the lower algae and in the beginning of the development of the embryo of higher plants growth is quite uniform; but it becomes localized as the plant body increases, *i. e.*, a portion of the protoplasm passes into the adult condition and ceases to grow, while the other portion remains active and this difference in the activity of the protoplasm is responsible for the inequality of growth and, hence for the form and shape of the plant body.

Q. 147. What is a growing point?
A. A growing point is a definite region of a tissue where cell-division still takes place; it is called growing "point" because ordinarily it is restricted to a small area, very often to a single cell.

Q. 148. How are growing points distinguished?
A. Growing points are distinguished, according to situation, into apical, marginal and intercalary.

Q. 149. Define these?
A. The apical growing point is situated at the apex of the stem or root, or, in fact, of any axis; the intercalary growing point is situated between the base and apex, while the marginal is situated on the

margin; often the whole margin of a thalloid plant is embryonic, *i. e.*, capable of growth.

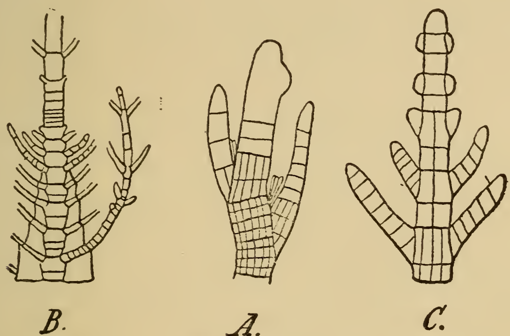

FIG. 20.—Growing points: *A*. Terminal (Stypoeaulon scoparium; 30 dia). *B*. Intercalary (Desmarestia ligulata, 60 dia.) *C*. Terminal (Chaetopteris plumosa, 40 dia.) branches arising from lateral divison of apical cell.

Q. 150. What other growing point or tissue is there?

A. The apical, intercalary or marginal growing points effect growth in length and also give rise to the normal lateral members; but many perennial plants, especially all perennial dicotyledons, grow in thickness each year; this is effected by growing or meristematic tissue surrounding the stem or root in the shape of a hollow cylinder, and is generally known as cambium or meristem.

CHAPTER XIV.

DICOTYLEDONS.

Q. 151. What are dicotyledons?

A. Dicotyledons are the highest class of flowering plants or rather of the whole vegetable kingdom; they are the dominant plants of the present geological era; they receive their name from the fact that the embryo of these plants, as contained in the seed, has two seed leaves or cotyledons.

Q. 152. Do the dicotyledons exhibit alternation of generation?

A. The dicotyledons normally have alternation of generations.

Q. 153. What is the relative development of the two phases?

A. The two phases are very unequally developed, that is to say, the gametophyte stage is very inconspicuous, while the sporophyte is highly developed, and is represented by that, which we call, "the plant" or "the tree."

Q. 154. What stages of development are comprised in the life-history of a dicotyledon?

A. All the stages from the germination of the ripe seed to the production of ripe seed.

Q. 155. Into how many kinds of plants are the dicotyledons divided with regard to the duration of their life-history?

A. With regard to the duration of their life-history, dicotyledons are divided into three kinds, *viz.*, annual, bi-ennial and perennial plants.

Q. 156. What is an annual dicotyledon?

A. It is one that completes its life history in the course of one season, *e. g.*, bean, pea, etc.

Q. 157. What is a bi-ennial dicotyledon?

A. A bi-ennial dicotyledon is one that completes its life-history only in the course of two seasons, *e. g.*, the beet, turnip, carrot, cabbage, etc. In the first season these plants germinate from the seeds and grow rapidly, but do not produce flowers or seeds; instead of it they store up nourishment in the fleshy roots, as for instance, the beet, carrot, or in the leaves, as the cabbage. The second season they produce flowers and seeds and then die a natural death.

Q. 158. What is a perennial dicotyledon?

A. A perennial dicotyledon is one whose life does not cease with the first production of flowers and seed, but which continues for an indefinite number of seasons to produce flowers and seed, as for instance, all dicotyledonous trees and shrubs.

Q. 159. What are the principal stages of development in an annual dicotyledon?

A. They are the following: 1. The embryo stage of the sporophyte. 2. The seedling or young growing sporophyte. 3. The fully developed sporophyte with mature spores in its flowers. 4. The male and female gametophyte. 5. Fertilization and development of seed.

Q. 160. What is the typical form of the embryo of dicotyledons?

A. The typical form of the dicotyledonous embryo has the following parts while still in the seed: 1. The descending axis, radicle or hypotyl. 2. Two cotyledons or seed leaves. 3. Plumule or epicotyl, the ascending axis.

Q. 161. Is there any differentiation of tissues in this stage of the sporophyte?

A. As a general rule there is very little if any differentiation into tissues, depending however somewhat upon the variable degree of development which the embryo of different plants attains in the seed; if any differentiation obtains, it consists of merisstematic parenchyma and prosenchyma.

Q. 162. By what changes does the embryo pass into the seedling stage?

A. Under the proper conditions of temperature, moisture and air the embryo in the seed begins to grow; this is called germination. First the radicle or hypocotyl elongates and grows down into the substratum; when it has secured a firm foothold, and not before, the plumule or hypocotyl elongates in its ascending growth; next the cotyledons may or may not be lifted above ground and begin to function, as leaves assisting the first small leaves formed on the epicotyl. Simple and unimportant as this last fact, namely, the elevation and transformation of the cotyledons into functioning leaves may appear at first sight, it involves, nevertheless, a reversion of the general tendency of growth of the radicle or hypocotyl; for the elevation of the cotyledons cannot be due to anything else than upward elongation of the hypocotyl, and yet the general tendency of growth of the hypocotyl is away from the light and towards moisture or nourishment and yielding to the pull of gravity. In spite of all, this difference of behavior does occur in closely related plants, *e. g.*, the ordinary garden bean and pea, the bean always elevates or at least attempts to elevate its cotyledons and transform them into green leaves, while the pea never makes an effort in this line.

Q. 163. What other changes take place during the change of the plant from the embryo to the seedling?

A. The hypocotyl produces the primary, and generally also secondary roots, the epicotyl produces leaves and branches, while the tissues undergo complete differentiation.

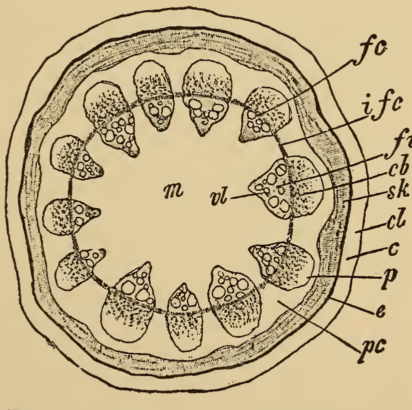

FIG. 21. Cross-section of young stem of Aristolochia Sipho; *c* parenchyma *cl* collenchyma, *sk* sclerenchyma belonging to pericycle *pc*, *ifc* interfascicular cambium, *fv* fibrovascular bundles, *fc* fascicular cambium, *vl* wood, *m* pith parenchyma, *p* young bast, *cb* sieve-tissue and bast.

Q. 164. What differentiation of tissue is found in the seedling stem of dicotyledons?

A. The seedling stem-tissue is the following: The outer layer of cells is the epidermis; the next, the cortex (parenchyma), then the fibro-vacular bundles arranged radially with connecting or intrafascicular cambium.

Q. 165. What differentiation of tissue is found in the root?

A. The same differentiation of tissue obtains in the roots as in the stem, only it is not so pronounced.

Q. 166. What new development does the fully developed sporophyte exhibit?

A. The only *new* development which the fully developed sporophyte shows is the reproductive organs or flowers.

Q. 167. What are flowers morphologically?

A. Morphologically flowers are leaves bearing reproductive cells called spores.

Q. 168. How many kinds of spores are there in dicotyledons?

A. There are always two kinds of spores in the dicotyledons, *viz.*, macrospores and microspores.

Q. 169. What are these spores?

A. The macrospore is the embryo sack of the ovule, the microspore is the pollengrain.

Q. 170. What is the gametophyte of dicotyledons?

A. The gametophyte of dicotyledons is of two kinds, *viz.*, the female and the male. The female gametophyte is the embryo sack with its development up to fertilization; the male gametophyte is the germinating pollengrain up to fertilization.

Q. 171. What is fertilization?

A. Fertilization is the union and fusion of the egg nucleus with the generative nucleus of the pollentube. From the oo-spore thus produced the embryo of the sporophyte is developed.

NOTE—In the seed ordinarily the embryo passes a resting stage, more or less prolonged.

CHAPTER XV.

MONCOTYLEDONS.

Q. 172. What is a monocotyledon?

A. A monocotyledon is an angiosperm whose embryo has only one cotyledon or seed leaf.

Q. 173. How does the germination of monocotyledons differ from that of dicotyledons?

A. Principally in this, that the single cotyledon is never elevated above ground, though it may persist for a long time. The other development is essentially the same.

Q. 174. How does the seedling of monocotyledons differ from that of a dicotyledon?

A. It differs essentially only in the distribution of the tissues.

Q. In what does this difference consist?

A. This difference consists in the irregular distribution of the fibro-vascular bundles and in the absence of true meristematic tissue or cambium. In dicotyledons the fibro-vascular bundles are arranged radially, *i. e.*, star-like, while in the monocotyledons there is no definite order beyond this, that they are more numerous toward the periphery.

Q. 176. How does the adult monocotyledon differ from the adult dicotyledon?

A. The adult monocotyledon differs from adult dicotyledon in following points: 1. A cross-section of the stem of the dicotyledon shows the fibro-vascular bundles arranged radially, *i. e.*, in rings, but the monocotyledon does not. 2. The leaves of the dicotyledons are typically netted-veined, while the leaves of the monocotyledon are paralled-veined. 3. The flower of the dicotyledon is generally on the plan of five or two or their mutiples, while that of monocotyledons is on the plan of three and its multiples.

Q. 177. What other difference is there between dicotyledons and monocotyledons?

A. There is another marked difference between these two forms in their adaption and manner of secondary growth, or growth in thickness. The dicotyledons have typically a special tissue to secure secondary growth, called cambium, which the monocotyledons do not have. The principal reason for this is that the monocotyledons, with the exception of palms and their relatives, are mostly annual plants, while the contrary is the case with dicotyledons and gymnosperms.

Q. 178. What plants belong to the monocotyledons?

A. All grasses, sedges, orchids, lillies, palms, cereals, etc.

NOTE.—Dicotyledons and monocotyledons together constitute the angiosperms, so called because their seeds are produced in a closed vessel.

CHAPTER XVI.

GYMNOSPERMS.

Q. 179. What are gymnosperms?

A. Gymnosperms are distinguished from angiosperms in this, that they have their seeds naked., *i. e.*, not contained in carpels.

Q. 180. How does the gymnosperm differ from the dicotyledon and monocotyledon?

A. It differs from these two: 1 In the number of cotyledons. 2. In germination. 3. In reproduction.

Q. 181. How does the gymnosperm differ from the angiosperms in number of cotyledons?

A. In this, that its embryo has more than two, up to fifteen cotyledons.

Q. 182. How does it differ in germination?

A. In this, that the whole seed is raised above ground where seed coats are cast off.

Q. 183. How does it differ in reproduction?

A. In this, that the spores are not contained in a closed vessel, but are naked, and hence the name of the class.

Q. 184. In what other respect do they differ from angiosperms?

A. Principally in this, that they have no true vascular tissue or ducts; but they agree with dicotyledons in secondary growth. Another difference is the arrangement of their flower into typical clusters called cones.

Q. 185. What plants belong to this class?

A. The conifers, as pines, spruces, firs, cedars, the Gnetaceae, cyras, etc.

Q. 186. What division of the vegetable kingdom do the plants so far specialized constitute?

A. They constitute the spermaphyta or seed-bearing plants.

CHAPTER XVII.

PTERIDOPHYTES.

Q. 187. What plants belong to this group?

A. To this group belong ferns and related plants, that is in descending order: 1. Clubmosses. 2. Horsetails and scouring rushes. 3. Ferns.

Q. 188. In what relation does this group of plants stand to the other plant groups?

A. It is the highest group of cryptogams, and the only one in which true vascular tissue is found, hence they are also called the Vascular cryptogams. They are the crytogams nearest in form and structure to the flowering plants, the spermaphytes.

Q. 189. Do the Pteridophytes have alternation of generations?

A. The Pteridophytes show a well-marked alternation of generations. That phase of them which is known as the "plant" is the sporophyte, while the inconspicuous gametophyte phase is called the prothallus or prothallium.

Q. 190. What is the relation of the plants of this group among themselves and to the spermaphytes as regards spore-characteristics?

A. As regards their spores, the Pteridophytes are of two kinds, *viz.*: 1. Homosporous, *i. e.*, spores produced are all alike. 2. Heterosporous, *i. e.*, spores produced are of two kinds, *viz.*, large ones, called macrospores, and small ones, called microspores. It is evident, therefore, that the latter, the heterosporous Pteridophytes, lead over to the Spermaphytes, while the homosporous forms lead down to the mosses.

Q. 191. Which plants of this group are heterosporous?

A. The heterosporous plants of this group are: 1. Selaginellaceae. 2. Isoetaceae or quillworts. 3. Hydropterideae, as Salvinia, Azolla, Marsilea, Pilularia.

Q. 192. Which are homosporous?

A. Homosporous are: 1. Lycopodiaceae and Psilotaceae or clubmosses. 2. Equestaceae or horsetails. 3. Ferns.

Q. 193. What are the principal stages of development from spore to spore?

A. They are: 1. Spore. 2. Prothallium or gametophyte. 3. Sporophyte.

Q. 194. What is the principal difference between homosporous and heterosporous plants of this group as regards the prothallium?

A. The principal difference is this: The homosporous spores generally develop into a prothallium which has male and female organs, while the heterosporous spores develop only male prothallia from the microspore and only female prothallia from the macrospore.

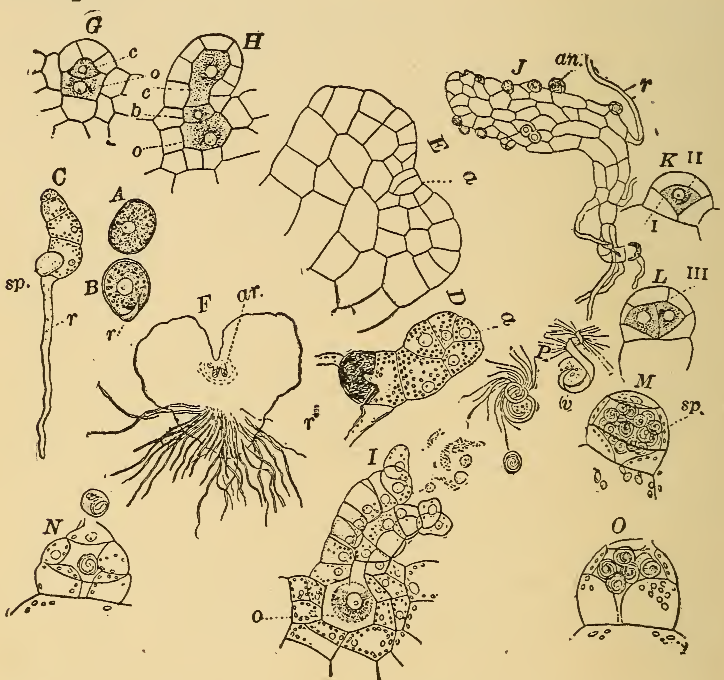

FIG. 22.—Development of gametophyte of ostrich fern (Onoclea); *A*. Spore without outer cot, *B* same germinating, *C* young prothallium, *r* rhizoid, *D* and *E* older prothallium, *a* growing point, *F* female prothallium from below, *r* rhizoids, *ar* archegonia (12 dia.), *G* and *H* longitudinal section of young archegonia, *o* egg, *b* lower, *c* upper canal cell (150 dia.), *I* ripe archegonium opening, *o* egg, *J* male prothallium (500 dia.) *an*, antheridia, *r* rhizoid *K*, *L* longitudinal section of young antheridia (300 dia.), *m* ripe antheridium (300 dia.), *sp* spermatozoids (300), *N* and *O* antheridia discharging spermatozoids, *P* ciliated free swimming spermatozoids, *v* vesicle (500 dia.).

Q. 195. Describe the gametophyte of these plants?

A. The gametophyte consists of a small, flat thallus of homogeneous tissue bearing the reproductive organs, *viz.*, antheridia and archegonia.

Q. 196. Describe the sporophyte?

A. The sporophyte is generally differentiated into stem, leaf and root. In the higher clubmosses the stem and leaves are above ground; in the equisetaceae the stem is partially beneath (rhizome), and partially above ground, as also in the case in the ferns.

Q. 197. What is the appearance of the gametophyte?

A. The gametophyte, whether male or female, or both, is generally a thalloid body of greater or less extent bearing the sexual organs on its lower side. In the heterosporous forms the prothallium is formed in the spore and projects only slightly from it, and produces either one antheridium or one archegonium. In the homosporous forms the prothallium is either a somewhat tuberous body, as in the clubmosses, or a more or less flattened thallus, as in the horsetails and ferns, but it becomes free from the spore.

Q. 198. Describe briefly the development of the sporophyte?

A. The spermatozoids produced and set free from the antheridium at the proper time and condition swim towards and enter the archegonium, then one of them fuses with the egg-cell, which then secretes a cell-wall so that no more can enter; after a period of rest this fertilized egg-cell develops directly or indirectly into the sporophyte.

Q. 199. How are these plants classified.

A. They are classified according to the character of the sporophyte, especially according to the way it bears the spores.

Q. 200. How are the spores borne in the plants of this group?

A. In the Selaginellaceae they are borne in more or less distinct cones; in the equisetaceae in distinct terminal cones; and in the ferns they are borne in sori or clusters on the dorsal sides of special leaves.

CHAPTER XVIII.

BRYOPHYTES.

Q. 201. What is the next lower group of plants?

A. The next lower group of plants includes the Mosses or Bryophytes.

Q. 202. What plants come under this heading?

A. Under this heading the liverworts and the true mosses are included.

Q. 203. What distinguishes them from the preceding group?

A. They differ from the preceding group principally in this, that they have no true roots nor true vascular tissue.

Q. 204. Do the plants of this group show a distinct alternation of generations?

A. They do; and just here is where the greatest difference, morphologically, between them and the preceding group comes in; in the foregoing group the sporophyte is principally developed, and is, therefore, called "the plant," while in this group the gametophyte is principally developed, and is called "the plant."

Q. 205. Describe the sporophyte of the bryophytes.

A. The sporophyte, called also sporogonium or sporophore, differs considerably in the two classes of plants of this group. In the liverworts it consists of a capsule or vessel raised on a stalk called seta; the capsule splits on maturity into a certain number of valves. In the true mosses the sporogonium consists of a spore-capsule raised, as a rule, on a foot or stock called seta; on maturity the capsule opens generally by a lid, or splits irregularly. In both, the sporophyte never becomes entirely independent of the gametophyte, but throughout its life draws nourishment from it.

Q. 206. What special arrangement is found in these plants for the disposal of spores?

A. In the true mosses the mouth of the spore-capsule is surrounded by a single or double wreath of hygroscopic hair, which open when moist and close when dry. In the liverworts, elaters or hygroscopic hair are developed among the spores; they curl up when dry and suddenly expand when moistened.

Q. 207. In what other plants are elaters found?

A. They are also found in the horsetails where they are attached to the spores.

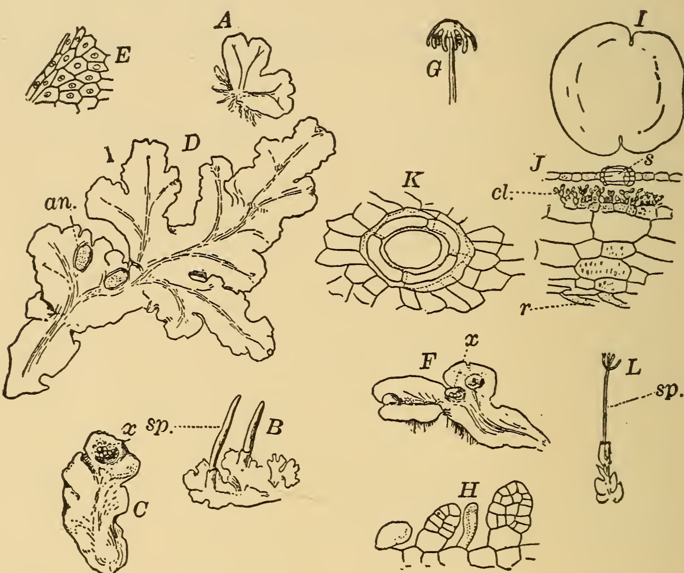

FIG. 23.—Forms of liverworts: *A.* Riccia (nat. size). *B.* Horned liverwort, *sp* sporogania. *C.* Lunuloria (nat. size), *x* gemmae. *E.* Piece of epidermis showing breathing pores in middle of cells. *D.* Giant liverwort (nat. size) *an* antherilia. *F.* Common liverwort, *x* cupules containing gemmae. *G.* Female receptacle of common liverwort (nat. size.). *H.* Two young gemmae (150 dia). *I.* Ripe gemme. *J.* Cross-section through thallus, *s* breathing pore (50 dia.). *K.* Breathing pore much enlarged. *L.* Jungermannia, *sp* sporogonium.

Q. 208. How do the gametophytes of the liverworts and mosses compare?

A. The gametophyte of the liverworts is a thalloid green body except in the Jungermanniaceae. In the same mosses the gametophyte is a leafy green shoot.

Q. 209. Briefly describe the life-history of a liverwort?

A. The spore, under favorable conditions of moisture and temperature, germinates and grows into a small, flat body called the prothallium, which in the thalloid forms develops directly into the mature

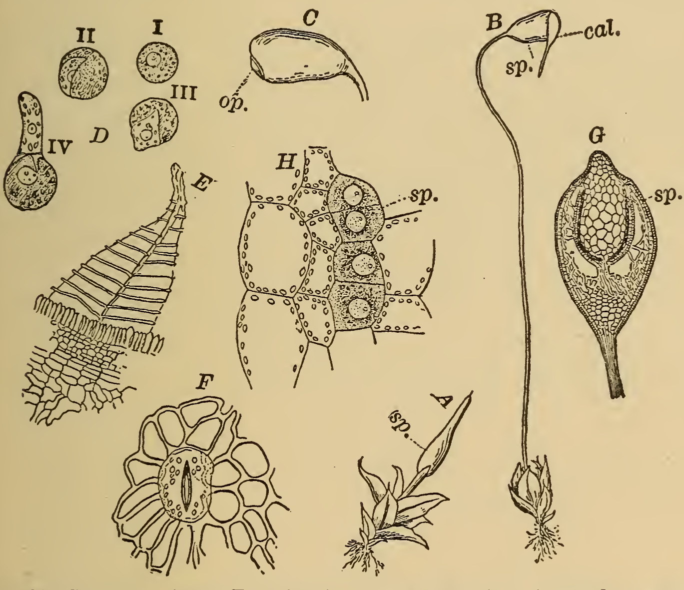

FIG. 24.—Structure of moss Funaria: *A*. Young sporophyte inserted on gametophyte, *sp* sporophyte. *B*. Mature sporophyte cal. calyptra, *sp* capsule. *C*. Capsule without calyptra, *op* lid. *D*. Spores; I fresh, II-IV germinating. *E*. Teeth from mouth of capsule (50 dia.). *F*. Epidermis of sporophyte with breathing pores or stama (150 dia). *G*. Longitudinal section of spore-capsule, *sp* spore-mother cells. *H* port *G* enlarged 300 times, *sp* spore-mother cells.

plant, but in the foliose Jungermanniace, a bud from it gives rise to the stem and leaves. The sexual organs, namely the female archegones and the male antherdia are born on the end of stem or branches in foliose forms, but they are sunk in the tissue of the thallus in the thalloid liverworts. Fertilization is brought about by the actively swimming antherozoids, one of which fuses with the egg-cell of the archegone. From the fertilized egg the sporophyte is developed.

Q. 210. Describe briefly the life-history of a true moss?

A. The spore and germination gives rise to a thread-like, green growth called the protonema. From buds on the protonema springs the gametophyte. The sexual organs, corresponding entirely with those of the liverworts, are situated on the end of the stem or lateral branches, and are surrounded by a rosette of leaves which gives them the appearance of small flowers. Fertilization takes place in the same way as in the liverworts, and also the development of the fertilized egg into the sporophore, only the wall of the archegone is generally carried upwards as a cap on the spore-capsule; it is called the calyptra.

CHAPTER XIX.

THALLOPHYTES.

Q. 211. What is the next lower group of plants?

A. The next lower group of plants is the thallophytes. In contradistinction to this group all the preceding groups together constitute the cormophytes, because in them only a true stem is developed, and this is what the name indicates, *viz.*, stem-plants; but in the thallophytes no true stem is ever developed, but only a thalloid plant-body, and hence their name.

Q. 212. What plants belong to the thallophytes?

A. To the thallophytes belong the plants known as Algae and Fungi.

Q. 213. How are they related to each other?

A. They differ from each other principally in this, that the algae have chlorophyl or leaf-green, while the fungi have not; the algae have mostly a true cellular structure, *i. e.*, they are made up of cells, while all fungi, except the unicellular ones, have a coenocytic structure, *i. e.*, they are made up of coenocytes;* in most other respects the two groups of plants are more or less parallel.

Q. 214. What are the principal plants belonging to the Algae?

A. They are: 1. Characeae. 2. Seaweeds. 3. Pondscum. 4. Waternets and green slimes.

Q. 215. Name the principal fungi?

A. They are: 1. Toadstools or mushrooms. 2. Puff-balls. 3. Rusts and mildews. 4. Moulds. 5. Bacteria and yeasts and, doubtfully. 6. The Myxomycetes or mycetozoa.

Q. 216. What other plants must be classed with these?

A. The lichens; these are very interesting on account of being partly fungus and partly alga, which

*Cocnocyte—nulti-mucleated cell.

have, as it were, formed a partnership for mutual benefit. The greater portion of the lichen-body consists of fungus hyphae, embedded among which are some of the lower Algae.

Q. 217. Do the thallophytes exhibit alternation of generations?

A. A few of them do, but many of them make up abundantly for this defect by an unexpectedly complicated polymorphism, which is very far from benig easily traced or understood.

Q. 218. Which of them have alteration of generations?

A. Among Algae, Rhodophyceae or Red Algae, and in most bright green algae, although the sporophyte is extremely rudimentary. Among fungi a sort of alternation of generations occurs in the moulds and Ascomycetes or sac-fungi.

Q. 219. What is the stage of plant which is ordinarialy called "the plant" in this group?

A. It is the gametophyte.

Q. 220. What is peculiar about the gametophyte of this group of plants?

A. The gametophyte of most of the plants of this group has the peculiar capacity of producing reproductive cells, almost or quite indistinguishable from spores, except for the fact that they are borne by the gametophyte, and hence, to distinguish them from true spores, they are called gonidia.

Q. 221. Under what two principal forms do they occur.

A. 1. As swarmspore or zoogonidia, consisting of naked cilated or flagellated cells having no cell-wall and capable of swimming in water. 2. Gonidia having a cell-wall and incapable of free movement.

Q. 222. Are the plants of this group of economic importance?

A. The Algae are of compartively little importance, but among fungi some of the most useful as also the most hurtful plants are found. Useful are the yeasts and ferment producing bacteria; hurtful and correspondingly feared and hated are the disease-producing bacteria. Many of the higher fungi are considered excellent food for man.

Q. 223. What is the mode of life of fungi?

A. Since fungi are without chlorophyll they are incapable of living on mineral food alone, as green plants; on this account the fungi all told must either be parasitic, *i. e.*, secure their food from a living host, or saprophytic, *i. e.*, secure their food from dead animal or vegetable matter.

CHAPTER XX.

PHYSIOLOGY.

Q. 224. How may we define plant physiology?

A. We may define it as the study of the vital activities of the plant.

Q. 225. From what must we carefully distinguish the vital activities of the plant?

A. We must carefully distinguish the vital phenomena or activities from merely chemical or merely physical phenomena.

Q. 226. Under what headings may the life activities of a plant be classed?

A. They may be classed into such as, **1.** subserve the development and maintenance of the individual plant; and, 2. Such as subserve the production of new individuals like itself, *i. e.*, the maintenance of the species.

Q. 227. What phenomena belong under these headings?

A. Here belong: 1. The absorption of new material. 2. Tranformation of this absorbed raw material or food into the body substance of the plant. 3. The oxidization of certain substances of the plant occasioned by the movements or work of the plant. 4. The special phenomena of reproduction.

Q. 228. By what processes does the plant absorb new material?

A. The absorption of water containing soluble substances is accomplished by a process called osmosis by physicists; it consists in the diffusion or passage of dissolved substances through a permeable membrane, which in the plant is the cell-wall. But the plant absorbs also gases, generally through special openings in the outer tissue, which are called stomata.

Q 229. Which parts of the plant absorb water and the substances dissolved in it?

A. Principally the roots and their analogues, the rhizoids, but in many submerged water plants, water is also absorbed by the leaves and stems.

Q. 230. What are the principal substances which the plant absorbs along with water and dissolved in it?

A. They are principally various salts of ammonia, potassium, calcium, sodium and magnesium for plants that have chlorophyl; parasitic and saprophytic absorb dissolved organic compounds, as peptones, sugars, etc.

Q. 231. What are the principal gaseous substances absorbed by plants from the air?

A. They are carbon dioxide and free oxygen for chlorophyl-possessing plants, and oxygen only, or oxygen and nitrogen for some of the lower fungi, *e. g.*, soil bacteria.

Q. 232. Why does the plant absorb just these substances?

A. Because they contain the food of the plant in a suitable form, that is, they contain those chemical elements which are indispensable to the plant's maintenance of life.

Q. 233. Which elements are necessary for the plant's life.

A. They are Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Iron and Potassium; of secondary importance are Phosphorus, Calcium, Sodium, Magnesium, Chlorine and Silicon.

Q. 234. Why are these substances necessary?

A. Because of them the living substances and its products, namely all other substances found in the different parts of plants, are composed.

Q. 235. What are the principal substances of which plants are composed?

A. They are: 1. Nitrogenous substances. 2. Non-nitrogenous, according to as they contain the element nitrogen or not.

Q. 236. Mention the principal nitrogenous substances?

A. They are: 1. Protoplasm. 2. Proteids. 3. Amides. 4. Alkaloids and some coloring matters.

Q. 237. Mention the principal non-nitrogenous substances?

A. They are classed: 1. Carbohydrates, namely, cellulose and starch and the sugars, glucoses and Sucroses. 2. Organic acids, as oxalic, malic, citric, tartaric, etc. 3. Glucosides, as amygdalin, myrosin, coniferin, salicin, tannin. 4. Fats and fixed oils. 5. Volatile or essential oils.

Q. 238. What is the process in general called by which the absorbed mineral substances are transformed into the organic substances?

A. The whole process is called by the general name metabolism. It consists of two opposite activities, namely the splitting up or breaking down of the complex chemical compounds, and then the combination or construction of the simpler elements or compounds into organic substance. The former series of processes is known by one general name, catabolism, the latter by anabolism, and both together constitute assimilation.

Q. 239. What are the conditions necessary for these processes to grow?

A. They are principally: 1. Supply of food. 2. Light. 3. Proper temperature.

Q. 240. Whence comes the energy necessary for the work preformed during these processes?

A. From one or both of the following sources? 1. From sunlight. 2. Chemical energy.

Q. 241. What process absolutely requires a certain amount of light?

A. The assimilation of carbon dioxide, which is accomplished by chloroplasts only in sufficiently intense light.

Q. 242. What temperature is necessary for these processes?

A. The range of temperature, in which these processes may take place, varies widely for different plants within the limits, 0° to 50°C. The best temperature, *i. e.*, the most favorable, ranges about from 25° to 35°C. There are, however, exceptions to both statements.

CHAPTER XXI.

SPECIAL PHYSIOLOGY OF MOVEMENT.

Q. 243. Why do we consider plants living things?

A. Principally because they exhibit movement, both automatic or spontaneous, and also induced or reflex movements.

Q. 244. Mention some of the principal movements of plants?

A. Automatic or spontaneous are: 1. Circulation or rotation of protoplasm. 2. Nutation of growing points. Induced movements: 1. Heliotropism. 2. Geotropism. 3. Hydrotopism. 4. Chemotropism. 5. Diurnal or periodic movements. It is often very difficult, if not impossible to distinguish spontaneous from induced movements, and it may perhaps not be wide of the mark to say that the two are never completely separated.

Q. 245. What is Heliotropism?

A. Heliotropism is the power or capacity of an organ of a plant to turn toward or away from light; in the former case it is called positive, in the latter negative Heliotropism.

Q. 246. What is Geotropism?

A. Geotropism is the capacity of an organ of a plant to move with or against the force of gravitation. The former is positive, the latter negative geotropism.

Q. 247. What is Hydrotropism?

A. Hydrotropism is the capacity of an organ to turn towards or away from moisture or water. The former is positive, the latter negative hydrotropism.

Q. 248. What is chemotropism?

A. Chemotropism is the capacity of an organ to turn towards or away from certain chemical substances; the former is positive, the latter negative chemotropism.

Q. 249. What is nutation?

A. Nutation is the motion of terminal growth-points in a plane perpendicular to their growth or extension in length; it is approximately either in circles or ellipses.

Q. 250. What other movements are there in plants?

A. Special movements in response to definite stimuli, as in insectivorous plants like sun-dew or the Venus fly trap; or the drooping of leaves and branches in consequence of a jarring, as in Mimosa pudica. Also many stamens are sensitive to contact, and some fruit capsules, as those of the Jewel-weed or Touch-me-not. This quality of the plants is called irritability, or rather it is the proof of it. Besides, there is the power of spontaneous movement in many of the lower plants, as diatoms,* desmids, flagellatae, and in the zoospores, gametes and spermatozoids of higher plants; and this is one of the factors which makes it so difficult to distinguish the lower plants from the lower animals.

CHAPTER XXII.

FUNCTIONS OF TISSUES.

Q. 251. What is the function of the epidermis?

A. The function of the epidermis is protection of the underlying tissues, from mechanical injury and especially from too much evaporation.

Q. 252. What is the function of vascular tissue?

A. The vascular tissues are comparable to a pipe

*It appears that the movement of diatoms is passive, *i. e.*, purely mechanical, induced by the emergence of the oxygen gas produced by the diatom.

system for the transfer or movement of liquids in the plant.

Q. 253. What is the function of fibrous tissue?

A. The function of fibrous tissue is to give firmness and rigidity to the plant body.

Q. 254. What is the function of sieve tissue?

A. The function of sieve tissue is believed to be principally the transfer of proteid matter.

Q. 255. What is the function of glandular tissue?

A. The function of glandular tissue is the production and secretion of special products.

Q. 256. What is the function of meristem?

A. The function of meristem or cambial tissue is secondary growth.

Q. 257. What is the function of parenchymatous tissue?

A. It is the seat of the metabolic processes and also of the sensitive phenomena.

CHAPTER XXIII.

DISTRIBUTION OF PLANTS.

Q. 258. How are plants distributed?

A. Plants are distributed with regard to region or country; with regard to environment and with regard to time.

The study of plants with regard to their regional distribution or occurrence, constitutes geographical botany; the study of plants with regard to environmental distribution, constitutes ecological botany or simply ecology; the study of plants in regard to distribution in time constitutes palaeobotany.

Q. 259. What are all plants naturally growing in a country or region collectively called?

A. They are called collectively the flora of the region or country.

Q. 260. How are plants to be distinguished in regard to their occurrence in a country?

A. Plants *native* to the country must be distinguished from those that have become naturalized in the country within recent time.

Q. 261. How may the native plants commonly be told from the naturalized ones?

A. From the mode of their occurrence; native plants occur throughout the region, wherever there is a favorable locality for them, while naturalized plants are more or less restricted to the localities, where they were introduced, as for instance, along railroads, harbors or ocean ports and along water courses; however, some weeds spread so rapidly; that the fact of their being naturalized and not native plants can only be determined from historical evidence.

Q. 262. Is there any great difference in range of distribution of the various plants?

A. There is a wide difference between various plants in this regard; some species being cosmopolitan, *i. e.* of almost universal occurrence, while the flora of almost every country contains a number of plants peculiar to it.

Q. 263. How may plants be considered from the stand-point of ecology.

A. In a two-fold way; 1. Vast areas or zones of plant-formations. 2. Local plant societies.

Q. 264. What are the principal plant formations of the first type?

A. They are: 1. Arctic tundras. 2. The coniferous and deciduous forests and the steppes and prairies of the temperate zones. 3. The desert plants of the temperate and the tropic zones. 4. The tropical evergreen forests.

Q. 265. To what factors are these plant formations due?

A. They are due to climatic factors, *i. e.*, to temperature, moisture and winds.

Q. 266. To what factors are the plant societies of the second type, *i. e.*, the smaller local plant formations due?

A. They are due in the first instance to the topography and soil conditions and secondarily to changes in these as well as in the struggle for existence of the plants themselves.

Q. 267. How are plants classified in regard to this secondary type?

A. They may be classified into hydrophytes, mesophytes and xerophytes.

Q. 268. What are hydrophytes?

A. Hydrophytes are such plants as grow only in water or at least require abundance of moisture in the soil.

Q. 269. What are xerophytes?

A. Xerophytes are such plants as may get along with a little or a minimum of moisture both in the soil and in the air.

Q. 270. What are mesophytes?

A. Mesophytes are such plants as in their general habits and requirements keep the golden middle between the two preceding types.

Q. 271. Where may plants belonging to the three types be readily found?

A. Generally on lake and river shores, where it is possible ordinarily to see the zones of the different plant societies merging into each other.

Q. 272. How are plants distributed in regard to time?

A. It is, in general, admitted that the more highly a plant is organized and specialized, the more recent it is in regard to its first appearance on the earth. The evidence for this is of course taken from geology; in a general statement, we may say that, the older astrata is in which plants are found, the lower and the less specialized are the fossil plants found therein.

Q. 273. What is the oldest geological age or period in which dicotyledons are known?

A. From the Cretaceous period upwards.

Q. 274. From what geological period are the monocotyledons first known?

A. From Triassic period.

Q. 275. In what formation or strata are the Pteridophyta found for the first time?

A. In the Devonian strata.

Q. 276. In what formation, the Bryophyta?

A. Throughout the tertiary period and probably in the mesozoic.

Q. 277. In what formation are Thallophytes first encountered?

A. In the Silurian period and they thus include the oldest known plant fossils.

Q. 278. What is to be noted about the fossil plants of the different geological periods?

A. The significant fact that each had its dominant plants, *i. e.*, plants which in that particular age attained their greatest development, both in individuals and in numbers. Thus just as flowering plants are the dominant plants at the present geological period, so formerly Gymnosperms, Pteridophytes and Thallophytes were the "*plants*" in their respective ages or periods.

CHAPTER XXIV.

USES OF PLANTS.

Q. 279. What is the relation of the vegetable to the animal kingdom?

A. There is an intimate relation between them in so far as the latter depends for its food, and hence its maintenance directly or indirectly upon plants; but the relation is mutual in so far as plants depend, to some extent at least, upon the carbon-dioxide which animals produce or exhale, for their food.

Q. 280. What are the principal uses that man makes of plants?

A. Plants supply directly or indirectly all the vegetable food of man and the domestic animals, *e. g.*, all the cereals, corn, rye, barley, wheat, etc., fruits, linen and cotton, paper, rubber, medicines, oils, liquors, wood for fuel and lumber; besides they free the air from the poisonous carbon-dioxide and adorn his gardens and parks and landscapes; while the higher plants are busily engaged in this work, the lower, especially fungi and bacteria are acting as scavengers, breaking up and decomposing organic substances, thus setting free the chemical elements composing them, making them available again for the plants; thus playing as it were the roll of the printer's devil as he reassorts the type-letters of a setting that has finished service. The only trouble about these lower plants is, that they are frequently too eager to begin their work of destruction, and so become harmful.

Q. 281. In what ways do plants become harmful to man?

A. Plants are harmful to the farmer, when under the name of weeds, they crowd out the crop he intended to raise, or when as parasites they destroy the crop, of as pathogenic, *i. e.*, disease-producing bacteria they destroy both animals and man himself.

CHAPTER XXV.

HISTORICAL BOTANY.

Q. 282. When and with whom may the origin of the scientific Botany be said to date?

A. Scientific Botany dates from Aristotle, 384-322, B. C., and his school, the Peripatetics. He wrote two books on Botany, which were lost. But his pupil and successor Theophrastus, wrote a history of plants about 300 B. C. Plants were also studied by the priests and physicians of the ancients, *e. g.*, by Aesculapius and his followers among the Greeks; also the cultivation of grain and fruits naturally led to a certain knowledge of plants. Among the Romans, Plinius the Elder should be mentioned, for he described several hundred plants, most of them being medicinal or believed to be so; according to his own words, his descriptions are compiled from other writers and not based on his own studies.

Q. 283. Who is the next notable author on Botany?

A. Botany made little or no progress from Pliny's time down to Blessed Albert the Great, Bishop of Ratisbon, 1193-1280—It was he who restored Aristotle, both in philosophy and the natural sciences. He wrote six books on plants; they are based on the preceding authors and also for a large part on his own observations. Descriptive and systematic Botany received a new impulse from Andrew Caesalpinus (1519-1603) professor of Botany at the University of Padua. The discovery of the microscope enabled botanists to study the minute anatomy of plants. The pioneers in this line of research were Nehemias Grew (1641-1712) secretary of the Philosophical Society of London; Marcello Malphigi, professor at Bologna (1628-1694) and the father of Microscopy, Anton van Leeuwenhoek (1632-1723); Rob. Morison (1620-1683), John Ray (1628-1705) and J. P. Tournefort (1656-1708) continued and advanced the work of Caesalpinus considerably.

Q. 284. Who is the founder of Modern Botany?

A. Modern Botany as well as modern zoology acknowledges Carl von Linné or Linnaeus (1707-1778), professor at the University of Upsala in Sweden, as their founder. He is the author of a system of classification of plants, based upon the reproductive organs, viz. stamens and pistils; he brought order into the confusion that reigned prior to him. To him is due the binomial system of naming plants and animals, which is now in universal use.

Q. 285. With what names of men is the History of Botany connected principally since Linn's time?

A. Linn's system was artificial, *i. e.*, it took no account whatever of the natural affinities of plants. A. L. de Jussieu (1748-1836) of Paris was the first to classify plants according to their natural affinities, whence his system is called the Natural system. His system was approved and improved by A. P. De Candolle (1778-1841), Robert Brown (1775-1858), and Endlicher (1804-1849). The next great advance in Botany is due to the establishment of the cell-theory by M. J. Schleiden (1804-1881) for Botany at the same time that it was established in Zoology by Theodore Schwan, Professor at Louvain (1838). Hugo von Mohl (1805-1872) was a successful worker in plant Anatomy and Physiology, and he is said to have given the living substance its present name protoplasm. Darwin (1809-1882), in his work, "The Origin of Species," in which he advances the celebrated theory of evolution of plants and animals by "natural selection," gave a great impulse to the study of natural science especially by his untiring zeal in the collection and arrangement of facts and observations bearing on the distribution, development and behavior of plants. Brogniart (1801-1876) developed the science of Fossil Botany; Alexander von Humboldt (1769-1859) rendered great service to plant-geography.

Q. 286. Mention the principal botanists that have written about North American plants?

A. They are the following: Michaux (1746-1802), Pursh (1774-1820), Rafinesque (1784-1842) and Nuttal (1786-1859), and especially, Asa Gray, Professor of Botany, at Harvard University, born 1810, died 1888, who was one of the leading botanists of his age.

CHAPTER XXVI.

ORIGIN OF PLANTS.

Q. 287. What is the origin of plants, *i. e.*, where did the first plants of each species come from?

There are two theories regarding the origin of plants, viz., (1) the theory of constancy or separate creation; (2) the theory of evolution.

Q. 288. What does the theory of constancy hold?

A. The theory of constancy holds that all the true species of plants that now exist or that existed in bygone geological ages, were each separately and distinctly created by Omnipotent God, the Lord and ruler of the universe.

Q. 289. What does the theory of evolution hold?

A. In the first place, it is to be noted that there are quite a number of so-called theories of evolution which agree only on one point, namely, in opposition to the theory of constancy, so that whereas the latter theory denies the possibility of true new species to arise from preceding ones according to the laws of nature and without the direct intervention of the Creator, the former holds and affirms this same possibility to exist.

Q. 290. What important distinction is there among the different theories of evolution?

A. The most important distinction between the theories of evolution rests upon the fact that one set of theories admits a personal Creator, and consequently the creation of matter, together with its properties and the laws of nature, as they are called; while the other set of evolutionary theories holds the eternity of matter, its properties and the laws of nature, and consequently denies the existence of a personal Creator. The adherents of the former are called the christian or theistic school of evolutionists, while the adherents of the latter are known as the atheistic, monistic, materialistic or rationalistic school.

Q. 291. Has any one of all these theories been proved to be true?

A. Neither the theory of constancy nor any of the theories of evolution has been demonstrated to be the true explanation of the origin of species, at least in detail; but it is undoubtedly true that the great majority of men skilled in the natural sciences, especially biologists, do admit the *fact* of evolution, although there is still great diversity of opinion among them as regards the cause and manner of evolution, so that no particular theory can be said to be universally accepted.

Q. 292. What are the most renowned theories of evolution?

A. They are the following: 1. Lamarck's theory of adaption (1809). 2. Chas. Darwin's, Herbert Spencer's, A. Wallace's. and Huxley's Theory of

"Natural Selection" or "Survival of the Fittest," (1859) and the latest, Hugo de Vries' Mutation theory (1901).

Q. 293. On what facts is the theory of constancy based?

A. On the following: 1. On the observed constancy of species in historical times as far as trustworthy records show. 2. On the infertility of hybrids, *i. e.*, offspring of distinct species. 3. On the important fact, that no new species, truly and strictly so-called, has actually been observed to arise.

Q. 294. On what facts are the theories of evolution based?

A. Following are some of the most important: 1. The variability of individuals within specific limits. 2. The fact that the fossil species exhibit a gradation in perfection of organization and specialization, which, at least in a general way, is in accordance with the geological age of the strata in which the fossils are found. 3. The fact, that many species, and of these, some in a remarkable and unmistakable manner, exhibit adaptation to their surroundings. 4. The widespread occurrence of metamorphosis. 5. The occurrence of rudimentary organs.

Q. 295. What are some of the principal facts opposed to the monistic theory of evolution?

They are the following: 1. The all but demonstrated impossibility of spontaneous generation. 2. The unmistakable evidences of purpose in nature as found especially in truly wonderful contrivances for cross fertilization in plants and equally in the instincts of animals. 3. The metaphysical contradiction, involved in the assertion of the eternity of matter and energy.

Say, what impels, amid surrounding snow,
Congealed, the Crocus' flamy bud to grow?
Say, what retards amid the summer's blaze,
The autumnal flower, till pale declining days?
The GOD OF SEASONS, whose pervading power
Controls the sun, and sheds the fleecy shower;
He bids each flower his quick'ning word obey,
Or to teach lingering bloom enjoins delay.

APPENDIX.

ON THE FORMATION OF AN HERBARIUM, OR HORTUS SICCUS.

THE description and figure of plants, however amply and correctly they may be given in books, can be neither so instructive nor so satisfactory to the young student in Botany, as when he has the works of Nature before him, and can examine and investigate for himself, without the danger of being misled by the errors or misconceptions of others. It will be proper, therefore, to give a few directions, by which the plants that he has examined may be preserved, and formed into a collection for occasional reference.

Several methods have been recommended for preserving plants, but the best appears to be that of drying them. Most plants dry with facility between the leaves of books or other paper; and a collection of bound newspapers will be found well adapted to the purpose. If there be a sufficiency of paper, they often dry best without shifting; but if the specimens be crowded, they must be taken out frequently, and the paper dried before they are replaced. Some vegetables are so tenacious of the vital principle, that they will grow between papers; but that inclination must be prevented by immersion in boiling water or by the application of a hot iron, such as is used for linen, after which they are easily dried.

In spreading the plants between papers, too much nicety and precision should not be observed in arranging their leaves and branches, in order to give them a picturesque appearance, as it takes away from their natural aspect; except, however, for the purpose of displaying the internal parts of one or two of the flowers, for ready observation. When properly dried, the specimens are best preserved by being fastened with weak carpenter's glue to detached sheets of paper, or in a blank book, with the name, the time, and place of finding, or any other concise piece of information, written on the opposite leaf. When the book is full, an alphabetical index may be made to the page. The herbarium thus formed will be found to keep best in a dry room without a constant fire.

Specimens should be gathered on a dry day, and carried home in a japanned tin box, in which they will keep for several days better than in water, should anything occur to prevent their immediate use. If the stem be woody, it may be thinned with a knife: and when the flower is thick or globular, as the thistle, one side of it may be carefully cut away, it being only necessary in a specimen to preserve the character of the class, order, genus, and species.

By this means the production of our own, or of the most distant countries, may be brought together under our eyes at any season of the year; and, in the midst of winter, our minds may be regaled with a semblance of spring, while the still verdant specimens will recall to our recollection the many pleasant excursions undertaken to procure them.