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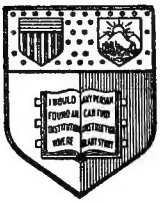

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GUIDE

FOR

LABORATORY PRACTICE

IN

PLANT MORPHOLOGY

BY

WILLARD WINFIELD ROWLEE, B.L., D.Sc.,
Assistant Professor of Botany in Cornell University,
Ithaca, N. Y.

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SEEDS AND THE MORPHOLOGY OF SEEDLINGS.

I. COMMON BEAN (*Phaseolus vulgaris*).

The Seed.

The point of attachment to the pod is the *hilum*.

A minute opening on one side of the hilum is the *micropyle*.

A slight ridge running from the opposite side of the hilum toward the end of the seed is the *rhaphe*. The ovule of the Common Bean is amphitropous. The seed is also amphitropous but the parts are more or less obscured by growth.

Where the rhaphe disappears near the end of the seed is the *chalaza*.

These parts, although evident in this seed, are usually more prominent in the ovule than in the seed.

Split the seed in two through the hilum and rhaphe.

Each half is one of the large *cotyledons*.

A small white cylindrical body lies imbedded between the cotyledons with its free end at the micropyle. This is the *hypocotyl*. This organ is called by some the "radicle"; by others the "caulicle."

The point where the cotyledons are attached to the hypo-cotyl is the first *node*.

Midway between the upper and lower sides of the cotyledon and near one end is a body, fish-tail in shape. This is the rudimentary first pair of leaves.

Between the base of the first pair of leaves and the first node is the first *internode*.

The first internode and the first pair of leaves, together constitute the *plumule*. The plumule is unusually developed in the seed of the Bean.

The cotyledons, hypocotyl, and plumule, together constitute the *embryo*.

This seed is *ex-albuminous*.

The outer-seed-coat or *testa* is brittle and highly polished.

Between it and the cotyledons is a chalky, less-coherent layer,—the inner-seed-coat or *tegumen*.

The Seedling of the Common Bean.

Select a seedling which has its first pair of leaves well-developed.

The seed-coats have been either partially or wholly thrown off.

The hypocotyl has lengthened. The *tap root* arises from its lower end. In the common Bean there are no roots arising from any part of the stem except the lower end of the hypocotyl. In the seedling of Indian Corn (Zea Mays) secondary roots occur. The roots of both plants are *fibrous*.

The first internode is greatly lengthened. The growing points of the embryo are at the lower tip of the hypocotyl and at the plumule. Here cell division takes place most rapidly. The growth of the other parts depends more upon the increase in size of cells already formed than upon cell division itself.

The first pair of leaves are simple, thus differing from the leaves of the mature plant. Note the gradation of leaves from the much modified cotyledons to the compound leaves of the mature plants. They have a blade, petiole, and stipules. The stipules of the Common Bean are inconspicuous and also vary, the first two pairs being very small and united, the later ones larger and free. Are the stipules of the single leaf united with each other? The stipules are much larger in the Pea. Both belong to the same Natural Order (Leguminosae). All plants of this order have leaves with stipules. This is said to be a character of the order.

The *terminal bud* is the continuation of the plumule.

Sketch one-half of the seed ($\frac{4}{1}$) indicating the parts noted.

Sketch a seedling ($\frac{1}{1}$) at two or more stages of development.

II. CASTOR OIL BEAN (*Ricinus communis L.*).

Upon the hilum is a wart-shaped appendage called a *caruncle*.

With this as head and the rest as body, this seed was thought by the ancients to resemble a "tick," a parasitic insect living upon sheep, hence the generic name "Ricinus" meaning a Tick.

The brittle outer-seed-coat is sculptured on the outside, a char-

acter often occurring in the seeds of plants belonging to the Order Euphorbiaceæ.

Remove the outer-seed-coat being careful not to injure the parts within.

The inner-seed-coat is delicate and membranous. It is apt to break if an attempt is made to remove it.

Split the seed in two.

Each half of the seed appears like a cotyledon.

A close examination will show that there is a considerable part of the seed between the margin of the cotyledon and the seed-coats. A cross-section of the seed shows this still more plainly. Closer observation will show that the embryo is completely surrounded by an oily albumen. The lower tip of the hypocotyl, the place where growth begins, comes nearer to the coats than any other part of the embryo. Further knowledge of the structure of the seed may be gained by making vertical sections at right angles to the plane in which the cotyledons lie. At the lowest point, *i. e.*, nearest the caruncle, will be seen the minute hypocotyl, the lower tip of which is always found close to the micropyle in any seed. This affords a "land-mark" from which the relations of the other parts may be determined.

The inner face of the cotyledon shows three veins arising from the base; the central one or mid-rib gives off lateral veins throughout most of its length. It is not often that the cotyledon shows its venation in the seed.

In the seed of Ricinus, the plumule is not developed until after the seed has germinated.

This is an *albuminous* seed. The contrast between an albuminous and an exalbuminous seed is well illustrated in the Castor Oil Bean and the Common Bean. It should be clearly understood that the words "albumen" and "albuminous," as used in Plant-morphology, do not refer to the chemical composition of the substance in question, but designate a particular part of the seed, the chemical composition of which varies in different seeds.

The germination of the seed of Castor Oil Bean exhibits certain very interesting features. Germination begins as in all seeds at the lower tip of the hypocotyl. This penetrates into the soil, its roots absorb the needed moisture. The cotyledons remain within the seed-coats absorbing the nourishment there stored in

the albumen. The outer-seed-coats are almost immediately thrown off; the inner coat remains upon the now much swollen seed thereby serving to protect the albumen from desiccation by too rapid evaporation. The seed swells to three or four times its normal size. Finally the food material in the albumen is absorbed by the cotyledons and only the membranous inner coat remains. The albumen absorbed, the cotyledons change from absorbing to assimilating organs. This is shown by the assumption of a green color.

At the base of the blade of each cotyledon are two, three, or four, reddish papillæ. These are foliar glands.

The plumule begins to develop only after the cotyledons begin to assimilate.

Compare the seed and seedling of the Castor-Oil Bean with that of the Common Bean and note the resemblances and differences.

Sketch a seed entire, also one-half of the seed showing the inner face of the cotyledon, the hypocotyl, and the albumen ($\frac{4}{1}$).

Sketch a vertical section of the seed showing the edges of the cotyledons and the thickness of the albumen behind them ($\frac{4}{1}$).

These drawings should be enlarged enough to show the parts distinctly.

Sketch the seedling in two or more stages of development ($\frac{1}{1}$).

III. INDIAN CORN (*Zea Mays*).

The kernel is the seed closely invested by the ovary coats. The seed is made up of two parts:—the embryo and the albumen.

The embryo is upon the upper side of the kernel outside the albumen. It appears like an oblong scar in the center of which is a slight ridge. This ridge is caused by the plumule and the hypocotyl.

The part of the kernel which lies between the plumule and hypocotyl and the albumen is of considerable thickness as may be seen by making a vertical section of it. It adheres to the albumen behind, and has its edges folded over in front enclosing the plumule and hypocotyl. This organ is the cotyledon. Corn belongs to the monocotyledons. The cotyledon as is readily seen is much modified in this plant as indeed it is in all the grasses. The cotyledon is called scutellum in some of the works of refer-

ence. Through this organ, the nourishment stored in the albumen is transferred to the growing seedling.

The albumen in the seed of Indian Corn is hard and starchy in the dry mature seed, but softens upon soaking in water. It is yellow or amber-colored in "common field corn," and is the part of the grain from which Indian meal is made.

The plumule is small but consists of two or three rudimentary leaves. In vertical section it appears like a young bud.

The hypocotyl is enclosed in a *root-sheath* through which it breaks when germination begins.

The scutellum is united with the embryo at the point of union of the plumule and the hypocotyl, *i. e.*, at the first node.

The ovary and seed-coats are blended in the mature seed so as not to be easily distinguishable.

The fruit of all grasses is called a *caryopsis*.

Study the development of the seedling of Indian Corn. Note the changes, if there are any, that occur in the scutellum and the root-sheath during the development of the seedling.

Sketch a kernel entire showing the upper side ; also a vertical section of the seed showing the parts mentioned.

Sketch two or more stages in the development of the seedling.

Observe and sketch the peculiar forms which the various parts assume in the following seeds and especially notice the modifications of the outer-seed-coat.

Catalpa. (Catalpa bignonioides).
Magnolia. (Magnolia acuminata).
Milk-weed or silk-weed. (Asclepias Cornuti).
Northern Pitcher Plant. (Sarracenia purpurea).
Columbine. (Aquilegia Canadensis).
Pigweed. (Amarantus retroflexus).
Bouncing Bet. (Saponaria officinalis).
Date. (Phoenix dactylifera.)
Blood-root. (Sanguinaria Canadensis).

Read—Gray's "Lessons" pp. 125–128, 15–26.
References:—Gray—"Structural Botany" pp. 305–314, 9–27.
Bessey—"Botany" pp. 451, 452, 474.
Bessey—"Essentials of Botany" pp. 241, 252.
Bastin—"College Botany" pp. 116–123.

BUDS AND METHODS OF BRANCHING.

It will assist materially in studying buds and methods of branching to bear in mind the following suggestive topics:

The annual growth, is it definite or indefinite? See Gray's "Lessons," p. 31.

When the amount of annual growth is definite note the fluctuation in amount of annual growth from year to year. Is this variation due to increase in length of internodes or to increase in number of internodes.

Arrangement of leaf scars—Phyllotaxy.

Variation in length of internodes in a single year's growth. Is this variation constant for the several years represented in the branch?

Relative size of terminal and axillary buds.

Number of scales in a bud determined, first by the scales themselves—or second by the scars of the scales of buds of previous winters. Is the number of bud scales constant during successive years? Are there as many scales upon axillary as upon terminal buds?

The nature of the bud scales; stipular or laminar.

The protection of buds by varnish, by hair.

The number of lenticels upon a stem to each square inch of surface.

From which of the nodes of a single year's growth are branches usually produced? (Compare a branch of oak, ash, and magnolia for differences in general character brought about by this tendency).

I. BRANCH OF HORSECHESTNUT TREE (*Aesculus hippocastanum L*).

"The cotyledons and plumule of the embryo are, morphologically, the first bud, on the summit of the initial stem, the caulicle (hypocotyl)." Gray "Structural Botany."

The *Terminal Bud* of the Horsechestnut is large and scaly. The scales and leaves follow the same law of arrangement, *i. e.*,

they are opposite, each pair decussating with the pair above and below.

At a distance of four or five internodes from each other, are the scars of the buds of previous winters. By these the amount of growth each year may be determined, also the age of a branch.

The terminal bud has two axillary buds very close to it. The first internode below the terminal bud did not elongate.

Two opposite leaf-scars at each node mark the position of the leaves of previous years. The half-dozen dots upon each scar are the points where the fibro-vascular bundles leading from the stem to the leaf were severed.

Buds and branches, normally occur in the axils of leaves. When it elongates sufficiently to bear leaves, an axillary bud becomes the terminal one of a branch.

The number of scales in a bud may be counted, or their number may be determined in buds of previous winters, by counting the scars of the fallen scales. In some cases the internodes between successive pairs of scales have not elongated enough to make the scars distinct.

The wart-like spots on the bark are *lenticels*. They admit air to the green tissue below the epidermis of the stem. Their function is the same as the stomates of the leaf.

A cross-section of the stem will show, (1) the pith at the center (2) a cylinder of wood outside of this, (3) the bark a cylinder surrounding this is green and is covered by a thin epiderms. Between the cylinder of wood and the cylinder of bark is the cambium-layer where growth of the stem in diameter, principally, takes place.

Sketch a branch ($\frac{1}{1}$) including the scars of two previous winter buds; also a cross-section of the stem, naming parts.

II. BRANCH OF TULIP-TREE OR WHITE-WOOD. (*Liriodendron tulipifera.*)

At the upper edge of each leaf-scar is a ring running around the stem. This is the scar of the stipules.

The scales of the terminal bud consist of the two stipules with their edges closely applied together. The outer pair are purple and leathery and not covered with hair as in Magnolia, nor covered with resin as in the Horsechestnut.

A small axillary bud occurs at the first node below the terminal bud.

Notice the scar of the leaf with which the modified stipules belong. This leaf never developed and only a faint trace of it remains. The line of union between the stipules passes from this rudimentary leaf-scar over the obtuse apex of the bud, to the axillary bud on the other side of the stem.

Carefully separate the stipules along the line of union. Within will be found a minute leaf (in some of the buds, the third pair of stipules, instead of the second, is the first to bear a leaf) with blade, petiole, and stipules. The stipules of each leaf enclose the whole of the next leaf above. Thus the stipules of every leaf form a protection to the next above, and, in fact, to all the leaves above.

The non-development of the leaf at the node where the winter bud is formed, indicates just where that bud was formed each winter during the growth of the branch.

The internodes are much shorter near the winter bud than in any other part of the year's growth; as a general rule branches are developed only at the two or three nodes just below the winter bud.

Notice that the bark on a branch changes its color when about three years old.

The lenticles which are not abundant, have their office performed by longitudinal ruptures in the epidermis. These ruptures generally occur through one or more lenticels.

Sketch a branch enlarged, with terminal bud dissected to show parts enclosed.

II. BRANCH OF COMMON LOCUST (*Robinia Pseudacacia*).

The terminal bud dies at the end of a season's growth. The branch is prolonged by a lateral bud which takes the place of the terminal one. This tree as well as the Sumach and Blackberry are examples of indefinite annual growth.

The buds are all *naked*. The stipules which in the Tulip-tree are modified to protect the growing point against extremes of temperature, here assume the form of spines.

Note that the growing point although without bud-scales, is protected by the corky tissue formed at the leaf scar, and still

more effectively by the dense mass of rust-colored hairs forming a coat beneath the above mentioned corky-tissue.

The arrangement of leaves on the stem is according to the two-fifths plan. The plan is usually disguised by the twisting of the stem.

Sketch a branch $\frac{1}{1}$, also a vertical section of a bud showing the parts mentioned $\frac{5}{1}$.

In general, branches arise from buds in the axils of leaves. Consequently all branching conforms to the one-half, one-third, two-fifths, or three-eighths, (etc.) plans. In the opposite arrangement as in the Horsechestnut, there would be two branches at every node; in the two-fifths plan there would be just five columns of branches around the stem. It is needless to say that such regularity is seldom seen in nature.

Variation from the typical methods of branching is brought about in several ways among which may be mentioned:—

1. Non-development of buds.
2. Non-elongation of internodes.
3. Twisting of the stem.

Study and sketch the peculiarities of the following buds:

Cucumber Tree. (Magnolia acuminata).
Hickory. (Carya alba).
Lilac. (Syringa vulgaris).
Balm of Gilead. (Populus balsamifera var. candicans).
Beech. (Fagus ferruginea).
Hobblebush. (Viburnum lantanoidea).
Sumach. (Rhus typhina).
Tartarian Honeysuckle. (Lonicera tartarica).
Butternut. (Juglans cinerea).
Red Maple. (Acer rubrum).
Bryophyllum Leaf. (Bryophyllum calycinum).
Willow. (Salix alba var. vitellina).
Striped Maple. (Acer Pennsylvanicum).

Read—Gray "Lessons," pp. 27–32, 38–41, 67–71.

References—Gray "Structural Botany," pp. 40–56, 110–140.
Bessey "Botany," pp. 140–144.
Bastin "College Botany," pp. 8–18, 182–193.

UNDERGROUND STEMS.

The following topics are suggested to assist in the observations upon underground stems and roots :

(1) The relation of each year's growth to that of the preceding year.

(2) The modification of leaves, also their arrangement.

(3) Definite annual growth in root-stocks.

(4) Fluctuation in internodal growth during a year.

(5) The form and method of branching of roots.

I. TUBER OF JERUSALEM ARTICHOKE. (*Helianthus tuberosus.*)

Each tuber has a strong terminal bud. This bud is clothed with a few opposite membranous scales. They are the much modified homologues of leaves.

There are several rings around the tuber. These mark the nodes. Careful observation will show that there are two modified leaves at each node. They appear as narrow folds meeting at their extremities, thus forming a complete ring. The true leaves upon the lower part of the stem of the Jerusalem Artichoke, are opposite ; the upper ones are alternate.

In the axils of the modified leaves of the tuber are axillary buds, sometimes apparently wanting, sometimes developed into almost independent tubers. Each pair decussates with the next pair above and with the next below. Notice that the buds are more strongly developed upon the upper than upon the lower side of the tuber. Secondary roots appear upon the lower side. This illustrates the positive geotropism of roots, and the negative geotropism of stems, even when both are below the surface of the ground.

What is the common form assumed by this tuber ?

Ways in which underground stems differ from other stems :

A. Entire absence of chlorophyll and hence of the green color.

B. Much greater irregularity in the length of the internodes.

C. Leaves usually modified into scale-like rudiments, protecting, more or less, the axillary buds, as in the plant last studied,

or sometimes thickened and gorged with plant food as in the Onion.

D. Abundance of secondary roots produced, for the most part, upon the lower side.

E. Buds only imperfectly, if at all, protected by bud-scales.

Sketch a tuber ($\frac{1}{1}$) naming all the parts mentioned.

ROOTSTOCK OF GINGER ROOT (*Asarum Canadense*).

There is a definite annual growth each year. The season's vegetative growth culminates in a pair of long petioled reniform leaves.

These by their scars indicate the limits of a year's growth. How old is the rootstock in hand? Note that decay begins when the rootstock is of about a certain age. Is there any difference in the appearance of the rootstock at different ages?

How many nodes in a single year's growth? Note that while the pair of leaves appear to be opposite they are in reality alternate as shown in the older rootstocks.

What is the arrangement of leaves upon the rootstock?

Is a flower borne between the leaves every year? Is it terminal or axillary?

From what node are branches most apt to spring? Note that after a certain number of years a branch becomes an independent plant. In this way a large number of separate plants may be but the parts of a single individual. Compare this with vegetative reproduction in the Jerusalem artichoke and the common potato.

Sketch the rootstock ($\frac{1}{1}$) showing parts mentioned.

II. ROOTSTOCK OF QUACK GRASS (*Agropyrum repens*).

This plant belongs to the Order Gramineae (The grasses). All the plants of this order have their leaves arranged according to the one-half plan.

There is a single sheathing rudimentary leaf at each node in the axle of which is a small white or pinkish bud.

Select any bud, and it will be found that the bud at the first node above and the first node below, are upon the opposite side of

the stem from it. This is the one-half plan of arrangement as expressed in the terms of phyllotaxy. If the rootstock were straight there would be two rows of branches. Notice whether these branches, if they should grow out straight from the rootstock, would spread horizontally or vertically.

Are the axillary buds, upon the lower side of the stem, as strongly developed as those upon the upper side?

Strong fibrous roots are given off on all sides of the rootstock, but most abundantly on the lower side. Notice the direction which all the roots take.

The terminal bud is very hard in this plant and will often penetrate objects of considerable firmness such as potato tubers or other rootstocks when it comes in contact with them. It is this power along with its persistency that makes it such a pest to agriculturists.

Sketch a rootstock ($\frac{1}{1}$) in the position which it occupies in the soil, naming parts.

Study the Underground Stems in the following plants:

Quack-grass (Agropyrum repens).
Canada Thistle (Cnicus arvensis).
Adder's Tongue (Erythronium Americanum).
Solomon's Seal (Polygonatum biflorum).
Trillium (Trillium grandiflorum).
Potato (Solanum tuberosum).
Indian Turnip (Arisaema triphyllum).
Onion (Allium sativum).
Lily (Lilium any species).
Bloodroot (Sanguinaria Canadensis).
Mandrake (Podophyllum peltatum).

Read—Gray "Lessons" pp. 42–48.

References—Gray "Structural Botany" pp. 56–84.
Bessey "Botany" pp. 159–165.

ROOTS.

Typical primary roots with their branches have already been studied in connection with seedlings. Secondary roots appear upon the rootstock of Johnson grass and upon the tuber of Jerusalem artichoke.

RADISH (*Raphanus sativus L.*)

In this plant, the edible portion is the thickened primary root. It is either red or white and is but sparsely branched. The plant is a biennial. During the first year, it is acaulescent, and the food assimilated in the leaves, is stored in the thickened root. The following season, this food is contributed toward producing flowers, and maturing seed.

Sketch the three type forms of roots :—conical, fusiform, and napiform,—selecting roots to represent them.

Sketch also the fibrous roots of Ribgrass (Plantago lanceolata) and the aerial roots of Trumpetcreeper (Tecoma radicans L).

Study the roots of the following species :—

Burdock (Arctium Lappa).
Ox-eye Daisy (Chrysanthemum Leucanthemum).
Carrot (Daucus Carota).
Dahlia (Dahlia variabilis).
Rue Anemone (Anemonella thalictroides).
Early Buttercup (Ranunculus fascicularis).

Read :—Gray " Lessons " pp. 34–37.
References :—Gray " Structural Botany " pp. 27–36.
Bastin " College Botany " pp. 4–8, 179–182.

THE LEAF.

The parts of a leaf are the stipules, the petiole, and the blade. The absence of either the first or the second of these parts is expressed by the terms, "exstipulate" and "expetiolate."

The general characters of a leaf (blade), so far as its gross anatomy is concerned, pertain to its (1) venation, (2) form, (3) surface and (4) texture.

Each student is expected to select leaves illustrating the characters indicated by the following terms, and sketch them in the same order in which the terms are given, emphasizing the characters indicated by the terms.

I Venation.

1. Palmately netted.
2. Pinnately netted.
3. Palmately parallel.
4. Pinnately parallel.

II. Form.

There are several lines of difference among leaves as to form.

A. General Outline.

(a) Leaves tapering, if at all, from the middle toward each end *i. e.*, widest at the middle.

1. filiform.
2. linear.
3. elliptical.
4. oval.
5. oblong.
6. orbicular.

(b) widest toward the base.

1. subulate.
2. lanceolate.
3. ovate.

(c) widest toward the apex.

1. oblanceolate.
2. spatulate.
3. obovate.

B. Apex.

1. acuminate.
2. acute.
3. obtuse.
4. truncate.
5. mucronate.
6. cuspidate.
7. aristate.
8. retuse.
9. emarginate..
10. obcordate.

C. Base.

1. acute.
2. cuneate.
3. obtuse.
4. rounded.
5. truncate.
6. cordate,
7. auriculate.
8. sagittate.
9. hastate.
10. reniform.
11. peltate.
12. perfoliate.

D. Margin.

(a) Form of indentations.

1. entire.
2. serrulate.
3. serrate.
4. denticulate.
5. dentate.
6. crenulate.
7. crenate.
8. repand.
9. sinuate.
10. undulate.
11. runcinate.
12. lyrate.
13. incised, cut, or jagged.

(b) Depth of indentations.

1. lobed.
2. cleft.
3. parted.
4. divided.

A great number of intermediate forms occur between the types indicated by the above terms. These may be indicated by qualifying terms such as "slightly," "somewhat," "narrowly," "broadly," "sharply," etc.; or by doubling terms, as "ovate-lanceolate," lance-awl-shaped," etc.

With reference to the margin of the leaf the most common qualifying terms are "finely," "coarsely," "doubly," etc.

III. Surface.

1. glabrous
2. glaucous
3. farinose
4. viscous
5. scabrous
6. rugose
7. punctate
8. squamate
9. chaffy.
10. hairy
11. pubescent
12. tomentose
13. sericeous
14. hirsute
15. hispid
16. ciliate
17. bristly

IV. Texture.

1. herbaceous
2. coriaceous.

Leaves may be (1) simple or (2) compound. The separate divisions of a compound leaf are called leaflets. The leaflet may be described by the same terms as the simple leaf.

Compound leaves are of two principal kinds:—pinnately-compound and palmately-compound, depending upon the arrangement of the leaflets upon the primary petiole or midrib. Their signification will be easily understood from the use of the same words in expressing methods of venation.

In addition to the modified leaves already studied in connection with underground stems, the following peculiar forms of leaves may be observed and sketched:—

Begonia (Begonia sp).
Onion (Allium sativum).
Northern Pitcher Plant (Sarracenia purpurea).
Holly (Ilex aquifolium).
Flowering dogwood (Cornus florida).

Read—Gray "Lessons" pp. 49–67.

References—Gray "Structural Botany" pp. 85–118.
Bessey "Botany" pp. 144–148.
Bastin "College Botany" pp. 18–47.

Phyllotaxy. (For different methods of leaf-arrangement see, "Methods of Branching," p. 10).

ANTHOTAXY.

I. WHOLE PLANT OF SPRING BEAUTY (*Claytonica Virginica*).

An obscurely organized tuber bearing at certain points upon it a few fibrous roots. Compare this tuber with that of Jerusalem Artichoke. Is the tuber annual or perennial?

Each year's growth above ground consists of several somewhat fleshy leaves direct from the tuber, and a rather weak stem bearing two leaves and terminated by a flower-cluster. The leaves may be alternate or opposite upon the stem.

The flower is a modified branch and bears as lateral members, the floral envelopes and essential organs. The flower-bearing branch is terminated by the pistil.

Each flower is borne upon a slender stalk, the *pedicel*. The pedicels of all the flowers are inserted upon a common axis called the *rhachis*, or sometimes the *axis of inflorescence*.

Usually each pedicel arises from the axil of a leaf. This leaf, especially if much modified, is called a *bract*. If the flower cluster be branched more than once, that is if it be compound, the ultimate subtending leaf structures are called *bractlets*. In Claytonia there are no bracts or bractlets.

The first flower to expand is that borne upon the lowest pedicel. The flowers succeed each other regularly toward the upper end of the rhachis. Where the appearance of flowers follows the order here shown, namely, the lower or outermost flowers expand first, the method of flowering (inflorescence) is *indeterminate*.

Where both the rhachis and the pedicels are elongated as here and the inflorescence is indeterminate, the flower-cluster is a *raceme*.

Sketch the flower-cluster of Claytonia ($\frac{1}{1}$) indicating by numbers the order in which the flowers appear.

Describe the roots, stem, leaves, and floral organs in terms already used. All flattened organs as petals, sepals and bracts may be described by terms used to describe leaf forms.

II. THE WHOLE PLANT OF THYME-LEAVED SANDWORT (*Arenaria serpyllifolia*).

The plant is a diffusely branched annual.

The oldest flower stands in the fork of two branches. This flower terminates the stem or properly the rhachis, and branches arise from the axils of the opposite pair of leaves immediately below the first flower. Each of these branches is in turn terminated by a flower below which is again a pair of leaves. From the axils of these leaves branches again arise. In this case the method of flowering is fundamentally different from that of Claytonia in that the order of flowering is from within outward or from above downward. It has been aptly described in the one case as centripetal, in the other as centrifugal.

The infloresence in Arenaria is *determinate.* Its flower-cluster is called a *cyme.*

Determinate infloresence may be distinguished from indeterminate infloresence, in alternate leaved plants by the position of the bracts.

Sketch the flower-cluster of Arenaria indicating by numbers the order of flowering.

Indicate the floral plan of the flower also whatever cohesion or adhesion may occur.

The general forms of flower-clusters depend principally upon four characteristics :

1. As to whether the infloresence is determinate or indeterminate.
2. The length of the rhachis.
3. The regularity or irregularity of branching of the rhachis.
4. The length of the pedicels.

TABLE OF FORMS OF FLOWER-CLUSTERS.

Inflorescence indeterminate.
- Branching of rhachis regular.
  - Rhachis elongated.
    - Pedicels elongated (a) Equal in length . . . . Raceme.
      (b) Lower elongated . . . . Corymb.
    - Pedicels short . . . . . Spike.
  - Rhachis short.
    - Pedicels elongated . . . . . Umbel.
    - Pedicels short . . . . . Head.
- Branching of rhachis irregular . . . . . Panicle.

The term *panicle* is used in compounds to indicate variations in length of rhachis or pedicels, as "corymbose panicle," or "paniculate spike."

Inflorescence determinate.
- Rhachis elongated.
  - Pedicels elongated . . . . . Cyme.
  - Pedicels short . . . . . Cymose spike.
- Rhachis short.
  - Pedicels elongated . . . . . Fascicle.
  - Pedicels short . . . . . Cymose head.

Sometimes the inflorescence is determinate and indeterminate in different parts of the same cluster. In such a case the inflorescence of the flower-cluster is spoken of as *mixed.*

Determine the form of flower-cluster in accordance with the above classification in :—

Button bush (Cephalanthus occidentalis).
Plantain (Plantago major).
Elder (Sambucus canadensis).
Teasel (Dipsacus sylvestris).
Dutchman's Breeches (Dicentra cucullaria).
Choke Cherry (Prunus Virginiana).
Wild Red Cherry (Prunus Pennsylvanica).
Bishop's Cap (Mitella diphylla).
Milk weed (Asclepias cornuti).
Corn Spurry (Spergula arvensis).
Bouncing Bet (Saponaria officinalis).

Read :—Gray, "Lessons," pp. 72–79.
References :—Gray, "Structural Botany," pp. 141–162.
Bessey, "Botany," pp. 427–429.
Bastin, "College Botany," pp. 53–60.