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Slightly cut around the edges of this mass and split it into two halves. What comes to light? This is the EMBRYO. Note its two delicate leaves called COTYLEDONS and its tiny stem below the cotyledons (hence HYPOCOTYL) to which they are attached. Are the cotyledons provided with VEINS? Toward which end of the seed does the hypocotyl point?

B. Draw the embryo as it lies surrounded by the endosperm (4 cm. long). Show around the endosperm the section of TESTA and TEGMEN.

C. Remove the embryo. Carefully separate its two cotyledons and make a careful sketch of it.

You will now be furnished with a germinating seed of Castor bean. Note the method by which it breaks through the soil. What about the ability of an arch to resist a strain? Carefully separate the parts, if Nature has not already done it for you, and identify each one. What force broke the testa? What is happening to the COTYLEDONS? HYPOCOTYL? ENDOSPERM? Does a tiny LEAF BUD appear between the cotyledons?

D. Make a careful sketch (twice natural size) of the germinating seed.

Examine the second stage of germination. The particularly important points to observe are: Fate of endosperm, COTYLEDONS, LEAF BUD, HYPOCOTYL. How does the color of the aerial parts compare with that of the same parts while still in the seed? How do cotyledons and first leaves differ in shape? Compare the second leaves with those taken from an old castor bean plant. On these leaves are usually found extra-floral nectaries; their function is in doubt. What other difference than mere size is seen? It is very probable that the ancient ancestors of castor beans had only the simpler type of leaf. Ontogeny is said to recapitulate phylogeny. What does this mean? Does your own ontogeny show the working of the same law?

E. Draw the fully established young plant, natural size or slightly smaller.

F. Draw side by side the outline of the cotyledon, of the first leaf, and of a mature leaf reduced or enlarged to the same size.

G. Write up your work on the seed of Ricinus according to the following outline:

I. Description of the seed - external and internal.
II. " " " developing seedling.
III. " " " established plant.
IV. Conclusions and inferences: (INDUCTIONS - See Lecture Notes.)
A. The provision made by the mother plant for the seedling and the necessity for this.
B. The adaptation of the seedling to its work of breaking through a load of soil.
C. The doctrine of recapitulation and how illustrated.

Exercise 3. The Exendospermous seed of the common bean. (Leguminosae; Pea Family.)

Examine the dry bean seeds furnished. On one side note the HILUM. At one end of the hilum lies a tiny heart-shaped CARUNCLE, but it is so small that it does not conceal the hilum as in the Ricinus seed. Atits other end lies a minute hole, the micropyle.

Examine two soaked seeds of bean furnished. One has had its micropyle covered with vaseline; the other was untreated. What is the difference between them? What then is one use of the micropyle?

A. Make a sketch 4 cm. long of the face of the soaked seed to show the hilum.

Remove the seed coat. Within lie two halves of the bean attached on one side to a small cylindrical structure. What is it? Toward what does this structure point? Separate the halves of the bean (what are they) and what appears? You are dealing with exactly the same parts as in the castor bean except that there is no endosperm and the embryo is more strongly developed. The two small leaves and the tiny EPICOTYL constitute the PLUMULE.

B. Draw the embryo from the face with testa removed.

C. Draw the parts visible when one cotyledon is removed.

How do the cotyledons differ from those of the castor bean? Would it seem probable that the cotyledons could form as efficient seed leaves as in the castor bean? At one time there was endosperm in this seed but the cotyledons began to feed on it when young and absorbed it all into themselves. What is the difference between garden bean and castor bean in this respect?

We will now study the germinating bean. Note how parts develop and compare with the castor bean.

D. Draw the germinating bean. Label cotyledons, epicotyl, first leaves, hypocotyl, primary root, secondary root.

The established seedling. The following points are to be noted.

1. What happens to the cotyledons at first; what eventually? Why?

2. Compare young and old leaves as you did in the castor bean.

E. Draw the growing plant.

F. Draw cotyledon, first and second leaves side by side.

G. Summary and conclusions:

1. Concise description of seed and seedlings.
2. Advance or modification over castor bean.
3. Result on functional power of cotyledons.

Exercise 4. <u>The exendospermous seed of pea</u>.

Examine the soaked seed. It belongs to the same family as the bean (Leguminosae) and is little different in anatomy except that the cotyledons are more bulky. You will see what this has led to. Open the seed - observe hemispherical cotyledons - hypocotyl and plumule.

A. Draw the embryo from the face with testa removed.
Examine seedlings well advanced in germination. What important difference over the last two studied in position of cotyledons? Of color of cotyledons with same in bean. What part of embryo has grown and pushed out of soil? Label it. What are the first leaves like? They represent stipules only. Is there any evidence at all of petiole or blade? Why don't the cotyledons attempt to serve as leaves (green) as they do in castor bean and garden bean?

B. Draw the germinating pea so that the seed part is 1.5 cm. in diameter. Show ground level.

C. Summary and conclusions:

1. Advance over garden bean and result on method of germination.

C. Construct a series of diagrammatic figures of the three germinating seedlings just studied with seed parts attached, and indicate homologous parts in each seedling.

The seedlings so far studied all have two cotyledons and belong to the division of seed plants known as dicotyledons. We will now study a member of the other division of seed plants: the monocotyledons. - Practically all monocotyledons have endospermous seeds

Exercise 5. The Onion Seed (Liliaceae - Lily Family)

Study the germinating onion seed furnished you, and verify the following description.

From the endospermous seed there comes out first the tip of the HYPOCOTYL just as in the seeds already studied. This moves downward in the soil. Slowly the single long COTYLEDON is drawn from the seed. Don't get confused just because it is elongated and not oval as in the bean or pea. It turns green - a primitive feature - and a strong arch with a knee in it develops. If hypocotyl is present at all it is very short - a mere knot. There is no apparent difference between hypocotyl and cotyledon. Sometimes the seed is pulled out of the soil into the air. Last of all the PLUMULE begins to grow from what seems to be the side of the cotyledon. It really is enclosed for some distance by the cotyledon sheath. Strip open the sheath and follow the plumule downward to hypocotyl region.

A. Sketch the germinating seedling twice natural size and show where plumule has its origin.

B. How do you imagine that the monocotyledonous seed came into being? Could it have arisen from an advanced type like bean or pea?

C. Draw a reconstruction of a purely hypothetical ancestor of the onion in the process of germination.

Exercise 6. The date seed and seedling. (Palmaceae: Palm family)

How does this seedling differ from that of the onion? Compare the shape of the first leaf with one from an old tree.

A. Sketch the seed and seedling natural size. Show level of ground and point where plumule has its origin.

B. Sketch the mature leaf much reduced.

Exercise 7. The corn grain and its germination.

Note in the soaked grain the shield-shaped single COTYLEDON and the yellow ENDOSPERM.

A. Sketch the grain from the face, two times natural size.

Split the grain through the small diameter and note the small EMBRYO lying on the face of the cotyledon. It has well developed ROOT and PLUMULE.

B. Sketch the longisection on a scale of 3.

Study the seedling and note what has happened to hypocotyl and epicotyl. Does the cotyledon leave the grain?

C. Draw the seedling about twice natural size and label cotyledon, endosperm, primary and secondary roots, adventitious roots, first node of growth, leaf sheath, leaf.

To what use has the cotyledon been adapted? (Important)!

Exercise 8. Summary: How do onion, date and corn show a series comparable to that of castor bean, garden bean, and pea? What, however, is the difference in function of the cotyledon in the two series?

Having seen how the young plant comes into existence we may now proceed to a study of the parts of the developed plant. A logical sequence may well be root, stem, leaf, flower, fruit and seed. Thus we shall come back to the starting point.

The Root - Subterranean.

Exercise 10. Fibrous root system of a small tree.

You have already studied the root of an herbaceous plant and have learned to recognize its parts. Observe the root system of a small tree. Is there a main root? The irregular branching and distal division into fibers is noteworthy as is also the corky layer which covers it. The cork often appears covered with longitudinal clefts due probably to what fact? Do any of the roots show flattened or hollowed areas on their surfaces? To what are these probably due? Consider the intense strains to which the root system of old trees is subjected. Is it adapted to these?

A. Sketch the root system accurately.

Exercise 11. <u>The tap-root of carrot or parsnip</u>.

How could this root be derived from one like that of the tree just studied? Can you see any advantage in the elongate form? Alfalfa has an extremely long tap root and is a remarkable plant for dry land farming. Why? Sketch root 2/3 natural size. Are lateral rootlets present at all? Split the root longitudinally through the center and note where the lateral rootlets originate. Peel away the bark. How did these rootlets reach the outside? This bark consists of three layers: (1) an outer delicate skin or EPIDERMIS, (2) a thick mass of CORTEX and an inner zone of PHLOEM. Inside the bark lies the WOOD and PITH. Cut a cross sectional slice through the root. Hold to light and note the whitish WOOD-RAYS running through the wood and phloem. Inside thw wood is found the pith.

Draw the root showing both its longitudinal and transverse aspects.

Taste a bit of the cortex. What seems to be present? Of what value can it be to the root? How shall we account for the swollen form of the root? What part of the carrot or parsnip root probably takes in water and salts? The main part of this root then has adapted itself to what function? The carrot and parsnip are biennial plants. How is this intimately related to the root form?

The dahlia; sweet potato; turnip and beet are also provided with storage roots.

Exercise. <u>Adventitious roots</u>: <u>PARSONSIA</u> or Sugar Cane

Observe cuttings that have been kept some time in water. The white roots which have come from the stem are conspicuous. (Of what possible advantage to a plant can this be in nature? Of what value to horticulturists is this ability of plants to form adventitious roots?)

A. Sketch the base of the cutting with its adventitious roots.

Exercise 13. <u>Adventitious roots</u>: <u>Bryophyllum</u>.

Observe the leaves of this curious plant which have been lying on wet sand and see what has happened. What other leaves will do this?

A. Sketch the leaf with the young plants and ADVENTITIOUS ROOTS:

B. Write a paragraph to explain the value to the plant of this ability to throw out adventitious roots. What value to gardeners? To your previous list of root adaptations you may add another. What?

The root - Aerial

Exercise 14. Climbing roots ~~FICUS~~ Stipularis.

Pieces of stem will be furnished. Note on which side of stem the roots originate and how they move away into dark crevices. Such roots always move away from light into the darkness and are said to be negatively phototropic. What adaptation to life conditions is evident? In what class of roots will you place these climbing ones?

A. Sketch the piece of stem given you.

Exercise 15. Prop roots: The corn plant.

Do they seem to be of any other use than for support? Here is another interesting adaptation of aerial roots. Whence do they spring. Note that they arise endogenously and break thru the outer tissues. Are other sets developing higher up? Such props are sometimes so extensively developed in some tropical plants as to conceal the whole stem. (Ohia, Banyan)

A. Sketch the base of the corn plant with is prop roots.

Exercise 16. Air roots for water absorption and food making.

Observe the aerial orchid and its pendent roots with papery covering. This paper outer layer is called the velamen and soaks up rain water or dew like a sponge. Note that the root is green underneath the white covering. This green matter (chlorophyll is of course particularly characteristic of leaves. You will learn that it is absolutely necessary to a plant which makes its own food out of gases and water.

A. Sketch one of the orchid plants.

B. Write a summary of the ideas developed from your work on roots. To assist you the following outline is suggested:

The subterranean root
1. Primitive functions
2. Secondary functions
   a. The biennial habit and adaptation to storage
   b. The effect of cultivation on storage
3. Adventitious roots: importance to plant; to gardeners.

The Aerial Root

1. Climbing adaptation
2. Adaptation to support
3. Adaptation to water absorption and food making.

THE STEM AND ITS MODIFICATIONS

Recall the study of the complete plant with which the laboratory work started and the facts learned about the stem.

Exercise 17. The study of a tree stem in the dormant condition:

From simple inspection and comparison what are some of the differences between this stem and that of the green plant previously studied? That plant wilted rapidly in the warm dry air. Why doesn't this one? What caused the horseshoe-like SCARS on the branch? The "nails" are the leaf trace scars. What stands above each scar on the last year's growth? How does last year's growth differ in color from the older parts? Just how far backward does last season's growth extend? What separates it from the growth of year before last? What stood at that point last spring? What produced these marks? How many nodes and internodes are represented by the girdle? On the older parts of the main axis do you still find buds? What does take their place? (Sometimes one does find so-called "RESTING BUDS" on such old growth). How old is the branch you have? Cut a cross-section through the base of the branch and count the rings of wood. Note the many tiny breaks in the epidermis scattered over the twig. These are called LENTICELS, through which gases pass in and out.

A. Sketch the whole branch natural size.

B. Sketch the area of junction between two years' growths to show the girdle of bud scars. Make drawing 2.5 cm. in diameter.

C. Sketch a leaf scar magnified to 2 cm.

Observe the TERMINAL BUD. Note how the scales overlap like shingles on a roof. They are said to be IMBRICATED. How does it differ from the terminal bud of the growing plant studied in Ex. 1. Carefully remove the scales. There is evidence that they are the flattened bases of leaf stalks. Search for it.

D. Sketch a developing leaf bud, and label BUD SCALES, SHOOT, and LEAVES.

E. Write up this work according to the following outline:

1. Markings on twig and their significance.
2. Method of computing age of branch.
3. The leaf buds.
    a. Positions
    b. Structure
    c. Development of parts in spring.
4. The adaptation of the branch to dormant conditions.
5. A comparison of such buds, etc., to those of a vigorously growing plant.

Exercise 18. The Stem. Its adaptations to leaf display; Phyllotaxy.

On the stem furnished select a certain leaf or bud and then move up the stem until you come to the next leaf directly above it. Stick two pins into the bases of these leaves. Starting with Number 1 count the leaves between Numbers 1 and 2. How many times do you circle the stem? If there are three leaves and you make one turn the plant has a 1/3 phyllotaxy; if there are five leaves in two turns the phyllotaxy is 2/5. The various phyllotaxies form a series as follows:

1/2, 1/3, 2/5, 3/8, 5/13, 8/21. What curious fact do you observe in the series? How do such arrangements conduce to the idea expressed in the heading to this exercise?

A. Write out your observations and inferences concerning Phyllotaxy. No drawing is required.

Exercise 19. Rosettes:

Study the rosette plant given you. How do the leaves avoid shading one another? Such an arrangement constitues a leaf mosaic. Many perennial herbaceous plants pass the winter in this condition. What advantage is it? Such plants are sometimes called stemless (acaulescent). Split the rosette through the crown and see if it really is stemless.

A. Sketch the half of the plant very carefully to show both top and cut edge. Remember each line in your drawing must have a definite meaning.

X Exercise 20. Creeping, Climbing, or Twining Stems:

Such as are available should be noted and their adaptation to leaf display thoroughly realized. What advantage to such a plant is its weak stem? Many such stems climb on walls and form elaborate leaf mosaics.

A. Write a brief description of these climbers or twiners.

Exercise 22. Modifications of Secondary Stem Axes.

Tendrils: To assist the weak stem of certain climbers in getting into the best light relation accessory stem modifications called tendrils are often instituted.

Tendrill-bearing plants available will be furnished. Members of the gourd family - comprising squashes, cucumbers, and melons - are provided with remarkably sensitive tendrils. The Passion flower is also of interest in this respect and the stem nature of its tendril is proved by its position. How?

A. Write a paragraph summarizing your work on tendrils.

The Stem: Its Adaptation to Food and Water Storage.

Modification of upright axes.

Exercise 23. The Kohl Rabi. The nature of this storage organ is evident from simple inspection. It is a stem behaving much in the same way as does the root of the parsnip.

A. Sketch the specimen.and show the ground level.

Exercise 24. The Corm of Crocus or Gladiolus. Study the Corm furnished you. Did it grow above or below the surface of the soil? What is the true nature of the papery coats on the outside? Are they of any value? What proves that the corm is a stem and not a root? Are there any LEAF BUDS on it?

A. Sketch the corm both as a whole and as cut longitudinally.

Modifications of the Creeping Axis.

The Stolon - Runner Series.

Exercise 25. STOLONS. Observe the radiating shoots from the base of the plants. These are stolons. Do any show evidence of rooting at their tips? Such tips take root and again send out stolons. What is the advantage of such a method of growth?

A. Carefully sketch the plant.

Exercise 26. THE RUNNER OF STRAWBERRY or of Jacquemontia. The runner is but an extensively developed stolon. Is the runner or the stolon more efficient?

A. Sketch the plant with is runners.

B. Write a paragraph on stolons and runners considering their uses, progressive efficiency, and horticultural importance.

If the stolon or runner becomes subterranean another interesting function is added to that of reproduction.

Exercise 27. The Rizome-Tuber Series.

Rhizome of Witch Grass. Study carefully and explain why this structure is not to be called a root. If it is a stem it should show NODES, INTERNODES, NODAL BRANCHES or BUDS and LEAVES. Is there evidence that old annual stems have died away in years past? Where do roots come out? What function besides that of reproduction can you infer?

A. Sketch a portion of the Rhizome, three times its natural size.

Exercise 28. THE RHIZOME OF NUT-GRASS (Cyperus rotundus). This interesting rhizome is to be carefully compared with the last. How does it differ? Cut a thin slice from the end of the rhizome and apply a little weak iodine. Result? swollen What meaning? Does this rhizome bear NODES, LEAVES, BUDS.

A. Sketch the rhizome.

Exercise 29. The Potato Tuber. State evidence that this too is a stem, not a root. What are the "EYES"? Look at the ridge under each eye for a tiny membraneous scale. What is it? When potatoes are exposed to light in a hill what happens?

A. Apply a drop of iodine to the cut surface of the potato. Result?

B. Draw the whole tuber natural size.

C. Draw the eye and its attendant parts, three times natural size.

D. Write a paragraph considering the rhizome tuber series.

Exercise 30. Modifications for Defense. (?) Observe the branches available and note that some of the spur shoots show a tendency to become pointed and harsh. Some have believed that these form a means of defense against browsing animals.

A. Sketch a branch with typical sharp spurs.

Exercise 31. Note the progressive perfection over the above. Why must these thorns still be considered as branches?

A. Sketch the branch with its thorns.

Exercise 32. The prickles of the raspberry: Are these of the same nature as the thorns you have been considering? Explain. What structure of irregular distribution have we found on plant stems which could give rise to such prickles?

A. Sketch a portion of stem, four times natural size.

B. Write a resume considering this series of thorns.

Stem modification to subserve the leaf function.

Exercise 35. Muhlenbeckia platyclada (The seaside grape)

Interpret the flat members of this curious plant. Are there any leaves at all?

A. Sketch portions to show its features.

Ruscus and Phyllanthus: If either of these plants is available it will be furnished. Work out the morphology of the leaf-like members (CLADOPHILS)

B. Sketch portions of the plants.

✓ C. Draw a portion of the plant.

Exercise 37. The Cactus Plant. (Apuntia and Cereus). These odd plants run into many forms. The flattened types are particularly interesting from our standpoint. In what places do Cacti grow? To what other use besides the leaf function are these stems being put? Many of them bear small leaves when young but these quickly dry up and fall off. The spines are probably to be interpreted as a branch system.

A. Sketch one of the plants.

B. Write a resume of the subject of stems serving as leaves.

C. Construct a careful outline and summarize the whole subject of the stem and its modifications to subserve various functions.

THE LEAF AND ITS MODIFICATIONS

Leaves in exactly the same way as stems can be moulded into many forms and adapted to many uses. In this regard there is such a richness of material that we shall study some of the most easily obtained and striking cases. They will be taken up according to the following scheme:

1. Leaf adapted to climbing
2. Leaves adapted to food and water storage
3. Leaves adapted to reproduction
4. Leaves adapted to the water life
5. Leaves adapted to eating meat (carnivorous nutrition)
6. Leaves adapted to withstanding arid conditions.

Exercise 38. Climbing leaves. Examine the leaves furnished you and study their special adaptation for climbing. Draw one leaf of each type enumerated above. Write a resume of leaf adaptations to the climbing function.

Leaves adapted to storage.

Exercise 39. The Agave or Century Plant. How do these leaves show that they are used for this purpose? Where do Agaves grow naturally? Is there any relation between the thick leaves and the rare flowering periods? No drawing is required. The Agave leaf may be called a dual purpose leaf. Why? Let us study now a set of leaves which are used for a single function.

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C. Construct a careful outline and summarize the whole subject of the stem and its modifications to subserve various functions.

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Exercise 40. The Cabbage Plant. Split a small cabbage through the middle. What name have we applied before to a set of leaves borne on a short axis and folded close together? Are there any axillary buds present? How do the inner leaves differ from the outer? Could they make food? Is a cabbage biennial or perennial?

A. Sketch the longitudinal section somewhat diagrammatized.

If the cabbage should retreat underground and its leaves should become even thicker it would constitute a bulb.

Exercise 41. The Hyacinth Bulb Split the bulb lengthwise through the middle. Is its nature clear? Note the dry distal extremities of the scales. What part of the leaf does the fleshy white part represent? What stem modification is analagous to the bulb? What is the structure found in the middle.

A. Draw the longitudinal section of the hyacinth bulb.

B. Write a resume of the leaf in relation to storage.

Leaves adapted to reproduction.

Exercise 42. Leaves of a fern will befurnished. How would the small plantlets become isolated and free eventually?

A. Sketch a portion of the leaf and write a brief note (consider your work on Bryophyllum also);

Leaves adapted to the water life.

Exercise 43. Growing water-plants will be furnished as well as preserved material. How is the whole plant adapted to the water life? How are the leaves particularly adapted? Are those under water the same as those on the surface? Can the upper surface be wet?

A. Draw a plant to show the weak habit and the two kinds of leaves.

The Water Hyacinth. This curious plant is a bad pest in the south as it blocks up the streams. How does it keep itself afloat? A section of one of the petioles will be handed around.

B. Sketch the growing plant and take notes on the structure of the petiole.

Leaves adapted to eating meat.

Exercise 44. Such specimens of these strange plants as can be obtained will be furnished and their habits explained. The three following are not rare in New England, the Sundews, the Pitcher plant, and the Aquatic Bladderworts.

A. Make sketches and take notes.

B. Write a resume on the subject of Leaf Adaptations.

Exercise 45. We shall now take up quite a different kind of work on the leaf from any that we have so far considered. The nature of the leaf furnishes an important means of identifying [illegible] plants. Before we can use them for this purpose however we must become familiar with many terms used to describe them. Three methods for fixing these in mind are to be used. Some students retain such facts better from a diagram of the object; others from the real thing; others from a description. Let us use all three methods. Simple keys have been prepared. Classify each leaf by use of the keys as to its voination, shape, apex, base, margin divisioning and surface character, Sketch each one as accurately as possible and underneath it place its Latin name and its description. If single terms will nct accurately describe the leaf use compounds such as lanceolate-ovate or serrate-dentate.

Key to Leaf Veiration

A. Leaf with numerous, approximately parallel veins, connected by MINUTE STRAIGHT veinlets. Margin of leaf usually entire. The typical leaf of Gymnosperms and Monocotyledons
------------Parallel veination.

(The three types of Parallel Veination are:

B. Veins running from midrib or costa to margin
------------Costal-veined or nerved

B. Veins running from base to apex.
   C. Veins undivided and approximately parallel - Basal-nerved or veined.
   C. Veins repeatedly forking (dichotomizing) but keeping roughly parallel. A fan-like leaf, Flabellinerved.

A. Main ribs serveral which may run straight to margin or may break up into slender veins and veinlets. Ribs connected by an ANASTOMOSING NETWORK (reticulum) of veins and veinlets. Margin of leaf entire or cut. The typical leaf of dicotyledonous plants. net or reticulate veination

(The two types of net veination are:

B. Main veins springing from midrib producing a feather-like effect. -------------------------Pinnately net-veined.
B. Main veins springing from apex of petiole like fingers of a hand. ---------------------Palmately net-veined.

Key to Leaf Shapes

A. Leaf longer than broad.
   B. Main body of about the same width throughout.
      C. Narrow and ribbon-like; often many times longer than wide. Typical of grasses ------------Linear
      C. About twice or thrice as long as broad-----Oblong
   B. Broadest below or in the middle
      C. More than twice as long as broad; widening above the base and tapering to the apex.----Lanceolate
      C. Not more than twice as long as broad.
         D. Broadest below.
            E. Shaped like the section of a hen's egg; viz the outline a flowing curve.----Ovate.
            E. Tapering by straight lines to the apex; viz. shapes like the Greek letter Delta--Deltoid
         D. Brâadest in the middle - the outline a flowing ellipse.

E. Breadth not more than one-half the length Elliptical

E. Breadth considerably more than one-half the length ------------------------------Oval

B. Broadest above the middle

C. Inversely lanceolate; viz., more than twice as long as broad, widening below the apex and tapering to the base.

D. Tapering by gentle curves Oblanceolate

D. Tapering by straight lines. Cuneate or wedge-shaped

C. Broad and rounded above - tapering abruptly below into a long narrow "handle" like a spatula---------Spatulate

C. Inversely ovate, viz. somewhat like the section of a hen's egg with the small end down.

D. Tapering downward by curved lines---------Obovate

D. Tapering downward by straight lines.-----Cuneate or Wedge-shaped

A. Leaf not longer than broad

B. Circular in outline or nearly so. Orbicular or Rotund

B. Elongate transversely with broad heart-shaped base Reinform or Kidney Shaped

Key to Leaf Apices

A. Leaf not turned in at the apex.

B. Apex sharp.

C. Leaf tapering to a point (viz. by lines concave inward)

D. Tapering gradually ---------------Acuminate (If the apex is long and tail-like, use--Caudate

D. Tapering abruptly to a small point, like a tooth.-----------------Cuspidate

C. Apex a sharp point like a projection of the Midrib.-----------------------Mucronate

C. Apex an acute angle (viz. by lines convex outwards) Acute

B. Apex not sharp.

C. Blunt or rounded --------------------------Obtuse

C. As if cut off transversely by shears.......----Truncate

A. Leaf turned in at the apex.

B. Reentrant angle a very slight depression-----Retuse

B. Reentrant angle a decided notch-------------Emarginate

B. Reentrant angle producing a heart-shaped apex.-Obcordate

Key to Leaf Bases

A. Leaf petiole attached to lower margin of leaf
  B. Leaf base not turned in to form a notch
    C. Base terminating in an acute angle----------Acute
    C. Base tapering to the petiole--------------Acuminate
    C. Base blunt ------------------------------ Obtuse
  B. Leaf base rounded and turned in (The following terms apply not only to bases but to a more or less ovate leaf with such a base.)
    C. Lobes rounded
      D. Lobes not elongate into ears
        E. Lobes equal in size --------------Cordate
        E. Lobes unequal in size ------------Oblique Cordate
      D. Lobes elongated into ears-------------Auriculate
    C. Lobes sharp pointed
      D. Directed backward parallel to the petiole Sagittate or Arrow Shaped
      D. Flaring away from the petiole Hastate or spear shaped

A. Leaf petiole attached to blade on the under side some distance from the margin Peltate or Shield shaped

Key to Leaf Margins

A. Margin an even continuous curve------------------Entire

A. Margin not an even continuous curve.
  B. Margin beset with teeth.
    C. Teeth sharp
      D. Teeth regular
        E. Teeth small and directed forward like those of a saw----------------------Serrate (or dimin. Serrulate)
        E. Teeth larger and not directed forward.--- ---------------- Dentate
      D. Teeth irregular, cutting less than one-half way to the midrib.---------------Segmentation)
    C. Teeth blunt and directed forward-------Crenate
  B. Margin a pronounced wavy line
    C. Depressions very slight----------Repand or Undulate Sinuate

Leaf Segmentation

A. Incisions or lobes rounded and reaching not more than half way to midrib --Lobed
A. Incisions or lobes sharp and reaching half way or somewhat more to midrib.-----------------------------------Cleft
A. Incisions or lobes either rounded or sharp.
  B. Incisions reaching almost but not quite to midrib--Q Parted
  B. Incisions severing the blade into distinct leaflets. Divided

The leaf then becomes compound

Express number and disposition of parts as follows: Pinnately Five-lobed, palmately three-cleft, - parted - divided, etc.

Compound Leaves

Express number and disposition of leaflets as follows:

Pinnately 10-foliolate leaf; palmately 3-foliolate (or trifoliolate). Pinnately unifoliolate. (Think carefully. Such a leaf is present. Primary pinnae of the leaf may also be pinnate or palmate. Then use terms like: bipinnate, tripinnate, etc., or use decompound as a general term.

Attachment

As to the Stem.

A. Leaf without a stalk or petiole
   Leaf attached to stem by narrow base ------------Sessile
   Leaf attached to stem by broad, partly circling base
   Sessile and Clasping
   Leaves opposite and seeming to have their bases grown together around the stem (stem perfoliate)----Connate
   Petiolate

As to Surface

A. Leaf with neither hairs nor other removable material on the surface---Glabrous
A. Leaf surface hairy
   B. Hairs soft to touch
      C. Hairs short and erect
         D. Hairs densely aggregated like very fine pile on velvet----------------------Pubescent
         D. Hairs soft but longer and individually distinct Pilose
      C. Hairs soft to touch but appressed
         D. Hairs straight and matted-------Tomentose
         D. Hairs twisted, curled and matted- Wooly
   B. Hairs harsher
      C. Hairs bristle like but not particularly harsh to touch Hispid
         (If weaker the term hirsute may be used)
      C. Leaf decidedly harsh to touch when stroked backwards Scabrous
A. Leaf surface bearing a coating other than hair
   B. Material of coat a whitish waxy bloom-----------Glaucous
   B. Material of coat a whitish dust or scurf------Pulverulent

Exercise 46. Go through this work on the leaf from page 33-38 - and construct an ideal sketch of each - shape, margin apex, etc. and hand in for correction.

Key to Inflorescences

A. Main axis of inflorescence not terminated by a flower: hence the axis may continue growth for some time. Indeterminate Inflorescence
- B. Lateral axes springing from axils of bracts, unbranched, and each terminating in a flower.
  - C. Flowers on pedicels.
    - D. Main axis elongate and pedicels about equal in length — Raceme
    - D. Main axis shortened. The lower pedicels elongate to form a rather flat topped inflorescence — Corymb
    - D. Main axis undeveloped. Pedicels radiating and about equal in length — Umbel
  - C. Flowers sessile
    - D. Main axis very short - leading to a globose — Head
    - D. Main axis elongate
      - E. Main axis erect and fleshy — Spadix
      - E. Main axis erect and not fleshy — Spike
      - E. Main axis scaly bracted and often drooping — Ament or catkin
- B. Lateral axis branched one or more and bearing clusters instead of single flowers.
  - C. Irregularly racemose or corymbosely branched — Panicle
  - C. Regularly compound leading to compound racemes, compound umbels, compound corymbs, compound spikes

A. Main axis of inflorescence terminated by a flower hence this axis cannot continue growth but lateral axes must take up the development of the inflorescence and in their turn give rise to terminal flowers. Determinate Inflorescence
- B. Flower stalk single and terminated by one flower--Scape
- B. Flower stalk branching
  - C. Two or more lateral axes developing at a node--Cyme
  - C. Only one lateral axis developing at a node--Sympodium or False Raceme

Exercise 47. Construct an ideal diagram of each of the above inflorescences. Use lines for axes and circles for flowers. Do not omit bracts.

The Flower

A foundational flower type - Nymphaeaceae Family:

Exercise 48. We will study first as a type a very simple and primitive flower, that of the water-lily (Castalia sp.). What terms will you apply to the leaf shape, margin and base? The flowers are borne on PEDUNCLES. Each consists of an outer set of members constituting the PERIANTH. Are the outermost ones colored at all differently from the innermost? In many flowers the outermost constitute a special green cup or calyx made up of sepals, while the inner brighter colored ones constitute a corolla made up of petals. We call all the outer members SEPALS, or collectively a CALYX. (It may also be called a diplochlamydeous perianth, (etymology?) How many sepals are there? Does the number vary in different flowers? Do they show any chlorophyll? How many petals are there? Does the number of PETALS vary? Inside the perianth lies the ANDROECIUM. The members are called STAMENS or MICROSPOROPHYLLS. Their large and indefinite number is again a primitive character. Inside the androecium stands the GYNOECIUM made up of several united CARPELS or MEGASPOROPHYLLS.

A. Draw the flower from its facial aspect 5 cm. across. Remove the perianth. Observe that the sepals rest on a slightly enlargee portion of the pedicel called the RECEPTACLE or TORUS. Note particularly the shape and veination of the sepal. To what category of organs does it belong?

B. Draw the sepal.

Detach several stamens and study with the lens. The stalk is called the FILAMENT; the distal swollen part, the ANTHER. If the anther is withered take fresh stamens from a nearly opened bud. See if you can determine that the anther consists of a middle CONNECTIVE and four elongate pouches (seemingly two), the pollen or ANTHER SACS (also called pollen cells, loculi, or MICROSPORANGIA).

C. Draw a stamen whose anther has not yet opened. (Make anther 4 cm. long)

D. Draw a stamen with opening anther on the same scale. Label the yellow granular POLLEN GRAINS or MICROSPORES.

Remove all the stamens from a flower rather advanced in age. The gynoecium alone remains on the torus. Carefully note the conical form of the TORUS and the SCARS left by the fall of perianth and stamens. These scars collectively form a low spirial around the torus. Such an elongate torus with spiral arrangement of floral parts is again very primitive. Approximately how many nodes and internodes make up this flower of castalia. Define a flower and explain why a flower with conical torus is more primitive than one with flat torus.

E. Draw the whole structure 4 cm. in diameter.

Study the gynoecium. This has become so modified that its structure may be confusing unless it be compared with that of a more primitive gynoecium.

F. Draw the gynoecium 3 cm. across, leaving sufficient room for labeling the different parts later on.

G. Draw a cross-section of the gynoecium.

Preserved material of Caltha is at hand showing the gynocium only, the other floral members having fallen off after flowering time. Note the TORUS AND THE SCARS left by perianth members and stamens. Note that the gynoecium is composed of a variable number of separate CARPELS. Such a synoecium is called an APOCARPOUS GYNOECIUM (etym?)

H. Draw.

1. Draw an individual CARPEL of Caltha. Its elongate and swollen basal part is called the OVARY. Its roughened tip constitutes the STIGMA. What was received here? Many carpels have an elongate narrow neck or style between ovary and stigma but in Caltha the stigma is practically sessile.

Slice open a carpel longitudinally with the razor. Its cavity is called the cell or LOCULUS. Inside it lies the OVULES. What will they become when mature? To what region are they attached? Do their MICROPYLES point inward toward the locular cavity or away from it toward the wall? What term is applied to their tiny stalks?

J. Draw the opened carpel 2.5 cm. across.

K. Slice open a carpel transversely and make a sketch of the section on thecsame scale.

L. Turn back to your drawings of the water-lily under F and G and label, when possible as for Caltha. Castalia differs cheifly from Caltha in having a SYNCARPOUS GYNOECIUM and not an apocarpous one (etym?) Be sure you understand their homologous structures. and how the Castalia gynoecium might have evolved from that of a flower similar to Caltha.

Exercise 49. A Liliaceous Flower. This flower shows considerable advance over those of Caltha and Castalia. Note first of all that the whole flower is put together on a plan of three.

Without tearing the flower determine how many STAMENS and what is their position as regards SEPALS and PETALS? How many PISTILS? How many OVARIES, STYLES and STIGMAS? Suppose one were to blend three carpels of Caltha into one but leave their tiny curved stigmas free would the result throw any light on the structure of the pistil here? It constitutes a syncarpous gynoecium, Caltha has an apocarpous gynoecium.

A. Draw the whole flower in its natural position and on a scale such as to show parts clearly.

Remove a stamen. How are the ANTHERS fixed to the FILAMENT? They are either ADNATE or VERSATILE.

B. Draw the stamen.

Remove all the stamens and draw the pistil. With sharp scalpel or razor slice the pistil through the ovary and examine the cut. section with lens. How many cavities or CELLS in the Ovary? There are then how many CARPELS fused together to make up this COMPOUND PISTIL? How many OVULES are visible? Slit one of the cells open lengthwise. How many rows of ovules? The ovules are attached by their FUNICLES to the fleshy axis of the ovary. Such ovules are said to possess AXILLARY PLACENTATION.

C. Make a careful sketch of the corss-section of the ovary 6 cm. across.

Exercise 50. We will now study a rather complicated flower, that of the pea family. At first glance how does it differ in its regularity from Castalia or Dracaena? It is wonderfully adapted to cross pollination by bees.

Starting as before with CALYX how many SEPALS do you find? (Look very closely at the lower or ventral lobe) Are they free as in castalia and Dracaena or UNITED INTO A TUBE? The corolla at first sight seems to have how many PETALS? Actually there are five for the two which stood below have fused together to form the curious boat-shaped structure. The parts of the corolla in such a flower have received special names. The large upright upper petal is called the STANDARD. The two lateral ones are the WINGS while the double bottom one is called the KEEL. The keel is the landing place for insects. Press down with your pencil on the Keel. What happens? Can you see how the bees' ventral surface would be powdered with pollen and how the stigma might receive a dusting with pollen brought from another flower? Note that when the anthers are sheeding pollen the stigma is concealed; after the anthers wither the sh style elongates and its stigma is exposed. A flower whose anthers mature first is called proterandrous. Devise a term for ones whose pistil matures first.

A. Draw a partial side view of the whole flower 4 cm. long.
B. Remove the whole calyx and draw it 2 cm. long.
C. Carefully remove standard, wings and keel and draw each one.

Now examine the ANDROECIUM and GYNOECIUM. With needle carefully separate the stamens and pistil. The ten stamens have their fibaments fused into a tube which embraces the pistil. Such an arrangement is said to be Monadelphous (one brotherhood).

D. Draw the Monadelphous stamens rather diagrammatically 6 cm. long.
The pistil alone remains. What would it have become at maturity? Note its OVARY, STYLE and STIGMA. How many of each?

E. Draw the pistil 5 cm. long.
Since it is easier to study the pistil when larger, examine the fruit. Note the persistence of calyx. The pod has a DORSAL SUTURE (where seeds are attached) and a VENTRAL SUTURE. At maturity it splits into two HALVES. With how many carpels are we dealing? Is this a simple or compound pistil? Such a fruit is called legume.

F. Draw the LEGUME natural size.

Open the pod and note the attachment of the SEEDS by their FUNICLES to the Dorsal suture.

G. Draw the opened pod.

Exercise 51. The flower of sunflower. A representative of the highest family of dicotyledonous plants (compositae)

In superficial appearance this flower seems to be somewhat like that of Dracaena. Actually, however, it is entirely different. Break one of the heads through the disc and remove some of the central structures. Each one is a separate flower or floret. Observe that the flowers expand centripetally. Explain how the Composite head probably came into existence. If sunflower heads are available, examine a floret from this plant. They are larger and more easily studied. At the base in what seems to be a seed. It is really a one-seed OVARY. On its top stands a tubular COROLLA with five lobes or PETALS. In other words the perianth has climbed up on top of the ovary and hence the ovary is said to be INFERIOR, or we speak of the perianth as being epigynous (etym). What term will we apply to the condition in the first three flowers studied? The calyx is quite or almost lacking. From the throat of the corolla projects a STYLE with two STIGMAS, while folded close around the style are five STAMENS.

A. Draw the whole floret 5 cm. long. Dissect away the corolla and expose the stamens: their anthers are grown together around the style - their filaments are free.

B. Sketch androecium. Slit open the anther tube and expose the style.

C. Draw the pistil.

Remove one of the MARGINAL or RAY FLORETS. Instead of a 5-petalled corolla, the corolla lobes have all fused and become elongated into a strap-shaped structure. A COROLLA TUBE is still present and is seated on the ovary just as in the disc floret. Are ANDROECIUM and GYNOECIUM present?

D. Draw the ray floret with strap-like corolla 5 cm. long.

Observe the flattened disc or receptacle upon which all the florets are seated. Sometimes tiny scales lie between the florets and constitute the CHAFF. Observe also the cup of green leaves which surround the head. This of course cannot be called a calyx but instead is called an INVOLUCRE and is made up of BRACTS.

E. Draw the whole head at least 6 cm. in diameter. Label RAY FLORETS, DISC FLORETS, INVOLUCRE, BRACTS.

F. Make a diagram of a longitudinal section taken through the disc and show the florets in position. If CHAFF is present show this also.

Exercise 52. The Grass Flower.

In taking up the structure of the grass flower we find a structure which is entirely different from any before studied. We know, however, that it has arisen from a modified lily flower. The grass furnished will be one with as large flowers as we can get. Are its flowers in a panicle or spike? On the tips of the ultimate PEDICELS we find the small green SPIKELETS. These consist of from one to many FLORETS.

A. Sketch a portion of the inflorescence natural size.

B. Remove a single SPIKELET. Use hand lens throughout the following. With needles remove the very outermost scale at the base of the floret. This is called the FIRST GLUME. Is it shorter or longer than the second scale? What is its shape? Remove the next scale directly opposite. This is the SECOND GLUME. The remaining structures each consist of two tiny leaves flattened together. The outermost is called the LEMMA; the innermost is called the Palea. Lemma and palea enclose 3 stamens and a PISTIL. The latter has a one-celled ovary, and two feathery stigmas.

Draw a spikelet 4 cm. long.

B. Diagram the structure of a single floret.

THE FRUIT AND SEED

Exercise 54. The fruit is the matured pistil sometimes with other parts of the flower attached. Its many modifications are largely adaptations to dispersal.

Let us start with a CAPSULE, viz., a dry papery fruit which splits open when mature and discharges seed. How many CARPELS are present? Do the carpels fall apart and then break open along the VENTRAL SUTURE (SEPTICIDAL DEHISCENCE) or does each carpel split down the back (LOCULICIDAL DEHISCENCE). Sometimes only the tip of the capsule opens. Do the seeds show axial, parietal or basal PLACENTATION?

A. Sketch the capsule entire.

B. Make a diagram to show the same capsule with top cut off (4 cm. diam.)

Exercise 55. A few of the more important fruits may now be considered along with the adaptations of fruits and seeds to dispersal.

1. Simple and dehiscent dry fruits.

The follicle:- From what kind of a pistil is this derived? What was the filamentous tip on each follicle? Does the follicle dehisce along the suture where the seeds are attached? After it has dehisced how does its appearance suggest that the word sporo-PHYLL is particularly appropriate? What is the relation of the follicle to the capsule?

A. Sketch the opened follicle 4 cm. long.

The Legume

Where have we seen this type of fruit before? How does its dehiscence differ from that of the follicle? What form do the valves of the pea and bean take on to facilitate dispersal?

B. Sketch the legume.

The Loment

How does it differ from the legume in its method of breaking? What adaptation to dispersal?

C. Sketch the loment 1.5 cm. in diameter.

D. Study such other types of fruit as are available.

Write up your work on fruits according to the following outline:

I. Definition of fruit.

II. The simple and dehiscent dry fruit - Origin of megasporophyll; modifications of a primal unilocular type.

IV The simple and indehiscent dry fruit: Primitive or reduced? Careful interpretation of the set of homologies analogies and dispersive mechanisms involved.

III. Origin of the capsular type.

V. The fleshy indehiscent fruit.

VI. Aggregate and multiple fruits - Interpret.

Typical questions based on Lecture I.

What is the derivation and the actual meaning of the word science? What is meant by philosophy; by metaphysics; by ontology? How do we gain the facts of science and how does the average man's factual content of mind differ from that of the scientist? What is meant by affirming that the senses are notoriously untrustworthy? What value can we see in college science besides its economic value? Contrast science with the humanities? Is there any proof that scientists become dehumanized thru their studies? What is an art? What are the fine arts? Are the following sciences or arts: Agriculture; Chemistry; Horticulture; Zoology; Painting and Sculpture? Which type of man is most rewarded by the commercial world - the devotee of pure or applied science? Is this as it should be? How do the two types of men differ? What is meant by the trinity of man's being? To what does extreme emphasis upon any one of these lead? Carefully distinguish between induction and deduction. Define Law, Theory and Hypothesis. What is meant by the field of sensible reality? What is research? Is the business world beginning to realize the value of research? Is there a danger in letting selfish men know too much? What do you suppose is the reason for the oath of secrecy to which members of certain occult schools are sworn? What did Christ mean by "Cast not your pearls before swine".

Exercise 1. Introductory study of a seed plant.

The plant used will be as typical a one as is available. Note the obvious divisions of its body into root, stem and leaf.

The root: How does its color compare with the parts of the plant above the soil? Is there a main axis or does the root divide at once into many rootlets? What is the oldest part of the root? Is it of a different texture here than in the younger part. Is the surface smooth or has it become rough through the formation of cork? The junction of the root and stem constitutes the COLLAR. At about what angle do ROOTLETS leave the main root? Is there any regularity in their distribution? Which are oldest? Do they pursue a straight course outward? If not explain reason. What is the function of the root? What is the value of so many ROOT FIBRILS?

A. Make a drawing of the root on such a scale that the collar shall be 5/10 cm. in diameter.

The Stem: Is there a main or PRIMARY AXIS? lateral or SECONDARY AXES? Is there regularity in the branching? Are the branches related to leaves? The points at which the leaves stand are called NODES; the length of stem between nodes are the INTERNODES. At what angle do the branches leave the main axis? The undeveloped upper branches are called BUDS. Can you detect young leaves in them? Are there terminal buds on the branches or does a flower terminate the branch? If the latter condition is found will that branch ever grow any longer? Normal buds or the branches which grow from them stand in the upper axil of a leaf invariably!

Is the stem smooth (glabrous) or hairy (pubescent)? Does it show traces of longitudinal grooving? If so, ridges mark the position of inner woody masses. Does the stem differ in texture below and above? To what is this due? Is the color as well as the pubescence different below from that above? Is there evidence that leaves have been lost below?

B. Draw the leafy stem on a scale to show these features clearly.

Are one or two leaves found at a node? Are the leaves of successive nodes attached to the same side of the stem? Where are the leaves youngest? Where oldest? Which are simpler in outline? It is often the case that the youthful structures formed by a plant are simpler than the adult.

The leaf consists of an expanded BLADE or LAMINA and a stalk or PETIOLE. There may be appendages at the base of the petiole called STIPULES. What are the most striking differences between stem and leaf? Such differences are related to their different functions. Is the leaf glabrous or pubescent? Are the two surfaces alike? Note that woody strands from the stem pass up the petiole and enter the blade. These are called LEAF TRACES. They become the RIBS and VEINS of the leaf. Hold the leaf to the light and note the complicated branching of the VEINLETS. What is one obvious use of the ribs and veins?

C. Draw a single leaf to show these features.

After plants have been lying on the table for some time how do the leaves differ from first appearance? Why? If flowers are present note their terminal or lateral position. By using a needle or scalpel note that the plant body is covered with a skin or EPIDERMIS. Below the epidermis of the stem lies the bark; its outer layer is green. Inside the bark lies the wood, while in the very center of the stem is found the pith.

THE ORIGIN OF THE SEED PLANT.

Exercise 2. The seed; its germination and evolution.

The Endospermous Seed of Ricinus - the Castor Bean. (Euphorbiaceae - Spurge family.)

Examine the soaked seeds given you. The hard covering constitutes the TESTA. Can you imagine any possible significance in the odd ornamentation? At one end is seen a curious outgrowth, the CARUNCLE. It is not present on most seeds. More or less hidden by the caruncle is the scar left when the seed fell from its attachment. This scar will be much better seen in other seeds. It is called the HILUM. Running from the hilum along one side of the seed is a narrow ridge, the RHAPHE. This is really the seed stalk grown fast to one side of the seed.

A. Draw the seed 4 cm. long to show these features. Represent markings by shading.

Remove the brittle testa and expose the "meat".
N. B. Do not eat these; they are poisonous.

Slightly cut around the edges of this mass and split it into two halves. What comes to light? This is the EMBRYO. Note its two delicate leaves called COTYLEDONS and its tiny stem <u>below the</u> cotyledons (hence HYPOCOTYL) to which they are attached. Are the cotyledons provided with VEINS? Toward which end of the seed does the hypocotyl point?

B. Draw the embryo as it lies surrounded by the endosperm (4 cm. long). Show around the endosperm the section of TESTA and TEGMEN.

C. Remove the embryo. Carefully separate its two cotyledons and make a careful sketch of it.

You will now be furnished with a germinating seed of Castor bean. Note the method by which it breaks through the soil. What about the ability of an arch to resist a strain? Carefully separate the parts, if Nature has not already done it for you, and identify each one. What force broke the testa? What is happening to the COTYLEDONS? HYPOCOTYL? ENDOSPERM? Does a tiny LEAF BUD appear between the cotyledons?

D. Make a careful sketch (twice natural size) of the germinating seed.

Examine the second stage of germination. The particularly important points to observe are: Fate of endosperm, COTYLEDONS, LEAF BUD, HYPOCOTYL. How does the color of the aerial parts compare with that of the same parts while still in the seed? How do cotyledons and first leaves differ in shape? Compare the second leaves with those taken from an old castor bean plant. On these leaves are usually found <u>extra-floral nectaries</u>; their function is in doubt. What other difference than mere size is seen? It is very probable that the ancient ancestors of castor beans had only the simpler type of leaf. Ontogeny is said to recapitulate phylogeny. What does this mean? Does your own ontogeny show the working of the same law?

E. Draw the fully established young plant, natural size or slightly smaller.

F. Draw side by side the outline of the cotyledon, of the first leaf, and of a mature leaf reduced or enlarged to the same size.

G. Write up your work on the seed of *Ricinus* according to the following outline:

I. Description of the seed - external and internal.
II. " " " developing seedling.
III. " " " established plant.
IV. Conclusions and inferences: (INDUCTIONS - See Lecture Notes.)
   A. The provision made by the mother plant for the seedling and the necessity for this.
   B. The adaptation of the seedling to its work of breaking through a load of soil.
   C. The doctrine of recapitulation and how illustrated.

Exercise 3. The Exendospermous seed of the common bean. (Leguminosae; Pea Family.)

Examine the dry bean seeds furnished. On one side note the HILUM. At one end of the hilum lies a tiny heart-shaped CARUNCLE, but it is so small that it does not conceal the hilum as in the Ricinus seed. Atits other end lies a minute hole, the micropyle.

Examine two soaked seeds of bean furnished. One has had its micropyle covered with vaseline; the other was untreated. What is the difference between them? What then is one use of the micropyle?

A. Make a sketch 4 cm. long of the face of the soaked seed to show the hilum.

Remove the seed coat. Within lie two halves of the bean attached on one side to a small cylindrical structure. What is it? Toward what does this structure point? Separate the halves of the bean (what are they) and what appears? You are dealing with exactly the same parts as in the castor bean except that there is no endosperm and the embryo is more strongly developed. The two small leaves and the tiny EPICOTYL constitute the PLUMULE.

B. Draw the embryo from the face with testa removed.

C. Draw the parts visible when one cotyledon is removed.

How do the cotyledons differ from those of the castor bean? Would it seem probable that the cotyledons could form as efficient seed leaves as in the castor bean? At one time there was endosperm in this seed but the cotyledons began to feed on it when young and absorbed it all into themselves. What is the difference between garden bean and castor bean in this respect?

We will now study the germinating bean. Note how parts develop and compare with the castor bean.

D. Draw the germinating bean. Label cotyledons, epicotyl, first leaves, hypocotyl, primary root, secondary root.

The established seedling. The following points are to be noted.

1. What happens to the cotyledons at first; what eventually? Why?

2. Compare young and old leaves as you did in the castor bean.

E. Draw the growing plant.

F. Draw cotyledon, first and second leaves side by side.

G. Summary and conclusions:
   1. Concise description of seed and seedlings.
   2. Advance or modification over castor bean.
   3. Result on functional power of cotyledons.

Exercise 4. The exendospermous seed of pea.

Examine the soaked seed. It belongs to the same family as the bean (Leguminosae) and is little different in anatomy except that the cotyledons are more bulky. You will see what this has led to. Open the seed - observe hemispherical cotyledons - hypocotyl and plumule.

A. Draw the embryo from the face with testa removed.
Examine seedlings well advanced in germination. What important difference over the last two studied in position of cotyledons? Of color of cotyledons with same in bean. What part of embryo has grown and pushed out of soil? Label it. What are the first leaves like? They represent stipules only. Is there any evidence at all of petiole or blade? Why don't the cotyledons attempt to serve as leaves (green) as they do in castor bean and garden bean?

B. Draw the germinating pea so that the seed part is 1.5 cm. in diameter. Show ground level.

C. Summary and conclusions:
   1. Advance over garden bean and result on method of germination.

C. Construct a series of diagrammatic figures of the three germinating seedlings just studied with seed parts attached, and indicate homologous parts in each seedling.

The seedlings so far studied all have two cotyledons and belong to the division of seed plants known as dicotyledons. We will now study a member of the other division of seed plants: the monocotyledons. - Practically all monocotyledons have endospermous seeds

Exercise 5. The Onion Seed (Liliaceae - Lily Family)

Study the germinating onion seed furnished you, and verify the following description.

From the endospermous seed there comes out first the tip of the HYPOCOTYL just as in the seeds already studied. This moves downward in the soil. Slowly the single long COTYLEDON is drawn from the seed. Don't get confused just because it is elongated and not oval as in the bean or pea. It turns green - a primitive feature - and a strong arch with a knee in it develops. If hypocotyl is present at all it is very short - a mere knot. There is no apparent difference between hypocotyl and cotyledon. Sometimes the seed is pulled out of the soil into the air. Last of all the PLUMULE begins to grow from what seems to be the side of the cotyledon. It really is enclosed for some distance by the cotyledon sheath. Strip open the sheath and follow the plumule downward to hypocotyl region.

A. Sketch the germinating seedling twice natural size and show where plumule has its origin.

B. How do you imagine that the monocotyledonous seed came into being? Could it have arisen from an advanced type like bean or pea?

C. Draw a reconstruction of a purely hypothetical ancestor of the onion in the process of germination.

Exercise 6. The date seed and seedling. (Palmaceae: Palm family)

How does this seedling differ from that of the onion? Compare the shape of the first leaf with one from an old tree.

A. Sketch the seed and seedling natural size. Show level of ground and point where plumule has its origin.

B. Sketch the mature leaf much reduced.

Exercise 7. The corn grain and its germination.

Note in the soaked grain the shield-shaped single COTYLEDON and the yellow ENDOSPERM.

A. Sketch the grain from the face, two times natural size.

Split the grain through the small diameter and note the small EMBRYO lying on the face of the cotyledon. It has well developed ROOT and PLUMULE.

B. Sketch the longisection on a scale of 3.

Study the seedling and note what has happened to hypocotyl and epicotyl. Does the cotyledon leave the grain?

C. Draw the seedling about twice natural size and label cotyledon, endosperm, primary and secondary roots, adventitious roots, first node of growth, leaf sheath, leaf.

To what use has the cotyledon been adapted? (Important)!

Exercise 8. Summary: How do onion, date and corn show a series comparable to that of castor bean, garden bean, and pea? What, however, is the difference in function of the cotyledon in the two series?

Having seen how the young plant comes into existence we may now proceed to a study of the parts of the developed plant. A logical sequence may well be root, stem, leaf, flower, fruit and seed. Thus we shall come back to the starting point.

The Root - Subterranean.

Exercise 10. Fibrous root system of a small tree.

You have already studied the root of an herbaceous plant and have learned to recognize its parts. Observe the root system of a small tree. Is there a main root? The irregular branching and distal division into fibers is noteworthy as is also the corky layer which covers it. The cork often appears covered with longitudinal clefts due probably to what fact? Do any of the roots show flattened or hollowed areas on their surfaces? To what are these probably due? Consider the intense strains to which the root system of old trees is subjected. Is it adapted to these?

A. Sketch the root system accurately.

Exercise 11. The tap-root of carrot or parsnip.

How could this root be derived from one like that of the tree just studied? Can you see any advantage in the elongate form? Alfalfa has an extremely long tap root and is a remarkable plant for dry land farming. Why? Sketch root 2/3 natural size. Are lateral rootlets present at all? Split the root longitudinally through the center and note where the lateral rootlets originate. Peel away the bark. How did these rootlets reach the outside? This bark consists of three layers: (1) an outer delicate skin or EPIDERMIS, (2) a thick mass of CORTEX and an inner zone of PHLOEM. Inside the bark lies the WOOD and PITH. Cut a cross sectional slice through the root. Hold to light and note the whitish WOOD-RAYS running through the wood and phloem. Inside thw wood is found the pith.

Draw the root showing both its longitudinal and transverse aspects.

Taste a bit of the cortex. What seems to be present? Of what value can it be to the root? How shall we account for the swollen form of the root? What part of the carrot or parsnip root probably takes in water and salts? The main part of this root then has adapted itself to what function? The carrot and parsnip are biennial plants. How is this intimately related to the root form?

The dahlia; sweet potato; turnip and beet are also provided with storage roots.

Exercise. Adventitious roots: PARSONSIA or Sugar Cane

Observe cuttings that have been kept some time in water. The white roots which have come from the stem are conspicuous. (Of what possible advantage to a plant can this be in nature? Of what value to horticulturists is this ability of plants to form adventitious roots?)

A. Sketch the base of the cutting with its adventitious roots.

Exercise 13. Adventitious roots: Bryophyllum.

Observe the leaves of this curious plant which have been lying on wet sand and see what has happened. What other leaves will do this?

A. Sketch the leaf with the young plants and ADVENTITIOUS ROOTS:

B. Write a paragraph to explain the value to the plant of this ability to throw out adventitious roots. What value to gardeners? To your previous list of root adaptations you may add another. What?

The root - Aerial

Exercise 14. Climbing roots. FICUS Stipularis.

Pieces of stem will be furnished. Note on which side of stem the roots originate and how they move away into dark crevices. Such roots always move away from light into the darkness and are said to be negatively phototropic. What adaptation to life conditions is evident? In what class of roots will you place these climbing ones?

A. Sketch the piece of stem given you.

Exercise 15. Prop roots: The corn plant.

Do they seem to be of any other use than for support? Here is another interesting adaptation of aerial roots. Whence do they spring. Note that they arise endogenously and break thru the outer tissues. Are other sets developing higher up? Such props are sometimes so extensively developed in some tropical plants as to conceal the whole stem. (Ohia, Banyan)

A. Sketch the base of the corn plant with is prop roots.

Exercise 16. Air roots for water absorption and food making.

Observe the aerial orchid and its pendent roots with papery covering. This paper outer layer is called the velamen and soaks up rain water or dew like a sponge. Note that the root is green underneath the white covering. This green matter (chlorophyll) is of course particularly characteristic of leaves. You will learn that it is absolutely necessary to a plant which makes its own food out of gases and water.

A. Sketch one of the orchid plants.

B. Write a summary of the ideas developed from your work on roots. To assist you the following outline is suggested:

The subterranean root
1. Primitive functions
2. Secondary functions
    a. The biennial habit and adaptation to storage
    b. The effect of cultivation on storage
3. Adventitious roots: importance to plant; to gardeners.

The Aerial Root

1. Climbing adaptation
2. Adaptation to support
3. Adaptation to water absorption and food making.

THE STEM AND ITS MODIFICATIONS

Recall the study of the complete plant with which the laboratory work started and the facts learned about the stem.

Exercise 17. The study of a tree stem in the dormant condition:

From simple inspection and comparison what are some of the differences between this stem and that of the green plant previously studied? That plant wilted rapidly in the warm dry air. Why doesn't this one? What caused the horseshoe-like SCARS on the branch? The "nails" are the leaf trace scars. What stands above each scar on the last year's growth? How does last year's growth differ in color from the older parts? Just how far backward does last season's growth extend? What separates it from the growth of year before last? What stood at that point last spring? What produced these marks? How many nodes and internodes are represented by the girdle? On the older parts of the main axis do you still find buds? What does take their place? (Sometimes one does find so-called "RESTING BUDS" on such old growth). How old is the branch you have? Cut a cross-section through the base of the branch and count the rings of wood. Note the many tiny breaks in the epidermis scattered over the twig. These are called LENTICELS, through which gases pass in and out.

A. Sketch the whole branch natural size.

B. Sketch the area of junction between two years' growths to show the girdle of bud scars. Make drawing 2.5 cm. in diameter.

C. Sketch a leaf scar magnified to 2 cm.

Observe the TERMINAL BUD. Note how the scales overlap like shingles on a roof. They are said to be IMBRICATED. How does it differ from the terminal bud of the growing plant studied in Ex. 1. Carefully remove the scales. There is evidence that they are the flattened bases of leaf stalks. Search for it.

D. Sketch a developing leaf bud, and label BUD SCALES, SHOOT, and LEAVES.

E. Write up this work according to the following outline:

1. Markings on twig and their significance.
2. Method of computing age of branch.
3. The leaf buds.
    a. Positions
    b. Structure
    c. Development of parts in spring.
4. The adaptation of the branch to dormant conditions.
5. A comparison of such buds, etc., to those of a vigorously growing plant.

Exercise 18. The Stem. Its adaptations to leaf display; Phyllotaxy.

On the stem furnished select a certain leaf or bud and then move up the stem until you come to the next leaf directly above it. Stick two pins into the bases of these leaves. Starting with Number 1 count the leaves between Numbers 1 and 2. How many times do you circle the stem? If there are three leaves and you make one turn the plant has a 1/3 phyllotaxy; if there are five leaves in two turns the phyllotaxy is 2/5. The various phyllotaxies form a series as follows:

1/2, 1/3, 2/5, 3/8, 5/13, 8/21. What curious fact do you observe in the series? How do such arrangements conduce to the idea expressed in the heading to this exercise?

A. Write out your observations and inferences concerning Phyllotaxy. No drawing is required.

Exercise 19. Rosettes:

Study the rosette plant given you. How do the leaves avoid shading one another? Such an arrangement constitues a leaf mosaic. Many perennial herbaceous plants pass the winter in this condition. What advantage is it? Such plants are sometimes called stemless (acaulescent). Split the rosette through the crown and see if it really is stemless.

A. Sketch the half of the plant very carefully to show both top and cut edge. Remember each line in your drawing must have a definite meaning.

Exercise 20. Creeping, Climbing, or Twining Stems:

Such as are available should be noted and their adaptation to leaf display thoroughly realized. What advantage to such a plant is its weak stem? Many such stems climb on walls and form elaborate leaf mosaics.

A. Write a brief description of these climbers or twiners.

Exercise 22. Modifications of Secondary Stem Axes.

Tendrils: To assist the weak stem of certain climbers in getting into the best light relation accessory stem modifications called tendrils are often instituted.

Tendrill-bearing plants available will be furnished. Members of the gourd family - comprising squashes, cucumbers, and melons - are provided with remarkably sensitive tendrils. The Passion flower is also of interest in this respect and the stem nature of its tendril is proved by its position. How?

A. Write a paragraph summarizing your work on tendrils.

The Stem: Its Adaptation to Food and Water Storage.

Modification of upright axes.

Exercise 23. The Kohl Rabi. The nature of this storage organ is evident from simple inspection. It is a stem behaving much in the same way as does the root of the parsnip.

A. Sketch the specimen and show the ground level.

Exercise 24. The Corm of Crocus or Gladiolus. Study the Corm furnished you. Did it grow above or below the surface of the soil? What is the true nature of the papery coats on the outside? Are they of any value? What proves that the corm is a stem and not a root? Are there any LEAF BUDS on it?

A. Sketch the corm both as a whole and as cut longitudinally.

Modifications of the Creeping Axis.

The Stolon - Runner Series.

Exercise 25. STOLONS. Observe the radiating shoots from the base of the plants. These are stolons. Do any show evidence of rooting at their tips? Such tips take root and again send out stolons. What is the advantage of such a method of growth?

A. Carefully sketch the plant.

Exercise 26. THE RUNNER OF STRAWBERRY or of Jacquemontia. The runner is but an extensively developed stolon. Is the runner or the stolon more efficient?

A. Sketch the plant with is runners.

B. Write a paragraph on stolons and runners considering their uses, progressive efficiency, and horticultural importance.

If the stolon or runner becomes subterranean another interesting function is added to that of reproduction.

Exercise 27. The Rizome-Tuber Series.

Rhizome of Witch Grass. Study carefully and explain why this structure is not to be called a root. If it is a stem it should show NODES, INTERNODES, NODAL BRANCHES or BUDS and LEAVES. Is there evidence that old annual stems have died away in years past? Where do roots come out? What function besides that of reproduction can you infer?

A. Sketch a portion of the Rhizome, three times its natural size.

Exercise 28. THE RHIZOME OF NUT-GRASS (Cyperus rotundus). This interesting rhizome is to be carefully compared with the last. How does it differ? Cut a thin slice from the/end of the rhizome and apply a little weak iodine. Result? swollen What meaning? Does this rhizome bear NODES, LEAVES, BUDS.

A. Sketch the rhizome.

Exercise 29. The Potato Tuber. State evidence that this too is a stem, not a root. What are the "EYES"? Look at the ridge under each eye for a tiny membraneous scale. What is it? When potatoes are exposed to light in a hill what happens?

A. Apply a drop of iodine to the cut surface of the potato. Result?

B. Draw the whole tuber natural size.

C. Draw the eye and its attendant parts, three times natural size.

D. Write a paragraph considering the rhizome tuber series.

Exercise 30. Modifications for Defense. (?) Observe the branches available and note that some of the spur shoots show a tendency to become pointed and harsh. Some have believed that these form a means of defense against browsing animals.

A. Sketch a branch with typical sharp spurs.

Exercise 31. Note the progressive perfection over the above. Why must these thorns still be considered as branches?

A. Sketch the branch with its thorns.

Exercise 32. The prickles of the raspberry: Are these of the same nature as the thorns you have been considering? Explain. What structure of irregular distribution have we found on plant stems which could give rise to such prickles?

A. Sketch a portion of stem, four times natural size.

B. Write a resume considering this series of thorns.

Stem modification to subserve the leaf function.

Exercise 35. Muhlenbeckia platyclada (The seaside grape)

Interpret the flat members of this curious plant. Are there any leaves at all?

A. Sketch portions to show its features.

Ruscus and Phyllanthus: If either of these plants is available it will be furnished. Work out the morphology of the leaf-like members (CLADOPHELS)

B. Sketch portions of the plants.

C. Draw a portion of the plant.

Exercise 37. The Cactus Plant. (Apuntia and Cereus). These odd plants run into many forms. The flattened types are particularly interesting from our standpoint. In what places do Cacti grow? To what other use besides the leaf function are these stems being put? Many of them bear small leaves when young but these quickly dry up and fall off. The spines are probably to be interpreted as a branch system.

A. Sketch one of the plants.

B. Write a resume of the subject of stems serving as leaves.

C. Construct a careful outline and summarize the whole subject of the stem and its modifications to subserve various functions.

THE LEAF AND ITS MODIFICATIONS

Leaves in exactly the same way as stems can be moulded into many forms and adapted to many uses. In this regard there is such a richness of material that we shall study some of the most easily obtained and striking cases. They will be taken up according to the following scheme:

1. Leaf adapted to climbing
2. Leaves adapted to food and water storage
3. Leaves adapted to reproduction
4. Leaves adapted to the water life
5. Leaves adapted to eating meat (carnivorous nutrition)
6. Leaves adapted to withstanding arid conditions.

Exercise 38. Climbing leaves. Examine the leaves furnished you and study their special adaptation for climbing. Draw one leaf of each type enumerated above. Write a resume of leaf adaptations to the climbing function.

Leaves adapted to storage.

Exercise 39. The Agave or Century Plant. How do these leaves show that they are used for this purpose? Where do Agaves grow naturally? Is there any relation between the thick leaves and the rare flowering periods? No drawing is required. The Agave leaf may be called a dual purpose leaf. Why? Let us study now a set of leaves which are used for a single function.

C. Construct a careful outline and summarize the whole subject of the stem and its modifications to subserve various functions.

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Exercise 40. The Cabbage Plant. Split a small cabbage through the middle. What name have we applied before to a set of leaves borne on a short axis and folded close together? Are there any axillary buds present? How do the inner leaves differ from the outer? Could they make food? Is a cabbage biennial or perennial?

A. Sketch the longitudinal section somewhat diagrammatized.

If the cabbage should retreat underground and its leaves should become even thicker it would constitute a bulb.

Exercise 41. The Hyacinth Bulb. Split the bulb lengthwise through the middle. Is its nature clear? Note the dry distal extremities of the scales. What part of the leaf does the fleshy white part represent? What stem modification is analagous to the bulb? What is the structure found in the middle.

A. Draw the longitudinal section of the hyacinth bulb.

B. Write a resume of the leaf in relation to storage.

Leaves adapted to reproduction.

Exercise 42. Leaves of a fern will befurnished. How would the small plantlets become isolated and free eventually?

A. Sketch a portion of the leaf and write a brief note (consider your work on Bryophyllum also);

Leaves adapted to the water life.

Exercise 43. Growing water-plants will be furnished as well as preserved material. How is the whole plant adapted to the water life? How are the leaves particularly adapted? Are those under water the same as those on the surface? Can the upper surface be wet?

A. Draw a plant to show the weak habit and the two kinds of leaves.

The Water Hyacinth. This curious plant is a bad pest in the south as it blocks up the streams. How does it keep itself afloat? A section of one of the petioles will be handed around.

B. Sketch the growing plant and take notes on the structure of the petiole.

Leaves adapted to eating meat.

Exercise 44. Such specimens of these strange plants as can be obtained will be furnished and their habits explained. The three following are not rare in New England, the Sundews, the Pitcher plant, and the Aquatic Bladderworts.

A. Make sketches and take notes.

B. Write a resume on the subject of Leaf Adaptations.

Exercise 45. We shall now take up quite a different kind of work on the leaf from any that we have so far considered. The nature of the leaf furnishes an important means of identifying ' l plants. Before we can use them for this purpose however we must become familiar with many terms used to describe them. Three methods for fixing these in mind are to be used. Some students retain such facts better from a diagram of the object; others from the real thing; others from a description. Let us use all three methods. Simple keys have been prepared. Classify each leaf by use of the keys as to its voination, shape, apex, base, margin divisioning and surface character, Sketch each one as accurately as possible and underneath it place its Latin name and its description. If single terms will not accurately describe the leaf use compounds such as lanceolate-ovate or serrate-dentate.

Key to Leaf Veination

A. Leaf with numerous, approximately parallel veins, connected by MINUTE STRAIGHT veinlets. Margin of leaf usually entire. The typical leaf of Gymnosperms and Monocotyledons ------------Parallel veination.

(The three types of Parallel Veination are:

B. Veins running from midrib or costa to margin ------------Costal-veined or nerved

B. Veins running from base to apex.
  C. Veins undivided and approximately parallel - Basal-nerved or veined.
  C. Veins repeatedly forking (dichotomizing) but keeping roughly parallel. A fan-like leaf, Flabellinerved.

A. Main ribs serveral which may run straight to margin or may break up into slender veins and veinlets. Ribs connected by an ANASTOMOSING NETWORK (reticulum) of veins and veinlets. Margin of leaf entire or cut. The typical leaf of dicotyledonous plants. net or reticulate veination

(The two types of net veination are:

B. Main veins springing from midrib producing a feather-like effect. ---------------------------Pinnately net-veined.
B. Main veins springing from apex of petiole like fingers of a hand. ----------------------Palmately net-veined.

Key to Leaf Shapes

A. Leaf longer than broad.
  B. Main body of about the same width throughout.
    C. Narrow and ribbon-like; often many times longer than wide. Typical of grasses -------------Linear
    C. About twice or thrice as long as broad-----Oblong
  B. Broadest below or in the middle
    C. More than twice as long as broad; widening above the base and tapering to the apex.----Lanceolate
    C. Not more than twice as long as broad.
      D. Broadest below.
        E. Shaped like the section of a hen's egg; viz the outline a flowing curve.----Ovate.
        E. Tapering by straight lines to the apex; viz. shapes like the Greek letter Delta--Deltoid
      D. Brâadest in the middle - the outline a flowing ellipse.

Exercise 46. Go through this work on the leaf from page 33-38 and construct an ideal sketch of each - shape, margin apex, etc. and hand in for correction.

Key to Inflorescences

A. Main axis of inflorescence not terminated by a flower: hence the axis may continue growth for some time. Indeterminate Inflorescence
  B. Lateral axes springing from axils of bracts, unbranched, and each terminating in a flower.
    C. Flowers on pedicels.
      D. Main axis elongate and pedicels about equal in length — Raceme
      D. Main axis shortened. The lower pedicels elongate to form a rather flat topped inflorescence — Corymb
      D. Main axis undeveloped. Pedicels radiating and about equal in length — Umbel
    C. Flowers sessile
      D. Main axis very short - leading to a globose — Head
      D. Main axis elongate
        E. Main axis erect and fleshy — Spadix
        E. Main axis erect and not fleshy — Spike
        E. Main axis scaly bracted and often drooping — Ament or catkin
  B. Lateral axis branched one or more and bearing clusters instead of single flowers.
    C. Irregularly racemose or corymbosely branched — Panicle
    C. Regularly compound leading to compound racemes, compound umbels, compound corymbs, compound spikes

A. Main axis of inflorescence terminated by a flower hence this axis cannot continue growth but lateral axes must take up the development of the inflorescence and in their turn give rise to terminal flowers. Determinate Inflorescence
  B. Flower stalk single and terminated by one flower--Scape
  B. Flower stalk branching
    C. Two or more lateral axes developing at a node--Cyme
    C. Only one lateral axis developing at a node--Sympodium or False Raceme

Exercise 47. Construct an ideal diagram of each of the above inflorescences. Use lines for axes and circles for flowers. Do not omit bracts.

The Flower

A foundational flower type - Nymphaeaceae Family:

Exercise 48. We will study first as a type a very simple and primitive flower, that of the water-lily (Castalia sp.). What terms will you apply to the leaf shape, margin and base? The flowers are borne on PEDUNCLES. Each consists of an outer set of members constituting the PERIANTH. Are the outermost ones colored at all differently from the innermost? In many flowers the outermost constitute a special green cup or calyx made up of sepals, while the inner brighter colored ones constitute a corolla made up of petals. We call all the outer members SEPALS, or collectively a CALYX. (It may also be called a diplochlamydeous perianth, (etymology?) How many sepals are there? Does the number vary in different flowers? Do they show any chlorophyll? How many petals are there? Does the number of PETALS vary? Inside the perianth lies the ANDROECIUM. The members are called STAMENS or MICROSPOROPHYYLS. Their large and indefinite number is again a primitive character. Inside the androecium stands the GYNCECIUM made up of several united CARPELS or MEGASPOROPHYLLS.

A. Draw the flower from its facial aspect 5 cm, across. Remove the perianth. Observe that the sepals rest on a slightly enlargee portion of the pedicel called the RECEPTACLE or TORUS. Note particularly the shape and veination of the sepal. To what category of organs does it belong?

B. Draw the sepal.

Detach several stamens and study with the lens. The stalk is called the FILAMENT; the distal swollen part, the ANTHER. If the anther is withered take fresh stamens from a nearly opened bud. See if you can determine that the anther consists of a middle CONNECTIVE and four elongate pouches (seemingly two), the pollen or ANTHER SACS (also called pollen cells, loculi, or MICROSPORANGIA).

C. Draw a stamen whose anther has not yet opened. (Make anther 4 cm. long)

D. Draw a stamen with opening anther on the same scale. Label the yellow granular POLLEN GRAINS or MICROSPORES.

Remove all the stamens from a flower rather advanced in age. The gynoecium alone remains on the torus. Carefully note the conical form of the TORUS and the SCARS left by the fall of perianth and stamens. These scars collectively form a low spirial around the torus. Such an elongate torus with spiral arrangement of floral parts is again very primitive. Approximately how many nodes and internodes make up this flower of castalia. Define a flower and explain why a flower with conical torus is more primitive than one with flat torus.

E. Draw the whole structure 4 cm. in diameter.

Study the gynoecium. This has become so modified that its structure may be confusing unless it be compared with that of a more primitive gynoecium.

F. Draw the gynoecium 3 cm. across, leaving sufficient room for labeling the different parts later on.

G. Draw a cross-section of the gynoecium.

Preserved material of Caltha is at hand showing the gynocium only, the other floral members having fallen off after flowering time. Note the TORUS AND THE SCARS left by perianth members and stamens. Note that the gynoecium is composed of a variable number of separate CARPELS. Such a synoecium is called an APOCARPOUS GYNOECIUM (etym?)

H. Draw.

1. Draw an individual CARPEL of Caltha. Its elongate and swollen basal part is called the OVARY. Its roughened tip constitutes the STIGMA. What was received here? Many carpels have an elongate narrow neck or style between ovary and stigma but in Caltha the stigma is practically sessile.

Slice open a carpel longitudinally with the razor. Its cavity is called the cell or LOCULUS. Inside it lies the OVULES. What will they become when mature? To what region are they attached? Do their MICROPYLES point inward toward the locular cavity or away from it toward the wall? What term is applied to their tiny stalks?

J. Draw the opened carpel 2.5 cm. across.

K. Slice open a carpel transversely and make a sketch of the section on thecsame scale.

L. Turn back to your drawings of the water-lily under F and G and label, when possible as for Caltha. Castalia differs cheifly from Caltha in having a SYNCARPOUS GYNOECIUM and not an apocarpous one (etym?) Be sure you understand their homologous structures. and how the Castalia gynoecium might have evolved from that of a flower similar to Caltha.

Exercise 49. A Liliaceous Flower. This flower shows considerable advance over those of Caltha and Castalia. Note first of all that the whole flower is put together on a plan of three.

Without tearing the flower determine how many STAMENS and what is their position as regards SEPALS and PETALS? How many PISTILS? How many OVARIES, STYLES and STIGMAS? Suppose one were to blend three carpels of Caltha into one but leave their tiny curved stigmas free would the result throw any light on the structure of the pistil here? It constitutes a syncarpous gynoecium, Caltha has an apocarpous gynoecium.

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A. Draw the whole flower in its natural position and on a scale such as to show parts clearly.

Remove a stamen. How are the ANTHERS fixed to the FILAMENT? They are either ADNATE or VERSATILE.

B. Draw the stamen.

Remove all the stamens and draw the pistil. With sharp scalpel or razor slice the pistil through the ovary and examine the cut. section with lens. How many cavities or CELLS in the Ovary? There are then how many CARPELS fused together to make up this COMPOUND PISTIL? How many OVULES are visible? Slit one of the cells open lengthwise. How many rows of ovules? The ovules are attached by their FUNICLES to the fleshy axis of the ovary. Such ovules are said to possess AXILLARY PLACENTATION.

C. Make a careful sketch of the corss-section of the ovary 6 cm. across.

Exercise 50. We will now study a rather complicated flower, that of the pea family. At first glance how does it differ in its regularity from Castalia or Dracaena? It is wonderfully adapted to cross pollination by bees.

Starting as before with CALYX how many SEPALS do you find? (Look very closely at the lower or ventral lobe) Are they free as in castalia and Dracaena or UNITED INTO A TUBE? The corolla at first sight seems to have how many PETALS? Actually there are five for the two which stood below have fused together to form the curious boat-shaped structure. The parts of the corolla in such a flower have received special names. The large upright upper petal is called the STANDARD. The two lateral ones are the WINGS while the double bottom one is called the KEEL. The keel is the landing place for insects. Press down with your pencil on the Keel. What happens? Can you see how the bees' ventral surface would be powdered with pollen and how the stigma might receive a dusting with pollen brought from another flower? Note that when the anthers are sheeding pollen the stigma is concealed; after the anthers wither the sh style elongates and its stigma is exposed. A flower whose anthers mature first is called proterandrous. Devise a term for ones whose pistil matures first.

A. Draw a partial side view of the whole flower 4 cm. long.
B. Remove the whole calyx and draw it 2 cm. long.
C. Carefully remove standard, wings and keel and draw each one.

Now examine the ANDROECIUM and GYNOECIUM. With needle carefully separate the stamens and pistil. The ten stamens have their filaments fused into a tube which embraces the pistil. Such an arrangement is said to be Monadelphous (one brotherhood).

E. Breadth not more than one-half the length
Elliptical
E. Breadth considerably more than one-half the length --------------------------Oval

B. Broadest above the middle
C. Inversely lanceolate; viz., more than twice as long as broad, widening below the apex and tapering to the base.
D. Tapering by gentle curves Oblanceolate
D. Tapering by straight lines. Cuneate or wedge-shaped
C. Broad and rounded above - tapering abruptly below into a long narrow "handle" like a spatula--------Spatulate
C. Inversely ovate, viz. somewhat like the section of a hen's egg with the small end down.
D. Tapering downward by curved lines--------Obovate
D. Tapering downward by straight lines.-----Cuneate or Wedge-shaped

A. Leaf not longer than broad
B. Circular in outline or nearly so. Orbicular or Rotund
B. Elongate transversely with broad heart-shaped base
Reinform or Kidney Shaped

Key to Leaf Apices

A. Leaf not turned in at the apex.
B. Apex sharp.
C. Leaf tapering to a point (viz. by lines concave inward)
D. Tapering gradually ---------------Acuminate
(If the apex is long and tail-like, use--
Caudate
D. Tapering abruptly to a small point, like a tooth.-----------------Cuspidate
C. Apex a sharp point like a projection of the Midrib.-----------------------Mucronate
C. Apex an acute angle (viz. by lines convex outwards)
Acute
B. Apex not sharp.
C. Blunt or rounded --------------------------Obtuse
C. As if cut off transversely by shears.......----Truncate
A. Leaf turned in at the apex.
B. Reentrant angle a very slight depression-----Retuse
B. Reentrant angle a decided notch-------------Emarginate
B. Reentrant angle producing a heart-shaped apex.-Obcordate

Key to Leaf Bases

A. Leaf petiole attached to lower margin of leaf
  B. Leaf base not turned in to form a notch
    C. Base terminating in an acute angle----------Acute
    C. Base tapering to the petiole---------------Acuminate
    C. Base blunt -------------------------------- Obtuse
  B. Leaf base rounded and turned in (The following terms apply not only to bases but to a more or less ovate leaf with such a base.)
    C. Lobes rounded
      D. Lobes not elongate into ears
        E. Lobes equal in size ---------------Cordate
        E. Lobes unequal in size -------------Oblique Cordate
      D. Lobes elongated into ears--------------Auriculate
    C. Lobes sharp pointed
      D. Directed backward parallel to the petiole
        Sagittate or Arrow Shaped
      D. Flaring away from the petiole
        Hastate or spear shaped

A. Leaf petiole attached to blade on the under side some distance from the margin Peltate or Shield shaped

Key to Leaf Margins

A. Margin an even continuous curve-------------------Entire

A. Margin not an even continuous curve.
  B. Margin beset with teeth.
    C. Teeth sharp
      D. Teeth regular
        E. Teeth small and directed forward like those of a saw-----------------------Serrate (or dimin. Serrulate)
        E. Teeth larger and not directed forward.---- ---------------- Dentate
      D. Teeth irregular, cutting less than one-half way to the midrib.----------------Segmentation
    C. Teeth blunt and directed forward-------Crenate
  B. Margin a pronounced wavy line
    C. Depressions very slight-----------Repand or Undulate Sinuate

Leaf Segmentation

A. Incisions or lobes rounded and reaching not more than half way to midrib --Lobed
A. Incisions or lobes sharp and reaching half way or somewhat more to midrib.------------------------------------Cleft
A. Incisions or lobes either rounded or sharp.
  B. Incisions reaching almost but not quite to midrib--Q Parted
  B. Incisions severing the blade into distinct leaflets.
    Divided

The leaf then becomes compound

Express number and disposition of parts as follows: Pinnately Five-lobed, palmately three-cleft, - parted - divided, etc.

Compound Leaves

Express number and disposition of leaflets as follows:

Pinnately 10-foliolate leaf; palmately 3-foliolate (or trifoliolate). Pinnately unifoliolate. (Think carefully. Such a leaf is present. Primary pinnae of the leaf may also be pinnate or palmate. Then use terms like: bipinnate, tripinnate, etc., or use decompound, as a general term.

Attachment

As to the Stem.

A. Leaf without a stalk or petiole
  Leaf attached to stem by narrow base -----------Sessile
  Leaf attached to stem by broad, partly circling base
  Sessile and Clasping
  Leaves opposite and seeming to have their bases grown together around the stem (stem perfoliate)--- -Connate
  Petiolate

As to Surface

A. Leaf with neither hairs nor other removable material on the surface--Glabrous
A. Leaf surface hairy
  B. Hairs soft to touch
    C. Hairs short and erect
      D. Hairs densely aggregated like very fine pile on velvet---------------------------Pubescent
      D. Hairs soft but longer and individually distinct
      Pilose
    C. Hairs soft to touch but appressed
      D. Hairs straight and matted-------Tomentose
      D. Hairs twisted, curled and matted- Wooly
  B. Hairs harsher
    C. Hairs bristle like but not particularly harsh to touch
    Hispid
    (If weaker the term hirsute may be used)
    C. Leaf decidedly harsh to touch when stroked backwards
    Scabrous
A. Leaf surface bearing a coating other than hair
  B. Material of coat a whitish waxy bloom----------Glaucous
  B. Material of coat a whitish dust or scurf------Pulverulent

Exercise 46. Go through this work on the leaf from page 33-38 and construct an ideal sketch of each - shape, margin apex, etc. and hand in for correction.

Key to Inflorescences

A. Main axis of inflorescence not terminated by a flower: hence the axis may continue growth for some time. Indeterminate Inflorescence
- B. Lateral axes springing from axils of bracts, unbranched, and each terminating in a flower.
  - C. Flowers on pedicels.
    - D. Main axis elongate and pedicels about equal in length — Raceme
    - D. Main axis shortened. The lower pedicels elongate to form a rather flat topped inflorescence — Corymb
    - D. Main axis undeveloped. Pedicels radiating and about equal in length — Umbel
  - D. Flowers sessile
    - D. Main axis very short - leading to a globose — Head
    - D. Main axis elongate
      - E. Main axis erect and fleshy — Spadix
      - E. Main axis erect and not fleshy — Spike
      - E. Main axis scaly bracted and often drooping — Ament or catkin
- B. Lateral axis branched one or more and bearing clusters instead of single flowers.
  - C. Irregularly racemose or corymbosely branched — Panicle
  - C. Regularly compound leading to compound racemes, compound umbels, compound corymbs, compound spikes

A. Main axis of inflorescence terminated by a flower hence this axis cannot continue growth but lateral axes must take up the development of the inflorescence and in their turn give rise to terminal flowers. Determinate Inflorescence
- B. Flower stalk single and terminated by one flower--Scape
- B. Flower stalk branching
  - C. Two or more lateral axes developing at a node--Cyme
  - C. Only one lateral axis developing at a node--Sympodium or False Raceme

Exercise 47. Construct an ideal diagram of each of the above inflorescences. Use lines for axes and circles for flowers. Do not omit bracts.

Part II

~~PART I~~

110 copies

THE ANATOMY AND PHYSIOLOGY OF SEED PLANTS

Up to date ~~Last spring~~ our studies dealt wholly with macroscopic features of the seed plants. Now we begin to go into details carrying our investigation of living plants as far as modern instruments will permit. After learning how the plant organs are put together (Anatomy, Histology and Cytology) we shall then logically take up their various activities (Physiology). Thereafter ~~course will end with a very brief resume of the various kinds of plants.~~ we will study systematically the Plant Kingdom beginning with the simplest of plants and ending with the most complex.

The Microscopic Anatomy of the Plant (Histology and Cytology)

You have seen that plants and plant parts differ much in texture. Some parts are soft and watery; some hard and woody; some dry and papery, etc. These differences are due to the differences of the microscopic parts of which plants are composed.

Just as the walls of houses are sometimes made of hollow tiles so the plant is built of tiny structures which we call cells. These cells, however, are not mere empty boxes but each contains within itself a living substance known as protoplasm. The cell then is really a small mass of protoplasm enclosed by a cell wall. We shall first consider the cell in some detail, then advance to a study of cells aggregated into tissues, and finally learn how these tissues are combined to form the organs which make up the plant and how these organs work. The sequence of study will be the same as that of ~~last spring~~, (the previous laboratory work) viz.: root, stem, leaf, flower, seed.

The Structure of the Cell

Exercise 1. Elder Pith - A plant tissue (parenchyma) made up of dead cell walls.

With the dissecting lens study the bit of elder pith that is given you. Note that it is made up of very small compartments or CELLS.

Make a water mount of a cross section of the pith tissue, and observe it with the low power of the microscope. This magnifies the cells about 90 times. The CELL WALLS now appear. What is the effect on the image of turning the fine adjustment screw to a new focus? Note more or less abundant heavy, refractive circles seen in some of the cells. Do they ever occur in the water outside the section? What are they? Study them under changing foci and never bother with them again.

It is easy to see that the compound microscope gives but a two-dimensional image - a so-called optical section. If you have a transparent object on the slide how will it be possible to study successive planes or optical images in it from top to bottom?

What is the general shape of the cells and at about what angle do their walls meet one another? Is the inner contour of the cells sharply angular? Note that they are often broken apart at the angles to form INTERCELLULAR SPACES. Do any of the cells show their walls in surface view? Is the wall perfectly plain or is it perforated by holes (SIMPLE PITS)? What is the probable use of these pits? The chemical substance of the walls is cellulose $(C_6H_{10}O_5)_x$ Paper consists of a fairly pure cellulose.

A. Draw about 5 of these dead cells, each about 2 cm. across. In any drawing of cells always start the walls of an adjoining row as though your fragment had been torn from a larger tissue.

Carefully put on high power. The walls will now be seen to have a definite thickness. Each cell has its own wall and between the two lies a very delicate MIDDLE LAMELLA or cementing substance which binds them together so that all three form a single membrane separating the two cells. In the formation of intercellular spaces the cells split apart through the middle lamella. Find a SIMPLE PIT which has been cut by the razof. Is the middle lamella also perforated by the pit?

B. Draw a few cells under h. p. Make each cell 4-5 cm. across. Include an intercellular space. Show by a double line the thickness of the wall and suggest the middle lamella. Show pits in face view and in sectional aspect.

Study a longitudinal section of the pith with l. p. Try to find a place where the cells lie in rows. Those with triangular ends were cut practically through their middle.

C. Draw about 5 cells.

D. Construct a diagram of an idealized pith cell in 3 dimensions. Such a drawing is called a stereogram (Etym.). Add the simple pits to the figure. What is meant by saying that the cell is the unit of structure of plant and animal bodies?

A plant tissue made up of thin walled and essentially isodiametric cells is called PARENCHYMA.

ok

Exercise 2. The inner epidermis of the onion - living cells.

With the dissecting lens study the concave surface of the onion scale given you. Note the delicate cells. With the point of the scalpel and forceps remove a small piece of the epidermis free from underlying tissue and mount on a slide, free side of epidermis up.

How does it compare with the elder pith: in shape of cells, in presence of intercellular spaces, in cell contents? How many cells thick is the epidermis? Are there pits in the outer walls? Would such be of advantage to the plant? Are there PITS between the cells? Is the pit really a complete hole or channel running from one cell to another? Focus carefully.

A. Draw some half dozen cells as seen under l. p.

With h. p. look carefully along the walls or at the angles of the cells and find the protoplasm. It forms a layer covering the wall (Primordial utricle) and often extends in strands thru the sap vacule.

B. Draw some half dozen cells, each 6-7 cm. long.

Is there any evidence of an oval, more densely granular body - the nucleus - in the cell?

Turn on l. p. Remove the slide from the stage, take off the cover glass and add a drop of iodine solution. Draw off excess iodine with filter paper. The tissue should appear deep yellow. Add more water if necessary, and remount. What changes can you see?

Put on h. p. Now carefully study the nucleus. What might lead you to believe that it is either chemically or physically different from the rest of the PROTOPLASM? A distinction may then be made between NUCLEOPLASM and CYTOPLASM. Are NUCLEOLI present? Can you detect the wall of the nucleus? Is there more than one nucleus per cell?

Add the nucleus to your drawing in B.

Exercise 3. The Stamen-hairs of Tradescantia, or Squash.

These long hairs are made up of bead-like cells and active streaming motion is usually visible in the wall layer of CYTOPLASM and in the strands and cables of cytoplasm which traverse the SAP-VACUOLE. If available it will be given.

The hairs of squash and pumpkin leaves will show the same movement of circulation and may be substituted for Tradescantia. Iodine will bring out the NUCLEUS.

A. Draw the whole hair merely to show the form and numbers of the cells.

B. Draw two cells, each at least 4 cm. across and put in all the details observed. Show the direction of protoplasmic streaming in the threads by adding arrows.

Exercise 4. The leaf cells of Elodea. Tear off a young leaf from the plant and make a water mount. With l. p. observe the cellular structure of the leaf. What is the nature of the MARGINAL TEETH? Note the midrib. Is the leaf more than one cell in thickness? Look carefully at the cells on either side of the mid-rib. Do the contents show any trace of motion? If so, put on h. p. and study carefully. The CHLOROPLASTS are now plainly seen; what is their shape? Do any show evidences of dividing into two parts?

A. Draw a cell to show details of structure and add arrows to indicate the direction of movement of the contents.

Exercise 5. Epithelial cells from the mouth. Gently scrape the surface of the tongue with the finger nail and transfer the sediment to a drop of water on a clean slide. Add a drop of iodine solution. Study with low power. Is a heavy wall visible on these animal cells as in plant cells? A NUCLEUS? PROTOPLASM? Are the cells all shaped alike? Are they isodiametric? Such a tissue is called PAVEMENT EPITHELIUM. Your body, then, is made of cells as is that of a plant.

A. Draw a few cells as seen free and also adherent in plates.

Having studied the grosser features of the cell we may now turn to a more detailed study, particularly of the nucleus. This requires sections cut by special machine to about 5 microns in thickness and stained with analine dyes.

Exercise 6.

With l. p. study the section of a rapidly dividing tissue which is furnished. Note the large nuclei in the cells. Very carefully put on high power. Observe that the nucleus is imbedded in CYTOPLASM and surrounded by a NUCLEAR MEMBRANE. Inside the nucleus observe NUCLEOLUS or NUCLEOLI. You will also observe dots and masses of densely stained material. This is CHROMATIN supposed to be the bearer of all the hereditary characters of the plant.

A. Draw the cell with nucleus 2 cm. in diameter.

THE ACTIVITIES OF THE CELL - PHYSIOLOGY

Now that we realize in some measure how the cell is constructed, let us briefly study a few of its functions.

Exercise 7. The relation of the cell to water.

Two sets of beet slices have been prepared. One set stood in pure water over night, the other in 5% salt water. What difference is seen in their condition?

Exercise 8. Very thin sections of beet cut with razor will now be furnished. Make a water mount. Observe the red color. This is due to a pigment, anthocyanin, dissolved in water and contained in a large central SAP-VACUOLE. The protoplasm consists of a very thin layer just inside the cell wall. This layer has been called by Von Mohl the PRIMORDIAL UTRICLE. It is probably too delicate to be differentiated.

A. Make a sketch of a few cells under h. p.

Remove cover glass and put a drop of salt solution on the section. Add cover, draw off excess liquid and study again. What change has taken place? Where does the layer of PROTOPLASM (PRIMORDIAL UTRICLE) now lie? Cells in this condition are said to be plasmolyzed. What now lies between the protoplasmic membrane and the cell wall? Has the anthocyanin from the cell sap diffused outward?

B. Sketch a few cells in this condition and label PROTOPLASMIC MEMBRANE, SAP VACUOLE, CELL WALL.

Remove the section to a drop of pure water. Rinse well and in a few minutes examine again. Result? Why did the beet sections become limp in salt water? What is osmosis? Is the cell wall the osmotic membrane in our experiment? What is turgor and what is its significance to plants? Strong fertilizers are said to burn roots. What probably happens?

Exercise 9. Osmosis. The above osmotic interchange of water through membranes may be simulated by a simple physical experiment. In the laboratory is set up an apparatus to demonstrate this. Make sure that you understand the essential principles and see the relation to plants.

Exercise 10. Dialysis. How do salts enter the cell?

A considerable amount of common salt solution is to be prepared. To a small portion in a test tube a few drops of silver nitrate ($AgNO_3$) is added. Result. Repeat the same test on pure water.

A parchment sac filled with pure water is to be suspended in the salt solution. In a few hours repeat the silver nitrate test on the water inside the parchment sac. Result?

Suppose we imagine the parchment sac replaced by a young cell and immersed in soil water which always contains certain salts in solution. Would results be similar? If the salt were continually removed from the cell sap as fast as it enters, what will happen? How could such constant removal be maintained? Some species of seaweed contain 0.6% of iodine, yet iodine occurs in sea water in a concentration of only $\frac{1}{1000000}$ of 1%.

Living protoplasmic membranes do not behave quite so mechanically as might be inferred from the preceding experiment on dialysis. According to strict physical laws of dialysis what should happen to the anthocyanin (a salt) of the beet cell-sap when beets are put in water? Did this happen? Let us see if living protoplasm differs from dead in this respect.

Exercise 11. Rinse a piece of beet root and place in water. Note that the water is not colored. Boil the beet. Result?

Exercise 12. Root hairs and Osmosis.

Examine the roots of young seedlings of the oat which have been germinated in a moist chamber. What appearance? Remove the last quarter inch of a seedling root, flood with water and add cover glass. Study with l. p. and h. p. What is the relation of the root hairs to the cells of the EPIDERMIS or outer layer of the root? What is the obvious function of these root hairs? What advantage do they get by gluing themselves to soil particles? What relation can you see between their structure and the experiment performed on osmosis? Work on this until you understand. Add a drop of iodine to the slide and see if you can detect cytoplasm and nucleus.

A. Sketch a portion of the epidermis and its hairs.

Mitosis or Karyokinesis

When the cell is about to divide the nucleus first passes through a series of remarkable changes which constitute the process of mitosis or karyokinesis. These changes effect the qualitative and quantitative division of the chromatin, and lead to the formation of two nuclei after which the cytoplasm itself is divided by means of a new cell wall thrown across the equator of the cell.

Exercise 13. Since it is difficult for the beginner to work out the process unaided we have set up a series of demonstration microscopes under which are mounted the main stages of karyokinesis.

Do not move the slide or touch the coarse adjustment. If the slide becomes displaced, call the attention of the instructor to the fact.

(1) The Prophase of Karyokinesis.

In the large nucleus observe the one to several NUCLEOLI and also a delicate coiled and tangled thread. The latter is called the SPIREME. Note that it is made up of thousands of delicate granules of chromatin. These are called CHROMOMERES and they rest here upon a delicate filament or LINEN THREAD.

A. Draw very accurately the field visible under the microscope. Make nucleus 2.5 to 3 cm. across.

(2) The Metaphase of Karyokinesis (Nuclear - plate stage)

The spireme has split crosswise into a definite number of CHROMOSOMES. The chromosomes have arranged themselves at the equator of the cell. To them are attached the SPINDLE FIBRES which run to them in two sets from the two poles. Remember that there are no centrosomes or asters in angiosperms. Is the nuclear membrane still present? Nucleoli? Observe chromosomes carefully. Can you see that they are horseshoe shaped? Do all lie in the same focus? How many can you count? Do their loops or their shanks point inward? How many spindle fibers would you estimate to be present?

.. Draw the mitotic figure 3 cm. across at the equator. Include cytoplasm and cell wall.

C Construct a stereogram to show this same stage. The effect of perspective can be brought out by making structures in the foreground much bolder.

(3) The Anaphase of Karyokinesis.

The individual CHROMOSOMES have now split lengthwise and one-half of each is being drawn to the pole. How are the loops now directed? Are the SPINDLE FIBRES still visible? Were all of the spindle fibres attached to the chromosomes?

D. Draw the apparatus 3 cm. across as in last figure.

(4) The Telophase of Karyokinesis. Note what has happened to chromosomes and spindle. Observe the two new NUCLEI (NUCLEOLI) and the delicate new CELL PLATE.

E. Draw the two cells with nuclei 2 cm. across.

F. Write a resume of your work on the cell according to the following outline. It represents a synthesis of the various types of cells studied.

- I. Definition of the cell
- II. Structure of the cell (cytology)
  - A. The cell wall: pits, middle lamella
  - B. The cell contents
    - 1. Cytoplasm (ectoplasm and endoplasm)
      - a. Chloroplasts, vacuoles, granules
    - 2. The nucleus (nucleoplasm)
      - Membrane, chromatin, nucleolus

III. Physiology of the cell
- A. Relation of the cell to water and salts
  1. Osmosis, plasmolysis and dialysis
  2. Living vs. dead protoplasmic membranes
  3. The root hair and osmosis
- B. Karyokinesis

THE ANATOMY OF THE VEGETATIVE SYSTEM

THE STEM

Exercise 14. Ironwood (Casuarina equisetifolia L.) ~~Red Cedar (Juniperus virginiana L.)~~ Sections of the trunk.

N. B. DO NOT MARK UP THESE BLOCKS WITH PENCIL!

Note PITH, HEART-WOOD, SAP-WOOD, ANNUAL RINGS. If KNOTS are present, study their relation to the wood. What is a knot?

A. Diagram the cross section to show these features.

Exercise 15. The Structure of the Pine Stem

We shall now turn to the study of the structure of the stem of the pine tree. It should be realized that no matter how complicated this structure may appear, yet all the various kinds of cells have arisen by karyokinesis and have differentiated to their present form.

Let us start with the cross section and use the dissecting lens on a 1-year old twig of Pinus austriaca.

The deep red arcs on the outer angles are modified sections of the outer hard tissue of the leaf cushions of ~~the scale~~ leaves. ~~What is the oval turtle shaped mass in the angle of some of the leaves and imbedded in the cortex?~~ Note the CORTICAL RESIN CANALS. On the inner border of the CORTEX lies a narrow purplish band of PHLOEM separated from the XYLEM or WOOD inside by a deeply stained line of CAMBIUM.

What causes the irregular outline of the wood? Observe the WOOD RAYS and RESIN CANALS in it. The arms which run out from the PITH and give the inner border of the wood its lobate outline are BRANCH GAPS, viz. they are the tongues of pith which run into the short shoots.

7. Last of all we come to the pith. What other tissue does it resemble? Observe the parenchyma of the BRANCH GAPS.

8. Review each of the above tissues and see if you can tell the function of each. Remember that you are dealing with a cross-section. The tracheids and sieve tubes are really much elongated vertically as you will see later.

B. Draw rather diagramatically a narrow band some 6 cells wide running from epidermis to pith. Make the cambium cells about 5 mm. long and keep the other cells in correct proportions.

Exercise 16. Cross-Section of Twig of the Spruce (Picea). Quickly compare with the twig of pine and observe close similarity. The spruce has no short shoots. The arms running from the pith are not then branch gaps, but instead they subtend the LEAF TRACES and constitute LEAF GAPS. Note the traces cut in various parts of their course.

Are the leaves as heavily buttressed with SCLERENCHYMA as in pine? Note how well the cambium shows. No drawing is required.

Exercise 17. The detailed structure of pine wood.

We shall now take up a careful and detailed study of the structure of pine wood both in its macroscopic and microscopic aspects. The following work demands particular care and thought.

Yellow Pine (Pinus rigida). These blocks have been prepared to exhibit TRANSVERSE (or cross), TANGENTIAL and RADIAL aspects of the wood.

A. Make a sketch of any cylinder (such as is the trunk of a tree) cut by a plane in these three aspects. Label each plane.

Carefully study the cross-section (transverse) of the block. In what direction lay the center of the tree? How do you know? Note the annual rings and wood rays which transverse the mass of dense wood cells or TRACHEIDS. How does the wood vary in density within a ring? The less dense part is formed in early spring and is called SPRING WOOD, the denser mass is called the SUMMER WOOD. One other feature, the RESIN CANAL, is visible.

B. Sketch a small portion of the cross-section.

Turn to the tangential face of the block and identify the same features as before by following their extensions over the edge. If the annual rings appear like "mountains and valleys" explain.

C. Sketch a small portion of the tangential section.

On the radial face again identify the parts.

D. Sketch a small portion of the radial section.

E. Combine the three sketches to make a perspective drawing of a block of pine wood. Represent resin canals in three aspects.

Exercise 19. Histological study of pine wood. A cross-section of a piece of pine wood with radial and tangential sections of same will be furnished. Identify each one with lens.

Pinus Strobus - A Coniferous or Soft Wood. Transverse section.

Under the low power observe the ANNUAL RINGS of wood traversed by the WOOD RAYS. The thick-walled cells of the wood are called TRACHEIDS. Are the tracheids all alike in size and thickness of wall? You can now see the reason for the rings of wood. Do the wood rays all run clear across the section?

Note the resin canals also. Is there any evidence that they link radially with others of like nature?

Focus carefully on the margin of annual ring with h. p. Each tracheid, particularly in the summer wood, can be seen to have a distinct thick wall, and is separate from its fellows by a darker narrow line. This is the MIDDLE LAMELLA and represents the wall which both cells once had in common before they acquired the secondary thickening of which almost all the wall is now made. Observe a SPRING TRACHEID. How do its walls compare with those of the SUMMER TRACHEIDS? Note in some of the radial walls an oval, radially elongate structure which usually shows a purple spindle-shaped area in its middle. The whole structure is called a BORDERED PIT. You are seeing it cut in section. Can you detect INTERCELLULAR SPACES? Is there any evidence of protoplasm or nuclei in tracheids?

A. Draw a group of about ten tracheids under h. p. to include both summer and spring wood. Do not darken the woody walls.

In what direction are the RAY CELLS elongated? Can you detect a nucleus in them? Protoplasm? How do they differ from the tracheids? Their walls may appear bulged out. You will find that these bulges push through a pit into an adjoining tracheid. Such a bladdery projection is called a TYLOSE.

Turn on l. p. and find a well-preserved RESIN CANAL. It is surrounded by an area of RESINIFEROUS PARENCHYMA. Do the cells contain protoplasm?

B. Draw the resin canal under h. p. (Use section of twig if they are better preserved there).

Turn the l. p. to the radial section. Distinguish ANNUAL RINGS and note difference between SPRING and SUMMER WOOD, the WOOD-RAYS, the LONGITUDINAL RESIN-CANALS. On all the tracheids you can now see the BORDERED PITS in face view. Search for a place where the ends of the tracheids are visible. What is the shape of the termini and how do they fit together? How do the spring and summer tracheids differ from one anther? Compare the pits. Turn on h. p. and observe a single tracheid. Try to find a place where it abuts on a ray. Can you see the MIDDLE LAMELLA? Look for evidence of oblique striations on the walls. Study a pit carefully and see if you can interpret the various concentric circles. Beneath each pit is often seen a darker band. It is a local modification of the cell wall and is called a BAR OF SANIO. It is only found in woods which are closely related to the pine. Observe the RAY CELLS. What is the character of their walls? Do they bear bordered pits? Search for pits between two adjacent cells which have been cut by the plane of section. Note the MARGINAL or RAY TRACHEIDS. Do they bear simple or bordered pits? What is their probable function? Do they stain the same color as the other ray cells?

C. Draw a portion of a ray crossing several complete tracheids.

Refer to the tangential section. Why do the rays have a different appearance in this section? How do the pits now appear? Do the termini of the tracheids look the same as in the radial section? What is the actual solid shape of a tracheid? Do the resin canals differ in this view from their appearance in radial aspect?

D. Draw a portion of the tangential section.

E. Construct a stereogram of a tracheid cut transversely through its middle; show all details.

This completes our study of one of the soft or gymnospermous woods. Let us compare it with one of the hard or angiospermous woods.

Excerise 20. <u>The Wood of the Oak</u>. <u>An Angiospermous or Hard Wood</u>. The blocks have been prepared to exhibit the structure of the wood in three planes: cross, radial, and tangential.

N. B. DO NOT MARK WITH PENCIL

Study the cross-section of the block. Observe the annual rings of growth - how old is the piece of wood you have? Using hand lens observe the openings of the water-conducting VESSELS. Where are the largest ones found? Note that the wood rays are of two kinds: large or COMPOUND RAYS and small SIMPLE or UNISERIATE RAYS. Two other types of tissue may also be seen; dense FIBER AREAS and more open areas made up of TRACHEIDS.

A. With hand lens study a stained and mounted section. Make a diagram about 4 cm. square, magnified 10 times.

Turn to the block again and study the tangential aspect. Identify ANNUAL RINGS, VESSELS, RAYS, FIBERS, and TRACHEIDS by following their extension from the cross-section.

Turn to the equivalent section on the slide: identify the areas as before.

B. Diagram the tangential section, as you did the transverse.

C. Repeat for the radial aspect of the block and the equivalent sectionon the slide.

D. Combine the three sketches into a stereogram of a block 8 cm. on a side.

Study various polished woods used for cabinet work. Make sketches and explain the meaning of the markings of the "grain". What is quarter-sawed oak and how is it prepared? What is veneer?

From the previous exercise you are able to identify the various areas on the sections.

<u>Cross-section</u>. Focus on the end of an annual ring where it is cut by a COMPOUND RAY and note the great differentiation of the cells, all of which are specialized for particular functions. The VESSELS and TRACHEIDS conduct water; the FIBERS add mechanical rigidity to the wood. Do these elements contain protoplasm? The RAYS conduct dissolved foods radially through the wood. They, also, along with the WOOD PARENCHYMA, serve for storage of food. Do the RAY CELLS and WOOD PARENCHYMA CELLS contain PROTOPLASM?

E. Draw with care a small portion of the cross-section.

Turn to the tangential aspect. You will observe delicate markings on the walls of TRACHEIDS and VESSELS; these are called PITS. They are tiny pores through which water moves from cell to cell. Note how the ends of the various cells fit together. The vessels are chennels formed by fusion of many large cells end to end.

F. Draw a small portion of the tangential section.

Turn to the radial section and repeat your observations.

G. Draw a portion of the radial section.

Exercise 21. The Bark (Cortex, Cork and Phloem) of Tilia - the Basswood or Linden.

Tilia is used instead of the oak because its phloem cells are larger and more easily studied.

Turn to the cross-section on the slide. On the outside lies a band of cork easily recognized by its files of tiny brick-like cells. The epidermis has died and has either been shed completely or crushed beyond recognition. Under the cork comes the cortex, while still farther inward another band of cork has arisen from another cork-cambium. (This latter corky layer has really started in the phloem and has cut off the tips of the phloem masses.) All the tissues outside the cork band will eventually die and scale off (scaly bark) since they are cut off from food and water by the impervious cork.

Inside this second band of cork lies the unmodified phloem made up of several kinds of tissue. Its banded appearance is due to annual rings of growth. The WOOD RAYS are conspicuous; they vary much in size.

Carefully turn on h. p. and study a small portion of the phloem. The masses of bright red angular cells with extremely small cavities are the protective BAST FIBERS; the large cells with square, crackled and glassy bodies within them are the CRYSTALLOGENOUS PHLOEM PARENCHYMA CELLS; the smaller cells with dark contents which run in rows at right angles to the wood rays are also PHLOEM PARENCHYMA CELLS. The large colorless cells are SIEVE CELLS; they conduct most of the food of the plant. They contain protoplasm but no nucleus. Note in their corners the very small angular COMPANION CELLS. It is the work of the latter to control the activities of the sieve cells. What is the origin of this mass of phloem?

A. Make a careful h. p. drawing of a bit of the phloem only, to show the above elements.

Exercise 22. The Phloem of *Tilia* - Radial Section

Identify all the elements which were seen in transverse aspect. The SIEVE TUBES are to be studied with great care in order that SIEVE PLATES may be seen and interpreted.

Note the length and wall thickening of the BAST or STEREOME FIBERS. What is the part of flax which is used in spinning cloth? What is the value of bast fibers to a plant?

A what plant may grow six feet high with a diameter at the base of 1/4 inch. If man could construct a tower on these principles, with a base 20 feet across, how high would it reach? What is the shape of the CRYSTALS in the CRYSTALLOGENOUS CELLS? Can you suggest any reason for storing up calcium oxalate in this form?

A. Draw a portion of the phloem in radial aspect to show all features.

THE HERBACEOUS STEM

We have now studied the two main types of wood and have also seen the important elements which constitute the phloem or bast of trees. The most important remaining subject connected with stem anatomy is the origin and structure of the herbaceous stem. Herbs have been derived from woody plants. We will study (1) a woody twig (Tilia); (2) a half woody stem and (3) an extreme herb.

Exercise 23. A Woody Stem. Tilia - the Basswood or Linden.

With dissecting lens work out the general topography of the cross-section furnished. In the center lies the MEDULLA or PITH. Note the dark masses in it. These are MUCILAGE CELLS, rather characteristic of the order of plants to which Tilia belongs. (Marshmallow is obtained from another genus in the order). The outer slightly bluer ring of pith constitutes the MEDULLARY SHEATH. It usually bears quantities of starch.

How old is the twig? Note three arms of pith running outward into the wood. At their outer ends there is an aggregation of denser and more deeply stained wood cells. The latter are LEAF-TRACES and the arms of pith are LEAF-GAPS (Foliar lacunae). This section was cut just below a node and the three leaf-traces are about to enter a leaf.

On the very outer border of the wood is a deep purple line. It is a cross-section of the CAMBIUM LAYER. The red pyramids outside it are masses of PHLOEM or BAST. They are separated by the flaring WOOD-RAYS. Outside the phloem lies the CORTEX bounded exteriorly by a broken EPIDERMIS.

A. Diagram the Tilia twig 7 cm. across.

B. Construct a stereogram of a half-cylinder cut longitudinally along a diameter so as to split a leaf trace and show its outward course.

Exercise 24. The Half Woody Stem ~~of ASTER PUNICEUS~~
We are now advancing toward the herbaceous stem condition. With the dissecting microscope study the cross-section of ~~Aster~~ stem. It is cut just below a node where the three LEAF TRACES are sweeping out to their leaves. See if you can detect them. One of the laterals is much farther out than the other. Note the LEAF GAP inside each trace and the broad parenchymatous LEAF RAY outside it and on its flanks. What is the physiological value of the leaf ray?

A. Diagram the stem. Bring out the leaf traces clearly and show parenchyma of leaf gap and leaf ray by shading.

Refer to chart showing the ~~aster~~ [partial woody] condition in stereogram and see that the anatomical features are clear.

Exercise 25. An Extreme Herb - Ranunculus - the buttercup.
The buttercup stem has attained the extreme limit in herbaceous evolution. From a study of the chart be sure you understand how this stem evolved from a type like that of aster. Note the following points:

(1) The amount of secondary wood is remarkably reduced and this is due to the fact that the CAMBIUM functions scarcely at all. Hence nearly all the wood of the leaf traces is primary (viz. derived from primary meristem - not from cambium.)

(2) Since there is almost no secondary wood there are no leaf rays. In order then for storage to go on the FLANKING PARENCHYMA becomes highly developed and strongly isolated the leaf traces or fibro-vascular bundles from one another.

(3) Support is gained thru heavy SCLERENCHYMATOUS BUNDLE SHEATHS around each bundle.

A. Copy the stereograms of [the partial woody stem and the] ~~aster and~~ of [the] buttercup from the chart. With dissecting microscope examine a stained section of the buttercup stem. Observe the cut ends of the leaf traces and their distribution. What about the destination of the larger ones? (If one were to follow these traces up or down thru the stem they would be found to link together at the nodes into a complex network.)

B. Diagram the stem 7 cm. across.

Study now with compound microscope. The traces with their curious BUNDLE SHEATHS are conspicuous. See that you understand how the topography conforms to the chart diagram. Note details. Observe PHLOEM made up of SIEVE TUBES and tiny COMPANION CELLS. Note the thick protective cap outside the delicate phloem. The CAMBIUM is well developed in each trace but observe that it no longer circles the whole stem but is confined to each bundle only (fascicular cambium). The XYLEM with its large VESSELS also shows up well. Sometimes the end wall of a vessel with its porous perforation is also visible. Toward the inside of the xylem there is much WOOD PARENCHYMA.
Note the FLANKING PARENCHYMA and the PITH. The latter has partly broken down leaving a hollow stem. What difference can you see between CORTICAL PARENCHYMA and that which lies deeper. Note EPIDERMIS.

C. Select a medium sized leaf trace and draw under h. p. with its accompanying flanking tissues, pith and cortex.

If the leaves of a plant became large and crowded on the stem and too many leaf traces were entering to be accomodated in a circle what path would they necessarily take?

THE STEM STRUCTURE OF MONOCOTYLEDONS

Exercise 26. The stem of Indian corn - ZEA MAYS.
Dissect the corn stem furnished and note the leaf traces. How does the arrangement differ from that of the buttercup stem? Count the number of traces passing in from a leaf and observe how closely set the leaves are. Did nature follow the logical path which you predicted above?
Study a stained cross-section of corn stem with dissecting microscope.

A. Diagram as for the buttercup.

Turn to compound microscope. Note that the bundles are rather similar to those of the buttercup. They have the BUNDLE SHEATH of sclerenchyma and their PHLOEM is very much the same. Is a cambium present? If not, you are dealing with what is called a "closed bundle" in opposition to an open one such as that of the buttercup. Most monocotyledons have closed bundles. Is the wood as abundant as in buttercup and is it primary or secondary wood? How many vessels can you find in each trace? Note the odd resemblance to a face; the "eyes" are two PITTED VESSELS; the others are SPIRAL and ANNULAR vessels. Beneath the "mouth" lies an irregular intercellular space (PROTOXYLEM CANAL). It arises thru disorganization of the earliest formed tracheids (protoxylem). Note that one can no longer distinguish between cortex, flanking tissue and pith. For what is this parenchymatous or FUNDAMENTAL TISSUE used? How is the stem stiffened? In what respects does the stem structure of corn show extreme specialization?

B. Select a well preserved trace and draw under h. p.

THE LEAF

Exercise 27. <u>The Anatomy of the Leaf</u>. Strip off a bit of the lower epidermis of leaf and make a water mount. Observe first with l. p. Note the STOMATA scattered over the leaf. Turn on h. p. and study a stoma in detail. How many cells comprise it? They are called "GUARD CELLS". What lies between them? Do they differ in contents from the other epidermal cells? What do you suppose is one function of the stomata?

A. Draw a portion of the tissue to show stomata and other epidermal cells.

Exercise 28. <u>The Vascular System of the Leaf</u>. Study with microscope mounted fragments of a thin leaf from which the chlorophyll has been removed by hot alcohol and which has been rendered transparent by chloral hydrate. Varying foci will show that there are several layers of cells. Red stained multicellular HAIRS also occur on the epidermis. The point to be particularly observed is the extensive ramification of the VEINLETS. High power will show that the cell walls of the veinlets are curiously thickened. How? The phloem is continued to the terminus of the vein in the form of elongate cells. What do you infer moves in these channels?

A. Draw a portion of the terminal region of a veinlet under h. p.

Exercise 29. Cross-section of a typical dorso-ventral leaf. Sections of a living ~~Rhododendron~~ leaf will be furnished. Note the heavy CUTICLE and double EPIDERMIS on the upper side. The MESOPHLL or CHLORENCHYMA (etym.) makes up the bulk of the leaf. It is differentiated into an upper PALISADE LAYER and a lower mass of SPONGY PARENCHYMA. How is the latter adapted to gas circulation? Where have you seen similar CHLOROPLASTS before? Observe that in the chlorenchyma are to be seen rather indefinite grayish masses. Our section is too thick to show their details. What are they? Is the lower epidermis also more than 1 cell in thickness? Sections of stomata will be better seen in the next leaf section.

A. Carefully draw under h. p. a portion of the cross-section.

Exercise 30. Stained cross-section of ~~the Iris~~ [the dicot?] [monocot] leaf. How does the position of the ~~Iris~~ leaf on the plant differ from that of ~~a Rhododendron~~? How does the CHLORENCHYMA of this leaf differ in appearance from that of the last leaf? In what direction are its cells elongated? Note CHLOROPLASTS. Observe that the edges of the leaf are heavily buttressed by a HYPODERMAL BAND of SCLERENCHYMA as are also the main veins. Carefully study the section of a VEIN. Two veins commonly lie together with their xylems touching or actually fused. Where have you seen essentially such structures before? Note PHLOEM with SIEVE CELLS and COMPANION CELLS. Is a CAMBIUM present? Is the iris a monocot or a dicot? The xylem is composed of VESSELS and WOOD PARENCHYMA. Look carefully along either epidermis and find a STOMA cut in section. Note its two small GUARD CELLS.

A. Draw a portion of the section to include two medium sized veins and a sectioned stoma.

COAL AND ITS FORMATION

Exercise 31. A Study of Coal and the Method of its Formation. Coal is largely formed of plant debris and this seems to be a good place to introduce its study. Let us first examine the primary materials from which coal is formed. Into a drop of water on a slide stir a little fine ~~pond~~ [a marsh] muck derived from ~~Lack's Pond~~. Examine with low power and see what you can identify. Look particularly for small rounded [yellow] unicellular bodies ~~with two balloon-like wings~~; they are ~~pollen grains of pines~~. [the spores of lycopods and ferns.]

A. Make a list of the materials which you can identify and call (judiciously) upon the instructors for help on things you cannot identify.

Examine mounted sections of a coarse muck taken from a lake in Province of Quebec, Ontario. Fragments of wood, pine needles, bark, charcoal, pollen grains may all be found. Such debris is the foundation of coal.

B. Make a list as before of the things which you have found.

Prepare a slide with spores (essentially pollen grains) of a club moss. You will find that these spores are all alike. During the coal period, however, giant club mosses growing 100 feet high flourished in the hot wet lands. They formed quantities of spores of two kinds. The small ones (microspores) corresponded to pollen grains, while the large ones (megaspores) corresponded to structures found inside the ovule of the seed plants.

C. Draw a few of the spores (isospores) from the living Lycopod.

<u>A Microscopic Study of Lignite</u>. Lignitic wood consists of wood which is about half way advanced to the bituminous coal condition. In ancient days it collected in bodies of water and was there silted in and preserved. It differs from wood in its higher carbon c ontent.

Pieces of lignitic wood will be furnished for observation.

<u>Sections of lignitic wood.</u>

Study the sections of lignitic wood furnished. How do they differ from ordinary wood in color? In s tructure? Observe carefully the effect of prolonged soaking and intense pressure to which the wood was subjected during the millions of years in which it lay buried. What part of the wood is least modified? Is it a hard (Angiosperm) or a soft (Coniferous) wood? Its age is roughly 75,000,000 year s.

D. Sketch a small portion as seen under h. p, A Study of Cannel Coal.

Cannel is known to have been formed in fresh water lakes and seems to represent the result of converting muck essentially like that we have studied into the coal condition.

8 E. Study the pieces of cannel handed around. Note its homogeneous texture and dull color.

On the slide furnished you there are three sections or fragments of them to be studied. The narrowest, often fragmentary, section lying next one side of the cover glass, is from a piece of cannel coal. It is cut transversely to the bedding planes.

See if you can determine what the details seen under the microscope really mean. Remember that these materials have lain here since the coal period - at least 300,000,000 years and are crushed flat by the tremendous weight of rocks above them.

6 F. Draw a bit under h. p. and label wood, megaspores, microspores.

A Study of Bituminous Coal.

With hand lens study the fresh surface of a piece of bituminous coal furnished you. In the face broken across the bedding planes observe the streaks of bright gleaming, "glance coal", and the duller streaks of "mat coal". On the surface cleaved parallel to the bedding planes fragments of friable charred "mother of coal" may sometimes also be found. This is only charcoal swept into the pond after some old forest fire.

7 G. Sketch a portion of the fragment broken across the bedding planes.

Mounted coal sections. Let us now find out of what the bands of glance and mat coal are really composed. Turn to the middle section on the mounted slide. It is cut from a piece of Illinois bituminous coal. Study and interpret.

8 H. Sketch a portion to bring out the banded structure. How will you account for the formation in bands? Does one of the glance or mat stripes at all represent the thickness of the layer when first deposited?

The third and last section on the slide is the same as the last coal only cut parallel to the bedding planes. Amorphous wood, yellowish spores, and sometimes pieces of charcoal are to be found.

I. No drawing.

THE PHYSIOLOGY OF THE VEGETATIVE SYSTEM

We have seen when studying the root-hair how water and salts enter the plant. We may now inquire as to the channels through which they rise to the parts above ground.

Exercise 32. The course of water in plants.
Examine various plants which have been kept some time in eosin solution. Study roots and stems and observe thru what channels the colored water moves.
Pull off the leaves from the stems and determine the channels through which the liquid enters and moves through the leaves. Recall the appearance of the ultimate veinlets in the blade.

Exercise 33. Relation of the leaf to water. - Transpiration.
Observe the apparatus set up to show that plants give off quantities of water.

We have learned that the plant through its root hairs takes up dilute salt solutions from the soil. The salts and water are carried to the leaves through the xylem and there elaborate chemical reactions take place.

No carbon comes from the soil, and yet plants contain a high per cent. of carbon. It is all derived from the carbon-dioxide gas of the air. This gas, under the influence of sunlight and the green chlorophyll of the leaf, combines with water to form starch. The process may be roughly represented thus:

$6\ CO_2$ plus $5\ H_2O$ under influence of sunlight —— $(C_6H_{10}O_5)_6$ plus $6\ O_2$
(carbon dioxide) (water) (energy) and chlorophyll (starch) (oxygen)

A compound such as starch made up of carbon combined with water is called a carbohydrate. Let us try to find it in green leaves.

Exercise 34. Remove a leaf from a plant that has been standing in bright sunlight for some time. Extract the green coloring matter by soaking in hot alcohol; dip into hot water to remove brittleness and then submerge the leaf in a solution of potassium iodide and iodine. What is the effect? The chemical compound to which the blue color is due can be best studied microscopically from certain tubers and seeds, whither it has been transported from the leaves.
Mount in water a thin section cut from a potato tuber and examine with l. p. What is found in the cells? Place a little weak iodine solution at the edge of the cover glass and draw it under with a piece of filter paper. Watch the section during the process. What happens? Does any of the material take a yellow color? What is it and what is its distribution?

A. Make a sketch of several cells and their contents.

Into the tube of starch paste on your table drop a little iodine solution. What results? Starch is the only known substance which gives this color with iodine.

Mount in water a bit of the milky liquid from the potato tuber and examine the starch grains again with l. p. Tap lightly on the cover glass to make them revolve. What is their real shape? With h. p. study very carefully and observe HILUM and LAMINAE.

B. Draw several forms as seen under h. p.

Return to l. p.; shut off most of the light, and draw a little potash solution under the cover glass. Watch carefully as it penetrates. What happens? Exactly the same thing occurs when starch is boiled to form starch paste. It is not in true solution but is in the colloidal (colla = glue) condition. (Forms of starch grains vary much among different plants, and adulterants in foods, etc., can often be thus detected.)

Starch, then, gave the bluish color to the leaf treated with iodine in a preceding experiment. What is the chemical formula for starch?

From a plant which has been kept at least 12 hours in a dark place detach a leaf. Remove the chlorophyll and test for starch. Result? Set the plant in sunlight and after a few hours test another leaf for starch. Result?

To the leaf of a plant taken from a dark place attach a light screen and after a few hours in sunlight remove the screen and test the leaf for starch. Result? (These leaves may be preserved in 50% alcohol - the color fades but may be restored at any time by treatment with iodine.) What conclusion do you reach from the last three experiments?

Select a leaf from a variegated Abutilon which has been standing in light; remove chlorophyll and test for starch. What result?

Exercise 35. A Study of Chlorophyll.
Take a test tube of alcoholic solution of chlorophyll solution and note the color of light reflected from the surface. Add a little carbon tetrachloride to the solution and shake. What happens? Carbon tetrachloride (CCI_4) is sold as a grease spot remover under the trade name of "Carbona". This suggests that chlorophyll is a fat which has been found to be true.

Stand a solution of chlorophyll in a lighted window and leave several days. Result? Does this suggest what happens to leaves ~~in autumn~~? of the Kamani before they fall and to the leaves of deciduous trees in autumn in temperate regions?

A. From careful consideration of all the above experiments and observations on Photosynthesis etc. write up a summary of the chemico-physical aspect of the process. Be sure you thoroughly grasp all the factors necessary.

Exercise 36. (a) Starch is formed in the leaves in the form of grains. Can it osmose from the cells and reach tubers, roots and stems? Set up an osmotic apparatus. Inside the membrane place a solution of cooked starch (water paste) into which has been stirred some uncooked starch. After a few hours determine whether it has dialysed into the outer water. What have we learned about osmotic properties of colloids? Let us see if we can determine in what form carbohydrates do move through the plant.
Translocation. Put a little starch paste into three test tubes and mix into one a weak solution (0/5%) of commercial diastase; into the second stir a little saliva, and leave the third untouched. In about 15 minutes test for sugar, using Fehling's test. Result? What name is applied to such substances as diastase, or ptyalin from saliva?
Do plants contain diastase? Examine grains of starch from ungerminating and germinating corn. Is there evidence of corrosion in either? Compare the taste of germinating corn grains with ungerminating. What results? A Fehling's test will prove the same thing.

A. Write up conclusions concerning translocation.

(At this point could be inserted the science of plant chemistry which is concerned wholly with anabolic and katabolic compounds.)

Energy for growth and all other activities is obtained by plants and animals through oxidation of foods. What compounds result from oxidation of carbohydrates? What becomes of the gas formed by an animal? What is an easy test to apply for this gas? Let us see if plants produce the same gas.

Exercise 37. Respiration.
1. Arrange a wide mouth bottle with a two-hole rubber stopper. Through one hole put a thistle tube. Through the second a curved tube for gas delivery. Place branches of a leafy plant in the bottle and set it aside in a dark warm place. After a few hours bubble the gas through fresh lime water by displacing it with pure water poured through the thistle tube. What is the gas?

A. Sketch the apparatus and discuss the experiment.
B. In a paragraph compare photosynthesis with respiration.

Exercise 38. The Utilization of food.
The energy contained in the food is utilized for chemical synthesis and decomposition, for growth, and for the manifestations of irritability. A few of the simpler activities will be exhibited.

A. Take notes and write out your observations.

THE FLOWER AND REPRODUCTION

The goal of the plant is to produce other plants like itself and all the elaborate vegetative functions we have been considering lead in the last analysis to this process. We shall now study the more minute features of sexual reproduction in the higher plants starting with the stamen.

Exercise 39. A Study of pollen.
Remove a fresh stamen (microsporophyll) from a flower and place a little pollen in a drop of water. Add cover. How many cells in

each spore? Is the surface smooth or ornamented? Are there any special caps or thin areas?

A. Draw a few pollen grains (microspores) and repeat for other flowers available.

Exercise 40. Production of pollen tubes. On the hardened surface of a 1% solution of agar-agar mixed with about 3-4% of cane sugar, pollen grains of a certain flower were thickly sown. This medium produces conditions so similar to those on a fresh stigma that the pollen grains quickly start to germinate.

Prepare water mount of a thin slice of the agar and add a cover glass. Press gently to flatten the mount. Note that the EXINES of the pollen grains have cracked open and that the INTINE is protruding through the crack as a long POLLEN TUBE.

A. Draw the germinating grains with the tubes in various stages of growth. Make grains 1.5 cm. broad.

- Thru this pollen tube two sperm nuclei are conducted to the ovule.

Exercise 41. The study of a flower of Caltha in cross-section. By imbedding Caltha buds entire in celloidin we can get sections of all the parts in one slide. The close resemblance of these cross-sections to our conventional "floral diagrams" is of interest. Study with l. p. Identify sections of SEPALS, ANTHERS (the epidermis is often torn off.) FILAMENTS, CARPELS, and OVULES.

A. Diagram the whole flower about 6 cm. across.

With h. p. observe the POLLEN GRAINS; many of them show the GENERATIVE and TUBE NUCLEI.

B. Sketch a bit of the anther with the pollen grains 1 cm. across.

With l. p. look at the carpels again and select one that contains an OVULE cut through the FUNICLE and MICROPYLE. What name is applied to such an inverted ovule? Within it note a more or less open cavity - the [illegible]. This lies inside an oval cellular mass, the NUCELLUS, which in its turn is enclosed by two integuments. The INNER INTEGUMENT is usually more advanced in growth than the outer at this stage of the ovule. What happens to the part of the OUTER INTEGUMENT on the FUNICLE side? Note MICROPYLE. What name did we give to the integuments of a mature seed?

C. Carefully put on h.p. and draw the ovule.

(Other and more modern terms for all the carpel and ovule structures should be learned. The following table homologizes them:

Carpel or simple pistil	Megasporophyll
Ovule	Megasporangium enclosed by two integuments.
Nucellus	Megasporangium itself
Embryo-sac	Megaspore

Inside the embryo sac or megaspore at maturity lie the following naked (viz. without walls) cells: at the micropylar end, two synergids and an egg or ovum; at the other end of the megaspore, three antipodal cells. In the middle of the embryo sac a primary endosperm nucleus.

Exercise 4a. It is practically impossible to furnish a large class with the stages of fertilization and embryo formation. These are to be copied from a chart hung up in the laboratory. The following list of labels is to be added to each figure. The parenthetical term is the newer one. It may be added in red ink if so desired.

Stage I. Two carpels (megasporophylls) (In the case here figured the two stigmas prove that you are dealing with a bicarpellary gynoecium but the loculus of only one carpel is diagramatically shown.)

Ovary, style, stigma, ovule (integumented megasporangium), funicle inner and outer integuments, micropyle, nucellus (megasporangium) embryo sac (megaspore), synergidae, egg, primary endosperm nucleus antipodal cells.

Stamen (microsporophyll), anther sac (microsporangium), pollen grain (microspore), pollen tube, tube nucleus, sperm nuclei.

Stage 2. Inner integument, nucellus and embryo sac, micropyle, synergiade, egg, endosperm nucleus, antipodals, broken pollen tube, sperm cells fertilizing egg and endosperm nucleus.

Stage 3. Inner integument, micropyle, nucellus, embryo sac, 3-celled embryo, 3 antipodal cells, endosperm formation with nuclei in anaphase and telophase.

Stage 4. Embryo with suspensor, endosperm, antipodals.

Stage 5. Mature seed: embryo with cotyledons, hypocotyl, plumule; endosperm, shriveled nucellus, tests, tegmen, raphe, hilum,

Stage 6. Germinating seed: testa, cotyledons, hypocotyl, primary root, hilum.

PART II.

A BRIEF INTRODUCTION TO THE KINDS OF PLANTS.

Unicellular and simple colonial Green Algae.

The simplest green plants known on earth are almost all aquatic and are called Green Algae. They are included in a great division of plants - the Thallophyta. These "thallus plants" have no stems, roots or leaves.

Exercise 4. Pleurococcus.

This is a good form to begin with. It is an exception to the ordinary aquatic life of algae since it forms the green film so common on tree trunks. Scrape off a bit into a drop of water; after finding a favorable small colony turn on h.p. Note that the individual globular cells adhere slightly to one another and that each is surrounded by a wall. Find a cell that has recently divided and note that the two DAUGHTER CELLS adhere for some time before separating and rounding off. The dense chlorophyll usually masks all internal structure; it is contained in a peripheral CHLOROPLAST.

A. Make a detailed drawing of several cells and colonies to show the above features.

If the cells be crushed by pressing on the cover glass the contents will exude and the CELL WALLS will remain as empty capsules. How might a Euglena become like Pleurococcus? Euglena actually does often encyst and then resembles Pleurococcus closely.

PART II

THE ANATOMY AND PHYSIOLOGY OF SEED PLANTS

Up to date our studies dealt wholly with macroscopic features of the seed plants. Now we begin to go into details carrying our investigation of living plants as far as modern instruments will permit. After learning how the plant organs are put together (Anatomy, Histology and Cytology) we shall then logically take up their various activities (Physiology). Tereafter we will study systematically the Plant Kingdom, beginning with the simplest of plants and ending with the most complex.

The Microscopic Anatomy of the Plant (Histology andCytology)

You have seen that plants and plant parts differ much in texture. Some parts are soft and watery; some hard and woody; some dry and papery, etc. These differences are due to the differences of the microscopic parts of which plants are composed.

Just as the walls of houses are sometimes made of hollow tiles so the plant is built of tiny structures which we call cells. These cells, however, are not mere empty boxes but each contains within itself a living substance known as protoplasm. The cell then is really a small mass of protoplasm enclosed by a cell wall. We shll first consider the cell in some detail, then advance to a study of cells aggregated into tissues, and finally learn how these tissues are combined to form the organs which make up the plant and how these organs work. The sequence of study will be the same as that of the previous laboratory work, viz.: root, stem, leaf, flower, seed.

The Structure of the Cell

Exercise 1. Elder Pith - A plant tissue (parenchyma) made up of dead cell walls.

With the dissecting lens study the bit of elder pith that is given you. Note that it is made up of very small compartments or CELLS.

Make a water mount of a cross section of the pith tissue, and observe it with the low power of the microscope. This magnifies the cells about 90 times. The CELL WALLS now appear. What is the effect on the image of turning the fine adjustment screw to a new focus? Note more or less abundant heavy, refractive circles seen in some of the cells. Do they ever occur in the water outside the section? What are they? Study them under changing foci and never bother with them again.

It is easy to see that the compound microscope gives but a two dimensional image - a so-called optical section. If you have a transparent object on the slide how will it be possible to study successive planes or optical images in it from top to bottom?

What is the general shape of the cells and at about what angle do their walls meet one another? Is the inner contour of the cells sharply angular? Note that they are often broken apart at the angles to form INTERCELLULAR SPACES. Do any of the cells show their walls in surface view? Is the wall perfectly plain or is it perforated by holes (SIMPLE PITS)? What is the probable use of these pits? The chemical substance of the walls is cellulose $(C_6H_{10}O_5)x$. Paper consists of a fairly pure cellulose.

A. Draw about 5 of these dead cells, each about 2 cm. across. In any drawing of cells always start the walls of an adjoining row as though your fragment had been torn from a larger tissue.

Carefully put on high power. The walls will now be seen to have a definite thickness. Each cell has its own wall and between the two lies a very delicate MIDDLE LAMELLA or cementing substance which binds them together so that all three form a single membrane separating the two cells. In the formation of intercellular spaces the cells split apart through the middle lamella. Find a SIMPLE PIT which has been cut by the razor. Is the middle lamella also perforated by the pit?

B. Draw a few cells under h. p. Make each cell 4-5 cm. across. Include an intercellular space. Show by a double line the thickness of the wall and suggest the middle lamella. Show pits in face view and in sectional aspect,

Study a longitudinal section of the pith with l. p. Try to find a place where the cells lie in rows. Those with triangular ends were cut practically through their middle,

C. Draw about 5 cells.

D. Construct a diagram of an idealized pith cell in 3 dimensions. Such a drawing is called a stereogram (Etym.). Add the simple pits to the figure. What is meant by saying that the cell is the unit of structure of plant and animal bodies?

A plant tissue made up of thin walled and essentially isodiametric cells is called PARENCHYMA.

Exercise 2. The inner epidermis of the onion - living cells.

With the dissecting lens study the concave surface of the onion scale given you. Note the delicate cells. With the point of the scalpel and forceps remove a small piece of the epidermis free from underlying tissue and mount on a slide, free side of epidermis up.

How does it compare with the elder pith: in shape of cells, in presence of intercellular spaces, in cell contents? How many cells thick is the epidermis? Are there pits in the outer walls? Would such be of advantage to the plant? Are there PITS between the cells? Is the pit really a complete hole or channel running from one cell to another? Focus carefully.

A. Draw some half dozen cells as seen under l.p.

With h. p. look carefully along the walls or at the angles of the cells and find the protoplasm. It forms a layer covering the wall (Primordial utricle) and often extends in strands thru the sap vacule

B. Draw some half dozen cells, each 6-7 cm. long.

Is there any evidence of an oval, more densely granular body - the nucleus - in the cell?

Turn on l. p. Remove the slide from the stage, take off the cover glass and add a drop of iodine solution. Draw off excess iodine with filter paper. The tissue should appear deep yellow. Add more water if necessary, and remount. What changes can you see?

Put on h. p. Now carefully study the nucleus. What might lead you to believe that it is either chemically or physically different from the rest of the PROTOPLASM? A distinction may then be made between NUCLEOPLASM and CYTOPLASM. Are NUCLEOLI present? Can you detect the wall of the nucleus? Is there more than one nucleus per cell?

Add the nucleus to your drawing in B.

Exercise 3. The Stamen-hairs of Tradescantia or Squash

These long hairs are made up of bead-like cells and active streaming motion is usually visible in the wall layer of CYTOPLASM and in the strands and cables of cytoplasm which traverse the SAP-VACUOLE. If available it will be given.

The hairs of squash and pumpkin leaves will show the same movement of circulation and may be substituted for Tradescantia. Iodine will bring out the NUCLEUS.

A. Draw the whole hair merely to show the form and numbers of the cells.

B. Draw two cells, each at least 4 cm. across and put in all the details observed. Show the direction of protoplasmic streaming in the threads by adding arrows.

Exercise 4. The leaf cells of Elodea. Tear off a young leaf from the plant and make a water mount. With l. p. observe the cellular structure of the leaf. What is the nature of the MARGINAL TEETH? Note the midrib. Is the leaf more than one cell in thickness? Look carefully at the cells on either side of the mid-rib. Do the contents show any trace of motion? If so, put on h. p. and study carefully. The CHLOROPLASTS are now plainly seen; what is their shape? Do any show evidences of dividing into two parts?

A. Draw a cell to show details of structure and add arrows to indicate the direction of movement of the contents.

Exercise 5. Epithelial cells from the mouth. Gently scrape the surface of the tongue with the finger nail and transfer the sediment to a drop of water on a clean slide. Add a drop of iodine solution. Study with low power. Is a heavy wall visible on these animal cells as in plant cells? A NUCLEUS? PROTOPLASM? Are the cells all shaped alike? Are they isodiametric? Such a tissue is called PAVEMENT EPITHELIUM. Your body, then, is made of cells as is that of a plant.

A. Draw a few cells as seen free and also adherent in plates.

Having studied the grosser features of the cell we may now turn to a more detailed study, particularly of the nucleus. This requires sections cut by special machine to about 5 microns in thickness and stained with analine dyes.

Exercise 6.

With l. p. study the section of a rapidly dividing tissue which is furnished. Note the large nuclei in the cells. Very carefully put on high power. Observe that the nucleus is imbedded in CYTOPLASM and surrounded by a NUCLEAR MEMBRANE. Inside the nucleus observe NUCLEOLUS OR NUCLEOLI. You will also observe dots and masses of densely stained material. This is CHROMATIN supposed to be the bearer of all the hereditary characters of the plant.

A. Draw the cell with nucleus 2 cm. in diameter.

THE ACTIVITIES OF THE CELL - PHYSIOLOGY

Now that we realize in some measure how the cell is constructed let us briefly study a few of its functions.

Exercise 7. The relation of the cell to water.

Two sets of beet slices have been prepared. One set stood in pure water over night, the other in 5% salt water. What difference is seen in their condition?

Exercise 8. Very thin sections of beet cut with razor will now be furnished. Make a water mount. Observe the red color. This is due to a pigment, anthocyanin, dissolved in water and contained in a large central SAP-VACUOLE. The protoplasm consists of a very thin layer just inside the cell wall. This layer has been called by Von Mohl the Primordial Utricle. It is probably too delicate to be differentiated.

A. Make a sketch of a few cells under h. p.

Remove cover glass and put a drop of salt solution on the section. Add cover, draw off excess liquid and study again. What change has taken place? Where does the layer of PROTOPLASM (PRIMORDIAL UTRICLE) now lie? Cells in this condition are said to be plasmolyzed. What now lies between the protoplasmic membrane and the cell wall? Has the anthocyanin from the cell sap diffused outward?

B. Sketch a few cells in this condition and label PROTOPLASMIC MEMBRANE, SAP VACUOLE, CELL WALL.

Remove the section to a drop of pure water. Rinse well and in a few minutes examine again. Result? Why did the beet sections become limp in salt water? What is osmosis? Is the cell wall the osmotic membrane in our experiment? What is turgor and what is its significance to plants? Strong fertilizers are said to burn roots. What probably happens?

Exercise 9. Osmosis. The above osmotic interchange of water through membranes may be simulated by a simple physical experiment. In the laboratory is set up an apparatus to demonstrate this. Make sure that you understand the essential principles and see the relation to plants.

Exercise 10. Dialysis. How do salts enter the cell?

A considerable amount of common salt solution is to be prepared. To a small portion in a test tube a few drops of silver nitrate ($AgNO_3$) is added. Result; Repeat the same test on pure water.

A parchment sac filled with pure water is to be suspended in the salt solution. In a few hours repeat the silver nitrate test on the water inside the parchment sac. Result?

Suppose we imagine the parchment sac replaced by a young cell and immersed in soil water which always contains certain salts in solution. Would results be similar? If the salt were continually removed from the cell sap as fast as it enters what will happen? How could such constant removal be maintained? Some species of seaweed contain 0.6% of iodine, yet iodine occurs in sea water in a concentration of only $\frac{1}{1000000}$ of 1%.

Living protoplasmic membranes do not behave quite so mechanically as might be inferred from the preceding experiment on dialysis. According to strict physical laws of dialysis what should happen to the anthocyanin (a salt) of the beet cell-sap when beets are put in water? Did this happen? Let us see if living protoplasm differs from dead in this respect.

Exercise 11. Rinse a piece of beet root and place in water. Note that the water is not colored. Boil the beet Result?

Exercise 12. Root Hairs and Osmosis.

Examine the roots of young seedlings of the oat which have been germinated in a moist chamber. What appearance? Remove the last quarter inch of a seedling root, flood with water and add cover glass. Study with l. p. and h. p. What is the relation of the root hairs to the cells of the EPIDERMIS or outer layer of the root? What is the obvious function of these root hairs? What advantage do they get by gluing themselves to soil particles? What relation can you see between their structure and the experiment performed on osmosis? Work on this until you understand. Add a drop of iodine to the slide and see if you can detect cytoplasm and nucleus.

A. Sketch a portion of the epidermis and its hairs.

Mitosis or Karyokinesis

When the cell is about to divide the nucleus first passes through a series of remarkable changes which constitute the process of mitosis or karyokinesis. These changes effect the qualitative and quantitative division of the chromatin, and lead to the formation of two nuclei after which the cytoplasm itself is divided by means of a new cell wall thrown across the equator of the cell.

Exercise 13. Since it is difficult for the beginner to work out the process unaided we have set up a series of demonstration microscopes under which are mounted the main stages of karyokinesis.

Do not move the slide or touch the coarse adjustment. If the slide becomes displaced, call the attention of the instructor to the fact.

(1) The Prophase of Karyokinesis.

In the large nucleus observe the one to several NUCLEOLI and also a delicate coiled and tangled thread. The latter is called the SPIREME. Note that it is made up of thousands of delicate granules of chromatin. These are called CHROMOMERES and they rest here upon a delicate filament or LINEN THREAD.

A. Draw very accurately the field visible under the microscope. Make nucleus 2.5 to 3 cm. across.

(2) The Metaphase of Karyokinesis (Nuclear - plate stage)

The spireme has split crosswise into a definite number of CHROMOSOMES. The chromosomes have arranged themselves at the equator of the cell. To them are attached the SPINDLE FIBRES which run to them in two sets from the two poles. Remember that there are no centrosmmes or asters in angiosperms. Is the nuclear membrane still present? Nucleoli? Observe chromosomes carefully. Can you see that they are horseshoe shaped? Do all lie in the same focus? How many can you count? Do their loops or their shanks point inward? How many spindle fibers would you estimate to be present?

Draw the mitotic figure 3 cm. across at the equator. Include cytoplasm and cell wall.

C. Construct a sterogram to show this same stage. The effect of perspective can be brought out by making structures in the foreground much bolder.

(3) The Anaphase of Karyokinesis.

The individual CHROMOSOMES have now split lengthwise and one-half of each is being drawn to the pole. How are the loops now directed? Are the SPINDLE FIBRES still visible? Were all of the spindle fibres attached to the chromosomes?

D. Draw the apparatus 3 cm. across as in last figure.

(4) The telophase of Karyokinesis. Note what has happened to chromosomes and spindle. Observe the two new NUCLEI (NUCLEOLI) and the delicate new CELL PLATE.

E. Draw the two cells with nuclei 2 cm. across.

F. Write a resume of your work on the cell according to the following outline. It represents a synthesis of the various types of cells studied.

I. Definition of the cell
II. Structure of the cell (cytology)
    A. The cell wall: pits, middle lamella
    B. The cell contents
        1. Cytoplasm (ectoplasm and endoplasm)
            a. Chloroplasts, vacuoles, granules
        2. The nucleus (nucleoplasm)
            Membrane, chromatin, nucleolus
III. Physiology of the cell
    A. Relation of the cell to water and salts
        1. Osmosis, plasmolysis and dialysis
        2. Living vs. dead protoplasmic membranes
        3. The root hair and osmosis
    B. Karyokinesis.

THE ANATOMY OF THE VEGETATIVE SYSTEM
THE STEM

Exercise 14. Ironwood (Casuarina equisetifolia L) Sections of the trunk.

N. B. DO NOT MARK UP THESE BLOCKS WITH PENCIL!

Note PITH, HEART-WOOD, SAP-WOOD, ANNUAL RINGS. If KNOTS are present, study their relation to the wood. What is a knot?

A. Diagram the cross section to show these features.

Exercise 15. The Structure of the Pine Stem

We shall now turn to the study of the structure of the stem of the pine tree. It should be realized that no matter how complicated this structure may appear, yet all the various kinds of cells have arisen by karyokinesis and have differentiated to their present form.

Let us start with the cross section and use the dissecting lens on a 1-year old twig of Pinus austriaca.

The deep red acrs on the outer angles are modified r' sections of the outer hard tissue of the leaf cushions of leaves. Note the CORTICAL RESIN CANALS. On the inner border of the CORTEX lies a narrow purplish band of PHLOEM separated from the XYLEM or WOOD inside by a deeply stained line of CAMBIUM.

What causes the irregular outline of the wood? Observe the WOOD RAYS and RESIN CANALS in it. The arms which run out from the PITH and give the inner border of the wood its lobate outline are BRANCH GAPS, viz. they are the tongues of pith which run into the short shoots.

A. Diagram the whole section 8 cm. in diameter.

Turn now to the compound microscope and use low power except where directed otherwise.

1. Focus on the outer border and observe the bands of thick-walled cells over the leaves. The very outermost row is the epidermis. Such a tissue constitutes SCLERENCHYMA. How does it differ from parenchyma? What name do we apply to the tiny pores which run thru the cell walls? Do those of separate cells meet one another? Do they ever branch? What name is applied to the dark cementing substance between the cells? How does such a tissue originate ontogenetically?

2. Just under this sclerenchymatous band lies several rows of very delicate large pale cells often crushed and distorted, They constitute CORK CELLS and were produced by the division of the narrow band of brick-shaped deeply stained cells just inside them. The latter is the CORK CAMBIUM or PHELLOGEN. If the cork continues to increase, what will eventually happen to the old leaf bases?

3. Passing thru the cork cambium we come to the CORTEX. To what category of tissues does it belong? Why is it so spongy? What is its color when alive? What are the large round openings in it? Observe their enclosing zone of SECRETORY CELLS.

4. Passing still inward note the PHLOEM. Carefully put on h. p. It will be seen that the phloem consists of rows of pink cells (SIEVE TUBES), inside each of which is a shrunken mass of protoplasm but never a nucleus. In addition one sees larger and oval cells (PHLOEM PARENCHYMA), along with the files of wood RAYS which run out from the wood.

5. Note carefully how the phloem cells grade away on their inner border into the delicate CAMBIUM LAYER and how this in its turn melts away into the wood, practically all of which came from its successive divisions.

6. The wood or Xylem. Go back to l. p. and study the wood. It is composed of rows of TRACHEIDS which have stained bright red. Do they contain protoplasm? Observe the WOOD RAYS traversing the mass and also the RESIN CANALS surrounded by nucleated RESINIFEROUS PARENCHYMA. We shall shortly study the wood in more detail so need not linger too long now on its structure.

7. Last of all we come to the pith. What other tissue does it resemble? Observe the parenchyma of the BRANCH GAPS.

8. Review each of the above tissues and see if you can tell the function of each. Remember that you are dealing with a cross-section. The tracheids and sieve tubes are really much elongated vertically as you will see later.

B. Draw rather diagramatically a narrow band some 6 cells wide running from epidermis to pith. Make the cambium cells about 5 mm. long and keep the other cells in correct proportions.

Exercise 17. The detailed structure of pine wood.

We shall now take up a careful and detailed study of the structure of pine wood both in its macroscopic and microscopic aspects. The following work demands particular care and thought.

<u>Yellow Pine (Pinus rigida)</u>. These blocks have been prepared to exhibit TRANSVERSE (or cross), TANGENTIAL and RADIAL aspects of the wood.

A. Make a sketch of any cylinder (such as is the trunk of a tree) cut by a plane in these three aspects. Label each plane.

Carefully study the cross-section (transverse) of the block. In what direction lay the center of the tree? How do you know? Note the annual rings and wood rays which transverse the mass of dense wood cells or TRACHEIDS. How does the wood vary in density within a ring? The less dense part is formed in early spring and is called SPRING WOOD, the denser mass is called the SUMMER WOOD. One other feature, the RESIN CANAL, is visible.

B. Sketch a small portion of the cross-section.

Turn to the tangential face of the block and identify the same features as before by following their extensions over the edge. If the annual rings appear like "mountains and valleys" explain.

C. Sketch a small portion of the tangential section.

On the radial face again identify the parts.

D. Sketch a small portion of the radial section.

E. Combine the three sketches to make a perspective drawing of a block of pine wood. Represent resin canals in three aspects.

Exercise 19. <u>Histological study of pine wood.</u> A cross-section of a piece of pine wood with radial and tangential sections of same will be furnished. . Identify each one with lens.

<u>Pinus Strobus - A Coniferous or Soft Wood.</u> Transverse section

Under the low power observe the ANNUAL RINGS of wood traversed by the WOOD RAYS. The thick-walled cells of the wood are called TRACHEIDS. Are the tracheids all alike in size and thickness of wall? You can now see the reason for the rings of wood. Do the wood rays all run clear across the section?

Note the <u>resin canals</u> also. Is there any evidence that they . link radially with others of like nature?

Focus carefully on the margin of annual ring with h.p. Each tracheid, particularly in the summer wood, can be seen to have a distinct thick wall, and is separate from its fellows by a darker narrow line. This is the MIDDLE LAMELLA and represents the wall which both cells once had in common before they acquired the secondary thickering of which almost all the wall is now made. Observe a SPRING TRACHEID. How do its walls compare with those of the SUMMER TRACHEIDS? Note in some of the radial walls an oval, radially elongate structure which usually shows a purple spindle-shaped area in its middle. The whole structure is called a BORDERED PIT. You are seeing it cut in section. Can you detect INTERCELLULAR SPACES? Is there any evidence of protoplasm or nuclei in tracheids?

A. Draw a group of about ten tracheids under h. p. to include both summer and spring wood. Do not darken the woody walls.

In what direction are the RAY CELLS elongated? Can you detect a nucleus in them? Protoplasm? How do they differ from the tracheids? Their walls may appear bulged out. You will find that these bulges push through a pit into an adjoining tracheid. Such a bladdery projection is called a TYLOSE.

Turn on l. p. and find a well-preserved RESIN CANAL. It is surrounded by an area of RESINIFEROUS PARENCHYMA. Do the cells contain protoplasm?

B. Draw the resin canal under h. p. (Use section of twig if they are better preserved there)

Turn the l. p. to the radial section. Distinguish ANNUAL RINGS and note difference between SPRING and SUMMER WOOD, the WOOD-RAYS, the LONGITUDINAL RESIN-CANALS. On all the tracheids you can now see the BORDERED PITS in face view. Search for a place where the ends of the tracheids are visible What is the shape of the termini and how do they fit together? How do the spring and summer tracheids differ from one another? Compare the pits. Turn on h. p. and observe a single tracheid Try to find a place where it abuts on a ray. Can you see the MIDDLE LAMELLA? Look for evidence of oblique striations on the walls. Study a pit carefully and see if you can interpret the various concentric circles. Beneath each pit is often seen a darker band. It is a local modification of the cell wall and is called a BAR OF SANIO. It is only found in woods which are closely related to the pine. Observe the RAY CELLS. What is the character of their walls? Do they bear bordered pits? Search for pits between two adjacent cells which have been cut by the plane of section. Note the MARGINAL or RAY TRACHEIDS. Do they bear simple or bordered pits? What is their probable function? Do they stain the same color as the other ray cells?

C. Draw a portion of a ray crossing several complete tracheids.

Refer to the tangential section. Why do the rays have a different appearance in this section? How do the pits now appear? Do the termini of the tracheids look the same as in the radial section? What is the actual solid shape of a tracheid? Do the resin canals differ in this view from their appearance in radial aspect?

D. Draw a portion of the tangential section.

E. Construct a stereogram of a tracheid cut transversely through its middle; show all details.

This completes our study of one of the soft or gymnospermous woods. Let us compare it with one of the hard or angiospermous woods.

Exercise 20. <u>The Wood of the Oak</u>. <u>An Angiospermous or Hard Wood</u>.

The blocks have been prepared to exhibit the structure of the wood in three planes: cross, radial, and tangential.

N. B. DO NOT MARK WITH PENCIL.

Study the cross-section of the block. Observe the annual rings of growth - how old is the piece of wood you have? Using hand lens observe the openings of the water-conducting VESSELS. Where are the largest ones found? Note that the wood rays are of two kinds: large or COMPOUND RAYS and small simple or UNISERIATE RAYS. Two other types of tissue may also be seen; dense FIBER AREAS and more open areas made up of TRACHEIDS.

A. With hand lens study a stained and mounted section. Make a diagram about 4 cm. square, magnified 10 times.

Turn to the block again and study the tangential aspect. Identify ANNUAL RINGS, VESSELS. RAYS, FIBERS, and TRACHEIDS by following their extension from the cross-section.

Turn to the equivalent section on the slide: identify the areas as before.

B. Diagram the tangential section, as you did the transverse.

C. Repeat for the radial aspect of the block and the equivalent section on the slide.

D. Combine the three sketches into a sterogram of a block 8 cm on a side.

Study various polished woods used for cabinet work. Make sketches and explain the meaning of the markings of the "Grain" What is quarter-sawed oak and how is it prepared? What is veneer?

From the previous exercise you are able to identify the various areas on the sections.

Cross-section. Focus on the end of an annual ring where it is cut by a COMPOUND RAY and note the great differentiation of the cells, all of which are specialized for particular functions. The VESSELS and TRACHEIDS conduct water; the FIBERS add mechanical rigidity to the wood. Do these elements contain protoplasm? The RAYS conduct dissolved foods radially through the wood. They, also, along with the WOOD PARENCHYMA, serve for storage of food. Do the RAY CELLS and WOOD PARENCHYMA CELLS contain PROTOPLASM?

E. Draw with care a small portion of the cross-section

Turn to the tangential aspect. You will observe delicate markings on the walls of TRACHEIDS and VESSELS; these are called PITS. They are tiny pores through which water moves from cell to cell. Note how the ends of the various cells fit together. The vessels are channels formed by fusion of many large cells end to end.

F. Draw a small portion of the tangential section.

Turn to the radial section and repeat your observations.

G. Draw a portion of the radial section.

Exercise 21. The Bark (Cortex, Cork and Phloem) of Tilia - the Basswood or Linden

Tilia is used instead of the oak because its phloem cells are larger and more easily studied.

Turn to the corss-section on the slide. On the outside lies a band of cork easily recognized by its files of tiny brick-like cells. The epidermis has died and has either been shed completely or crushed beyond recognition. Under the cork comes the cortex, while still farther inward another band of cork has arisen from another cork-cambium. (This latter corky layer has really started in the phloem and has cut off the tips of the phloem masses). All the tissues outside the cork band will eventually die and scale off (scaly bark) since they are cut off from food and water by the impervious cork.

Inside this second band of cork lies the unmodified phloem made up of several kinds of tissue. Its banded appearance is due to annual rings of growth. The WOOD RAYS are conspicuous; they vary much in size.

Carefully turn on h. p. and study a small portion of the phloem. The masses of bright red angular cells with extremely small cavities are the protective BAST FIBERS: the large cells with square, crackled and glassy bodies within them are the CRYSTALLOGENOUS PHLOEM PARENCHYMA CELLS; the smaller cells with dark contents which run in rows at right angles to the wood rays are also PHLOEM PARENCHYMA CELLS. The large colorless cells are SIEVE CELLS; they conduct most of the food of the plant. They contain protoplasm but no nucleus. Note in their corners the very small angular COMPANION CELLS. It is the work of the latter to control the activities of the sieve cells. What is the origin of this mass of phloem?

A. Make acareful h. p. drawing of a bit of the phloem only, to show the above elements.

Exercise 22. The Phloem of Tilia - Radial Section

Identify all the elements which were seen in transverse aspect. The SIEVE TUBES are to be studied with great care in order that SIEVE PLATES may be seen and interpreted.

Note the length and wall thickening of the BAST or STEREOME FIBERS. What is the part of flax which is used in spinning cloth? What is the value of bast fibers to a plant?

A what plant may grow six feet high with a diameter at the base of 1/4 inch. If man could construct a tower on these principles, with a base 20 feet across, how high would it reach? What is the shape of the CRYSTALS in the CRYSTALLOGENOUS CELLS? Can you suggest any reason for storing up calcium oxalate in this form?

A. Draw a portion of the phloem in radial aspect to show all features.

THE HERBACEOUS STEM

We have now studied the two main types of wood and have also seen the important elements which constitute the phloem or bast of trees. The most important remaining subject connected with stem anatomy is the origin and structure of the herbaceous stem. Herbs have been derived from woody plants. We will study (1) a woody twig (Tilia); (2) a half woody stem and (3) an extreme herb.

Exercise 23. <u>A Woody Stem</u>. <u>Tilia - the Basswood or Linden</u>

With dissecting lens work out the general topography of the cross-section furnished. In the center lies the MEDULLA or PITH. Note the dark masses in it. These are MUCILAGE CELLS, rather characteristic of the order of plants to which Tilia belongs. (Marshmallow is obtained from another genus in the order). The outer slightly bluer ring of pith constitutes the MEDULLARY SHEATH. It usually bears quantities of starch.

How old is the twig? Note three arms of pith running outward into the wood. At their outer ends there is an aggregation of denser and more deeply stained wood cells. The latter are LEAF-TRACES and the arms of pith are LEAF-GAPS (<u>Foliar lacunae</u>) This section was cut just below a node and the three leaf-traces are about to enter a leaf.

On the very outer border of the wood is a deep purple line. It is a cross-section of the CAMBIUM LAYER. The red pyramids outside it are masses of PHLOEM or BAST. They are separated by the flaring WOOD-RAYS. Outside the phloem lie the CORTEX bounded exteriorly by a broken EPIDERMIS.

A. Diagram the Tilia twig 7 cm. across.

B. Construct a stereogram of a half-cylinder cut longitudinally along a diameter so as to split a leaf trace and show its outward course.

Exercise 24. The Half Woody Stem.
We are now advancing toward the herbaceous stem condition. With the dissecting microscope study the cross-section of the stem given you. It is cut just below a node where the three LEAF TRACES are sweeping out to their leaves. See if you can detect them. One of the laterals is much farther out than the other. Note the LEAF GAP inside each trace and the broad parenchymatous LEAF RAY outside it and on its flanks. What is the physiological value of the leaf ray?

A. Diagram the stem. Bring out the leaf traces clearly and show parenchyma of leaf gap and leaf ray by shading.

Refer to chart showing the partial woody condition in stereogram and see that the anatomical features are clear.

Exercise 25. An Extreme Herb - Ranunculus - the buttercup
The buttercup stem has attained the extreme limit in herbaceous evolution. From a study of the chart be sure you understand how this stem evolved from a type like that of aster. Note the following points:

(1) The amount of secondary wood is remarkably reduced and this is due to the fact that the CAMBIUM functions scarcely at all. Hence nearly all the wood of the leaf traces is primary (viz derived from primary meristem - not from cambium).

(2) Since there is almost no secondary wood there are no leaf rays. In order then for storage to go on the FLANKING PARENCHYMA becomes highly developed and strongly isolates the leaf traces or fibro-vascular bundles from one another.

(3) Support is gained thru heavy SCLERENCHYMATOUS BUNDLE SHEATHS around each bundle.

A. Copy the stereograms of the partial woody stem and the stem of the buttercup from the chart. With dissecting microscope examine a stained section of the buttercup stem. Observe the cut ends of the leaf traces and their distribution. What about the destination of the larger ones? (If one were to follow these traces up or down thru the stem they would be found to link together at the nodes into a complex network).

B. Diagram the stem 7 cm. across.

Study now with compound microscope. The traces with their curious BUNDLE SHEATHS are conspicuous. See that you understand how the topography conforms to the chart diagram. Note details. Observe PHLOEM made up of SIEVE TUBES and tiny COMPANION CELLS. Note the thick protective cap outside the delicate phloem. The CAMBIUM is well developed in each trace but observe that it no longer circles the whole stem but is confined to each bundle only (fascicular cambium). The XYLEM with its large VESSELS also shows up well. Sometimes the end wall of a vessel with its porous perforation is also visible. Toward the inside of the xylem there is much WOOD PARENCHYMA.
Note the FLANKING PARENCHYMA and the PITH. The latter has partly broken down leaving a hollow stem. What difference can you see between CORTICAL PARENCHYMA and that which lies deeper. Note EPIDERMIS.

C. Select a medium sized leaf trace and draw under h. p. with its accompanying flanking tissues, pith and cortex.

If the leaves of a plant became large and crowded on the stem and too many leaf traces were entering to be accomodated in a circle what path would they necessarily take?

THE STEM STRUCTURE OF MONOCOTYLEDONS

Exercise 26. The stem of Indian corn - ZEA MAYS.
Dissect the corn stem furnished and note the leaf traces. How does the arrangement differ from that of the buttercup stem? Count the number of traces passing in from a leaf and observe how closely set the leaves are. Did nature follow the logical path which you predicted above?
Study a stained cross-section of corn stem with dissecting microscope.

A. Diagram as for the buttercup.

Turn to compound microscope. Note that the bundles are rather similar to those of the buttercup. They have the BUNDLE SHEATH of sclerenchyma and their PHLOEM is very much the same. Is a cambium present? If not, you are dealing with what is called a "closed bundle" in opposition to an open one such as that of the buttercup. Most monocotyledons have closed bundles. Is the wood as abundant as in buttercup and is it primary or secondary wood? How many vessels can you find in each trace? Note the odd resemblance to a face; the "eyes" are two PITTED VESSELS; the others are SPIRAL and ANNULAR vessels. Beneath the "mouth" lies an irregular intercellular space (PROTOXYLEM CANAL). It arises thru disorganization of the earliest formed tracheids (protoxylem). Note that one can no longer distinguish between cortex, flanking tissue and pith. For what is this parenchymatous or FUNDAMENTAL TISSUE used? How is the stem stiffened? In what respects does the stem structure of corn show extreme specialization?

B. Select a well preserved trace and draw under h. p.

THE LEAF

Exercise 27. <u>The Anatomy of the Leaf</u>. Strip off a bit of the lower epidermis of leaf and make a water mount. Observe first with l. p. Note the STOMATA scattered over the leaf. Turn on h. p. and study a stoma in detail. How many cells comprise it? They are called "GUARD CELLS". What lies between them? Do they differ in contents from the other epidermal cells? What do you suppose is one function of the stomata?

A. Draw a portion of the tissue to show stomata and other epidermal cells.

Exercise 28. The Vascular System of the Leaf. Study with microscope mounted fragments of a thin leaf from which the chlorophyll has been removed by hot alcohol and which has been rednd rendered transparent by chloral hydrate. Varying foci will show that there are several layers of cells. Red stained multicellular HAIRS also occur on the epidermis. The point to be particularly observed is the extensive ramification of the VEINLETS. High power will show that the cell walls of the veinlets are curiously thickened. How? The phloem is continued to the terminus of the vein in the form of elongate cells. What do you infer moves in these channels?

A. Draw a portion of the terminal region of a veinlet under h. p.

Exercise 29. Cross-section of a typical dorso-ventral leaf. Sections of a living leaf will be furnished. Note the heavy CUTICLE and double EPIDERMIS on the upper side. The MESO-PHLL or CHLORENCHYMA 9 etym.) makes up the bulk of the leaf. It is differentiated into an upper PALISADE LAYER and a lower mass of SPONGY PARENCHYMA. How is the latter adapted to gas circulation? Where have you seen similar CHLOROPLASTS before? Observe that in the chlorenchyma are to be seen rather in-definite grayish masses. Our section is too thick to show their details. What are they? Is the lower epidermis also more than 1 cell in thickness? Sections of stomata will be better seen in the next leaf section.

A. Carefully draw under h. p. a portion of the cross-section.

Exercise 30. Stained cross-section of leaf. How does the position of the monocot leaf on the plant differ from that of the dicot? How does the CHLORENCHYMA of this leaf differ in appearance from that of the last leaf? In what direction are its cells elongated? Note CHLOROPLASTS. Observe that the edges of the leaf are heavily buttressed by a HYPODERMAL BAND of SCLERENCHYMA as are also the main veins. Carefully study the section of a VEIN. Two veins commonly lie together with their xylems touching or actually fused. Where have you seen essentially such structures before? Note PHLOEM with SIEVE CELLS and COMPANION CELLS. Is a CAMBIUM present? Is the iris a monocot or a dicot? The xylem is composed of VESSELS and WOOD PARENCHYMA. Look carefully along either epidermis and find a STOMA cut in section. Note its two small GUARD CELLS.

A. Draw a portion of the section to include two medium sized veins and a sectioned stoma.

COAL AND ITS FORMATION

Exercise 31. A Study of Coal an. the Method of its Formation. Coal is largety formed of plant debris and this seems to be a good place to introduce its study. Let us first examine the primary materials from which coal is formed. Into a drop of water on a slide stir a little fine muck derived from a marsh Examine with low power and see what you can identify. Look particularly for small rounded yellow unicellular bodies. they are the spores of lycopods and ferns.

Make a list of the materials which you can identify and call (judiciously) upon the instructors for help on things you cannot identify.

Prepare a slide with spores (essentially pollen grains) of a club moss. You will find that these spores are all alike. During the coal period, however, giant club mosses growing 100 feet high flourished in the hot wet lands. They formed quantities of spores of two kinds. The small ones (microspores corresponded to pollen grains, while the large ones (megaspores corresponded to structures found inside the ovule of the seed plants.

B. Draw a few of the spores (isospores) from the living Lycopod.

A Microscopic Study of Lignite. Lignitic wood consists of wood which is about half way advanced to the bituminous coal condition. In ancient days it collected in bodies of water and was there silted in and preserved. It differs from wood in its higher carbon content.

Pieces of lignitic wood will be furnished for observation.

Sections of Lignitic wood.

Study the sections of lignitic wood furnished. How do they differ from ordinary wood in color? In structure? Observe carefully the effect of prolonged soaking and intense pressure to which the wood was subjected during the millions of years in which it lay buried. What part of the wood is least modified? Is it a hard (Angiosperm) or a soft (Coniferous) wood? Its age is roughly 75,000,000 years.

C. Sketch a small portion as seen under h. p.

A Study of Cannel Coal

Cannel is known to have been formed in fresh water lakes and seems to represent the result of converting muck essentially like that we have studied into the coal condition.

D. Study the pieces of cannel handed around. Note its homogeneous texture and dull color.

On the slide furnished you there are three sections of fragments of them to be studied. The narrowest, often fragmentary, section lying next one side of the cover glass, is from a piece of cannel coal. It is cut transversely to the bedding planes.

See if you can determine what the details seen under the microscope really mean. Remember that these materials have lain here since the coal period - at least 300,000,000 years and are crushed flat by the tremendous weight of rocks above them.

E. Draw a bit under h. p. and label wood, megaspores, microspores.

A Study of Bituminous Coal.

With hand lens study the fresh surface of a piece of bituminous coal furnished you. In the face broken across the bedding planes observe the streaks of bright gleaming, "glance coal", and the duller streaks of "mat coal". On the surface cleaved parallel to the bedding planes fragments of friable charred "mother of coal" may sometimes also be found. This is only charcoal swept into the pond after some old forest fire

F. Sketch a portion of the fragment broken across the bedding planes.

Mounted coal sections. Let us now find out of what the bands of glance and mat coal are really composed. Turn to the middle section on the mounted slide. It is cut from a piece of Illinois bituminous coal. Study and interpret.

G. Sketch a portion to bring out the banded structure. How will you account for the formation in bands? Does one of the glance or mat stripes at all represent the thickness of the layer when first deposited?

The third and last section on the slide is the same as the last coal only cut parallel to the bedding planes. Amorphous wood. yellowish spores, and sometimes pieces of charcoal are to be found.

I. No drawing.

THE PHYSIOLOGY OF THE VEGETATIVE SYSTEM

We have seen when studying the root-hair how water and salts enter the plant. We may now inquire as to the channels through which they rise to the parts above ground.

Exercise 32. The course of water in plants.
Examine various plants which have been kept some time in eosin solution. Study roots and stems and observe thru what channels the colored water moves.
Pull off the leaves from the stems and determine the channels through which the liquid enters and moves through the leaves. Recall the appearance of the ultimate veinlets in the blade.

Exercise 33. Relation of the leaf to water. - Transpiration. Observe the apparatus set up to show that plants give off quantities of water.

We have learned that the plant through its root hairs takes up dilute salt solutions from the soil. The salts and water are carried to the leaves through the xylem and there elaborate chemical reactions take place.

No carbon comes from the soil, and yet plants contain a high per cent. of carbon. It is all derived from the carbon-dioxide gas of the air. This gas, under the influence of sunlight and the green chlorophyll of the leaf, combines with water to form starch. The process may be roughly represented thus.:

$6\ CO_2$ plus $5\ H_2O$ under influence of sunlight $(C_6H_{10}O_5 \times 6$ plus $6\ O_2$
(carbon dioxide) (water) energy) and chlorophyll (starch) (oxygen)

A compound such as starch made up of carbon combined with water is called a carbohydrate. Let us try to find it in green leaves.

Exercise 34. Remove a leaf from a plant that has been standing in bright sunlight for some time. Extract the green coloring matter by soaking in hot alcohol; dip into hot water to remove brittleness and then submerge the leaf in a solution of potassium iodide and iodine. What is the effect? The chemical compound to which the blue color is due can be best studied microscopically from certain tubers and seeds, whither it has been transported from the leaves.
Mount in water in a thin section cut from a potato tuber and examine with l. p. What is found in the cells? Place a little weak iodine solution at the edge of the cover glass and draw it under with a piece of filter paper. Watch the section during the process. What happens? Does any of the material take a yellow color? What is it and what is its distribution?

A. Make a sketch of several cells and their contents.

Into the tube of starch paste on your table drop a little iodine solution. What results? Starch is the only known substance which gives this color with iodine.

Mount in water a bit of the milky liquid from the potato tuber and examine the starch grains again with l. p. Tap lightly on the cover glass to make them revolve. What is their real shape? With h. p. study very carefully and observe HILUM and LAMINAE.

B. Draw several forms as seen under h. p.

Return to l. p.; shut off most of the light, and draw a little potash solution under the cover glass. Watch carefully as it penetrates. What happens? Exactly the same thing occurs when starch is boiled to form starch paste. It is not in true solution but is in the colloidal (colla = glue) condition). (Forms of starch grains vary much among different plants, and adulterants in foods, etc., can often be thus detected).

Starch, then, gave the bluish color to the leaf treated with iodine in a preceding experiment. What is the chemical formula for starch?

From a plant which has been kept at least 12 hours in a dark place detach a leaf. Remove the chlorophyll and test for starch. Result? Set the plant in sunlight and after a few hours test another leaf for starch. Result?

To the leaf of a plant taken from a dark place attach a light screen and after a few hours in sunlight remove the screen and test the leaf for starch. Result? (These leaves may be preserved in 50% of alcohol.- the color fades but may be restored at any time by treatment with iodine). What conclusion do you reach from the last three experiments?

Select a leaf from a variegated Abutilon which has been standing in light; remove chlorophyll and test for starch. What result?

Exercise 35. A Study of Chlorophyll.
Take a test tube of alcoholic solution of chlorophyll solution and note the color of light reflected from the surface. Add a little carbon tetrachloride to the solution and shake. What happens? Carbon tetrachloride (CCI_4) is sold as a grease spot remover under the trade name of "Carbona". This suggests that chlorophyll is a fat which has been found to be true.

Stand a solution of chlorophyll in a lighted window and leave several days. Result? Does this suggest what happens to leaves of the Kamani before they fall and to the leaves of deciduous trees in autumn in temperate regions?

A. From careful consideration of all the above experiments and observations on Photosynthesis etc. write up a summary of the chemico-physical aspect of the process. Be sure you thoroughly grasp all the factors necessary.

Exercise 36. (a) Starch is formed in the leaves in the form of grains. Can it osmose from the cells and reach tubers, roots and stems? Set up an osmotic apparatus. Inside the membrane place a solution of cooked starch (water paste) into which has been stirred some uncooked starch. After a few hours determine whether it has dialysed into the outer water. What have we learned about osmotic properties of colloids? Let us see if we can determine in what form carbohydrates do move through the plant. Translocation. Put a little starch paste into three test tubes and mix into one a weak solution (0/5%) of commercial diastase; into the second stir a little saliva, and leave the third untouched. In about 15 minutes test for sugar, using Fehling's test. Result? What name is applied to such substances as diastase, or ptyalin from saliva?
Do plants contain diastase? Examine grains of starch from ungerminating and germinating corn. Is there evidence of corrosion in either? Compare the taste of germinating corn grains with ungerminating. What results? A Fehling's test will prove the same thing.

A. Write up conclusions concerning translocation.

(At this point could be inserted the science of plant chemistry which is concerned wholly with anabolic and katabolic compounds.

Energy for growth and all other activities is obtained by plants and animals through oxidation of foods. What compounds result from oxidation of carbohydrates? What becomes of the gas formed by an animal? What is an easy test to apply for this gas? Let us see if plants produce the same gas.

Exercise 37. Respiration.
1. Arrange a wide mouth bottle with a two-hole rubber stopper Through one hole put a thistle tube. Through the second a curved tube for gas delivery. Place branches of a leafy plant in the bottle and set it aside in a dark warm place. After a few hours bubble the gas through fresh lime water by displacing it with pure water poured through the thistle tube. What is the gas?

A. Sketch the apparatus and discuss the experiment.

B. In a paragraph compare photosynthesis with respiration.

Exercise 38. The Utilization of food.
The energy contained in the food is utilized for chemical synthesis and decomposition, for growth, and for the manifestations of irritability. A few of the simpler activities will be exhibited.

A. Take notes and write out your observations.

more or less open cavity - the EMBRYO SAC. This lies inside an oval cellular mass, the NUCELLUS, which in its turn is enclosed by two integuments. The INNER INTEGUMENT is usually more advanced in growth than the outer at this stage of the ovule. What happens to the part of the OUTER INTEGUMENT on the FUNICLE side? Note MICROPYLE. What name did we give to the integuments of a mature seed?

C. Carefully put on h. p. and draw the ovule.

(Other and more modern terms for all the carpel and ovule structures should be learned. The following table homologizes them:

Carpel or simple pistil	Megasporophyll
Ovule	Megasporangium enclosed by two integuments.
Nucellus	Megasporangium itself
Embryo-sac	Megaspore

Inside the embryo sac or megaspore at maturity lie the following naked (viz. without walls) cells: at the micropylar end, two synergids and an egg or ovum; at the other end of the megaspore, three antipodal cells. In the middle of the embryo sac a primary endosperm nucleus.

Exercise 42. It is practically impossible to furnish a large class with the stages of fertilization and embryo formation. These are to be copied from a chart hung up in the laboratory. The following list of labels is to be added to each figure. The parenthetical term is the newer one. It may be added in red ink if so desired.

Stage I. Two carpels (megasporophylls) (In the case here figure d the two stigmas prove that you are dealing with a bicarpellary gynoecium but the loculus of only one carpel is diagramtically shown).

Ovary, style, stigma, ovule (integumented megasporangium) funicle inner and outer integuments, micropyle, nucellus (megasporangium) embryo sac (megaspore), synergidae, egg, primary endosperm nucleus antipodal cells.

Stamen (microsporophyll), anther sac (microsporangium), pollen grain (microspore), pollen tube, tube nucleus, sperm nuclei.

Stage 2. Inner integument, nucellus and embryo sac, micropyle, synergiade, egg, endosperm nucleus, antipodals, broken pollen tube, sperm cells fertilizing egg and endosperm nucleus.

Stage 3. Inner integument, micropyle, nucellus, embryo sac, 3-celled embryo, 3 antipodal cells, endosperm formation with nuclei in anaphase and telophase.

Stage 4. Embryo with suspensor, endosperm, antipodals.

Stage 5. Mature seed: embryo with cotyledons, hypocotyl, plumule; endosperm, shriveled nucellus, testa, tegmen, raphe, hilum.

Stage 6. Germinating seed: testa, cotyledons, hypocotyl, primary root, hilum.

Kazuhara Murakami

Desk Copy

1659

GENERAL BOTANY

First Semester

UNIVERSITY OF HAWAII

Introductory Directions

1. Provide yourself with a 4H pencil, an eraser, ~~a hand lens~~ and a loose-leaf note book.

2. Follow directions carefully and before advancing from one exercise to the next make sure you grasp its full meaning.

3. Do not bind the pages of the laboratory outline into the notebook. Keep free so that they may be constantly in view while you are working.

4. At intervals throughout the term the laboratory notebooks will be called in for correction. Keep work up to date.

5. Lecture notes will also be called in from time to time and are to be written up in ink or typed in a neat and concise manner.

6. The liberty is reserved of requiring any carelessly executed work to be repeated.

Drawings and Written Exercises.

1. Write or draw only on the right hand page.

2. Use a 4H pencil for drawing and labeling.

3. ~~All written work is to be done in ink.~~

4. In the drawing work we insist upon care and accuracy. The following scheme of procedure is to be practiced till it becomes an established method.

   a. Enter the exercise number and topical heading.

   b. Decide on the position of the drawing and its size. The size is often indicated; if not it should be large enough to permit you to draw easily the smallest detail which is to be shown. Avoid the extremes of tiny drawings and of excessively large ones.

   c. With light lines establish dimensions, proportions and the various angles at which the parts of the object meet one another.

Outline for 1924

Herbarium and Related Work
for
Botany 3.

One of the aims of the required courses in Botany is to familiarize the student with the common native plants. To insure that this shall be accomplished, each student will be examined toward the end of the spring term and again in the fall term on his knowledge of fifty species of flowering plants. For the spring examination, he shall present a list of twenty-five species of wild plants upon which he stands prepared to be examined. In the fall, he shall do the same thing with a second list of twenty-five species.

No herbarium is required yet it will be found that the simplest and safest way to know these plants is to collect, press and mount them. They may, however, be placed in a large book unmounted, or preserved in any other way the student may see fit to employ.

The examination may be based on either living or pressed specimens. These may not always be in flower, hence the plants should also be known from their leaf and fruit characters.

Each student may be examined on his knowledge of the following points:

1. The Latin and common name of the plant and the derivation of the Latin name.
2. The Latin and common names of the family to which the plant belongs and also whether it is a gymnosperm or an angiosperm and whether a monocotyledon or a dicotyledon.
3. The characteristics of the following plant families and why certain plants of this list are placed in one of them: Pinaceae, Gramineae, Liliaceae, Ranunculaceae, Cruciferae, Rosaceae, Leguminosae, Umbelliferae, Labiatae, Scrophulariaceae, Compositae.
4. The native home and present American range of the species; station where collected by the student, habitat and soil, whether a hydrophyte, mesophyte, xerophyte or tropophyte.
5. Character of the underground part; tap or fibrous rooted, cormose, bulbous, rhizomatous; ecological features connected therewith.
6. Type of stem; shape and veination of leaves; ecological or evolutionary features of significance.
7. The inflorescence type, time of flowering and fruiting.

d. Block in the outline with light free lines using wrist and forearm motion as much as possible.

e. Go over the light sketch with a bolder and heavier line and introduce details.

f. Erase all guide lines. Make sure that every line which remains has a definite meaning. Never let two lines over-lap or cross. Leave no gaps.

g. Label the drawing by means of broken lines drawn with a ruler outward and at the end of these print horizontally in small letters every term which appears in capital letters on the outline.

5. Several drawings may be placed on the same page provided each has correct heading and is not crowded.

8. The flower as to size, color, odor, monoecious, dioecious or perfect; method of pollination.
9. The fruit as to kind, special mechanisms for distribution and morphology of such devices.
10. Economic importance--as a weed, a poisonous plant, food of man or animals, timber, or uses by aborigines.

We prefer that the study be made on the common weeds of cultivated ground, on grasses and clovers and on the native shrubs and trees, both evergreen and decidous. Not only are such plants more important to the beginner but we wish also to avoid the wholesale destruction of our delicate woodland plants by large college classes. The examination will be based particularly on the groups of plants suggested above.

Each student who fails signally in the examination will be conditioned in the course.

The following list of reference works should be useful in preparing for the examinations.

A. For the study of Family Features:
1. Baillon. Histoire Naturelle des Plantes, 13 vols. Paris 1869. English translation by Hartog, H. London, 1871.
2. Engler and Prantl. Die Naturliche Pflanzenfamilien; 20 vols. Leipsig, 1900.
3. Sargent, F. L. Plants and their uses. New York, 1913.
4. Strasburger's Text-book of Botany, Part 11, Division 11. Translated by Lang, W. B. Fifth English Edition, London, 1921.
5. Thoday, D. Botany for Senior Students. Section 4. Cambridge, 1919.

B. For species identification and description.

1. Britton and Bfown. Illustrated Flora of the Northern United States and Canada. New York, 1913.
2. Dana, Mrs. W. S. How to know the Wild Flowers, New York, 1893.
3. Gray's Manual of Botany. 7th edition. New York, 1908.
4. Lounsberry, A. L. A Guide to the Wild Flowers, New York, 1899.
5. Peterson. How to know the Wild Fruits. New York, 1905.

C. Work on Economic Botany.
1. Bailey, L. H. Cyclopedia of Horticulture, 6 vols. New York, 1914.

8. The flower as to size, color, odor, monoecious, dioecious or perfect; method of pollination.
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C. Work on Economic Botany.
1. Bailey, L. H. Cyclopedia of Horticulture, 6 vols. New York, 1914.

B. Size of subject: According to Engler and Prantl there are about 50 orders of Vascular made up of 300 families of which 23,700 species are monocots and 108,800 are dicots.

C. The major problem of Botany is to trace the course of evolution--the past dealt with a special Creation.

D. General Principles.

1. Darwin's Theory of Evolution based on Overproduction, Struggle for Existence, Variation, Natural Selection or the Survival of the Fittest, and Heredity.
2. Lamarck's theory is that change in an organism during ages is caused by the use or disuse of parts--this belief of late years has been rather abandoned although Kammerer in "The Inheritance of Acquired Characteristics" published in 1924 again champions this view.
3. Weissmann opposes Lamarck's view--this is still an open question --possibly both cases are true.
4. DeVries Mutation Theory is that rather extreme unaccountable changes occur from one generation to the next and that such a change remains relatively constant in future generations.
5. Three R's of Comparative Anatomy of Jeffrey (Anatomy of Woody Plants, Chap. XVII): Retention , Reversion, and Recapitulation.
6. Biogenetic Law.

D. Evidence employed to show how species originate and how they are related taxonomically.

1. Direct origin of species has been observed.

a. Examples.

1. Seeds were grown from the same plant and striking variations were noted.

2. In 1590 in the garden of Sprengel, a Heidelberg apothecary the Greater Celandine, Chelidonium majus, gave rise to a new species now called the Fringed Celandine, C. laciniatum, and this has bred true ever since.

3. The purple beech has appeared historically as a mutant among ordinary beeches upon at least three occasions in widely separated localities, and it has always given rise to a constant progeny.

4. A large number of new cultivated forms or incipient species are know to have arisen repeatedly such as apricots from peaches, double flowered plants from single flowered, cert certains forms of sugar-cane from bud sports, etc., etc.

5. Zaco, a Portuguese, in 1420 set free on the island of Porto Santo a female rabbit and her litter. After 400 years it was classified as a new species beause the rabbits are smaller, differ in color, and nocturnal, wild, and will no mate with ordinary rabbits.

b. Difficulties encountered.

1. Sometimes when we think we see new species arise, we see but the breaking up into Mendelian ratios of and organism whose parent or earlier ancestor was a hybrid.

Example: DeVries Oenothera

2. Only a very few so-called new species have ever been ob-

served to arise in nature - this gives us no clue to the evolution of even genera of plants, much less of important evolutionary links.

2. Geographical distribution, especially with aid of fossils.
   a. Ancient groups of plants tend to have an almost world-wide distribution- the older they are, the more time they had for dispersal.
   b. Seeds in general are so easily distributed, that rather recent plants may have a wide distribution also.
3. Serodiagnostic evidence- this is giving much important evolutionary evidence of a comfirming nature, This method, however is still in the experimental stage.
4. Comparative anatomy of living forms.
   a. This gives us the best practical clue as the the evlution of plants, but it does not give us exact information-merely a clue.
   b. Difficulties encountered.
      1. None of the present day plants could possibly be the direct ancestors of other present day plants-all we have are plants that have evolved at different rates so that a recent primitive plant is not the ancestor of a recent highly evolved plant, but at most merely shows us not what the ancestor was but it might have been. Here of course the mar margin of error must be enormous.
      2. Dangers of confusing homologous and analogous features: Euphorbias vs. Cacti; Phyllocladus and pinnate-leaved plant
      3. Dangers of misinterpreting cases of prallel evolution.
         a. Scleria testacea of Hawaii may be identical to a Scleria of Cuba, or this may be merely a case of parallel evolution.

b. Acacia Koa of Hawaii may be identical to and Acacia growing in Mauritius, or tis may be merely a case of parallel evolution.

4. It is frequently impossible to tell whether a plant is more pr primitive than another, or whether it merely appears more primitive due to degeneration-thus one might accidently read the evòlutionary series of the Lemnaceae from Wolffia to Lemna and then to Spirodela instead of from Spirodela to Lemna then to Wolffia, which is correct.

5. Palaeobotanical evidence is the most reliable.

a. Advantages.

1. It shows us the actual ancestors of the living plants. For example, annectant groups or groups that have char acteristica between those of two others are frequently found. The Cycadofilicales are an annactant group betw between the Filicales and the Cycadales.

2. It shows us exactly ar what period of geologic time th the direct ancestors of the recent plants lived. Nothi Nothing higher tnan bacteria and algae was found in Proterozoic Era, then Psilophytales and primitive Ly Lycopsida and Pteropsida in Devonian, then Lepidodendr and Cycadofilicales in Carboniferous, then Ginkgos and Cyacds in Triassic, then Pines and Araucarians in Comanchian, and finnally most of the present day famil families of higher plants form the Cretaceous on.

b. The difficulties that minimize palaeobotanical evidence is the paucity of fossil material and the imperfect preservation of the few fossils that we do find.

E. The naming of plants.

1. For rules see Hitchcock "descriptive Systematic Botany" and s see "American Code of Botanical Nomenclature" in Bull. Torr. Bot. Club 34 : 167-178. 1907.

2. Units of Classification with their endings:

a. Phylum.	
b. Division.	
b! Subdivision.	
c. Class.	
c! Subclass.	
d. Order	-ales
d! Suborder.	-ares
e. Family	-aceae
e! Subfamily	-atae
f. Tribe	-eae
f! Subtribe.	-anae
g. Genus	
g! Subgenous	
(h Section)	
(h Subsection)	
i. Species	

i! Subspecies or variety (variety according to American Co Code is relegated to horticultural usage, but hardly anyone follows this).

Cohort is an indefinite subdivision- it has been used ins tead of Order which is incorrect

Class Angiospermae (vessel" # "seed" -plants with seeds enclosed in an ovary).

Subclass Dicotyledoneae ("two"# " seed-lobe"--plants with 2 cotyledons

Cohort Archichlamydaea ("ancient" # "mantle"-generally with unfused petals or sepals).

I. Order Anonales (derivation of name probably aborginal)-Custard Apple Order.

A. Magonoliaceae. Mognolia Family.

1. Named after Pierre Magnol (d. 1715), Prof. of Bontany at Montpelier.

2. Floral Formula:

3. Affinities and characteristics.

a. Thought by Arbor and Parkin to have derived from Probennettitales.

b. Are probably the most primitive angiosperms--their primitive features are:

1. All trees or shrubs--the herbs are supposed to have been derived from trees.

2. Floral axis elongated and strobiloid with flowers usually spirally arranged.

3. Large and indefinite number of perianth parts.

4. Perianth parts free from one another.

5. Gradual transition from green bracts to perianth parts.

6. No differentiation of perianth into calyx or corolla in most genera.

7. Pollen powdery.

8. Microsporophylls leaf-like and pollen sacs exceded by connective.

9. Flowers actinomorphic, not zygomorphic.

10. No style.

11. Seeds large and fleshy

12. Seed lacking distributive mechanism.

13. Embryo very small and embedded in large amount of endosperm.

14. Two cotyledons.

15. Leaves simple in outline.

c. Other characteristics

1. Alternate position of leaves, which is not a primitiv character as the opposite position is said to have preceded.

2. All aromatic.

4. Distribution.

a. Especially common along Atlantic coast of North America and in Japan, and as fossils practically circumpolar. Now they are chiefly subtropical, which of course indicates that past climates differed from the present.

b. Gray's glacial theory partly explains the queer distribution of this family. He thinks that when the glaciers moved southward they pushed the plants ahead of them. The Magnolias died out in Europe as they could not pass the Alps and Himalayas, while in America they had little difficulty in migrating southward as the cold advanced, Then when the glaciers began to recede, they crawled northward again to their present range.

5. Genera.

a. Magnolia.

1. There are 21 living species in tropical Asia, Eastern Asia, and North America; while 30 fossils are described from the Tertiary of North America, Greenland, Spitzbergen, all of Europe, Japan, and

Australia. This wide distribution indicates extreme ag age. Magnolia has Bars of Savis in root-good evidence of antiquity.

2. M. grandiflora L. is occasionally planted in Hawaii and commonly in other countries as an ormental. It is native to the Atlantic coast from North Carolina to Florida, where it is a tree 100 feet or more high with stiff evergreen shiny Stipulate leaves bearing large wax-like fragrant flowers 7-8 inches across that resemble a water lily. According to Rock, it is stunted and barely 20 feet high when grown in Hawaii. The seeds are red and hang from the inflorescence by probably the funicle. According to Engler and Prantl the odor of the flowers is deadly to bees while Pammel says that it is injurious to some people. According to Loudon who wrote in 1860, "the flowers are pickled in some parts of devonshire, England, and are considered exquisite in flavor." This possibly is due to the aromatic oils found in the family. Webbstein pg. 604 E. and P.3.2:15

3. M. yulan of China and Japan is used in similar fashion to M. grandiflora. the Chinese pickle the flower-buds, after having removed the calyx, and then use them for flavoring rice.

4. M. glauca of the Middle and Southern U.S.. is used in medicine. The bark contains a volatile oil, resin, tannin, coloring matters, gum, and an important crystalline glucoside magnolin which is used as a diaphoretic, tonic, and febrifuge.

5. Many hybrids are grown in temperate climates for ornament. The Asiatic species usually bloom before producing leaves in Spring while the American ones flower

flower after produc ing leaves.

b. Michelia is practically the some as Magnolia except that there is a definite node between androecium and gynoecium. M. champaca L., mative of India, is a small tree cultivated in Honolulu where it is known as Mulang. The fruit is said to be edible. M. fuscata Blume, native of China, is a bush also cultivated here. Both are very fragrant and are used in perfumery.

c. Liriodendron, the tulip tree, lived in North America and Europe in the Tertiary, Now L. tulipifera is found from Vermont and Michigan to Mississippi. A form sometimes called L. Chinense, is found in China. The plant occurs no other place. This is more evidence for Gray's Glacial Theory. The ancient type of leaf was simple as is that of present seedling. All transitions from simple leaf in the se seedling to palmate in the mature plant exist, showing evidence of the Theory of Recapitulation. The tree in North America may become 190 feet high and have diameter of 5-6. It has stipules. The wood is called white wood or "White poplar" becouse it is soft and flexible. One cubic foot wieghs 26 lbs. This is the most valuable timber tree of the family. The root was formerly used to prepare an agreeable liquor while the Candians according to Baillon (1871) use the root to correct the bitterness of spruce beer and to give it a lemon flavor. An infusion of the bark is now used as a tonic, febrifuge, and vermifuge. Liriodendron is distinguished from Magnolia chiefly by the aspect of the extrorse anthers and by the fact that the carpels ripen int samaras which fall from a common axis when ripe. It is thus "a Magnolia with extrorse antherse and samaroid carpels which deparated from the common receptacle" Webb

Webbster p. 604 Britton & Brown II:73

d. Drimys is without stipules. The gynoecium consists of but one row of carpels, thus a reduced Magnolia in that respect. there are 10 species: 1 in New Guinea, 1 in Bornea, 4 in Ne New Holland, 2 in New Zealand, 1 in New Caledonia. This wide distribution again indicates great age. It has no true vessel in its wood. Lotsy therefore erroneously thought that this plant was primitive and called it"coniferen-holtz", but this lack of vessels has been proven to be due to degeneration, not to primitiveness. D. Winteri Forst. in several varieties from Mexico to Terra del Fuego has an aroma similar to cinnamon. The bark of this tree, called Winter's Bark in the trade, was formerly much used in medicine,

e. Illicium is Confined to 2 species in Florida, 2 in India, 2 in China and 1 in Japan while in the Tertiary it grew in England and in the Pliocene in Australia. This genus is ~~sim~~ similar to Drimys.

   1. I. religiosum is cultivated near Buddhist temples in Japan as a holy tree and there called "shikimi" or "shikimi-no-ki". It has a nonpoisonous seed surrounded by the poisonous pericarp containing sikimin.

   2. I. verum (apparently incorrectly named I. anisatum) of China has a nonpoisonous fruit about an inch in ~~dia~~ diameter which forms an important article of commerce. The Chinese mix the fruit with coffee and tea to impro improve the flavor. The Mohammedans of India season ~~so~~ some of their dishes with the capsules. The capsules ~~a~~ are also largely imported as star anise into Germany, France and Italy where they are used in the manufacture of the liqueur anisette.

Webbstein Handb. Syst. Bot. pg. 604.

B. Anonaceae-Custard Apple Family.

1. Name from the aboriginal.
2. Floral formula P3 # 6 Amany G (many)
3. A tropical family of Asia, Africa and America and a few in Australia.
4. Affinities and characteristica: This family seems to differ from the Magnoliaceae chiefly in having ruminated endosperm and that usually the perianth is convolute in the bud instea of imbricated. It may be significant that the numerical arrangement of flowers pollen development. Vorblabbstellung is as in the
5. Genera:
   a. Asimina triloba, the North American Papaw, is like a much reduced and numerically stable magnolis. I t is a small tree with 3 sepals and 6 petals in 2 rows, stamens many, and several 3to 7 inch long sweet, edible, oblong fruits. Flint, writing in 1828 says " The pulp of the fr fruit resembles egg-custard in consistence and appearanc It has the same creamy feeling in the mouth and unites the taste of eggs, cream, sugar, and spice. It is a natural custard too lucious for the relish of most people. The fruit is nutritious and a great resource to the savages. " While the papaw is edible, there are some cases of poisoning on record. The leaves contain alkaloids. (see Britton & Brown 2: 82. & Engler&Prant 3.2:24.) Wettstein 606
   b. Anona muricata)., the Soursop, American but introduce in Hawaii, is a small branching evergreen tree with 6-8inch fruit somewhat dark green, heart-shaped, with very many soft spines pointing toward the apex. The smell and tas taste of the fruit, flowers, and whole plant resemble mu

much those of the black currant. The pulp of the fruit is soft, white and of a sweetish taste, intermixed with oblong, dark colored seeds, and, according to Sloane, th the unripe fruit dressed like turnips tastes like them. Morelet says the rind of the fruit is thin, covering a white unctuous pulp of a peculiar, but delicious taste, which leaves on the palate a flavor of perfumed cream

(Wider, Fruits of the Hawaiian Islanda)

c. Anona squamosa,. the sugar Apple, American but introduced in Hawaii, is similar but the fruit is not spiny. It is about the size of an orange and composed of loosely cohering rounded carpels that readily fall apart. The flesh is white, full of ling, brown granules, very aromatic and of an agreeable strawberry-like, piquant taste, Rhind (1855) says the pulp is delicious, having the odor of rose water and tasting like clotted cream mixed with sugar. Master ((1870) says the fruit is highly relished by the Creoles but is little esteemed by Europeans. Drury (1858) says th the fruit is delicious to the taste and on occasions of famine in India has literally proved the staff of life of the natives. (see Engler & Prnatl 3.2:37)

d. Anona reticulata, the Bullock's Heart or Custard Apple, American but introduced in Hawaii, has a non-spiny fruit in which the carpels do not fall apart. It is edible but not as good as other species. (Wilder. Fruits Haw. Is. p 115)

e. Anona Cherimolia, the Cherimoya, native of Peru but introduced in Hawaii, has leaves velvety pubescent beneath. The fruit is said to be delious. (Wilder Fruits Haw. Is. P. 112)

f. Artobotrys uncinatus of India has been planted near the Normal School. It is a climber. A related spécies, if n not this one,.has strong hooking side branches for the purpose of climbing. (see Lotsy p. 466)

g. Canangia odorata, the Ylang Ylang of the Philippines is not uncommonly planted in Hawaii. The flowers are very fragrant and greenish but turn yellow at maturity. The fruit is a cluster of distinct carpels borne on stalks. The oil from the flowers produces a perfume. (See Wettstein p. 606)

h. Polyalthia, a genus of about 70 species, is found chiefly in Malaysia. One tree is growing in the Queen's Hospital grounds.(Wilder p. 239)

i, Sageraea cauliflora is a natice of India. It produces flowers directly on the trunk. At the base of the tree and even under the soul, pistillate flowers are borne w which produce 3 inch fruits while the upper part of th the trunk bears the staminate flowers.(see Lotsy p. 459

C. Myristicaceae-Nutmeg Fmaily.

1. Name from the Greek. alluding to the aromatic qualities.

2. Floral formula: p 3 A 3 -18 G 0; P 3 A 0 G 1 .

3. The fmaily is entirely tropical. According to Prantl in Engler & Prantl, the family is limited to the genus Myristica only with 80 species,. But in the supplement to the same work writted by Warburg, there are 15 genera and 235 species; namely 179 in Asia, 38 in South America, 4 in Madagascar, 11 in Africa, 2 in Australia, and 3 in Polynesia.

4. Affinities and characteristics: The Myristicacea may be considered reduced or degenerated Anonaceae:

   a. The flowers have changed from perfect to unisexual condition-namely there are definite staminate and pistillate flowers and these are found on separate plants.

   b. The double circle of perianth members has been reduced to one circle and here furthermore they are united almosted to tip.

   c. The variable number of stamens in Anonaceace. has remained the same in the staminate flowers of the Myristicacea.

   d. The free characters of the stamens has changed to stamen with united filaments.

   e. The varible number of carpels has been reduced to a single one (although we get in the nutmeg quite often a reversion to 2 carpels, seldom to 3, and extremely seldom to 4).

   f. The seeds of Anonaceae and of Muristicaceae both possess ruminated endosperm.

   g. The Myristicaceae possess a third seed coat called aril which is irregularin shape.

   h. None are herbs, indicating primitiveness as in the other fmailies.

i. Most of them are striking aromatic as in the other families.

5. Myristica fragrans, the nutmeg, is the only really important plant. It is endemic to the Molucca Islands where it has long been cultivated by the Dutch who jealously tried to keep the monopoly. But now it is cultivated in other tropical countries. The chief plantations are on Banda Island, an island of the Moluccas less than a square mile in area, and from here 40% of the World's supply comes. The nutmegs are harvested in April, July and November, and the seed cured with lime. The plant is a very symmetrical tree. The fruit is said to be the size of a pear, having a fleshy and edible pericarp which is also frequently cooked with sugar to make candy. Mushrooms that grow on the decaying fruits are especially palatable. When ripe the fleshy pericarp splits open and exposes the irregular third seed coat or aril. This when fresh is red but yellow when dried. The dried aril is the mace of commerce while the seed is the nutmeg. The seed has a dark ruminated testa, lighter endosperm and a minute embryo. Nutmegs seem to be poisonous. A boy who ate two died. The oil contained in it seems to act on the central nervous system and the symtoms are burning pain in the stomach with anxiety or giddyness followed by drowsiness, stupor, and diplopia. The plants seem to be disseminated by queer fruit pigeons of the genus Mysristicivora. Connecticut is the nutmeg state, a nickname alluding to the accusation that in that state wooden nutmegs are manufactured and palmed off on purchasers as genuine. A single nutmeg tree, a male, grows in Mrs Foster's garden in Honolulu. (Wettstein 607, Engler & Prantl III. 2:41)

D. Calycanthaceae

1. Name

2. Floral formula: P4-many A many G many

3. Distribution: There are 4 species-1 in Japan, 1 in California, and 2 in Eastern North America.

4. Affinities and charactristics:

a. Related to the Magnoliaceae and Anonaceae. In fact, they may be considered as Magnolias with sunken carpels.

b. Differ from Magnoliaceae and Anonaceae:

1. In having opposite leaves instead of alternate ones-this is probably a more primitive characteristic as evidenced by the fact that the cotyledons of plants are always opposite and naturally the first leaves of a plant should simulate more or less the shape and position of the early ancestors of the plant-ontogeny recapitulates phylogeny.

2. In having a large embryo with spirally wound cotyledons and almost no endosperm-this is a advanced characteristic since it means that the female gametophyte called endosperm in seed plants has been almost completely absorbed by the young sporophyte or embryo previous to the germination of the seed. An analogous instance is observed in animals. Primitive animals lays eggs or potential embryos while in the more highly evolved animals the eggs develop into complex embryos previous to birth.

3. In having inferior gynoecium-this is an advanced characteristic since the perianth had to grow up to surround the pistils.

c. At least 17 common plants have a peculiar purplish-brown color as appears in the flowers of Caycanthus, but when studied we find that it is not due to the same substance. Calycanthus is purplish-brown because of a mixture of the pigments anthocyanin and anthophaein, both in solution in the cell sap. These same pigments are also found in a single legum (Vicia faba), in 2 Ranunculaceae (Delphinium triste and D. ~~ela-~~ elatum), and in a single orchid (Coelogyne Massangeana). This may mean that the Legumes, Buttercups, and Orchids have come from the Anonales and that these families therefore have the potential ability to manufacture these 2 pigments and that 3 or 4 of the species actually did do so.

5. Caycanthus is the only genus.C. floridus, the Strawberry Bush, of the Eastern U.S. is the best known. The flowers have a delious ~~od~~ odor.(Engler & Prantl 3.2:93) Staminvdia are present.

E. Monimiaceae.

1 Name.

2. Floral formula

3 Distribution: Possibly 100 species entirely tropical or subtropical and concentrated in Southern Hemisphere such as in Polynesia, Australia, and somewhat in South America.

4. Affinities shown to:

a. Magnolia in respect to:

1. Sweet scent.

2. Female flower like Magnolia flower with carpels sunk in torus.

b. Calycanthus in respect to:

1. Carpels sunk in torus but separate.

2. Staminodia sometimes present.

c. Lauraceae in respect to :

1. Aromatic

2. Anthers opening by valves.

3. Carpels 1 or 3.

F. L auraceae.

1. Name.

2. Floral formula: P 3 # 3 A 3 # 3 G 1

3. Distribution: About 40 genera found mostly in the tropics. They first appeared in the Cretaceous Period while in the Tertiary they ran far north into Europe to be pushed south by the ice later on. In fact, fossil flowers (Cinnamomum prototypum and Trianthera ensideroxyloides) belonging to plants of genera still existing today were found perfectly preserved in amber on the shores of the baltic. At present in North America, Massachusetts is about the northern limit of the family.

4. Affinities are with the Monimiaceae as the following shows:

a. The carpels from 3 have been reduced to 1 with 1 hanging seed yet in some Lauraceae the stigma is deeply 3-cleft while in others the single ovary is sutured and may even bear more than one ovule. This of course suggests that they are derived from a tricarpellary gynoecium as found in the Monimiaceae.

b. Anthers open by valves.

c. Oil cells abundant, especially easily seen in the sepals.

d. Ovary often sunken in receptacle.

e. Stamens in 3-4 whorls, the inner being often changed to scales or glands as in the Calycanthaceae.

f. Calyx often united.

5. Genera.

a. Cinnamomum zeylanicum, the Cinnamon Tree, is a native of India and Malaya but now cultivated throughout the tropics. One tree grows on the Campus. The tree is 20-30 feet high and bears 3-nerved evergreen leaves. It is now cultivated extensively in Ceylon for the bark which is the cinnamon of commerce.

The plant was first cultivated about 1770 but know in a wild state long before and even used by the ancient Romans. Herodotus who lived around 450 B. C., even knew of it and said that "The bark was the lining taken from birds' nests built with clay against the face of precipitous mountains in those countries where Bacchus was nurtured." The cinnamon we buy is merely the bark peeled from shoots which are 3 or 4 but preferably 8 years old. The enitre plant is very aromatic due to ethereal oils but these are different in root, bark, and leaf The spice is frequently used in medicine to hide disagreeable flavors. (Lotsy 480)

b. Camphora camphora, the Camphor Tree, is a large tree over 40 feet high with long petioled leaves that are pinkish when young. Any part of the plant will give of a strong odor of camphor when bruised. The plant is native to Asia but widely planted. A huge tree is found near Lihue while many smaller o ones grow in Honolulu. The older the trees are the more camphor will they produce. So trees 50-60 or more years old are cut into small pieces. These are then put in wooden tubs with holes in the bottom, and these in turn placed in a metal distillary. When heat is applied, the distillate composed of water, comphor and comphor oil is collected. The camphor and oil soon concentrates on top, is removed and filtered through straw. By further purification, pure camphor is obtained. Camphor probably actually does not occur in the living plant. An ethereal oil occurs which upon oxidation then changes to camphor. Beside its insect repelling qualities, camphor is used in medicine. It is frequently mixed with olive oil for external use in colds, while in herat disease a tincure or mixture of camphor and alcohol is sometimes injected into the veins as a strong heart stimulant.

c. Laurus nobilis is the Sweet Bay or Laurel of the Europeans whic must not be confused with the American Laurel (Kalmia)which belongs to the Heath Family and has nothing in common except that in both cases the leaves are evergreen and shiny. The Sweet Bay is an evergreen tree 40 feet high with still dull gre green leaves and small dark purple berries. It grew thruoghout Europe before the Ice Age but now is native only to the eastern Mediterranean. Because of its aromatic odor and taste, the Greeks finally considered it an emblem of victory sacred to Apollo. Victorious general and athletes of the Olympic Games were crowned with it as a mark of the highest honor. This honor was later transferred to poets who then became "poets laureate" Baccalaureate arises from bacca laurea, meaning "laurel berry". Laurel oil which is greenish in color due to chlorophyll is pressed from the fruits. It is used as a salve. Alexander's soldiers, according to Xenophons "Anabasia", during the campaign in Asia Minor became sick from eating wild honey which bees had made from the nectar of the laurel. (Strasburger 641)

d. Cinnamomum Cassia of China produces a common but inferior substitute for the true cinnamon but the bark is thicker, coarser and not as delicately floavored. This plant as well as C. ~~zeyld~~ zeylanicum seem to have been known since earliest times. It is the "kinnamomum" of Herodotus, a name which he states the Greeks learned from the Phoenicians. It is spoken of in Exodus, is referred to by Hippocrates, Dioscorides, Pliny and other ancient writers.

e. Persea gratissima, native of tropical Mexico, is the Avocado or Alligator Pear. The name "avocado" is a corruption of the Mexico "ahuaca". The plant is a small tree with yellow flowers. The fruit is very oily and eaten as a salad. The flesh can also be made into a delicious sauce with citron juice and sugar. It is said that the immature fruit is very poisonous. The first tree grown in Hawaii was probably planted by Don Marin in Pauoa Valley in Honolul (Lotsy 481)

f. Cinnamomum protocypum is the fossil cinnamon which lived in the Cre Cretaceous 100,000,000 years ago. Its flower was found perfectly preserved in Baltic amber. This amber is merely the fosilized resin of Pinus succinifera in which a flower of the Cinnamon was surrounded. Due to its water content, the resin did not impregnate the flower. Now the amber contains an exact mold of the flower, while t the flower itself consists merely of a few black particles of carbon. (Lotsy 480)

g. Cassytha filiformis is the only representative of the entire order which is parasitic. It is practically cosmopolitan and also indigenous to Hawaii. Because of its parasitic mode of life, it is now a rootless, pale green vine with scale-like leaves and numerous haustoria. Trees in Kauai and Hawaii somtimes are covered by the plant to such an extent that they appear as though light green fishnets had been thrown over them. (Lotsy 485)

h. Cryptocarya Mannii is the second indigenous representative of the Lauraceae. It is found in Kauai.

G. Lactoridaceae.

1. Distribution: This is a monspecific family limited to the small island of Juan Fernandez.
2. Floral formula: Imperfect lowers are produced as well as perfect ones with the formula P 3 A 3 # 3 G (3)
3. Description: Lactoris fernandeziana is a much branched shrub a few feet high with alternate leaves. The nodes are swollen.
4. Affinities: Lactoris was first put into the Peper Family. Its swollen nodes certainly give it a superficial resemblance to many of them. Engler, however, says that the plant is related to the Magnoliaceae, not far from Drymis. For want of a better link, we will take this as a transitional plant belonging to the Anonales which leads to the Piperales. We must emphize, however, that we are very uncertain about the correctness of this view.

II. Piperales.

A. Saururaceae-Lizzard's Tail Family.

1. Distribution: A very small family, the genus Saururus consist ing of 2 species, one in the Eastern U.S. and the other in

2. China. Floral formula of Saururus is usually P O A 3 # 3 G 3 while Houttuynia of Asia shows reduction to P O A 3 # O G (3) Engler and Prantl 3.1:2

3. Affinities: This may be closely related to Lactoris since it has the same floral formula except that the perianth is wanting (If lack of perianth is due to degeneration, we are probably on the right track. But if the perianth is wanting because the plant is primitive and has not yet evolved one, then we are wrong about its relationship. Engler believes the has not yet evolved a perianth and therefore says that it shows no relation to the Magnoliaceae but has evolved from the Casuarinaceae or Ironwood Family.) Whether we are correct or not in linking the Anonales with the Piperales through Lactoris and Sururus, we are at any rate correct in putting the Sauruzaceae into the Piperales.

B. Piperaceae.

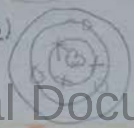
1. Distribution: A fimly of over 1000 species which are chiefly tropical. The two important genera are Piper and Peromia, both consisting of over 500 species. The plants possess endosperm as well as perisperm which is the nucellus of orole charged with starch.

2. Affinities: The Piperaceae are still more reduced than the Saururaceae as the floral diagrams show

SAURURACEAE-

Saururus: P O A 3 # 3 G 3

Houttuynia P O A 3 # O G (3)



PIPERACEAE-

Piper Amalago	P O A 3 # 3 G (3)	
piper sp.	P O A 3 # 1 G (3)	
Piper sp.	P O A 3 # 0 G (3)	
Piper sp.	P O A 3 # 0 G (3)	
Piper nigrum	P O A 2 # 0 G (1)	but with evidence of 3 corpels because of its 3 stigmas.
Peperomia sps.	P O A 2 # 0 G 1	stigma brushlike

3. Genera.

a. Piper nigrum is a woody vine sometimes 20 feet long with swollen nodes and alternate leaves. The flowers are spikate and sunken into the axis which partly covers it over like a roof. The ripe fruits are red. The plant is native to India and Cochin-China. The unripe berries are dried to form the black pepper of commerce. White pepper, on the other hand, is formed from the ripe fruit which is allowed to lie in water for a few days to soften the pericarp or skin which is then rubbed off. The aromatic and stimulant properties of pepper depend on a volatile oil $C_{10}H_{16}$ while the pungent taste and medicinal activity are mainly due to a resin called chavicin. This pepper was frequently mentioned by the early Romans and much used by them. The spice was in a such demand that when Alaric the Goth besieged Rome in 408 he asked for a ransom of 5000 lbs. gold, 30,000 lbs silver, 4,000 silk dresses, and 3,000 lbs pepper. (Lotsy 496)

b. Piper methysticum or awa of the Hawaiians is grown in several varieties in Hawaii and some other Polynesian Island where it is native, It is a large branching shrub agout 8 feet high with a spongy root. The odor is fragrant, like a perfume rather then a spice while the taste is slightly ben-

benumbing. The plant is used as a remedy in the treatment of diseases of the mucous membrane, as tonic to the digestive o organs, and as a stimulant to the nerves. It contains methysticin, $C_{15}H_{14}O_5$. By the Hawaiians it was drunk as an intoxicating beverage. The preparation of the drink is interesting. A Group of people with awa would sit around a large bowl and then add woter. This material, after being at strained through coconut husks, was ready for drinking.

c. P. betle, or Betel Pepper, of the East Indies and Malaya is introduce in Honolulu. It is used extensively in the Orient for wrapping pellets of Betel nut, the 3 cm. long cinnamon-colored seed of the palm Areca catechu which is removed from the oval yellow to orange fruits. To this is added lime and the whole mass is then chewed like tobacco. It is hot, acrid, astringent, and reddens the saliva and finally corrodes the teeth. (Engler-Prantl 3.1:9)

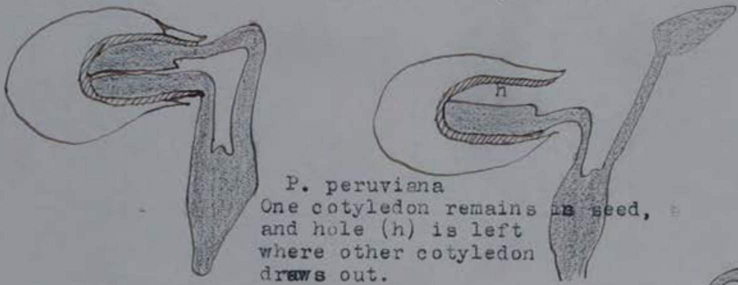
d. Piper cubeba, the cubeb pepper, native of the East Indies, is a climbing, almost tree-like vine. Its fruits can be distinguished from that of P. nigrum in being stalked. The unripe fruits are dried and used as an expectorant in lung disease The leaves are also dried and smoked medicinally. (Strasburger 6222, Engler-Prantl 3.1:8)

e. Peperomia is a huge genus distinguishable from Piper in having a single carpel without clear evidnece of its having for form-from the union of 3, by confluent anther sacs, and by a single seed coat. The plants are usually small epiphytes or terrestria herbs with thick water-storage tissues. Casimir DeCandolle, who recently died, was the specialist of this very critical genus. He described 73 species from Hawaii,67 being endemic. There are no doubt twice as many species in these islands still to be discovered. There are two general types of Peperomia, those with opposite leaves and those with apparently verticillate or whorled leaves. This last appearance is due to the shortening of alternate internodes so as to bring 2 nodes with their leaves together. Peperomia is extremely important as it introduces us to the Theory of the Origin of Monocotyledony:

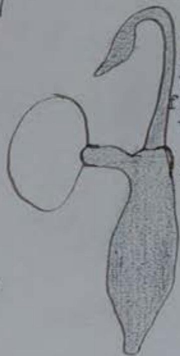
1. Miss Sargent thinks that monocotyledony arose by the growth of both cotyledons into one. This view is probably incorrect in this case.
2. Hill showed that in Peperomia one of the cotyledons becomes modified into an absorption organ and does not leave the seed. This fact leads directly over to the Araceae, one of the monocots. It is significant that Peperomia has even monocot stem anatomy. Hill's evidence is best shown by the following figures:

Hill's Theory on the Origin of Monocotyledony

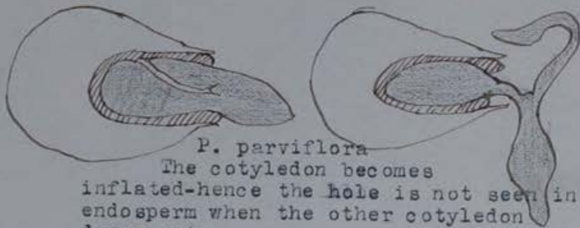
Peperomia pellucida
2 Perfect coytledons.



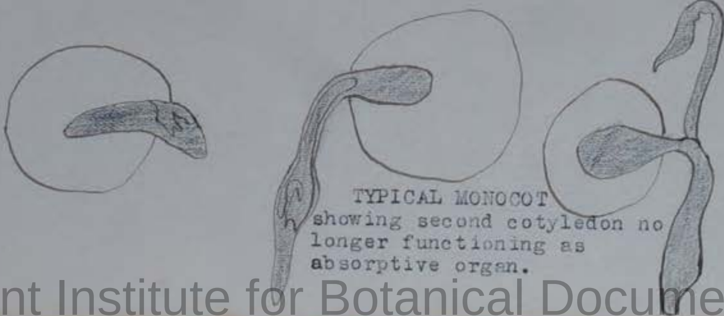
P. peruviana
One cotyledon remains in seed,
and hole (h) is left
where other cotyledon
draws out.



Arisaema
dracontium
with so-call
first leaf
which Hill
says is the
free cotyled
on.



P. parviflora
The cotyledon becomes
inflated-hence the hole is not seen in the
endosperm when the other cotyledon
draws out.



TYPICAL MONOCOT
showing second cotyledon no
longer functioning as
absorptive organ.

III. Spadiciflorales-as the name implies, this order includes heterocotyledonous families characterised by the presence of a spathe that protects the spadix.

A. Araceae-Arum Family.

1. Distribution: There are over 100 genera and over 1,500 species. The family is essentially a tropical one with about 8% extra tropical while no representatives are found in cold regions.

2. Affinities: This family joins into the Piperaceae through their simplest subfamily Pothoideae (Acorus for example) which exhibit piperaceous characters such as having flowers in catkins, having seeds with perisperm, germinating like Peperomia with heterocotyly, having net-veined leaves, and being aromatic.

3. Characteristic: Herbs or even trees, and very commonly lianes or vines; some epiphytic with clinging and adsorptive roots like those of some orchids. They often have latex, crystals of calcium oxalate as raphides, and are frequently poisonous. The leaves vary being either parallel-or net-vein and some have even holes in them. The spadix is enclosed by a spathe which may or may not be brilliantly colored. The flowers theoretically have the floral formula P 3 # 3 A 3 # 3 G (3) but almost all possible reductions and variations occur, the most frequent resulting in unisexuality. The plants generally have a putrid odor and are pollinated by flies. The fruit is usually a red, bluish, or white berry.

4. Genera.

a. Acorus, consisting of 2 species, is the most primitive genus since the spathe acts as a leaf and the flowers have a perianth. A. gramineus of Japan has normal pollen and ovules, and produces many seeds. A. calamus, the Sweet Flag. also a marsh plant, is said to have been brought from Eastern Asia to Europe by Clusius about