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sterile stamen
Prunella vulgaris
part of corolla

Hence what kind of an inflorescence? Cf. with the inflorescence of Scabiosa. Study a disc floret. What condition of the calyx? Split open the corolla and note position of united anthers around the style. Split the anther tube. Note introrse dehiscence and non-receptive condition of the stigmas. Follow the pollen presentation mechanism through to expansion of the stigmas and see how pollen is pushed up.

A. Habit sketch of inflorescence.
B. Draw the bud closed and also on a large scale as seen in longisection. C. Repeat for flower shedding pollen.
D. Repeat for flower with stigma expanded.
E. Draw the fruit. What is it called? Any dispersal mechanism?
F. Draw ray-floret. Is it fertile? Perfect?

COMPOSITAE - Liguliflorae:
156. Compare with the last. What is the condition of the sap?

A. Study individual floret and fruits. Interpret and make the necessary drawings.

Nigella P_{5-8} A_8 $G_{(4-5)}$
Berberis $P_{2+3+3+3}$ A_{3+3} $G_{\underline{1}}$
Helobiales P_∞ A_∞ G_∞
Potamogeton P_4 A_4 G_4
Ceratophyllum P_{9-10} A_∞ $\underline{G}_1$

Nelumbo nucifera — trade lotus
Nymphaea caerulea & lutea — true — lotus
Zizyphus lotus — Tennyson's lotus
Genus Lotus is a legume.
Liriodendron P_{3+3+3} A_∞ $G_{\underline{\infty}}$

Rules of Botanical Nomenclature Adopted by the Vienna Congress June 1905

"Every individual plant belongs to a species, every species to a genus, every genus to a family, every family to an order, every order to a class, every class to a division". If one considers subordinate groups, the arrangement for wild plants only may be carried to 21 degrees as follows: 1. Plant Kingdom, 2. Division, 3. Subdivision, 4. Class, 5. Subclass, 6. Order, 7. Suborder, 8. Family, 9. Subfamily, 10. Tribe, 11. Subtribe, 12. Genus, 13. Subgenus, 14. Section, 15. Subsection, 16. Species, 17. Subspecies, 18. Variety, 19. Subvariety, 20. Form, 21. Individual.

In general the suffixes of the different divisions are the following, with exceptions:

Order — ales
Suborder — ineae
Family — aceae
Subfamily — oideae
Tribe — eae
Subtribe — inae

Protophyta
Bacteria ~~?~~ are the most important of the Protophyta have no nucleus
lime secreting bacteria bees break up nitrates in sea-water to ammonia and the ammonia unites with the Calcium Sulphate liberated by others giving following reaction
$(NH_4)_2 CO_3 + Ca SO_4 - (NH_4)_2 SO_4 + Ca CO_3$
Others not important.
Thallophytes have a thallus which is very simple.
Algae develop chlorophyll and live in sunlight. ~~[illegible]~~ They are well represented in rocks chiefly as lime secreting forms called millipores and silica secreting forms called diatoms.
Many impressions found on rocks supposed to be fucus are ~~[illegible]~~ probably mechanical. These were called fucoids.
Fungi not known geologically very much
Lichens were undoubtably important but not much known about them geologically
Bryophytes are known fossilly from Tertiary but doubtfully from Mesozoic
~~[illegible]~~
Pteridophytes were of great importance
Equisetum - Calamites were the earliest - have hollow stem.
Sphenophyllia Late Palaeozoic ~~[illegible]~~ extinct since mesozoic
Lycopod has central cylinder surrounded by bark, have creeping rootstock. Spores formed in cones
Lepidodendron is "extinct club moss" showing diamond shaped "leaf bases in spiral rows.
Sigillaria has leaf impressions in vertical rows
Stigmaria are the roots of Lepidodendron and Sigillaria.
Filicales ~~[illegible] Palaeozoic~~
Cycadofilicales true ancestors of flowering plants.
Spermatophytes - represented in Palaeozoic by Cycadofilicales. In Mesozoic times a flower-like organ was developed. Gingko was abundant in Mesozoic
Oldest coniferous trees were Cordiates, leaves long and strap shaped (8 ft long.) Had highly developed structure. Modern Conifers were abundant in Mesozoic, Cretaceous and Tertiary
Angiosperms first abundant in Cretaceous. Insects became important during this time.

ORDER SCITAMINALES. - This is an extravagant order which may be characterized as follows: The whole flower is zygomorphic or wholly irregular. Ther perianth is of 6 leaves which may or may not be differentiated into calyx and corolla. The stamens were originally 6 in 2 circles but usually only a part of them are fertile; sometimes only one, the others forming corolla-like staminodia. The ovary is inferior and 1 - 3 celled. The seeds usually have an aril and also endosperm and perisperm. All in all they represent the Lily type gone wild over irregularity.

A. MUSACEAE.

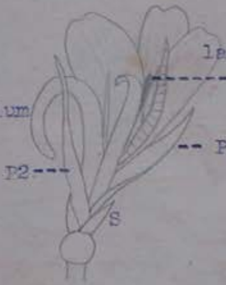
1. Affinities: These stand lowest and have 5 fertile stamens, with only one staminodium or even this may be gone. In RAVENALA madagascariensis, in fact, all 6 are fertile, while in MUSA Ensite all are fertile but the posterior median one is smaller than the others.

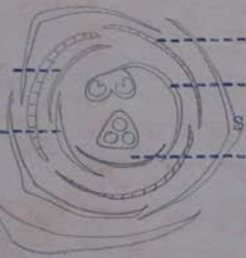
2. Genera.

a. RAVENALA madagascariensis is the Traveler's Tree of Madagascar. It collects so much water in the leaf sheath that it can serve for drinking purposes. This genus once had a wide distribution though now the only other species is R. guyanensis of Guinea and North Brazil. The former tree is a weird looking growth, some 10 meters high with leaves growing in two rows thus forming a perfect fan. The blade has a strong midrib with many veins running to the margin. Thus it is easily split by the wind. The flowers are protected by great spathes in axillary inflorescences. It is only slightly zygomorphic. There are 3 pointed elongate sepals and the 2 lateral petals are like these but the median one is shorter. There are 6 fertile stamens and a style with 3 stigmas. The seed has a slitted splendid sky-blue aril.

b. STRELIZIA is closely related to RAVENALA but is much more zygomorphic. The 2 lateral petals are fused and enclose the 5 stamens. The third petal is reduced to a three-cornered broad short leaf. The style sticks out between the fused petals while the 2 lateral sepals are hollow and the third long pointed. One species commonly cultivated in greenhouses whose fused petals are blue and the other parts orange is pollenated by birds. [illegible]

c. MUSA has all its perianth leaves except the median inner one cohering. Often all 5 points can be seen but in M. ENsite and allies the 2 laterals are reduced and so only 3 points are seen. The median posterior stamen is usually absent but may produce a staminodium. The flowers of this genus are unisexual. Honey is secreted in the female from a septal gland (cf. Bromelias) while in the male the ovary rudiment turns into a nectary. The female flowers are below while the male are above. Bisexual flowers have been observed in the middle bracts. Tischler has made a study of pollen in Bananas. The cultivated species produce no seed but the wild speciesh have many, the fruits looking like Iris capsules. Tischler found that the Bananas have different chromosome numbers. Thus M. sapientum, "Dole" has 8; "Rajah of Siam" 16; "Kladi" 24 in the haploid generation. There





CANNA sp.

MANTISIA saltatoria

... saxifrages to remain ... proposition ...
10 sps of Rosales though the family boundaries are very indefinite
legumes terminate tal zygomorphic line.
... of progressive epigyny terminates in Myrtales and Umbellales.

Saxifragaceae

Flower P5+5 A5+5 G 2 fleshy endosperm
Derived from Ranales by zonal growth and reduction of carpels to 2 as in Hamamelids. Then Astilbe goes over to Rosaceae (Spiraea) though carpels ripen into dry capsule which has many albuminous seeds.
Saxifraga is extremely plastic in relation to gynoecium since it varies from hypogyny to epigyny and from no disc to well developed disc, and from "union of carpels
Chrysosplenium - Golden Saxifrage - earliest swamp flower.
Hydrangeas are more primitive than S. because they are woody and have many stamens.
Many Hydrangeas have entomophilous modification in outside display flo...
Philadelphus coronarius - Mock orange
Ribesoideae extreme floral type of S. because of epigyny and 2 celled ovary, berry fruit.
Ribes section:
1. Ribes proper -
2. Grossularia -
Gooseberries and grapes here must because of mildew - barber white pine blister rust.

Crassulaceae P5+5 A5+5 G 5 like above except fleshy, no disc, habit.
Sempervivum tectorum - "hen and chickens"
Bryophyllum on 4 plan

Podostemaceae - gill tufted plants

Rosaceae woody or herbs with alt. leaves and stipules, fls 5-parted, actinomorphic, carpels 1-∞, receptacle flat raised, or sunken.
Seeds generally exendospermous
Fruits: capsules, follicles, achenes, stone-fruits, berries.
1. Spiraeoideae. primitive because of 5 carpels, woody, disc, flat receptacle, capsular fruit.
Physocarpus has no disc. "Nine bark"
2. Rosoideae - no follicular fruits
a. Kerrieae - achenes
b. Rubieae - coherent drupelets on elongate torus.
Fruits with torus coming off with it and others where it stays
c. Potentilleae
d. Dryadeae - achenes with tails - Geum has flat torus others tend to cink gynoecium.
e. Sanguisorbeae - Agrimonia - few achenes enclosed in hollow receptacle
f. Roseae - receptacle a fleshy cup.
3. Pomoideae
apple is Spiraea whose capsular fruit is sunken into fleshy torus.
Pomariae - carpels with several non stony kernels.
Crataegareae - " " single stony kernel.

Amygdalin in leaves and seeds.
Nuttallia is most primitive in having 5 fleshy ...
Chrysobalanaceae: flowers actinomorphic to zygomorphic
stamens ∞ often partly sterile
Connaraceae:
pinnate leaves, like legumes except in absence of stipules and presence of 5 carpels.
Leguminosae 11000 + sps. stipules pinnate or palmate leaves.
Mimosoideae
Acacias are thorny - stipules often thorns.
A. sphaerocephala - thorns > ant nests.
A. Senegal > gum arabic chiefly
Prosopis glandulosa, - mesquite
Mimosa pudica - sensitive plant
2. Caesalpinoideae: $P_{5+5} A_{5+5} \underline{G_1}$ only slightly zygomorphic
~~Hatm~~ Hymenaea > Amerinin copal.
Myrtales - mostly woody, tetramerous $\underline{G}$ style 1, inner phloem.
Thymelaeaceae
Daphne introduced from Europe escaping.
Lagetta lintearia - lace bark
Dirca palustris used by Indians for thongs.
Elaeagnaceae - silvery scurfy star-shaped or shield-shaped hairs.
Shepherdia argentea - buffalo berry
Lythraceae
Cuphea tomo breaks open in back so that placenta with seeds grows out of it.
Trimorphic flowers in Lythrum
Lawsonia inermis - source of henna
Decodon verticillatus produces aerenchyma at H_2O submerged parts
Rhizophoraceae
Lecythidaceae - flower helmet-shaped due to numerous stamens
Lecythis - Monkey pot, Bertholletia excelsa - Brazil nut
Myrtaceae - Oil canals ∴ odorous $P_{5(4)+5(4)} A\infty \underline{G} (\overline{1-\infty})$
leaves evergreen
Leptospermoideae - trees easily torn from fruit dry - Eucalyptus tropic A. and Australia
Punicaceae - no oil - 2 tiers of carpels - lower part has 3 carpels with placenta in inner angles; upper, has 5 carpels with parietal placentation.
Melastomaceae anthers often with beak, leaves lanceolate with 3-9 bow shaped veins. - South American chiefly.
Rhexia virginica.
Onagraceae $P_{4+4} A_{4+4} \underline{G} (\overline{4})$ - pollen triangular - in masses.
~~Lamar~~ DeVriesian theory of mutation
Hydrocaryaceae
Trapa ... established in ... River - ...
... lake dwellings, heterostyly

LAMIALES (DIOVULATAE)

148. Take any mint available and observe first the vegeta features such as decussate leaves, stem shape, odor. Study the flower and note how it simulates that of the Scrophulariaceae. How many sepals? Is the calyx bilabiate? Remove the corolla and split open. How many stamens and what stigma position?

A. Habit sketch.
B. Sketch of single flower enlarged.
C. Drawing of corolla to show androecium.

Under lens observe gynoecium. What shape? Is the style terminal or gynobasic?

D. Draw the gynoecium.
E. Study the mature fruit and sketch.

INFERAE
RUBIALES

To what group do they seem to attach below?

Family RUBIACEAE

149. Galium sp.
What ovary position? How about the nature of the calyx? What is the numerical plan of the flower? What happens to the fruit at maturity? Why not put the genus in the Umbelliferae? Part of the leaves are claimed to be enlarged stipules. Any evidence?

Family CAPRIFOLIACEAE

150.- Diervilla:
Draw the fruit of this plant. What important calyx feature that points forward?

Family VALERIANACEAE

151. Valeriana officinalis.
Note character of the inflorescence. What family is it approximating.

A. Habit sketch.

Study a single flower. What is the symmetry? Is there any irregularity in the throat? What is the ovary position? Section the ovary and determine the number of carpels. What is the condition of the calyx? How many stamens?

B. Draw the flower and diagram it.

Study the fruit. How many carpels have matured? What is the method of seed dispersal? To what family do the fruit features point?

C. Draw the fruit and also a section of it.

Family DIPSACACEAE

152. Scabiosa
Observe inflorescence and note the mimicry of a composite. In what part are the older flowers found? What sort of an inflorescence has been congested to form this one? Remove flowers from the inner part and from the margin of the inflorescence. Boil and study. Observe the epicalyx. What may have been its origin? Into what does the calyx mature? How many carpels? Stamens?

A. Draw a flower of each type and also a diagrammatic longisection of the fruit.

153. Dipsacus

A. Habit sketch. What does it simulate?

INFERAE - CAMPANALES

Family CAMPANULACEAE

154. Campanula.
Study the flower; note particularly the inferior ovary of 3 carpels and the pollen presentation mechanism.

A. Sketch flower and its longisection.

COMPOSITAE - Tubuliflorae.

155. Study as a review any member of the sub-family available. Note involucre, disc, ray-florets and chaff. Where are the florets oldest?

is a difference between disc and ray florets which brings
suall gical analogy to a single flower: thus the involucre acts l
the ray florets like corolla, while the central florets
ke sex apparatus.
individual flowers are basically the old actinomorphic tube
zygomorphy leads to the extreme ligular type. As to mod-
the following occur.

le flower head is of perfect ♂ flowers	- Eupatorium
" " " " " strap "	- Dandelion
" " " " " 2 lipped "	- Mutisreae
tubular but central perfect, outer ♀	- Gnaphalium
ct flowers, tubular, & central - ♀ or	
sse strap shaped marginal	- Chrysanthemum
All tubular, central ♂; peripheral ♀.	- Conyza
Central tublar and ♂; peripheral ♀ and strap	
All tubular	
Dioecious- all tubular -	- Antnnaria.
Perfect flowers, central; perfect and ♀, 2 lipped and also ♀ strap flowers peripheral.	

t are entomoph. (anemophily) in Artemisa)
ogamy and even Parthenogensis are not rare. Proterandry common.
len presentation as in other Campanales. In Centaurea the stamens
irratable and the filaments contract when disturbed- thus the
en is swept out. Parthenogensis in Taraxacum, Hieracium, and
aria sps.
n distribution the pappus plays a great role as a flying, swimming,
clutching apparatus.
A most difficult family to classify since there are over 11,000 sps.
d in all directions with one another thru transitional forms.
a very young family caught in the acme of evolution:
neral it is easy to classify into 2 great groups- the Liguliflorae
orae. This is natural for the last have tubular, 2-lipped and
flowers along with resin canals; while the first have only
rs and milk canals. Modern systems are placing much weight
of the stigma. Many contain ethereal oils and are or have
medecine- some for salads- Lactuca sativa, Cichorium Endiva,
us, the articoke; Helianthus tuberosus "Jerusalem artichoke"
ed for flowers- Bellis, Callislephus, Aster, Ageratum,
nnia, Helianthus, Chrysanthemum, Calendula, Tagetes,
etc.

s - 119 lV Teil lV- V Abt.

Family Gesneriaceae
Why probably closely related to the Orobanches? What advance in the position of the ovary? What cultivated flower stands here?

Family Acanthaceae
How do they represent an extreme type of the Personales in corolla, stamens (anthers), pollen, and fruit (retinaculae). What of interest about Acanthus spinosus?

Family Bignoniaceae
What general habit? What one tree is familiar? What floral characters and could they come from the advanced Scrophulariaceae? What familiar woody vine in the family and how is it pollinated?

Family Pedaliaceae
What fruit features? What is Sesamum indicum? What is the nature of the fruit of Martynia?

TETRACYCLIDAE - TUBIFLORALES

DIOVULATAE or LAMIALES

Characterize the vegetative habit and floral structure of the main Family Labiatae.

TETRACYCLIDAE - INFERAE - RUBIALES

What 4 characters (P 179) distinguish the Inferae and how does the group compare with the Tubiflorales? With what other line does the Rubialian show close affinity.

Rubiaceae: From what general stock would they seem to have been derived? Characterize this ancestral stock and also the Rubiaceae derivatives. What small feature is usually held to separate the Rubiaceae from the Caprifoliaceae? What are the two tribes under the family Rubiaceae? Give an important genus under each.

Caprifoliaceae: Point out wherein the following features begin to mimic the Compositae: Inflorescence of Viburnum Opulus or of V. alnifolium; ovary state of the Viburnums; calyx of Diervilla.

Family Valerianaceae:
Describe the flower of a Valerian and point out its striking composite features.

Family Dipsacaceae
Repeat for Scabiosa and Dipsacus. Why are these plants not put with the Compositae.

INFERAE CAMPANALES

What stock gave rise to this Order? Why not put in the Rubiales? What is meant by the pollen-presentation mechanism and how does it function? What vegetative features hold these plants together? [illegible] is the usual condition of the carpels? How do the Lobeliaceae [illegible]

Candolleaceae, Goodeniaceae

compositaean inferior bicarpellary unilocular ovary arose?

Family Compositae

Describe the composite infloresscence and an individual flower of the two main types. Give the two sub-families and characterise vegetatively and on floral features.

Liguliflorae

Tubiflorae

Order Rosales

What term does Hallier apply to all the remaining orders of the Plant Kingdom? How many species of the Rosales and what about family boundaries? What family terminates the zygomorphic line? What one terminates a line of progressive epigyny?

Family SAXIFRAGACEAE
Describe flower; what affinity below and what above? How different from Rosaceae? What rosaceous genus parallels Astilbe? The genus Saxifraga is extremely plastic as to gynoecium. How? What habit and habitats? What does the name mean? What geographic range? What common native sps? Common name of Tiarella cordifolia; of Mitella diphylla? Of Chrysosplenium? How do the Hydrangeas represent a more primitive group than the Saxifragas? What entomophilous modification of the cyme of many Hydrangeas? What is Philadelphus coronarius? What common name is falsely applied? How do the Ribesoideae represent the extreme floral forms of the Saxifragaceae? What two sections of the Genus Ribes? Why are gooseberries so little grown with us? Why are we attempting to exterminate the wild species? What about Ribes rubrum as an escape?

Family CRASSULACEAE
Habit and as an "ideal flower". Derivation of the name Sedum? of Sempervivum? What are "hen and chicken plants"? What about "the vegetative reproduction of Bryophyllum? What floral formula?

Family PODOSTEMACEAE
Give description of habitats and habits, colors, gill-tufts, etc.

Family ROSACEAE
Characterize the family. What plastic torus character is dominant? What fruits? What seed features?

1. Spiraecideae: What does Spiraea mean? Why is the genus primitive? What is Physocarpus?

2. Rosoideae: How have the fruits been modified over the last?

A. Kerrieae: What two genera in cultivation here? What about the seed?

B. Rubineae: What is meant by drupelets and what two sorts of fruits as regards torus? Notes on Rubus arcticus, R. Chamaemorus, R. occidentalis, R. odoratus, R. idaeus, R. strigosus, R. alleghenienisis, R. ursinus. What about hybrids among Rosaceae?

C. Potentilleae: What fruit character and what terminal member of the Tribe?

D. Dryadinae: What achene feature and how does Geum differ from Dryas?

E. Sanguisorbeae: What torus feature and what representative with us?

F. Roseae: How different from the last?

3. Pomoideae: Describe an apple botanically. Distinguish between Pomariae and Crataegareae. Notes on Pirus communis, P. Cydonia, P. germanica, P. Malus, P. aucuparia and P. americana - hybrids of last with P. melanocarpa. What of Crataegus as to species? What are Amelanchiers and are they of any value?

4. Prunoideae: Flower and fruit characters? What poisonous principle in many? What physiological effect on animals? Why is Nuttallia a significant genus? Notes on Prunus americana, P. armeniaca, P. avium, P. domestica, P. maritima, P. pennsylvanica, P. persica and its chimaeras, P. serotina and P. virginiana.

Family CHRYSOBALANACEAE
Characters: symmetry, stamens, style, nectary of extreme forms, what points to the Rosaceae? What to the Leguminosae?

Family CONNARACEAE
Note leaves, floral symmetry, gynoecium and fruits. What separates from the Leguminosae? From what group of Rosaceae would they have to come?

Family LEGUMINOSAE
Number of species, habit. Distinguishing leaf and gynoecial features.

Sub-family Mimosoideae
How related thru Connaraceae to Rosaceae? Why may not Affonsea be placed in the Connaraceae? What characterizes the Acacias? What are the Acaciae-Phyllodineae? What of interest about A. sphaerocephala? From what plant is gum arabic derived? What other economic products from the genus? What is Mimosa pudica? Prosopis glandulosa and its economic value?

Sub-family Caesalpinoideae
Describe flower and state how it is moving toward the papilionaceous type. Characterize: Hymaenia, Tamarindus, Amherstia, Cercis. Whence comes the common name of the last? What is Bauhinia and what is meant by its cleaved stem? Notes on Gleditsia trichanthos and "espina de corona Cristi."

Tribe Papilionoideae: Describe the flower. What habit is more common in this tribe than in the others? Notes on Cladrastis, Baptisia, Crotalaria, Lupinus, Medicago, Melilotus, Trifolium, Indigofera, Arachis hypogaea, Robinia, Wistaria; Astragalus and its physiological effects, Desmodium, Vicia, Lens, Lathyrus, Pisum, Phaseolus.

Order MYRTALES

Characterize by numerical plan, gynoecium, style, and anatomical features. What derivation?

Family THYMELEACEAE
What native genus and how used by the Amer-indians? What European genus is introduced? What is Lagetta lintearia?

Family ELEAGNACEAE
What epidermal character? What is Shepherdia argentea? Any economic Eleagnus species?
Family LYTHRACEAE: What is meant by trimorphic flowers? What introduced species around Amherst? How do certain Cupheas shed seeds?

TETRACYCLIDAE

TUBIFLORALES

Characterize the group Tubiflorales. Give the three Bentham and Hooker Orders of them and characterize each as to position in the progressive ascent.

Order POLEMONIALES

Family Convolvulaceae: - Meaning of the name
Why considered apocynal descendants? Describe a Convolvulus flower. Why are the Dichondreae placed in the most primitive position? What is Ipomaea Batata? I. leptophylla? I. pandurata? I. purpurea?

Family Borraginnaceae
What striking carpel character in the family and what family effects the transition from the Convolvulaceae? What vegetative and inflorescence character to the Borages? Mention a few important genera.

Family Polemoniaceae
How does it differ in gynoecial features from the other Tufiflorales? How far back would you have to go for an ancestry? Give two genera of importance.

Family Solanaceae
How different in ovule character from the last families? Describe a solanaceous flower. What affinity do they show with a lower family? What group affects the transition to the Scrophulariaceae and what stem feature separates the Solanaceae from the Scrophulariaceae. Characterize: Atropa Belladonna (derivation of terms?), Hyoscyamus niger, Physalis, Capsicum, Solanum tuberosum, Mandragora, Datura, Nicotiana; meaning of Salpiglossis and how do its flowers melt into the Scrophulariaceae?

TETRACYCLIDAE - TUBIFLORALES

PERSONALES or MULTIOVULATAE

Be sure you realize the significance of the above terms. How do these differ from the Polemoniales.

Family Scrophulariaceae
Sub-family Pseudosolanae.
What plant stands here and why is it most primitive of the scrophularians in its flower structure? Describe a more typical scrophularian as to corolla, stamens and gynoecium. Significance of P[illegible] stemon. What half-parasites stand here and whither do they lead?

Family Lentibulariaceae
What ovary character separates from Scrophulariaceae and h[illegible] the transition affected? Describe the insect trap of the Utric[illegible] What is another genus and how does it trap insects?

F[illegible] [illegible]banchaceae
[illegible] habits? What placental evolution in Oro[illegible] [illegible]tion differ from that of the Scrophul[illegible] [illegible]cribe Lathraea Squamaria.

... are used for salad
... V. offi...
...ran, or St. George's H... b used in medecine.
...nys Satamansi of India gives the perfume known as ...

In conclusion though the family seems to simulate the Compositae it must be merely the independant working out of basic principles common to both- for zygomorphy and trilocularity of Valeriana militates against their close relationship..

<u>Dipsacaceae.</u> (Scabiosaceae)

Now we have the climax of aggregation of the line and the individual flowers give 2 types of '/'.
(1) The ray flowers get their '/' as a resultof aggregation while (2) the disc flowers bring over the old entomophilous condition.

They are haerbs u. with opposite leaves without stipules. Flowers with an epicalyx and also involucre of bracts and stand in heads. Calyx 5-4 toothed. Teeth often bristly or absent. Corolla '/' 5-4 lobed (in last case the union of 2 parts.) Stamens 4 or less. Ovary 1 loculed and 1 seeded. Ovule hanging. Fruit and achene.
Flowers blossom from center out- congested cymes.

This represents the terminus of the line the 2 sterile carpels of Valerians have gone completely. Payer says a second carpel appears as a primordium. Just as in Valerian, the calyx assumes new role. Wernham says: "In a close inflorescence the mere crowding of the florets provides a source of mutual protection among them; and the calyx being no longer required for purpose of protection is pressed into the service of fruit dispersal." Wettstein says as to position: Trotz der grossen Ahnlichkeit mehrerer Gattungen (Dipsacus, Cephalaria) mit Compositen whelche auf einem ahnlichen Baue der Inflorescenz, auf ahnlicher Ausbildung des Kelches und der Frucht beruht, ist an eine nahere Vernandschaft mit diesen nicht zu denken; die vernandschaftlichen Beziehungen zu den Ubrigen Rubiales sind klar."

The epicalyx of the Dipsicalian flower is an odd thing which envelopes the inferior ovaru. It may have arisen from concrescence of 2 bracteoles.

Warming divides into 2 groups.
A. With a scarious bract to each flower. Scabiosa has epicalyx a callar while its calyx is of 5 bristles. Dipsacus,the teasel, large spiny herb with capitula resembling composites. Epicalyx almost entire. Leaves unite in pairs and rain water collects.
B. Bristles, but no true bract to each flower.

Dipsacus heads used in fulling cloth. D. fullorum.
Scabiosa cultivated as " mourning bride"

Use of Lawsonia inermis? What odd feature of Decodon verticillatus?

Family Rhizophoraceae
Etymology of the name? Describe vegetative form of Rhizophora Mangle. What about the ecology of the family? Note leaf character, vivipary and ecology of the seedling.

Family Lecythidaceae
Describe the odd flower. Is it primitive? What curious androecial modification? What is Lecythis? Bertholletia excelsa?

Family Myrtaceae
Vegetative, leaf and flower characters. Notes on Myrtus, Psidium guava, Pimenta, Eugenia caryophyllata and other economic species. What are the Leptospermoideae and what is their native home? What size and what economic genus?

Family Punicaceae
What odd ovary character of Punica? Meaning of mala punica?

Family Melastomaceae
Meaning of the name? what vegetative and androecial characters make them easily recognized? What native plant? Where is the geographical center?

Family Onagraceae
Floral formula and pollen character? What about hybrids in the group and to what theory of evolution did the Oenotheras give rise? Describe proterandry and subsequent autogamy in Epilobium angustifolium. Why is the plant called a fire weed? Notes on Fuchsia and the Circaeas.

(Family Hydrocaryaceae Engler - What does the name mean)?
What odd plant stands here? Describe habit, fruit and the seed germination. What economic value? Where found in Mass? What part has it played in human history and palaeobotany? Meaning of caltrops?

PARIETALES

Following Wettstein characterize the orders Guttiferales and Parietales. Suggestion of the derivation from what group?

GUTTIFERALES

Characterize Actinidia and give the family. What odd pollination device in Macgravia?

Family Theaceae
Describe the Thea flower. What is the origin of the tea plant? What is its active principle? What effect on animals? Difference between green and black tea? What about tea adulterants and how can they be detected?

Family Guttiferae or Hypericaceae
How separated from the Theaceae? What prevalent androecial character? What is an aril? An ariloid? What odd embryo character in the extreme Guttiferae? What is the mangosteen and who first described it? What is the So. American apricot? What about Pentadesma butyracea? Etymology of the name Dipterocarpaceae?

ORDER PARIETALES s. str.

How different from the Guttiferales? Give families and notes on the following: Helianthemum canadense, Hudsonia sps.; the plant which yields "arnatto." (Whence the genus name)? What is "manna?"

Family Droseraceae
Describe the way in which Drosera catches insects. Repeat for Dionaea, Drosophyllum, describe Aldrovanda and its trap mechanism; on what does it feed?

Family Violaceae
Habit of certain tropical violets? How is zygomorphy expressed? What pollination mechanism? What about cleistogamous flowers and hybrids? Give latin name of the pansy; of the violet of floriculturists.

Family Flacourtiaceae
What of significance in Homalium and Bembicia? Whence does Phyllobotryum derive its name? What of economic importance derived from Gynocardia odorata? How do Malesherbiaceae give a slight hint of the next family?
Passifloraceae: Describe habit and flower. What place in legend?

Family Caricaceae
Describe habit and fruit of Carica Papaya. What significant chemical substance and how utilized in cookery? Many Loasaceae have odd androecia - how?

Family Begoniaceae
What habit, leaf shape, flowers? What two groups? What is the most primitive genus and where does it grow? What is the reason for the name Begonia phyllomaniaca?

Family Cucurbitaceae
Where does Engler put the family? What habit? What fibro-vascular feature? Is the corolla ever archichlamydeous? What seems to be the morphology of the tendril? As to androecium characterize Fevillea and explain what takes place in the ascendant series as regards stamen position. What odd anther evolution? What sort of anther has Cyclanthera? How many carpels usually in the family? What position? What is the name applied to the fruit? Why should cucurbits be placed as highest members of the Parietales? What about their distribution over the earth? Notes on Acanthosicyos horrida, Luffa, Ecballium, Citrullus vulgaris, Cucumis melo, Cucumis sativus, Lagenaria vulgaris, Cucurbita maxima, C. moschata, C. pepo. Echinocystis (etym.)

Order UMBELLALES

Give features which put these in the highest position among the Archichlamydeae. How do Araliaceae differ from Umbelliferae in fr[uit] characters? Notes on Tetrapanax (Fatsia) papyrifera, Panax quinquef[olium], P. ginseng, P. trifolium, Aralia nudicaulis, A. racemosa.
Umbelliferae: their floral formula is the same as that of what sympetalous family? Why difficult to classify and upon what feature is the classification based?

Describe the fruit and define terms: schizocarp, mericarp, carpophore, stylopodium, primary and secondary ridges (juga primaria and secondaria) valleculae, vittae. What endosperm character? Notes on Hydrocotyle, carrot, parsley, celery, caraway, asafoetida, Arracia xanthorrhiza. What about poisons in the family? Note on Conium maculatum. What historical crime connected with it? What is the cowbane? What other common species of the same genus? When parsnips run wild do they become poisonous?
Cornaceae: Note on Nyssa sylvatica and Cornus spp? What display mechanism in C. florida?

The SYMPETALAE

Give the typical formula. Characterize habit, calyx, corolla, androecial position, ovules.

I. Notes on androecium and obdiplostemony, symmetry, choripetaly, carpels.

II. Notes on androecium, symmetry, aggregation and consequent calyx modification; ovary.

Order ERICALES

Floral formula; origin according to Warming? What stamen feature and what B. and H. name was founded thereon? What two groups are still apopetalous? How do the Pyrolas lead to the Monotropas? Nutrition of the latter? How do the former effect ontogeny if necessary?

Family Ericaceae
Describe the flower of Erica. Why do some systematists try to throw out the Vaccinioideae from an ericalian affinity? Notes on the Rhododendrons as to floral symmetry and distribution. What is our swamp pink? The rhodora? What is Ledum groenlandicum? Describe Kalmia as to pollination mechanism and poisonous principles. Note on Arctostaphylos Uva-ursi, Gaultheria procumbens, G. Shallon. What about Ericas as horticultural plants? What is Calluna? Economic of Chiogenes hispidula? What is the difference between huckleberries and blueberries? What is the scientific name of the low or early blueberry; of the high blueberry? What historical matter connected with Vaccinium Vitis-Idaea? What are the cranberries? Where do the Epacridaceae grow and what is their habit? What is the habit of the Diapensias? of the Pyxie-moss?

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ACEAE.

Flowers perfect and u. '/' Calyx small, seldom lacking. Petals more or less united. Stamens 5, alternate and free or epipetalous. Anthers introrse, and free or united. Ovary 1 or 2 loculed, inferior or half inferior. The 1 locule arises because of an imperfect septum. The style is beset below the stigma with a 2 lipped pollenbeaker - a so called " indusium". Fruit u. a capsule, sometimes a drupe or nut.

At the extreme of the family stands 1 sp. Brunonia in the Sub Family Brunonoideae. sometimes raised to family rank. It has the stigmatic cup. zygomorphic flowers and also has an involucrate capitulum and an unilocular inferior ovary with 1 ovule Its fruit is a small nut with feathery calyx segments B. australis lives in Australia and Tasmania.

CANDOLLEACEAE.

Flowers perfect or unisexual thru abortion, '/(or seldom *, P 5+5, St. 2 and united to the style. Anthers extrorse . Ovary 2 locular or wholly 1 locular. Fruit a capsule. Small grass-like herbs of the Australasian realm.

Calyceraceae.

Calyx superior and leaf-like. Corolla 4-6 parted. Stamens u. isomerous. Filaments u. united. Anthers free and opening inwardly. Ovary 1 loculed and with 1 anatropous hanging seed. Herbs or shrubs with flowers united into heads and surroundedby an involucre, A curious thing is the fact that the marginal flowers are perfect while the disc florets are staminate thru reduction. This has not been seen in the Composite. Hence when fruit ripens, the head is beset with fruit around margins with sterile flowers in middle. Each fruit remains crowned with the horny calyx. All S. American. mostly in Andes. 3 genera and some 23 sps.

COMPOSITAE.

Plants of very different habit. Flowers always in heads with sterile involucre. Calys reduced or changed into a pappus. Corolla * or '/', u. pentamerous. Stamens as many as the lobes with anthers united to a tube. Ovary inferior, 1 chambered with a basal anatropous ovule. Fruit an achene without endosperm.

Histologically: inulin, schizogenous oil canals, or milk tubes, often with inner phloem.

The largest plant family varying much in vegetative organs, herbs, shrubs, and trees, climbing plants, xerophytes, and succulents. But in spite of vegetative changes the inflorescence and florets are stereotyped. Variations lead to unisexual heads elongation of axis, compound heads (Echinops) Disc may bear chaff or not. Involucre may be foliar, leathery, thorny, or even petaloid.

Parietales

[illegible]

Guttiferales - [illegible] woody [illegible] stamens fused, 4
Parietales - [illegible]

Dilleniaceae Actinidia → greenish edible berries.
Macgraviaceae Macgravia flo. associated with spoon-shaped bracts filled with nectar.
Theaceae or Ternstroemiaceae
Thea flo perfect or imperfect, $P_{5-7} + 4-9$ $A\infty$ $(G\frac{3}{}-\infty)$ seeds axillary
Tissue contains sclerides, active principle theine, central and cardiac stimulant
Guttiferae or Hypericaceae differs from Theaceae in ~~[illegible]~~ presence of resin canals.
Aril grows out from funicle
Arilloid " " " micropyle
Cotyledon almost gone in extreme types
Mangosteen, Garcinia - described by Capt. Cook
S. A. apricot - Mammea americana
Lainlies:
Helianthemum canadense - rock rose one of Cistaceae - 2 kinds of flo.
Hudsonia spp - Cistaceae
Bixa → annatto, red dye - Bixacea
Tamarix → manna
Droseraceae
Dionaea - Venus fly trap.
Drosophyllum - like Drosera - hung in houses to catch flies.
Aldrovandia - feeds on diatoms etc
Violaceae
Certain tropical forms woody
Flacourtiaceae
Homalium
Bembicia - flo epigynous
Phyllobotrys flowers from leaf midrib
Gynocardia odorata - Chaulmoogra oil to cure leprosy
Malesherbiaceae > Passifloraceae by presence of gynophore and absence of aril
Caricaceae
Loasaceae - basally pentamerous but sts. rise to 20 or more and often partly change into staminodial nectaries.
Begoniaceae herbs with watery stems
♂ P_{2-4} $A\infty$
♀ P_{2-5} $G\overline{(2-6)}$
Hillebrandia, most primitive genus - st. free
Fibrous and tuberous rooted types

Engler puts them with Campanulaceae
Habit — vines. Fruit generally special kind of berry called pepo
Bicollateral fibrovascular bundles.
Fevillea has 5 free stamens → zygomorphy
originally 5 but → 3 commonly

Acanthosicyos horrida — grows on sand dunes
Luffa — made into sponge
Ecballium — squirts out seeds.
Citrullus vulgaris — watermelon
Cucumis melo — Cantaloupe
" sativus — cucumber
Lagenaria vulgaris — gourd
Cucurbita maxima — Turban squash
C. moschata — crookneck
C. pepo — pumpkin
Echinocystis — native wild one

Umbellales P_{4-5} A_{4-5} G_{2-5} epigyny and umbellate inflorescence

Araliaceae — have berries
Umbelliferae with composite floral formula

Under I come the Nicandreas already mentioned under Solaneae stand many economic plants - most of which are poisonous. Atropa Belladonna is a tall glabrous herb with perennial rootstock native to So. Europe and Asia Minor atropin used for dilating the pupil of the eye - Note sp. name. Hyoscyamus inger is the black henbane. Corolla dull yellow reticulated with purple veins. An annual or biennial common N. S. to Mich. The drug hyoscyamin $C_{17}H_{23}NO_3$ which has a sharp disagreeable taste, is obtained from seed. Very similar to atropin. A powerful depressant to brain - produced death from paralysis of respiratory center. Several cases of children poisoned by eating the seeds.

Nicandia

Physalis - the ground cherry or Husk tomatos are herbs of warm climates - grown for fruits and some for decorative seed pods. The common one of this region grown in gardens is P. pubesceus a spreading plant with abundant fruit. Long in cultiv.- figured by Dillenius in 1774 from S. A. Another sps. with brilliant red pods and red berries is P. Alkekengi. A variety of it var. Franchetii (perhaps a species) is sold as Chinese Lantern Plant. We get P. heterophylla here as an escape. Gray 15 sps. in the Manual range. Sturtevant 9 edible species.

Capsicum - the peppers. Originally from C. Am. but escaped in Old World. About 90 sps. have been named but they are now reduced to 2 and all considered as forms C. annum is the Cayenne Pepper. Too much will cause death. The pungent principle is capsacutin so intense that 1 part in 11,000,000 of water will impart the pungent taste. Very variable plant. C. frutescens is a shrubby perrenial cultiv. in south. There is also 1 Japanese sp. C. anomalum. Solanum is the big genus of 900 sps. Sturtevant 23 sps. in use as food plants.

As a genus the calyx is 5-10 toothed unchanged in fruit or only a little enlarged. Corolla with 5 points (in 1 section 1). Filaments very short and epipetalous. Anthers pressed tight together around the style or stamen monadelphous. Anthers open by a terminal pore or short inner split. Fr. a berry. Herbs, shrubs or trees - creeping, climbing etc. Fls. white, yellow, purple or red. South and C. Am. most sps; Europe has 12, Asia 32, Africa 27, Australia 10.

S. melongena is the Egg plant, Jews' apple or Mad apple. From Old World Tropics. First reference in Europe about 13th century. Claimed to mentioned in Chinese work of 5th century. First ones in Europe were grown for ornament - size of egg. Four varieties now grown in America can be traced far back in Europe.

S. Dulcamara S. tuberosum

S. tuberosum - the potato comes from W. S. Am - was cultiv. by Incas in Chile and Peru. Now grows wild in Argentina with small tubers, oval, 2 inches in diameter and have insiped watery but true potato flesh. Grow down to lat. 50°. Earliest mention is by Peter Martyr who referring to Columbus' voyage says: that the Indians of Darien "dygge also out of the grounde certayne rootes growing of themselves, which they call betatas or mushroomes of the earth. Howsoever they be dressed, eyther fryed or sodde, they give place to no suche kynde of meate in pleasant tendernes. The skinne is

D. MARANTACEAE.

1. Affinities and general features. - This family has gone the limit in departure from the Lilies. The flower is very irregular and cannot be divided into equal parts. They are perennial herbs with rhizomes. The leaf has a sheath, and at the junction of blade and stem is a pulvinus. The perianth is composed of two trimerous whorls. Generally 2 or 1 member produces petaloid staminodia. The posterior stamen of the inner whorl has a half anther while the other half is a staminodium. The laterals of the inner whorl are petaloid; the one being hooded and enclosing the style and stigma while the other forms a broad, leathery and warted structure. The inferior ovary, which has a septal nectary, is tri- or unilocular, each loculus having one ovule. An aril and perisperm are both present.

2. MARANTA arundinacea, the West Indian Arrowroot, has been known in European gardens as far back as 1732.

ORDER MICROSPERMALES (ORCHIDALES) - The flowers of this order are cyclic and derived from a pentacyclic trimerous type but often with great reduction in the androecium. The ovary is inferior, unilocular or trilocular with many small ovules. The fruit is a capsule containing many minute seeds with thin membraneous testa and a small few celled undifferentiated embryo. The endosperm is either present or absent, and upon this fact two families are made:

1. BURMANNIACEAE - usually actinomorphic and endospermous.
2. ORCHIDACEAE - usually zygomorphic and exendospermous.

A. BURMANNIACEAE P 3 # 3 A 3 # 3 (or A 3) G ($\overline{3}$)

1. Affinities: This family is an interesting link between the epigynous LILIALES such as the Amaryllids and the Orchids which they resemble in having many tiny seeds with undifferentiated embryo. All except certain BURMANNIA species are leafless saprophytes or rarely parasites.

2. Distribution: This family is small but remarkably wide spread in the tropics. There are 12 genera and 60 species. Of BURMANNIA there are 20 species in the tropics of both hemispheres. GYMNOSIPHON is found in the tropics of all 3 great continents; DICTYOSTEGIA is found in America and Africa; THISMIA in Asia and America. The great center is the Malay Archipelago and Brazil. Thus its distribution shows that it must be a very ancient family.

3. THISMIA javanica grows on hills around Buitenzorg. It is a saprophyte with only the flower stalks above ground. The underground organs, which are roots, are peculiar white or brownish threads 1 mm. in diameter, growing sometimes in knots or skeins. A few thicker and darker ones run horizontally and on these many adventive shoots arise. They would seem at first sight to be rhizomes but they have no leaf scales, bear root caps and have root anatomy. Hence the plant is one which produces root sprouts. The shoots, which have 6 - 8 scales, are white and 1.4 - 2.5 cm. long. The vascular bundle is in a circle with excellent endodermis, which is as good as in root. The stems produce 2 - 3 flowers that have a furrowed tube, white with orange stripes. Inside these are 12 ridges netted up with cross-beams. At the base is a ring. There are 3 calyx teeth while the 3 corolla teeth are remarkably long because of a great 1.3 cm. appendage. The 6 stamens, which have very well developed connectives, are on the tube.

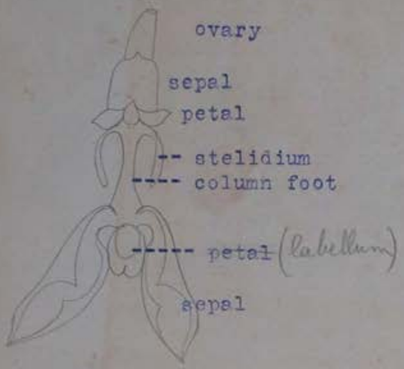
NEUWIEDIA

APOSTASIA

CYPROPEDIUM

ORCHIS before resupination

ORCHIS after resupination



DRYMODA

There are perhaps 100 species throughout the tropics 8

b. Hymenocallis, the Spider lily, consists of about 40 tropical American species. Here the filaments are broadened at the base and grown together to form a funnel-shaped structure. Several species are cultivated here.

c. Narcissus, composed of 25-30 species, has its home along the Mediterranean through Asia to China and Japan. N. poeticus is the Poets' Narcissus or true Narcissus. N. pseudo-narcissus is the daffodil, N. Tazetta is the Polyanthus Narcissus or Tazetta Narcissus, and N. Jonquilla is the jonquil. N. Tazetta var. orientalis is the Chinese Sacred Lily.

d. Zephyranthes, composed of over 50 American species, is commonly planted for ornament, 3 or 4 being planted in Hawaii. The interesting part of these plants is that they hybridize with plants of the genus Cooperia, the results being bigeneric hybrids.

[illegible] Iridaceae - Iris Family.

[illegible] species

and 2 petals. Not only may the anthers be upright and free but they may form a sharp angle with the column. Usually the anthers bend over toward the inside of the column and become or hanging. The anther may remain after the loss of the pollen; but usually the anther is so easily detached that it falls when the pollen is removed. Among the PLEONANDRAE all three stigma lobes are fertile and pollinia fail. Among the CYPRIPEDILINAE the pollen grains are also free or bound into tetrades. With the MONANDRAE, however, the third stigma is sterile and built into a rostellum around the pollinia. In certain orchids (CEPHALANTHERA) this stigma remains rudimentary and the mealy pollen falls out directly on the fertile stigmas and effects self-pollenation. In most orchids, however, the pollen is in waxy pollinia. In DENDROBIUM an insect merely knocks these out and it depends on chance whether they reach the stigma. Usually the pollinia form a stem-like process termed caudicle which comes into association with a sticky mass of degenerated rostellar tissue; or a part of the rostellum itself forms a stem process called a stipe. Thus in either case, a stalk forms and bears on its end a sticky disc. If this stalk is attached to the tip of the pollinia the orchid is called acrotont; if at base, basitont. When an insect touches the disc, it draws out the caudicle or stipe with the pollinia. The whole is called a pollinarium. The mucilage of the disc hardens and thereby quickly bends down the stalk to a horizontal position in place to touch the stigma of another flower. In ORCHIS mascula this takes about 30 seconds. When the insect enters another flower, part of the pollen mass is torn off by the sticky stigma. Often the pollinia are compound in small massulae. The rostellum is of many shapes, and sometimes even pouched. The labellum, originally the petal next the axis, is usually strongly modified. It often shows a partition into an end part, epichilium; a mid part, mesochilium; and a basal hypochilium. The seeds of some orchids can be made to develop parthenogenetically if the stigma be stimulated by means of a brush. At time of pollination the ovules are undeveloped. The stimulus of pollination causes the ovary to increase, placentae become conspicuous and minute anatropous ovules develop. The seeds are scattered by elator-like hygroscopic hairs developed on the interior of the capsule valves.

3. Genera.

a. CATASETUM, a Bornean orchid, has 3 kinds of flowers on the same plant which have actually in times past been placed in 3 separate genera: CATASETUM, MYANTHUS, and MONACHANTHUS.

b. RENANTHERA Lowii, studied by Winkler, produces an inflorescence some 4 meters long bearing many flowers. The largest number of flowers found was 38, separated by internodes 5-6 cm. long. At the base of the inflorescence (above) there was a space of 17 cm. between flowers 2 and 3. The 2 lower flowers differ from all the others in form and color; the petals being broader and shorter, and the color sulphur yellow strewn with red spots. The other flowers are pale yellow with many brown spots that have almost faded out. The labellum and the sex organs are alike. Only the two odd flowers are scented. This plant is then a biological analogy to the ray and disc florets of COMPOSITAE. The 2 strongly perfumed flowers remain fresh until all others have withered above.

base of the style. This structure is termed a septal gland.

3. General features.

a. It is a tropical and subtropical American Family very often living among rocks or as epiphytes and but seldom on the earth. The epiphytes live in the rain forests, and have many curious adaptations for collecting water and humus. This water may become so abundant in the leaf axil that Utricularias will grow in it. These then send out stolons which reach other "fountains", thus looping from one Bromelia to another. This water is absorbed by curious hairs, peltate in shape. Perhaps organic matter is also so obtained since fragments of rotting leaves and insects get into it. Thus Mez kept a VRIESIA suspended for a year in good health by filling the sheath cavity with water containing inorganic nutrient solution.

b. The leaves possess strong xerophytic characters, having a strong cuticle and water storage parenchyma between epidermis and chlorenchyma. The leaf margins are often spiny with ferocious appendages. Thus PUYA chilensis has hooks used for fish-hooks by the natives. Sometimes the leaves are used for grasping, forming a rigid crook or being tendril-like. The primary root is short lived but many adventive roots develop. In epiphytes, the root is used for fixation or soon become lost. Some of these plants even secrete an adhesive gum.

c. Some genera are very shy on flowers. Thus CRYPTANTHUS reproduces almost wholly by stolons. The flowers are short lived, brilliant, and often associated with colored bracts. The floral axis is sometimes persisting for several years, becomes woody and produces new flowers wach season.

4. Genera.

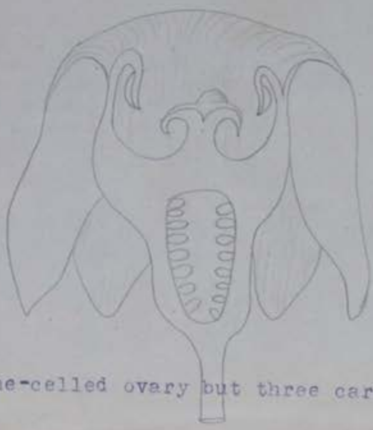
a. TILLANDSIA, the Spanish Moss, is a gray lichen-like plant which has no roots when adult curls around a support. Even when the fleshy parts have died, a horse-hair-like sclerenchymatous strand remains to keep it moored. It is a shy seeder but the wind drifts bits around and birds use it for nests which start growing. Since this plant seems to shed water, it was named for Dr. Tilland, a friend of Linnaeus who could not stand the water because of seasickness. T. usneoides runs farthest north of this family while other Tillandsias reach the southern limit in Argentina and Chili.

b. ANANAS, the name of which originated among the natives, is most important. The whole inflorescence axis, bracts, and abortive flowers become succulent and produce a big syncarp Furthermore, the axis proliferates and produces a crown of leaves. This plant plant contains citric and malic acids, a proteolytic enzyme papaein which resembles trypsin, and also a milk-curdling ferment. The bast fibers are used for textiles.

F. DIOSCOREACEAE.

1. Affinites: This family seems best detived from the Smilaxes since they are both climbers. and both generally produce berries. The flower is of the general lily type with the stamens all fertile or the three inner changed into staminodia (cf. Amaryllids). The ovary is inferior and tubular. Thus this family seems to be another lily derivative.

TACCA cristata



one-celled ovary but three carpels

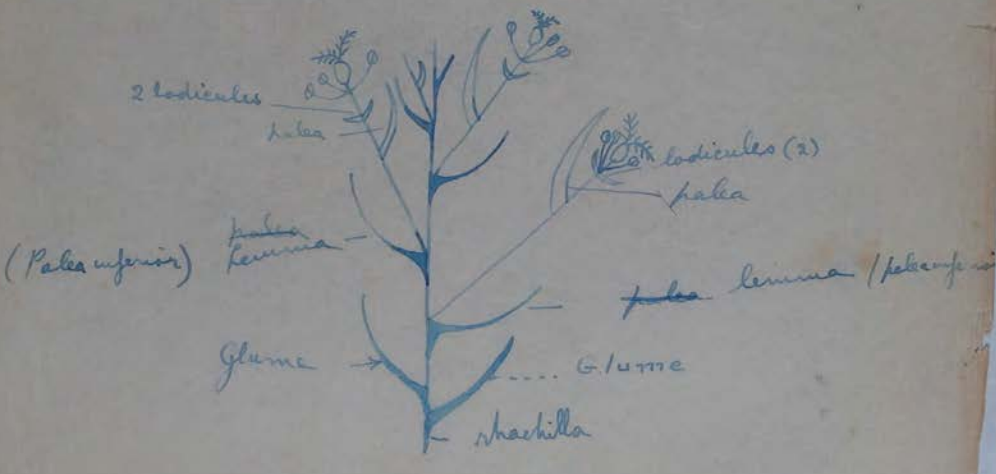
176.Name the annectant group between the Juncaceae and Cyperaceae and describe and name the representative native to Hawaii.177.Characterize the Glumiflorales and name families contained therein.178.Characterize the Cyperaceae.179:Why is Oreobolus important?180.How could we derive Cyperus from Oreobolus.181.What is the scientific name of the nut grass.182.Describe fruit of Carex.183.Describe the fruitnof the Hawaiian Uncinia and indicate its origin from Carex.184.Is there anything strange about the distribution of the Hawaiian Scleria?185.Show how the Grass flower probably evolvedffrom that of Carex?186.Characterize the Gramineae.187.Draw the theoretically elongated spikelet of a grass and label all parts thoroughly. 188.Why is Streptochaeta important?189.Define chorisis.190.Describe the original condition of the tassel and of the ear of the corn plant.191. Describe the inflorescence of Job's Tears and give scientific name of the plant.192.Discuss bamboo.193.How does the grass Cenchrus occasionally kill cattle?194.Give scientific name for the rice plant and explain why it grows best in marshes containing algae.195.What is Bromus secalinus?196.What is the scientific name of Barley and how long has the plant been cultivated by man?197.Give the scientific name of the Sugar Cane and discuss the plant 198.Give scientific name of wheat.199.To what group of plants did the grasses give rise?200.Describe condition of ovary in Hypoxidaceae and Agavaceae.201.How long do Century Plants live?202.In whatvcountry do the Agaves live?203.Howedoes Fourcroya differ from Agave?204.Give common name of Polianthes tuberosa.205.Characterize the "Great Mogul".206.How do the Amaryllids differ from the onions?207.Give the common and scientific names of species belonging to the genus Narcissus.208.Describe the gndroecium of the Iridaceae.209.From what plant is saffron derived.210.Compare the androecium of Marica with that of Iris.211.What is the fleur-de-lis?212. What evidence has Heinricher to show that the Iridaceae are Amaryllid derivatives?213.From what plant is orris root derived and what is a sachet?214. Is the Blue-Eyed Grass a grass?215.Why is Belamcanda named Blackberry Lily or Pardanthus?216.Is Gladiolus zygomorphic or actinomorphic?217.What families possess septal glands?218.Give general characteristics of the Bromeliads.219.Give scientific name of pineapple and describe morphology of fruit 220.Where are the adventitious roots formed?221.Describe the method of collecting water and organic matter by Billbergia.222.Describe Tillandsia usneoides fully and describe its economic value.223.State names of the 2 species of Dioscorea found in Hawaii and differentiate each.224.Give probably affinities of the Taccaceae.225.Give morphology of filiform structures found in Tacca, and give economic value of plant.226.Characterize the Scitaminales.227.Describe Ravenala.228.Describe the fruit of the travelers tree.229.What is Strelizia?230.Describe inflorescence and flower of banana fully.231.Has the banana a true stem?232.What is Musa Fehi?233.What is Abaca and from whatnplant is it derived?234.Differentiate Heliconia from Musa.235.Give genera of Cannaceae.236.Fully describe flower of Canna and state probable affinity to other genera.237.What is tous les mois? 238.Describevfully the flower of Languas.239.Give affinity of Zingiberaceae 240.What is turmeric?241.What is the Dancing Girl?242.What economic value has Maranta arundinacea and to what higher group of plants has it evolved? 243.State the two chief differences between the Burmanniaceae and the Orchidaceae?244.Between what two families is Burmannia a probable annectant species?245.Give general characteristics of the Ochidaceae.246.What is a gynandrium?247.Describe Taeniophyllum.248.What is strange about Catasetum and Renanthera?249.What are myrmecophilous domatia, velamen,and pollinarium 250.Give name of the only economically valuable orchid outside of floricultural values, and give names of the three orchids endemic to the Hawaiian Islands.

c. VANILLA planifolia is the only economically important orchid outside of floricultural values. It is a native of Mexico. The flavoring, vanilla, is derived from its capsules. It was cultivated in England by Miller in 1759.

d. Hybrids: The first hybrid was CALANTHE Dominii, a cross of C. mascula and C. furcata. Now about 3000 - 4000 hybrids have been produced. 23 cases of bigeneric hybrids are known.

4. Historica: In the middle of the 19th century there was a craze for striking floral species. In 1855 one plant of AERIDES Schroederi brought $430, in 1875 a plant of DENDROBIUM Wardianum was sold at auction for $500, and the same year a plant of SACCOLABIUM guttatum was sold for $313. Collectors risked their lives all over the world to get new species.

3. Characteristics: They have hollow jointed stems which in the Bamboos may be 40 inches long. The sheaths are usually open. Between sheath and lamina lies a ligule which is usually dry, membranous, and colorless. A nerve is often well developed on the bracts of the flower and ~~the~~ thus the awn when present is probably the nerve of the lemma. The leaves are usually in two rows and the flowers in a spikelet stand the same. The fruit is usually a caryopsis, namely a fruit whose carp wall takes over the function of testa. Other kinds of fruits are rare: achenes in Sporobolus, Eleusine, edible berries even of the size of apples in Melocanna bambusoides. The embryo is small and lies ~~against one~~ on one side. The shield-shaped scutellum is the cotyledon, thus these plants are heterocotyledonous probably. The structure of the grass flower can best be understood by drawing a diagram of it as though all the internodes had not shrunken. Then we find that the flower is really without perianth but enclosed by various bracts.



rotundus is the nutgrass, a [illegible]
[illegible] which produces corms.
. Scirpus, Bulrush, is composed of about 150 species, 2 of which are at least found here. Here the flowers are arranged not distichously but in a whorl. The upper are frequently staminate.
d. Eriophorum, the cotton grass, consists of about 15 species in which presumably the perianth has been shred up into hairs.
e. Carex, composed of over 1000 species, has about 5 species in Hawaii. The flowers may be unisexual and even the plants according to the species. Here two bracts surround the ovary and grow together to form the perigynium. The nutlet is thus enclosed in a husk or utricle.
f. Uncinia is a genus represented in Hawaii. It is really a Carex in which the utricle has been prolonged into a tube that is frequently barbed.
g. Scleria is a genus in which the nutlet is very hard and shiny. The species found here ~~[illegible]~~ cannot be distinguished from one growing in Cuba — parallel evolution?
h. Many other genera are found here, most of them needing revising.
B. Gramineae — Grass Family.
1. Distribution: A huge family of about 5000 species of usually herbs, though some are trees, growing everywhere. Some are aquatic
2. Affinities: There is some evidence that the Carex utricle is really ~~[illegible]~~ a degenerated inflorescence containing a single pistillate flower and possibly the bracts of other flowers. A diagram of a grass flower shows that it may have come from a plant like Carex in which, however, the stamens of the pistillate had not degenerated.

Carex

Grass

Aspidistra, consists of about 4 species of Asia. A. commonly used as a potted plant in houses in E and other places and is sometimes called the "cast iron plant" ... is grown in Hawaii. The flowers are purple brown, about inch in diameter, and produced singly at the surface of the ground.

p. Convallaria consists of the single species C. majalis, the [illegible] of the valley. It is found in Europe and Siberia and in the Alleghanies of America. It is an important cardiac tonic.

q. Trillium, the Wake Robin, of the Eastern States, consists of about 15 species of northern Asia and Northern North America. This is a lily with net-veined leaves.

r. Sansevieria consists of 50 or more African and Asiatic species. The leaves are stiff and often variegated. S. zeylanica grown here, is the New Zealand hemp which is manufactured into ropes.

s. Smilax, consisting of over 200 species, is found especially in the tropics. The plants are dioecious creepers with greenish flowers, having its stipules modified into tendrils. From the roots of the South and Central American species, Sarsaparilla is made. Several species are endemic to Hawaii. The so-called Smilax of the gardener is a species of Ruscus belonging to the same family.

B. Juncaceae - Rush Family.

1. Distribution: About 8 genera of 300 species, only Juncus and Luzula containing many species. Most of these are found in marshy places in cold countries.

2. Affinities: They have the exact floral structure of a lily but are dry and sedge-like in aspect. They might actually be considered as [illegible] anemophilous lilies.

[illegible] grass-like plant with small [illegible] like flowers having the lily formula. The pith is composed of delicate stellate cells.

Genera:

a. Juncus consists of about 250 species. Here many se[eds are] contained in the gynoecium. [The plants are always glabrous.] Some are found in

b. Luzula ~~consists of~~ (or more correctly Juncoides) co[nsists] of about 60 ~~sp~~ very variable species. Here only 3 seed[s] are contained in the gynoecium and the plants are usua[lly] hairy. ~~The~~ A species and probably several varieties of Luzula are endemic to the Hawaiian Islands at the highest elevations.

c. Marsippospermum grandiflorum of Terra del Fuego has a large pith which was formerly used as lamp wicks and still now in India and China used ~~to~~ in the manufacture of especially light hats.

C. Flagellariaceae

1. Distribution: A family of 3 genera and about 7 species of Polynesia and Ceylon.

2. Affinities: These ~~are still~~ have a still more reduced perianth than Luzula ~~and thus are constitute an annectant group between Juncaceae and Cyperaceae~~ while some have unisexual flowers. Thus the Flagellariaceae are practically an annectant group between Juncaceae and Cyperaceae.

3. Genera

a. Joinvillea consists of 2 or 3 species, one of which is found on these islands where it is called ohe. The plant resembles a small bamboo[,] has red fleshy berries. It is quite rare and [im]perfectly studied.

Now let us forsake the Liliales for a time and run to an end the evolutionary line begun by the Flagellariaceae.

[A]gave is composed of about 300 species, in [the] tableland of Mexico. The Agaves are very interesting xer[ophytes] which resemble Aloe species very closely and are often called "hundred-year aloe". Although called Century Plants they actu[ally] flower at a much younger age when conditions are favorable. Fruiting kills the plant. Some species have never been known [to] flower. We think of them only as decorative plants yet in Mexico they furnish fiber, soap, pulque and mescal. Pulque comes particularly from A. atrovirens. Sisal for the manufacture of rope comes from A. rigida chiefly. The name Sisal is derived from the name of the port in Yucatan from which much was shipped. The plant has been grown here extensively for commercial purposes but the industry failed. A. americana, the Century Plant, is also grown here. Stamens exceeding flower; adapted to pollination by Sphynx moths.

b. Fourcroya differs from Agave in having short stamens. F. gigantea is grown here. It frequently reproduces by producing adventitious buds or bulblets in the inflorescence.

c. Polianthes tuberosa of Central America is the Tuberose commonly cultivated.

F. Amaryllidaceae (sensu stricto)

1. Distribution: Found throughout the tropics
2. Affinities: Often included with the Hypoxidaceae and Agavaceae to form in a more inclusive way the family Amaryllidaceae. We, however, have split the other groups off. The true Amaryllidaceae might easily be derived from the Onions since they differ from them primarily in having an inferior ovary. Both have bulbs, umbels, and ~~[illegible]~~ umbel protecting bracts. (The resemblance of Agapanthus among the Allioideae to Hessi[a] the Amaryllidaceae is very close.) ~~[illegible]~~ Pax divides this family into two groups according to the absence or presence of a corona.
3. Genera
   a. Crinum is of interest among the cultivated genera because of its large size, the bulbs becoming even 2-3 feet long. In some species the flowers are a foot long — six inches wide, while the leaves may be 6 ft. long and 6 inches wide. The "Great Mogul", C. augustum [of] Barbados, has such a tremendous umbel 4 ft. [high] with about 20 flowers that it falls over. Three [[illegible]] species are introduced in Hawaii and escaped along the

...is the burr grass. ...
g. ...ry painful when stepped upon with ... to ... cut giving cattle ulcers and even causing death when g... ... n enteron.

9. ...za sativa, rice, has 6 stamens and is aquatic. This plant pr... ...plies more human beings with food than any other plant. It ...bably indigenous to India. It grows best in water in whi... ...ae algae are growing because these furnish oxygen to the ...bmerged part of the plant.

Bromus secalinus often gets into wheat fields and is called Chess ... cheat. There is a curious agricultural tradition that Chess is ... degenerate wheat due to action of frost, etc.

i. Hordeum sativum, Barley is another grain supposed to be from Asia. It was widely grown before the Christian Era, and is known to have been cultivated in Egypt in 2440 B.C.

j. Saccharum officinarum, Sugar-cane, is supposed to have originated in farther Asia or the East Indies, although it has not been found wild. Cultigen? It does not bloom in the States but in Hawaii, the inflorescence being a panicle 1 to 2 ft ~~high~~ long.

k. Triticum vulgare, wheat or corn of Europeans, is of unknown origin. But in the clay paving stones of Pyramids in Egypt fragments were found that must have been cultivated 3000 B.C. In China it was cultivated in 2000 B.C. Aaronsohn in Gilead near Jericho, in 1908 found a wild species, (T. dicoccum) which probably is the ancestor of the cultivated species. Test to here

VI. Liliales (continued)

D. Hypoxidaceae

1. Distribution: A small family of the tropics and subtropics. Hypoxis being about the largest genus with 50 species.

2. Affinities: Somewhere related to the Liliaceae from whom they differ chiefly by epigyny, namely the ovary is inferior. ~~The~~ ~~plants have~~

E. Agavaceae

1. Distribution: Entirely American (with the largest genus Agave) except for one Australian genus (Doryanthes).

2. Affinities: May have originated from the Dracaena or possibly Yucca like ancestors through epigyny.

3. Genera

[Stre]ptochaeta is perhaps the …
[o]ne species namely S. spicata which grows in …
[ch]aracters are as follows:

[a]. The spikelets have the florets in spiral order like those [of] the Juncaceae or most Cyperaceae (but first as in latter distich[ous] arose at times so it arose and became the rule in grasses).

b. The ovary consists of 3 fused carpels. In most grasses the anterior one is reduced. Sometimes it has a third stigma and but rarely do all the stigmas fuse.

c. There are 6 stamens in 2 circles. In modern grasses the inner circle aborts and even the outer circle may reduce to 2 or 1 (2 in Anthoxanthum, Hierochloe while 1 in Cinna, many Festuca and Andropogon species).

d. The perianth consists of 3 chaff-like leaves. Other grasses have 2 lodicules.

e. There are 2 paleae which in other grasses unite to form 1.

f. There is 1 lemma

g. There are several glumes.

b. Certain grasses have 40 (Pariana sps) or even 120 (Ochlandra) stamens per flower. One might at first sight think that these are the more primitive and gave rise to the others by reduction. But investigators proved that only a small correct number of fibrovascular bundles began to go toward the stamens and that they branched into 40 or 120 to go into the stamens. Consequently these grasses have evolved from the typical type by chorisis or the splitting of a few stamens to form many.

c. Zea mays, Indian Corn, although of American origin, is nowhere found wild. It has been cultivated for many centuries by the Indians and may possibly be derived from teosinte or a hybrid of teosinte and some unknown plant.

d. Coix lacryma-Jobi is Jobs tears, native of Eastern Asia but widely introduced. The pistillate spikelets are borne inside a hollow globular body representing a leaf-sheath which at maturity becomes a very hard structure that is used as a bea[d].

e. Panicum miliaceum is the broom corn millet cultivated in the Old World since prehistoric times for forage and its seed for human food.

grown in the subtropics. They grow
monsoon region of Asia where a
160 species ~~grow~~ occur. In all there are about
and 200 species. There are 70 in America
Africa. They grow from sea level to an elevat
10,000 feet in the Himalayas and 15,00
in the Andes. They may become 100 or 200
high with a diameter of 8-12 inches. Cer
bamboos require many years to attain
age. After flowering and fruiting they die in
cases this flowering takes place over a who
at one time.

PLANT PHYSIOLOGY - First Semester

I. The two primary divisions of the Science of Botany or Phytology are:

A. Plant Morphology.

1. The word morphology is derived from the Greek *morpha* meaning *form*, and *logos* meaning *discourse*.

2. Plant Morphology may thus be defined as the study of forms and structures of plants. Consequently we could go into a museum, drag out musty specimens collected and killed hundreds of years ago, and study their morphology, or form, with almost as much ease as though we had living specimens before us.

B. Plant Physiology.

1. The word physiology is derived from the Greek *phusis* meaning *nature* and *logos* meaning *discourse*.

2. Plant Physiology may be accurately defined as the science which deals with the functions of plants. It is the science dealing with the different phenomena of life manifested in the plant body. Or following Thomas Huxley, we can define Plant Physiology as the science of vital powers in plants.

3. Because of the nature of this study, we must deal chiefly with living material. And in order to find out exactly how the plant functions under normal conditions, we subject it to controlled artificial environments in the laboratory and watch its behavior. Knowledge of Plant Physiology then, like that of Physics and of Chemistry, is based primarily on experimentation.

II. The main results of physiological investigation.

A. There is no common quality in living matter that some form of non-living matter may not posses except life itself - a definition of life is therefore difficult to give.

1. In spite of the large amount of water which an organism contains, it is generally a solid and has the physical properties of such a body as weight, rigidity, elasticity, and conductivity for light, heat, and electricity.

2. Protoplasm is colloidal, as we will study more fully later. This certainly does not distinguish itbfrom non-living glue, gelatine or mayonnaise dressing. It is more complex - that is all.

3. Protoplasm is an elaborate mixture of organic compounds largely proteidal and containing much water. But here again there is no fundamental distinction for any chemist can put together a complex mixture of organic compounds in water.

4. Protoplasm is very labile; its molecules are constantly changing. Here at first sight there seems to be a distinction from inanimate matter. Suppose a Portuguese man-of-war and a steamer are both wrecked on the seashore. The Portuguese man-of-war compounds break up in a few hours; the steamer compounds lie decaying and rusting for perhaps a century. These are of course extreme cases, but they can be matched by their opposites. Flesh can be kept almost indefinitely in co cold storage, while on the other hand, certain organic chemical compounds break up spontaneously in a few minutes after their formation. Hence stability or instability of their chemical constituents does not differentiate dead from living matter.

5. Protoplasm exhibits the phenomena of osmosis and turgor, which we will study fully later on. Yet a dead membrane p possesses the same properties as a living one.

6. Protoplasm exhibits metabolism and growth.

a. An organism does not consist of the same unchanged material even when no further growth in size is taking place. While its external form remains constant, progressive changes go on internally - Here, if anywhere, we feel that a distinction ought to exist and yet, strange as it may seem, the chemist can construct certain "chemical seeds" which will grow and carry on a simple metabolism. If a bit of copper sulphate to which sugar has been added is planted in an aqueous solution containing 2 to 4% of potassium ferrocyanide, 1 to 10% sodium chloride and other salts, and 1 to 4% gelatine, the "seed" germinates in a few hours to a few days. The copper sulphate reacts with the potassium ferrocyanide to form a membrane of cuprous ferrocyanide which behaves like any osmotic membrane, and the whole vesicicle begins to grow. If turgor pressure ruptures the sac, the drop of exuded liquid is directly filmed over with a membrane. Such growths may come to be several inches high and may curiously simulate certain low forms of plant life. The student must not be swept off his feet by these facts. Such osmotic growths are not living plants; they are made of raw inorganic chemicals. Yet they certainly do exhibit features whichvwere once held to characterize living things only. MacFarlane says: "These are the necessary stages and phenomena that carry us from inorganic colloids with complex molecular composition and a high degree of intramolecular energy to the varied series of organic colloids in which a still higher or biotic energy resides. Each osmotic growth has an evolutionary existence; it is nourished bu osmosis and intussusception; it exercises a selective choice on the substances offered to it; it changes the chemical constitution of its nutriment before assimilating it. Like a living thing, it ejects into its environment the waste products of its functions. Moreover it grows, develops structures like those of living organisms and it is sensitive to many exterior changes which influence its form and development. But these very phenomena - nutrition, assimilation, sensibility, growth and organization - are generally asserted to be the sole characteristic of life."

b. Metabolism as a rule does not proceed so that the absorption and giving off of material are equal. More is absorbed than is given off and the mass of the organism thus is increased - it grows. Growth is also known in the case of chemical precipitates or deposits, and of chrystals. In chrystals no essential change of shape takes place during growth while in precipitates the changes in shape are accidental and irregular. Chrystals that have some of their faces broken can even be "nursed" back into shape. The organism by changes of its form assumes quite definite shapes which follow in regular order. We might ascribe this to entirely physico-chemical reasons since the organism is a complex of many substances, some of which tend to precipitate out while others tend to chrystalize out.

7. Is irritability a phenomenon of living matter alone? Irritability has been defined as the property which protoplasm possesses of reacting to stimuli. Yet a moment's thought teaches us that non-living things react to stimuli in a similar manner. Irom, for instance, exhibits irritability toward a magnate. It has been known for some time that when light falls on the mineral selenite, electric currents are set up. Some years ago an ingenious physicist constructed the "selenite dog". This is an apparatus which is essentially a box with two selenite eyes, a motor inside and wheels beneath. When light falls on the "eyes" a current is generated; through the motor it is relayed to thecwheels which begin to turn. If I go out at night with a lighted lantern, the "dog" will follow down the street; if I turn a corner, the "dog" also turns, since one eye is receiving stronger illumination. Hence, it is generating a stronger current and the wheels are so wired that the outer ones receive the stronger stimulus. The selenite dog is no more remarkable than the strange machine which not long ago was guided through the streets of New York by wireless waves.

Let us attempt an interpretation of the action of one of the simplest of plants, namely a green phototropic flagellate. Light falls on the protoplasm; certain light-sensitive chemical compounds are decomposed (even as on a photographic plate), energy is released and is conducted to the flagellum; active rhythmic contraction is set up, the flagellum moves and the small plant cell is whipped forward into the light.

Let us apply the same line of reasoning to an animal. A moth flies into a room where a candle burns and hurls itself into the flame. We may say that the pigment ofvthe retina of the eye undergoes a chemical change due to the entering light. Energy is released; it sweeps through the optic nerve to the brain ganglia, is relayed through chains of neurons along the nerve cord to the muscles of the wings; the muscles contract, the wings beat and the moth is propelled into the flame. Many times, however, such insects fly about the flame without entering it. We may realize that our selenite dog would behave in the same erratic manner if it possessed wings and had its eyes unequally lighted, for one wing would beat faster than the other. Thus itritability fails us as a feature of distinction between animate and inanimate worlds.

8. Another function of living things is reproduction. This need not detain us when we realize that simple reproduction is only a kind of division andathat from osmotic growths certain portions will often break off and start new growths. A striking case of reproduction is found in supersaturated and in supercooled liquids. So for instance water if not in contact with ice may be cooled several degrees below zero and still remain liquid. But on touching this supercooled water with even a minute ice crystal, the entire mass immediately congeals into a solid mass.

9. A directing principle of organization is held to characterize higher types of organisms. For example, we see that root, stem, leaf, flower are not separate parts of a plant, each carrying on its activities independently, but they are bound into a harmonious and cooperating system. It has been discovered that this harmony depends in part, at least, upon

chemical regulators which migrate from one part to another and control the physiological activities. We all know that when a terminal shoot of a tree is removed the lateral buds begin to develop to take the place of the lost member. This looks like a conscious or intuitive attempt to restore harmony. Actually, it has been proved that the terminal bud secretes certain substances which drift backward along the twig and inhibit the growth of the laterals. When the terminal bud is destroyed, the inhibition is removed. This directing principle of organization is thus apparently a purely chemical phenomenon.

10. From the above we must come to the conclusion that so far as science can go, there is no special property or set of properties which separates the non-living from the living world. LeDuc says: "Considering the impossibility of defining the exact demarcation between animate and inanimate matter, it is astonishing to find so much stress laid on the supposed fundamental difference between vital and non-vital phenomena. There is in fact no sharp division, no precise limit where inanimate nature ends and life begins. The transition is gradual and insensible."

B. There is no fundamental distinction between the vital phenomena of animals and plants.

1. At first sight we would be inclined to say that the physiological processes for instance of a horse galloping around in a pasture are entirely different from those of a tree standing quietly in the same pasture. But when we concentrate our attention, not on the complex cell colony which consti-

tutes horse or tree, but on a single cell of the horse and of the tree, we find that in both cases in spite of extreme morphological differences the life processes are essentially alike.

2. The reason why the physiological processes of animals and of plants are essentially alike becomes evident when we remember that plants and animals have evolved from the same unicellular organisms. These are generally characterized by being unicellular, at some stage of their development being motile and possessing a flagellum or whip-lash which propels them through the water, being green with chlorophyll and thus being able to manufacture their own food with the aid of sun-light or being colorless and therefore forced to live on food that has already been manufactured by some other organism. In general, however, we might say that although the physiological processes are essentially the same in plants and animals,

   a. The net result of the physiological processes of plants is the formation of body substance.

   b. The net result of the physiological processes of animals is the utilization of food for the production of energy and this energy is manifested as animal work or animal heat.

III. Mechanism vs. vitalism.

A. Mechanism.

1. Biologists who affirm that the activities of living organisms are wholly explainable on a chemico-physical basis are called mechanists.

2. Jacques Loeb, a mechanist, says, "Living organisms are chem-

ical machines, consisting essentially of colloidal material which possessed the peculiarities of automatically developing, preserving, and reproducing themselves."

3. One mechanist has even ventured to say "that the brain secretes thought just as the liver secretes bile."

B. Vitalism.

1. Biologists who affirm that living things are really alive, viz., that they are chemico-physical machines plus something else which they call a vital force or life principle, are called vitalists.

2. Sir Oliver Lodge, a vitalist, says, "Life is neither matter nor energy, nor even a function of matter or of energy, but is something belonging to a different category -; it is dependent on matter for its phenomenal appearance, but otherwise I conceive that it is independent, that its essential existence is continuous and permanent, though its actions with matter are discontinuous and temporary; and I conjecture that it is subject to the law of evolution - that a linear advance is open to it whether it be in its phenomenal or in its occult state."

3. Thoughts and emotions have never been detected by the physical senses of the scientist, yet they certainly exist.

4. The trend of modern biological thought seems to be along vitalist lines yet the great danger of the vitalistic attitude is that metaphysical explanations may be assumed for events which are purely physical. The world has seen that kind of biology before and it spelled scientific stagnation.

IV. The origin of life.

A. Spontaneous generation or abiogenesis.

1. The Egyptians believed that mice and frogs were generated from the mud of the Nile.

2. Virgil tells us a story about bees being spontaneously produced from a dead bullock.

3.m In the Middle Ages there was a famous recipe for generating mice: Place old rags and corn in a jar; set it aside for a time and mice will spontaneously appear there.

4. Milton in Paradise Lost gives us spontaneous generation with a vengeance in his realistic description of how lions arose from the dust of the earth:

"The grassy clods now calved; now half appears
The tawny lion, pawing to get free
His hinder parts - then springs as broke from bonds
And rampant shakes his brindled mane."

5. Redi, an Italian, in 1680 disproved the old belief that maggots spontaneously arose in decaying meat by the simple method of screening the meat from flies.

6. The invention of the microscope renewed the belief in spontaneous generation because it was discovered that microscopic organisms would spring up even in boiled and stoppered nutrient solutions. Today we realize that the reason for this lies in the fact that certain bacteria when in a special resting condition or spore-stage can withstand the temperature of boiling water, and also that bacteria can easily contaminate sterilized solutions by getting into them with dust from the air.

7. Pasteur (1822 - 1895) disproved spontaneous generation theory by hermetically sealing a test-tube containing agar-agar. No

life appeared

8. Tyndall constructed a dust-proof box with small windows on two sides and also a glass front. The inside of the box was coated with glycerine to catch any dust particles which might be present to begin with. In the bottom of the box was inserted a plate pierced with holes through each of which was sunken a test-tube so that most of its length hung below the box, but its mouth was open to the dust-free atmosphere inside. In the top of the box was inserted glass tubes bent into several loops and coated inside with glycerine. These were for the admission of air, since the spontaneous generationists had argued that air was necessary to initiate life. So Tyndall permitted the air to enter freely, but no dust ever passed beyond the second loop of the tubes. Through the top of the box was also thrust a thistle tube which penetrated a rubber diaphragm. This was to permit one to pour materials into the test-tubes inside. Tyndall now set the apparatus aside and waited till a ray of light passing through the box between the windows was no longer visible. This meant that all the dust had been caught on the glycerine-covered walls. Then he filled the test-tubes with various sorts of good "spontaneous generation media", such as cheese, beef broth, etc., and last of all, he plunged the free bases of the test-tubes into boiling oil to destroy any living thing which might be present. He now had tubes of sterile material opening into a dust-free atmosphere and he set his box aside to watch developments. Result: the solutions remained indefinitely unchanged and no living thing ever appeared in them.

9. As far as we are concerned all life comes from pre-existing life; "Omne vivum ex vivo." But geology and astronomy teach us that there was a time when the earth was without any living organism. If this be so, there must have been a definite beginning of life on earth. Possibly two partial answers can be given, as follows:

B. Arrhenius, a Swedish physicist, has suggested that the orginal germs of life may have come from another planet borne by waves of light - this leaves the question of the beginning of life itself unsettled because he does not explain how life originated on the other planet from which it is supposed to have been driven.

1. We know that living particles are small enough that waves of light could push them through space.
2. We suspect that the cold of interstellar space would not destroy life because if bacteria can withstand the temperature of liquid air, they probably would be able to withstand almost any degree of cold.

C. The mechanistic view that postulates a primal spontaneous generation seems the most plausible. As MacFarlane suggests: "Living substance very gradually originated among chemically acting and reacting inorganic compounds in aquatic situations and where colloid as well as crystalloid bodies tended to rise through environmental agency. From long continued interaction of emulsoid and suspensoid types of colloid compounds, a chemically sensitive and yet stable mixture of several colloids resulted, that we now call protoplasm."

V. Kinds of life.

A. Active life.

1. Characterized by a continuous vital activity.

2. Since all protoplasm respires when alive and consequently gives off CO_2 , if a delicate enough test for the gas occurs, we can decide whether the organism is actively living or not. An apparatus for this test consists essentially of a chamber inside which the seed or other body to be tested is placed. The original gases in the chamber are then displaced with some inert gas such as hydrogen. Along with the body to be tested is a tube of fresh barium hydroxide solution. The whole is carefully sealed. If carbon dioxide is evolved from the seed, it will produce a trace of insoluble barium carbonate on the baryta water. The smallest trace of this can be searched for with a compound microscope and if found, it means that the object is still actively alive.

B. Latent life.

1. Characterized by the arrestation of all vital activities.

2. If we take a handful of wheat and place it in liquid air (having a boiling point at -194° C.), all evolution of CO_2 ceases and the seeds appear dead. But when removed and planted, they will germinate, showing that they were not dead, or at any rate if dead, they had come to life again. This tends to substantiate the conclusion that the protoplasmic system is like a machine whose activities can be inhibited by cold in a manner analogous to the way a clock "freezes up" in cold weather due to the thickening of the oil in its works.

3. Many resting stages of plants, such as seeds and spores,

pass into the state of latent life and become then as a rule far more resistent to dessication, heat, and cold than organs in an active condition of life. Spores of bacteria and seeds of Medica can thus withstand a temperature of 100° C. Some spores withstand as low a temperature as -253° C.

VI. The cell.

A. History.

1. Robert Hooke, an amateur botanist who had been playing with a microscope, published in 1665 his "Micrographia" or "Some Physiological Descriptions of Minute Bodies made by Magnifying Glasses with Observations and Inquiries Thereon." In this book for the first time appeared rather crude drawings of cells, one of them being of bottle-cork. According to his own words Hooke had been "slicing up indiscriminately animal and plant tissues" and while examining charcoal, cork, etc., he saw that they were "all perforated and porous, much like a honeycomb." It is said that he gave the term "cell" to the little cavities because they reminded him of the cells in monasteries (from Latin <u>cella</u>, akin to <u>celare</u> to hide; a very small and close apartment in a monastery or convent.)

2. The first idea of cells was the wholly mistaken one that the wall system or "interstitia", as Hooke called their substance, was the living part and that the cavities were only for the circulation of juices.

3. In 1831 Robert Brown, who was also the discoverer of "Brownian Movement" saw and named the nucleus. This was found long before the cytoplasm of the cell.

4. Dujardin, 1835 a zoologist working on protozoa, applied the

name sarcode to the protoplasm of their bodies.

5. Purkinje, a human physiologist, in 1840, gave the name protoplasm to the substance composing human cells.

6. Von Mohl, a German botanist, in 1844 boldly announced that the slimy lining of the vegetable cell was a living substance and was the primary and most important constituent of the cell. He adopted Purkinje's name protoplasm for it.

7. Later when it was realized that certain cells might exist without walls, the concept of the cell changed to the present accepted view that the cell is a unit mass of protoplasm with a nucleus and that the cell wall is non-essential. This history of the cell theory illustrates very well the way in which a scientific concept progresses toward truth. Founded on imperfect observation and faulty interpretation, a theory is propounded; other workers try to check it up, and discover facts which do not agree; thus the theory is modified over and over again until at last all are agreed that their own experience tallies. Then the theory takes its permanent place in the body of accepted scientific generalizations.

B. Definitions.

1. It is a morphological and physiological unit of living matter.

2. It is a unit mass of protoplasm.

3. It is a mass of cytoplasm enclosing a nucleus and usually enclosed by a cell wall.

C. Size.

1. The largest single cell is the ostrich egg, which holds about two quarts of liquid. The bulk of this material, however, is chiefly non-living food which is to be utilized by

the developing chick.

2. The smallest single cell is so small that it cannot even be seen by the highest power of the microscope. Many common bacteria are so small that 1 cubic mm. of water could easily contain one billion of them.

D. Structure of a typical cell derived from the meristem or growing point and consequently not yet differentiated for special functions.

1. Cell wall.

a. Usually not present in sexual cells as that would hinder union, nor in the vegetative cells of the more primitive

b unicellular organisms.

b. Almost invariably present in the higher plants.

c. Not a part of the living cell or protoplast but a dead substance gradually excreted or secreted by the protoplast as it matures.

d. Its formation.

1. The cell wall usually arises first by the formation of a membrane called a middle lamella for the reason that it always lies between two cells when they are touching as they do in a tissue. This middle lamella, commonly composed of a pectic substance staining yellow with chlor-zinc-iodide, usually shuts the protoplast completely off from the outer world except for minute threads of cytoplasm by which the protoplast remains connected with its neighbors.

2. A thicker secondary layer is the deposited on the inside of the middle lamella, consisting usually of cellulose. The protoplasmic strands still remain intact.

3. A third layer which is very thin is then ffequently deposited inside of the secondary one.

e. Its growth may occur,

1. By apposition - the protoplast swells with water and thereby stretches the cell wall, and thereupon additional material is deposited on the original wall in layers.

2. By intussusception - the protoplast swells as before and then new material is inserted between the particles of the existing wall.

f. The cell wall may be subject to partial or complete removal by the protoplast, or it may be impregnated with various substances.

e. Chemical nature.

1. Usually composed of different kinds of celluloses in the higher plants, a substance peculiar to plants and to the Tunicates; while in Fungi and Bacteria it is composedd of chitin, formerly thought to be a substance peculiar to animals.

2. Cellulose walls frequently become transformed into a gelatinous or mucilaginous mass which swells greatly in water.

3. Cellulose walls frequently undergo lignification, which diminishes the extensibility of the cells and increases their rigidity without lessening the permeability of the wall to water and dissolved substances.

4. Cellulose walls frequently undergo suberisation and cutinisation, and such corky or cutinised walls are relatively impermeable to water and gases and thus great-

ly diminish evaporation.

5. Cell walls are frequently impregnated with tannins as i in the heart-wood of many trees and in seeds, thus protecting them from decay.

6. Cell walls of Equisiti, grasses, diatoms, etc., are heavily silicified.

7. Cell walls of Chara are impregnated with calcium carbonate, making the plant rigid and brittle.

2. Protoplasm.

a. Theories as to structure.

1. Reticulate or netted - this theory may have been based on material that had been badly preserved, thereby causing artifects or artificial structures due to coagulation etc., of protoplasm.

2. Fibrillar or thread-like - composed of threads that lie in entangled masses in the fluid of the cell and which possess a worm-like motion. Vorticella, one of the Infusoria, has a stalk which rapidly contracts to draw the organism away from danger. Yet the organism is unicellular. Obviously the protoplasm making up the stalk must have a fibrillar and not a foam-like or alveolar structure.

3. Alveolar or foam-like - composed of many bubble-like droplets of different fluids which will not mix. Because they press against each other they are not spherical but have flat faces. This according to antagonists of the other two theories makes the structure of protoplasm appear as though it were formed of a network of material.

We must admit that we know very little about the structure of protoplasm - it does exhibit, however, certain properties that are common to colloids and this fact seems to indicate that it probably possesses alveolar structure.

b. Seems to be a viscid, practically colorless jelly consisting frequently of 90% water and containing innumerable minute granules composed of different chemical substances.

c. Parts.

1. Cytoplasm is the protoplasm not found in the nucleus.

2. Metaplasm constitutes the non-living constituents of the protoplasm such as,

   a. Foof materials like oil droplets, starch granules, etc.

   b. Excretory or waste materials such as crystals of calcium oxalate, calcium carbonate, etc. Since plants have no excretory system, the crystals probably represent waste chemical compounds which have been stored away in inactive form, thereby being made harmless.

3. Vacuoles are more or less globose cavities filled with liquid, chiefly water, containg acids, salts and other chemical substances in solution. In old cells a single large vacuole may occupy the middle of the cell, the cytoplasm being reduced to a thin membrane lying against the cell wall.

4. Chondriosomes seem to be normal constituents of young cells. It is claimed that they have been seen in active motion and that they change their shape from threads to

rods, club-like bodies or dumb-bells. Their function is unknown.

5. Plastids are conspicuous structures in many plant cells which are concerned with special physiological activities. The more important kinds are,

a. Chloroplasts which are green in color - the most common shape is ellipsoid or globose but in some algae they are spiral ribbons or are stellate. These occur usually only in plant-parts exposed to the light, and then photosynthesize food-material. A chloroplast immersed in alcohol loses its green color, which proves that the plastid is colorless itself but holds the green pigment chlorophyll.

b. Leucoplasts are colorless - when exposed to the light they frequently change into chloroplasts.

c. Phaeoplasts, common in the Brown Algae, carry a brown pigment.

d. Rhodoplasts, common in the Red Algae, carry a red pigment.

e. Chromoplasts are plastids which carry any color - these often color the petals of flowers, though usually this is caused by a colored cell sap contained in the vacuoles.

6. f. Nucleus.

a. Seems to be the most important protoplasmic mass in the cell, showing remarkable changes during cell-division. If in certain unicellular plants and ani-
b. mals the nucleus is destroyed, the cell dies. If the

cell be cut into two parts, the enucleated fragment dies. If, however, the nucleus itself be cut in half, then both fragments of the cell will continue to live.

b. Is commonly globose or ellipsoid and larger in young than in old cells.

c. Is surrounded by a tough nuclear membrane and contains a clear watery nuclear sap or karyolymph.

d. A mass of fibrous material called linin runs like a network throughout the nucleus. Upon it are massed and scattered numerous granules of chromatin.

e. One or two nucleoli, small round bodies, usually lie in the nucleus.

f. Chromatin is essentially the germ-plasm, and is the substance handed down from parent to offspring in reproduction. The head of the male element, or sperm of animals, is composed of almost pure chromatin. It is possible to collect sperm in quantity from male fish at the breeding season. The vibratile tails of the sperm can be centrifuged off and then the chromatin collects at the bottom of the jar in the form of a whitish gel. Under chemical analysis it breaks down into two final major constituents called respectively nucleic acid and protamine. Nucleic acids derived from all fishes are either identical or very similar in composition. It is extremely complex, its formula being something like $C_{40} H_{56} N_{14} O_{16}, 2P_2 O_5$. The protamines are the simplest known proteinds and those from different fishes are all different. Thus from the codfish (Gadus) comes a protamine which has been called gadin; from the herring (Clupeus) one called clupein; from the salmon (Salmo) one known as salmin.

VII. Tissues.

A. A tissue may be defined as a collection or association of similar cells doing a similar work.

B. Kinds.

1. Meristematic or formative tissues - tissues whose cells are in process of rapid division and growth. They are usually full of cytoplasm, are without conspicuous vacuoles and possess very large nuclei. They of course gradually become differentiated into the permanent tissues such as primary wood, pith, etc.

a. Primary meristems arise by the division of the germ cell and at first compose the whole embryo. Later they become localized at the growing points of the branches and roots. In grasses the basal region of the internodes remains meristematic for a long time.

b. Secondary meristems arise either from inactive remains of primary meristems or are newly formed from the cells of the permanent tissue which alter their function and become rejuvenated.

1. True cambium forming wood and phloem.
2. Cork cambium forming cork.
3. Growing layer of a callus.

2. Permanent tissues - tissues whose cells are no longer dividing. They are usually larger than the meristematic cells, possess relatively little protoplasm or are entirely dead,

have usually large vacuoles, have cell walls usually variously thickened and chemically altered.

a. Parenchyma - thin-walled tissues containing much protoplasm and possessing usually intercellular spaces.

1. Chlorenchyma contains numerous chloroplasts for the purpose of photosynthesis., as in leaf.

2. Storage parenchyma contains much sugar, starch, fatty oils or proteids, etc.

3. Water storage parenchyma consists usually of large thin-walled cells, with abundant mucilaginous cell sap, as in Cacti.

4. Aerenchyma has large intercellular spaces and serves for ventilation or the storage of gases as in the pneumatophores of mangrove.

b. Boundary tissue - tissues marking off or bounding certain other tissues so as to prevent evaporation, protect from excessive heat or against the loss of diffusible substances.

1. Epidermal tissues.

a. Epidermis - typically a single layer of tubular or elongated living cells without intercellular spaces between them. In the lower plants they contain chloroplasts but in the higher plants where progressive division of labor has arisen, chloroplasts are wanting except in the guard cells. The outer walls in aerial parts of plant are usually thickened and covered with a cuticle which is only with difficulty permeable to water and gases. In some cases deposits of wax in shape of grains or small rods may cause a bloom as exemplified by plums and some grapes. In some cases the epidermis is hardened with calcium carbonate or with silicates. In Equisetum this silification is so great that the tissue has been used for polishing tinware, while in Coix lachryma-Jobi the pericarp is almost as hard as opal.

b. Guard-cells - always found in pairs and always contain chlorophyll - these will be studied in detail later.

c. Trichomes or hairs - either unicellular or multicellular and unbranched or branched or stellate. Some are peculiarly modified into stinging hairs while others are scale-like.

d. Emergences - projections frequently like hairs except that more than the epidermis is involved in their structure. Thorns or roses and prickles of raspberry belong here.

2. Endodermis - frequently encloses and bounds as a sheath of but one cell in thickness, living tissues usually situated within the plant.

3. Cork - formed by a secondary meristem, the cork cambium or phellogen, usually where the epidermis has been thrown off or where living parenchyma has been exposed by wounding. The cells usually contain air, are dead, and prevent all interchange of gases. For this reason lenticels often form. These are composed of non-corky tissue rich in intercellular spaces.

c. Mechanical tissue - tissues possessing as their main function the mechanical strengthening of the plant.

1. Sclerenchyma - these are dead cells with strongly thickened walls.

   a. Sclerenchyma cells or stone cells are more or less isodiametric as in the case of the gritty cells in the flesh of the pear.

   b. Sclerenchyma fibres are narrow, elongated, spindle-shaped cells, as found in the trunk of the oak.

2. Collenchyma cells are living cells capable of growth, having an isodiametric or more often an elongated shape and an unequal thickening of their cellulose walls.

d. Conducting tissue - tissues employed in the rapid conduction of food materials.

1. Tracheids are dead thick-walled elongate cells with walls often pitted, reticulated, or spirally thickened.

2. Vessels are dead thick-walled cell-structures with the end walls more or less removed so as to form an uninterrupted passage for water, and with the side walls variously covered with different kinds of pores.

3. Sieve tubes are living cells without nuclei that serve for the transportation of proteids and carbohydrates. They often possess sieve plates, and always have an abutting companion cell whose nucleus apparently regulates the action of the protoplasm in the sieve cell.

e. Secretory and glandular cells, tissues, spaces.

1. Solitary secretory cells differ mainly from other cells in their contents which may consist of mucilage, gums, ethereal oils, resin, tannin, alkaloids, crystals.

2. Secretory cells sometimes fuse by the elimination of their cross-walls, so as to form ducts or canals. Such arè the non-septate lactiferous cells of the rubber which contain the milky secretion latex.

3. Lysigenous intercellular spaces containing secretions frequently arise by the dissolving of the walls of a group of cells which have already formed secretions. Süch reservoirs filled with ethereal oils are found in the citrus fruits.

4. Schizogenous intercellular spaces containing secretions frequently arise by the splitting apart of cells, thus forming a canal or reservoir into which the cells can po pour their secretions.

5. Glandular cells are often found on the epidermis which excrete substances from their protoplasts to the outside. Such cells or groups of cells for instance secrete nec-tar in the flower or digestivevjuices in the carnivorous plants.

VIII. The plant in its relation to water.

A. The water content of plants.

1. To ascertain the water content of a plant, the specimen must either be placed in a dessicator or dried at a temperature of over 100° C., because even if exposed indefinitely to the air the plant will retain a large amount of moisture.

2. The proportion of water in actively growing plants is very considerable, in woody plants about 50% being water, in juicy herbs 70 to 80%, in succulent plants and fruits 85 to 95%, in algae 95 to 98% by weight:

a. Corn plant 80%.

b. Cabbage 90%.

c. Apple 83%.

d. Cucumber 95%.

e. Onion 88%.

f. Potato 80%.

g. Beets 88%.

3. Due to some special adaptation a few plants during a part of their life history can withstand an exceptional amount of dessication but even though the air is quite dry, about 9% - 14% of hygroscopic water is still present. In fact, over the sulphuric acid dessicator, seeds may retain 6% or more of their weight for several weeks.

a. Some Algerian species of Isoetes and the Central American Selaginella lepidophylla can withstand droughts of many months' duration and then at the first rain burst into life again to resume their growth.

b. Many mosses, liverworts, lichens and algae growing on bare rocks naturally are forced to withstand protracted dessication.

c. Seeds and spores in most cases are abnormally resistant to drying but the reason for this is undoubtedly because the plant in this stage exists in a condition of latent lf life.

B. The importance of water to the plant.

1. All the chemical changes which take place in the metabolism of the plant are carried out in water.

2. The chemical elements which form water, namely hydrogen and

oxygen, in combination with carbon form one of the most important ingredients that go into the make-up of plants, as for instance carbohydrates and proteins.

3. Raw salts and dissolved food materials are transferred from one part of the plant to another by means of water.

4. Most plants owe their rigidity or stiffness to hydrostatic pressure or turgor unless extensive special mechanical tissues occur, just as a rubber baloon owes its shape to the air that distends it.

C. The water absorbing system of the plant.

1. In the lowest plants such as the algae and fungi, many of the liverworts and mosses, in the youg stages of even higher plants and in the submerged aquatic higher plants, the entire organism is readily permeable to water and to the various solutes. When rhizoids or roots occur, they therefore function chiefly as organs for anchorage and not for absorption.

2. In the higher plants, with a few curious exceptions, roots are the sole organs of absorption for the plant.

a. In the Hanging Moss or Spanish Moss (Tillandsia usneoides) plate-like epidermal hairs absorb moisture and hold it until the plant has had time to absorb it, while in the pitcher plants water is absorbed which falls into the pitcher-shaped leaves.

b. The importance of the root is demonstrated by the seedling This generally produces a root before any other structure for the reason that water is the most immediate necessity since plenty of reserve food has generally been stored up in the cotyledon or endosperm. Seeds apparently do not store up water as they do food because then they would not be able to resist adverse conditions so sucessfully.

c. Rooting habit.

1. Different species of plants are very variable in their rooting habit, yet these generally will fall roughly into two systems.

   a. The formation of a tap root and many lateral roots developing from it as exemplified by the carrot.

   b. The formation of many roots, none of which seem to to take the lead in growth as exemplified in the grasses, onion, and most monocots. This is probably due to the arrested development of the tap root in the seedling stage.

2. Special adaptations in the rooting habit.

   a. Xerophytes such as the Kiawe, Cactus and typical plants of desert regions usually have an extensive yet very shallow rooting system. This allows them to quickly absorb the sparse rain before it has had time to evaporate or becomes scattered through the soil. Because of this rooting habit of the Kiawe, these trees more than any others are blown down by violent wind-storms in Honolulu. Under xerophytic conditions, though not typical desert conditions, in which a certain amount of water is located in the ground or where seepage from wetter forehills occurs, the vegetation generally is provided with tap roots of exceptional length.

   b. Hydrophytes such as the Mangrove and the Southern Bald Cypress which grow in tidal flats and marshes possess special lateral roots called ~~hydathodes~~ pneumatophores which grow up to the surface until they reach the air.

These are richly supplied with aerenchyma and thus permit the submerged roots to exchange gases with the atmosphere.

c. Many epiphytic orchids and arums have long aerial roots covered with a many-layered envelop called velamen composed of empty cells communicating with each other and with the exterior by means of pores. When rain falls on this sheath, the water sinks into the velamen as into a sponge and from there the living cells of the root cortex absorb it.

d. Prop roots, which arise adventitiously, are found commonly in species of Ficus and in corn.

e. Buttress roots are found among species of Ficus and other tropical plants to aid in the support of the trunk of the tree.

d. Extent of the rooting system.

1. The root length of a large pumpkin has been estimated at 25 kilometers or nearly 16 miles.

2. Seeds of fir, spruce and pine were planted and allowed to grow for a year. The length of their roots was then measured and found to total 99 cm for the fir, 194 cm for the spruce, and 1200 cm for the pine. The efficiency of the root-system in different plants apparently varies greatly. The pine for example is in contact with a considerable mass of soil and this probably explains why it succeeds in rather unproductive soil.

3. A one-year-old wheat plant has a total root-length of 500 to 600 meters.

e. The origin of lateral roots.

1. Because of the internal structure of the parent root, lateral roots always develop in longitudinal rows. For instance in a tetrarch root or one having four points of xylem as in the radish, the lateral roots will occur in four rows, one for each xylem point.

2. Roots always arise endogenously and before reaching the surface must break through the surrounding and overlying tissue of the parent root, by the ruptured portions of which they are often invested at the base as with a collar.

f. Structure and growth of the root.

1. The root-cap consists of a group of cells which form at the tip of the root to slough off and become gelatinous thereby protecting the growing point of the root f from injury while it pushes through the soil.

2. The root-hairs.

a. Immediately in back of the growing point innumerable epidermal cells produce prolongations called root-hairs which flatten out against the soil particles and thus become extremely efficient absorbing organs.

b. Root-hairs usually only live a few days, the older ones dying off as new ones form nearer the tip. Thus only a limited zone of the young root a few centimeter or millimeters in length is clothed with them.

c. Root-hairs occur in enormous numbers, 420 occurring per square millimeter in corn.

d. Root-hairs vary in length according to the kind of plant from 150 micra to 8 mm.

e. Root-hairs may enlarge the surface area of the root as much as 12 times.

f. Root-hairs do not occur in all plants, many water plants and most gymnosperms with mycorrhiza lacking them.

g. Root-hairs absorb most of the water for the plant, the older part of the root acting chiefly for anchorage and transportation for the material that the root_hairs have absorbed.

D. Soil texture and water-holding capacity in reference to plants.

1. Soil texture.

a. The following mechanical classification of soils has been largely adopted by agronomists:

COARSE SAND	1/25 - 1/50	inch in diameter.
MEDIUM SAND	1/50 - 1/100	
FINE SAND	1/100 - 1/250	
VERY FINE SAND	1/250 - 1/500	
SILT	1/500 - 1/2000	
FINE SILT	1/2000 - 1/5000	
CLAY	1/5000 - 1/25000	

b. The water which percolates into the soil enters the spaces between the soil particles, which it fills more or less, driving out the air and adhering in the form of films to the component particles, when it does not fill the spaces completely. The thicker the films, the less firmly the molecules more distant from the surface of the soil particles are held: so that gravity suffices to carry down to lower and lower levels a certain amount of the percolating water. This may drain away as subterranean streams or may remain, saturating the soil at a certain level and forming thus the "water table", approximately parallel to the surface and at a variable distance from it.

2. Water-holding capacity.

a. The water-holding capacity of soils depends largely on the size of its particles, on its compactness, and on the amount of humus or organic matter contained in it. The following examples are illustrative: Quartz sand with particles 1 - 2 mm. in diameter holds 3.66% water by volume; .25 - .5 holds 4.38% ; .11 - .17 holds 6.03% ; .01 - .07 holds 35.5%. Humus soil holds 55% water by volume; clay soil, 53%; fine sandy soil, 30%; coarse sandy soil, 10%.

b. Since the water-holding capacity of soils is proportional to the smallness in size of the soil particles it is evident that the plant roots in a fine soil cannot abstract so much water. Thus we can state that the available amount of water for a plant in a soil is inversely proportional to the size of the soil particles. Duggar gives the figures at which certain plants wilt on two types of soils as follows:

	%ON CALCAREOUS SOIL	% ON PEATY S OIL
OATS	8.4	32.3
BARLEY	9.98	33.3
RYE	9.55	32.8
RED CLOVER	10.28	34.3
POTATOES	5.07	41.4

c. The coefficient of wilting for different plants varies on a given soil.

d. Soil mustvcontain air if the ordinary plants are to grow in it.i

IX. Conditions and principles of absorption.

A. Mechanical suspensions, true solutions, and colloidal solutions compared.

1. Mechanical suspension.

a. Example: If very fine sand is stirred up in water, it remains but a short time in suspension and then sinks to the bottom leaving the water clear.

b. The properties of the sand which is distributed in the water is as follows:

1. In mechanical subdivision merely.
2. Visible under the microscope or to the naked eye.
3. Greater than one micron in diameter.
4. Will not pass through filters nor parchment membranes.
5. In gravitational movement.

c. The mixture,

1. Has no osmotic pressure.
2. Is generally opaque.
3. Will not gel.

2. True solution.

a. Example: If a salt or sugar is placed in water, it soon dissolves and remains in that state.

b. The properties of the salt which is distributed in the water is as follows:

1. In molecular subdivision.
2. Invisible.
3. Less than one double micron (1 millionth of a mm.) in diameter.
4. Pass through filters and parchment membranes.
5. In molecular motion.

c. The mixture,

1. Has high osmotic pressure.

2. Is transparent.

3. Will not gel.

3. Colloidal solutions.

a. Example: If fine clay is stirred into water, the clay will remain in suspension indefinitely although it has not dissolved.

b. Thomas Graham, an English physicist, in 1851 began the study of colloids.

1. He first divided all chemical substances into crystalloids and colloids, theffirst including those substances that diffuse through a parchment membrane and the second those which diffused at an extremely slow rate or not at all.

2. He later discovered that the same individual chemical element or compound may exist sometimes in crystalloidal, and sometimes in colloidal, form.

3. This lead to the modern view that the state of a substance when existing alone may be either gaseous, liquid, or solid, and that its condition when in solution may be either crystalloidal or colloidal. To state that a substance is a colloid therefore merely distinguishes it from being a gas, a liquid, or a solid.

c. The colloidal condition exists when one substance is distributed through the mass of another substance. The term colloidal condition is commonly used only when a solid or a liquid are dispersed in a liquid, although the examples below are all actually in the colloidal condition:

1. The outer phase a gas.
   a. Inner phase a liquid, as mist in air.
   b. Inner phase a solid, as smoke or dust in air.
2. The outer phase a liquid.
   a. Inner phase a gas - foams.
   b. Inner phase a liquid - emulsions.
   c. Inner phase a solid - suspensions.
3. The outer phase a solid.
   a. Inner phase a gas - solid foams, pumice stone.
   b. Inner phase a liquid - liquid inclusions in crystals.
   c. Inner phase a solid - alloys, colored glass.

d. The property of the clay, which is distributed in the water in the example given is as follows:

1. In colloidal subdivision.
2. Visible under the ultramicroscope.
3. One double micron to one Micron in diameter.
4. Pass through filters but not through parchment.
5. In Brownian motion.

e. The mixture,

1. Low osmotic pressure.
2. Exhibits Tyndall phenomenon. The particles themselves are not seen but the flash of light which gleams from them when light is passed through the solution. This is an effect similar to that which causes a beam of light in dust-filled atmosphere in a dark church-building (for instance.)
3. Forms gels.

B. Forms of colloidal mixtures.

1. Sols.

a. Fluid and mobile colloidal mixtures like a true solution.

b. The solid particles of the inner phase all carry a charge of electricity of the same kind and thus repel one another while the fluid particles of the outer phase all carry the opposite charge.

c. Sols may be easily converted or set into a semisolid or jelly-like form called gels by phase reversal which may be caused by,

1. Changes of temperature.

2. Changes in the electrolyte content.

3. Changes in the concentration of the mixture.

d. Usually gels can be changed back into sols but in many cases this is irreversible.

e. Sols are of two kinds,

1. Sols in which the inner phase is a solid are suspensoids.

2. Sols in which the inner phase is a liquid are emulsoids such as Scott's emulsion, mayonnaise dressing, milk.

2. Gels.

a. Colloidal mixtures which are firm and jelly-like.

b. Easily formed from sols by a usually reversible process.

c. Either rigid or more frequently elastic such as gelatin, egg-albumin, agar.

d. When a sol changes into a gel, phase reversal has occurred by the solid becoming the outer system and the liquid the inner system - This phase reversal occurs in death and constitutes rigor mortis.

e. When a sol changes into a gel and this condition is irreversible, the substance is said to have coagulated.

C. One should know a little about the properties of mechanical suspensions, true solutions, and colloidal solutions because the protoplast or naked cell is made up of substances which exist in these three conditions:

1. Substances in true solution in the cell.

a. Various salts and acids contained in the karyolymph or "juice" of the nucleus.

b. Various sugars, organic acids such as malic and tartaric, and mineral salts which are of the same general nature as those found in sea-water. These are contained in the cell sap.

2. Substances in mechanical suspension in the cell are chèefly metaplasm such as,

a. Starch grains.

b. Proteins, found especially in seeds and called aleurone grains.

c. Crystals of calcium oxalate, calcium carbonate, crystals of albumen (especially in Brazil nuts).

d. Pyrenoids found in algae. A pyrenoid is a crystalin albumin surrounded by small grains of starch.

3. Substances in colloidalmcondition in the cell.

a. Any one of the substances descibed above provided they are small enough - namely one double micron to one micron in diameter.

D. Imbibition.

1. Imbibition occurs when water or some other liquid forces

apart the molecules of the solid thus causing it to swell.

a. Peas when imbibing water swell to more than twice their their original size and become soft and elastic because the particles of solid matter are forced apart to such an extent.

b. A brick when absorbing water undergoes no change in size, or elasticity because the internal attraction of the molex cules of the brick is too great to permit them to be forced apart by the water.

c. Imbibition gradually intergrades into solution. For instance gum arabic when first treated with water swells into a stiff gel. Then into a soft gel, and finally dissolves into a true solution.

2. Swelling by imbibition will take place even against enormous pressure. For examples it has been found that the dry gel from sea-weeds will swell to 330 per cent of its dry volume if immersed in water under ordinary conditions. But it will swell 16% when moistened and under a pressure of 42 atmospheres.

3. During the swelling of gels bu imbibition of water, the total volume of the system (i.e., that of the original dry gel plus that of the water absorbed) becomes less. For example a mixture of gelatin and water will, after the gelatin has swollen to its utmost limit, occupy less space than the total volume of the original gelatin and water. It has been computed that a pressure equivalent to that of 400 atmospheres would be necessary to compress the water to an extent representing this shrinkage in volume.

E. Diffusion, osmosis, and allied phenomena.

1. Diffusion.

a. By diffusion is meant the penetration of a substance into space not previously occupied by it, and independently of external forces. Examples:

1. Upon pouring a little bromine into a closed vessel by means of a thistle tube, the vapor that arises at ordinary room temperature gradually penetrates to all parts of the vessel.

2. Upon pouring a solution of copper nitrate in the bottom of a cylinder of water, the blue solution will gradually diffuse upward until eventually the whole is colored blue.

b. How can we explain why the substances moved upward against the pull of gravity?

1. Molecules of gases, liquids and dissolved substances are all supposed to be in constant motion.

2. In the bromine example if there were no air in the vessel, the molecules would instantaneously move upward because no other gas molecules would be present for them to hit against. But because of the molecules of the air being in the way, diffusion is comparatively slow.

3. In the copper nitrate example we find a similar situation. The molecules here collide with the water molecule

4. Naturally the concentration of bromine and c pper nitr rate is greatest at the bottom. So we can conclude that substances diffuse from points of high concentration to points of low concentration.

5. Furthermore the rate of diffusion of each solute, or dissolved substance depends on the solute, on the solvent, and on thecdifference in concentration (also heat).

a. When a lump of sugar is put in ice-tea, it dissolves and diffuses rapidly at first because a high concentration is next to a low concentration. But the rate of diffusion constantly falls off as diffusion progresses because the difference at any two points is becoming less and less marked.

b. When a lump of sugar is put in hot tea it dissolves and diffuses rapidly. This is because the molecules are in more rapid motion.

2. Semipermeable membrane.

a. This is a membrane that will allow the molecules of the solvent (or tea in the former case) to pass through but not the solute (or sugar).

b. Many membranes of that kind are known such as parchment paper, bladders of animals, celloidin, certain chemicals such as copper ferrocyanide, and the protoplasmic lining of cells.

c. An ideal semipermeable membrane would make a sharp separation of the two kinds of molecules, letting only one kind pass through it. This does not exist.

d. If a sugar solution be placed in a vessel on one side of a semipermeable membrane and plain water be placed on the other side, one will find that the level of the liquid will rise in the section in which the sugar is dissolved. The exact explanation of the semipermeability of membranes is not definitely known. Two theories have been advanced:

1. Sieve theory. This theory assumes the presence in the membrane of minute pores or passages. When the molecules of the two substances, salt and water, bombard each

other at the membrane surface, the salt moleculesis too large to pass through the membrane while the water molecule can easily do so. Thus more and more water enters where the salt is contained, and the level of the liquid rises.

2. Solvent theory. This theory assumes that the membrane acts as a solvent for the substances that pass through it while substances that do not dissolve in it cannot pass through it. Example: Take a thistle tube with semi-permeable membrane attached and after wetting the membrane place it in an atmosphere of hydrogen. No increase in pressure occurs because hydrogen is only slightly soluble in water. But now substitute for the hydrogen ammonia gas and this will quickly pass through the membrane

X. Possible factors accounting for the ascent of sap.

A. Osmosis.

1. Since most evaporation occurs from the leaves, the sap in that region is the most concentrated while that in the root-hairs is the most dilute. Thus we can easily imagine that the flow of water would be from the root to the top of the tree.

2. This does not account for the entire flow of the sap up a tree because,

a. The difference in concentration between root-sap and leaf-sap would be too small over such a distance to allow for any appreciable osmotic flow.

b. The sap flows too rapidly.

B. Capillarity.

1. Water rises in fine capillary tubes to great distances.

2. Water does not rise to any noticeable distance in plants due to capillarity because of the cross-walls in the xylem.

C. Root pressure.

1. When a plant is decapitated, sap frequently excapes from the wound due to root pressure.

2. a.Ascent of sap cannot be explained by this because,

a. One does not always find root pressure.

b. Sometimes the cut end will absorb water instead of giving it off.

c. The force is too insignificant.

D. Cohesion Theory of Joly-Dixon: There is a chain of water molecules all the way from root to leaf. One molecule pulls up the other, the uppermost being evaporated from the leaf.

X. Loss of water by the plant.

A. Guttation.

1. Guttation is the discharge of water in the liquid state from a plant structure.

2. This occurs especially when the plant is saturated with water and the air is saturated with water vapor - early morning is the best time to notice this phenomenon. For that reason these drops are usually attributed to dew. They, however, glisten mor more than pure water due to the presence of salts and are situs ated at definite regions on the plant.

3. Guttation drops are pressed out ofbusually special structures called hydathodes or in the case of molds and similar plants are pressed directlybthrough the cell wall.

4. Commonly observed at tip of leaf of corn seedling, at ends of veins in nasturtium leaves and in the leaves of taro.

5. Amount of water given off by plant in guttation.

a. Colocasia nymphaefolia dischatges 200 drops to a height of 1 cm. in one minute while 100 cc, may be secreted in a single night.

b. Merulius lacrymans, the dry rot fungus "weeps" so much water that it accumulates in big drops on the surface of its sheet-like mycelium.

6. The water exuded is not pure.

a. It usually contains salts and sometimes organic material in solution. In some cases thecsalt in the exuded water is so abundant that after evaporation a slight incrustation is found on the leaves - a phenomenon readily noticed in the saxifrages where calcium carbonate is given off.

b. It may constitute the nectar of nectaries, fluid on stigma, and the enzymatic juice on the digestive glands of insectivorous plants.

7. Value of guttation is probably to allow the sap to flow through the plant when transpiration stops due to the saturation of the atmosphere. This point is very doubtful.

8. Cause is no doubt turgor pressure.

B. Transpiration.

1. Transpiration is the giving off of water vapor by a plant.

2. Mechanism of transpiration.

a. Epidermal cell exposed to air loses some of the water of imbibition from its cell wall by evaporation.

b. Cell wall then draws on water of imbibition from its protoplast which in turn gets it from the sap vacuole.

c. The cell sap being concentrated, water is absorbed from an adjoining cell which in turn adjoining cell which is not transpiring. Thusxwater from the

3. innermost cells of leaf is withdrawn.

3. Kinds of transpiration.

a. Cuticular.

1. Plants inhabiting damp localities like the filmy ferns have much cuticular transpiration.

2. Young parts of plants have cuticular transpiration but this soon stops as the tissues mature so that this kind of transpiration is negligible.

b. Stomatal.

1. Since leaves of most plants have a water impervious cuti-cle, transpiration is limited to special pores called stoma-ta.

2. Size of opening is about 7 mu.

3. Medium sized cabbage leaf has 11,000,000 and sunflower leaf 13,000,000 stomata.

4. There are 40 to 300 stomata per sq. mm. on plants.

5. Brown and Escombe have shown that the movement of diffus-ion through a typical leaf provided with stomata is practi-cally the same as though no cuticle were present. Diffusion of gases is not proportional to the area of the hole but to its radius. But since stomata are elyptic, diffusion is proportional to the radius of the circle having the same area as that of the elypse.

6. Transpiration is really a menace to life but this cannot be helped because in some way gases must gain exit and en-try to the leaf.

7. Amount of transpiration of plants, practically all of it

through stomata:

a. Sunflowerv6 feet high in one day gives off 1000 cc. of water.

b. Birch with about 200000 leaves gives off 300 - 400 liters of water in one day.

8. When stoma openings are decreased in size the amount of CO_2 diffusion decreases much less rapidly than does the amount of water transpired.

VI. Ecological classification of plants based on their relationship to water.

A. Xerophytes.

1. Xerophytes are plants adjusted to physiological dryness.

2. Conditions under which they live and general characteristics of the plants.

a. Inhabiting desert regions. - Cactus, Compass Plant

b. In rock crevices - saxifrages

c. Living epiphytically - many ferns and orchids.

d. On rocks - lichens.

e. In alpine regions and in tundras and steppes.

f. Along the coast } halophytes Mangrove

g. In saline regions } Russian Thistle

h. Parasites - Viscum.

i. Many trees in tropical rain forests - reason still obscure.

j. Bog plants possibly because a deficiency of oxygen may make absorption difficult.

B. Tropophytes are plants adjusted to periodically moist and dry climates - in other words seasonally mesophytic and xerophytic.

1. Plants of tropics adjusted to dry and rainy season as plants on Manoa Valley sides.

2. Plants in the north adjusted to frozen winter season and to moist summer season.

C. Mesophytes - adjusted to neither an excessively wet nor an excessively dry environment.

Mineral Nutrients

A We learned that plants are chiefly composed of water:

woody plants 50%
herbs 70-80%
succulent plants and fruits 85-95%

Upon burning, the water as well as carbon and nitrogen is driven off, leaving the ashes which are technically termed "ash". The amount of ash remaining varies from 1.5 to 10 (or even 30% of the dry weight of the plant, when large quantities of unnecessary salts are taken up).

31 elements have been found in the ash of different plants but only the following are necessary for growth in the higher plants: Nitrogen, Sulphur, Phosphorus, Potassium, Calcium (not for fungi, algae), Magnesium, Iron and sometimes Chlorine. CHOPKNS Ca Fe Mg

Aluminium and Manganese in traces.

B None of us doubt but that the ash substances come from the soil. But formerly even after the discovery of the law of indestructibility of matter, famous academies suggested prize essays with the object of discovering whether plants did not actually make the substance from which the ash resulted.

In 1800 the Berlin Academy formulated the following question to stimulate research along this line: "By what means are the earthy constituents obtained, which as a result of chemical analysis, are found to be in the various indigenous cereals? Do they enter these plants in the same form as they are found in them, or are they produced by the agency of the vegetative organs themselves?"

Schrader won the prize with his essay, the summary stating: "Plants develop these ash constituents by their own vital force."

About 30 years later De Candolle disproved Schrader's ridiculous statement but no one paid much attention to what he said. But with further experiments made by other men, (Wegmann & Polstorff) most botanists by 1850 were convinced that plants derived their ash material from the soil and did not produce elements out of nothing.

C. Two methods of determining necessary plant foods.

1. Using insoluble artificial soils such as platinum pumice, pure quartz sand, or carbon and adding the salts to be tested. This was the earliest method employed and by it Prince Salm-Horstmar in 1856 discovered that some elements found in ash of plants are not essential

2. Using water cultures

If a plant does grow to maturity in a culture solution lacking an essential element is no proof that the element is lacking for the plant. A sufficient amount may be stored up in the seed for the plant to draw upon during its life time. A bean can even grow to maturity and flower in pure water due to prod in cotyledons

D. Plant requires a certain definite amount of each essential element. If too little of one element be present the plant is unable to develop healthily, even if the others be present in excess. This is an example of the Law of the minimum

E. Only one essential element is absorbed by the plant in the elemental form, namely Oxygen.

F. Ash of plants contains by no means all the mineral matters which occur in the soil or in the water. Aluminium is widely distributed in nature but nevertheless it is entirely or almost entirely absent from most plants. The amount of aluminium in Lycopods, on the other hand, is over 16%

Iodine occurs in sea-water only in such small amount that it can hardly be detected, yet many algae take up a huge amount of it.

G. Different species of plants growing in the same soil take up different amounts of ash substances and the ash of the different elements vary in their proportions: Rumex 8%, Geranium 10%, Sedum 12%, Myosotis 18% of dry weight. Seashore plants contain much more ash; Aster trifolium 17%, Artemesia maritima 18, Chenopodium maritimum 32%

H. Plants which transpire freely are far richer in ash than those which transpire feebly, and the leaves, being the organs of transpiration, appear to contain most ash.

I. Sodium is not even indispensable to halophytes in which it is present in greatest amounts. These plants grow in soils rich in sodium chloride not because this substance is necessary to them but because they bear it better than other plants do. Sodium, however, is indispensable to Diatoms as well as Silicon.

J. Many substances though not indispensable are really beneficial to the plant as Silicon to grass and Equiseti to harden the stem to keep it from lodging and to inhibit insect and fungus attacks

K. Water plants are richest in ash and woody plants the poorest. This shows that the tissues richest in ash are those in which living cells are most numerous such as those of algae and the leaves and cortex. Dead cells contain much less ash since the salts begin to pass out at about the time death occurs.

L. Ash content of organs changes in age. In leaves it increases while in roots and stems it decreases because here the number of dead cells, poor in ash, increase with age.

M. Relationship of the minerals to one another is little understood. If plants be grown in solutions of calcium chloride or magnesium chloride, they will die; but if the two be mixed, they will live in spite of the fact that the two chemicals do not react upon each other.

N. Not correct to state plant requires particular element. Just as H and O is not substitute for water so elements found in ash are not suitable – must be in form of salts

O. Aluminum in soil an inessential element, causes the red flowered hydrangea to produce blue fls. Zinc in soil changed one violet (V. tricolor) to the different form, variety of species called V. calaminaria

1. Sulphur - in protein - minute quantity needed, that of seed frequently sufficient

2. Nitrogen stimulates vegetative growth and retards flowering.

3. Phosphorous - in nucleus - hastens seed production and root formation

4. Potassium - necessary for carbohydrate production - aids in cell wall formation - if scarce to certain extent can be substituted by sodium

5. Calcium - possibly acid neutralizes - frequently unlocks soil salts from soil - seems to be antagonistic to excess of Mg

6. Magnesium - carrier of phosphoric acid - catalytic agent for chlorophyll formation.

7. Iron - catalytic agent for chlorophyll - necessary for plants without chlorophyll as well.

8. Chlorine - unessential?

Aluminium - entirely or almost entirely absent from most plants hydrangea

10. Manganese

11. Boron

12. Sodium - apparently not even necessary for halophyte - seems to substitute for K to certain extent.

13. Silicon - possibly essential in traces - if not essential at least frequently beneficial to stiffen plant.

Functions of Minerals

1. Phosphorus - hastens seed production; is constituent of nucleus - abundant in meristematic cells - promotes cell division - promotes root formation and therefore is beneficially applied to root crops.

2. Potassium - necessary for carbohydrate production and since sugar and starch are carbohydrates, its application will stimulate sugar and starch production by plants. Aids in cell wall formation and thus increases resistance to fungus attacks. Is absolutely necessary to plant but if it is scarce, the addition of sodium benefits plant. Most abundant in growing parts and then disappears with age.

4 Magnesium - seems to carry the phosphoric acid
found in meristematic tissue.
necessary for chlorophyll production.

5. Calcium - in vegetative parts
- aids starch digestion
- possibly neutralizes acids in plants - oxalic acid to calcium oxalate.
seems to neutralize injurious effect of too much Mg.

6. Iron - necessary for chlorophyll production but not part of it - lack results in chlorosis.
must also be necessary for other unknown functions since it is essential to plants lacking chlorophyll.

7. Sodium - unessential - seems to take place of K to certain extent.

8. Chlorine - not essential

9. Sulphur – in albumen – minute quantity required

10. Silicon – not essential – prevents lodging of grasses

11. Nitrogen – foliage increased and thus flowering retarded –

    1. excessive use weakens stem possibly due to rapid growth and no time to mature cell walls so that lodging results
    2. susceptible to disease and freezing.

11 Tincture of chlorophyll transmits light green and reflects light red.

12. Not all light is used for photosynthesis - red to largest extent, and greens the least ∴ chlorophyll looks green

13. After light has passed through 1 or 2 leaves, the valuable rays are absorbed so that other leaves beneath derive no benefit - reason for avoiding overlapping.

14. The amount of CO_2 in air is practically constant around .03-.04% This amount is not sufficient for the most efficient photosynthesis of plant. Since much CO_2 escapes from soil where decaying material is located, some believe that plants have become rosetted to gain extra supply.

15. Only about 1% of the solar energy is utilized by plants - wasteful

16 Autotropic plants that are not green also possess chlorophyll, this merely being masked by the other pigment.

17. Chlorella so sensitive to light that if match be struck and burned 1 sec. at distance of 10 cm. O. is produced.

18 Plant is very inefficient in taking use of light. 12,000 calories of heat are available per square meter of leaf per hour and of this less than $\frac{7}{1200}$ or .6% is used. This is sufficient to form about 1 gram starch. Gasoline engines utilize as much as 35%. Perhaps leaf is so inefficient because it cannot get enough CO_2 from air?

19. By bacteria method it may be shown that CO_2 is decomposed simultaneously with illumination while starch forms some time after (in Spirogyra 5 minutes). This indicates that starch is not the direct result of CO_2 decomposition. From this we assume that certain plants produce some other carbohydrate - sugar and store them as such (lilies etc.) which soluble form and store them as such ... others change the soluble carbohydrate gradually into starch.

Starch accumulation has nothing to do directly with assimilation of CO_2. Plants freed from starch can form it from sugar solution in the dark.

In general 1 sq. meter of leaf surface will in one hour produce ½ to 1 gr. of starch.

Certain plants which form sugar in normal atmosphere form starch in an atmosphere rich with carbon.

CO_2 in land plants cannot pass through cuticle but in aquatic plants since cuticle is wanting it diffuses into leaf just as water does.

CO_2 ~~cannot be~~ is the only compound of C that can be synthesized by chlorophyll.

1. The greatest part of the dry weight of plants is compound of carbon. This, as water cultures attest, is in green plants derived not from the soil but from the air.

2. Since carbon is an element that readily combines with others in a great number of different ways, we find it to be the greatest constituent of living matter except H and O.

3. Two kinds of plants exist according to their method of carbon assimilation:

a. Autotrophic plants are those which by means of photosynthesis can build up carbonaceous food for themselves.

b. Heterotrophic plants are those which are unable to photosynthesize food and consequently are parasites or saprophytes.

4. Chlorophyll, with a few exceptions as embryo of pine, is only found in plant structures exposed to light.

5. In the leaf of higher plants, the epidermis has become so specialized to perform its function of a boundary tissue that all the cells except the guard cells lack chloroplasts. The latter possess chloroplasts by this means they can change their osmotic pressure and open or close aperture.

6. Chlorophyll is absolutely necessary for photosynthesis as is CO_2 and light: Proof - Bacterium thermo and Spirogyra chloroplast.

7. Chlorophyll is complicated chemical located in stroma of of chloroplast usually in chlorenchyma.

8. Chlorophyll consists of at least two separate substances:

a. Cyanophyll, a blue-green substance, soluble in benzol and related to haemaglobin,

b. Carotin or relative, yellowish, soluble in alcohol.

9. Probable method of photosynthesis:

$$CO_2 + H_2O \rightarrow \underset{\text{carbonic acid}}{H_2CO_3}$$

$$H_2CO_3 \xrightarrow{?} \underset{\text{aldehyde}}{CH_2O} + O_2$$

$$6\,CH_2O \xrightarrow{?} \underset{\text{sugar}}{C_6H_{12}O_6} \rightarrow \underset{\text{starch}}{(C_6H_{10}O_5)_n} + H_2O$$

10. Formaldehyde even in traces is extremely poisonous to plant.
11. Tincture of chlorophyll transmits light green and reflects light red.
12. After light has passed through 1 or 2 leaves, the valuable rays are absorbed so that other leaves beneath derive no benefit — reason for phyllotaxy.
13. Amount of CO_2 in air is practically constant at .03-%
14. Amount of CO_2 in air is insufficient for the most efficient photosynthesis of plant. Since much CO_2 escapes from soil where decaying material is located, some believe that plants have become rosetted to gain extra supply.
15. Only about 1% of solar energy is utilized by plant — wasteful
16. Autotrophic plants that are not green also possess chlorophyll but it is masked by some other pigment.
17. Chlorella is so sensitive to light that if match be struck and burned one second at distance of 10 cm O is evolved.
18. Of the 1,200,000 calories of heat available from sun per square meter of leaf surface per hour less than .6% is utilized by plant. This is sufficient to form about 1 gram starch. Gas-engines utilize 35% of power. Perhaps leaf is so inefficient because it cannot get enough CO_2 from air?

1. Over 75% of the air is composed of nitrogen and yet the green plant is powerless to make use of it, while less than 1% of air is CO_2 and plant derives all of its C from the air.

2. The soil is continually being depleted of nitrogen which in many cases volatilizes. The supply, however is put back by:
   a. Death of organisms and their waste products which are broken down into simpler compounds by bacteria
   b. Fixation of atmospheric nitrogen by plant-inhabiting bacteria
   c. Fixation of atmospheric nitrogen by free-living soil bacteria and fungi.
   d. Ammonia caught in rain.
   e. Thunderstorms forming nitrous and nitric acid which is washed by rain to ground from air

3. Ammonium salts are readily absorbed and held by the soil as reserve plant food while nitrates readily leach out thus causing deficiency of N in most soils

4. Nitrates of Ca, Mg, K, and Na are the best source of nitrogen for plants but compounds of ammonia can also be utilized as long as they are not injurious to the plant because of their alkalinity. Nitrites can also be used but if too concentrated are injurious.

5. For Fungi in general ammonia, not nitric acid, is the best form of N for assimilation.

6. Nitrification in soils is due to bacterial action. Thus complex nitrogenous compounds from dead animals and plants which higher plants cannot utilize are broken down by decay bacteria finally to Ammonia NH_3. This ammonia is then converted to nitrites by sp. of Nitrosomonas in the Old World and Nitrosococcus in the New World and these nitrites are oxidized further to nitrates by Nitrobacter. Then best available for higher plants.

7. Certain bacteria and fungi living in soil fix free atmospheric nitrogen: Clostridium Pasteurianum and Azotobacter chroococcum

8. Legumes and a few other plants can grow in nitrogen-free soil because of their symbiotic relationship with nitrogen fixing bacteria.

9. Bacillus radicicola infests roots of most Leguminosae forming hypertrophied tissue. Here atmospheric nitrogen is fixed. The bacteria penetrate the root cortex through a root hair and then give rise to tubercles. The bacteria live on carbohydrates supplied by the host and use N_2 from air to build up their protein. Many of these bacteria degenerate, became excessively enlarged, and often branch. Such are called bacteroids. They die in the older part of the tubercle are then digested and absorbed by the legume.

10. If the soil in which legume is growing is rich in nitrates, the bacteria seem to be injured and produce practically no nodules. The plant then utilizes the N in the soil.

11. Green manuring with legumes increases the fertility of the soil due to the atmospheric N formed by them.

12. Root tubercle bacteria of legumes are frequently specialized to definite species or genera. The Soya plant cultivated in America forms no root-tubercles while in Japan it does - probably due to lack of specific bacterium.

13. In many of the Rubiaceae (Ardisia) one finds bacterial nodules in the leaves. In this case infection is not accidental as in the legumes but the bacteria are present in the embryo and if artificially kept from egg cell, the plant fails to grow normally.

14. Insectivorous plants or carnivorous plants capture insects, dissolve, digest, and absorb them by means of enzymes. Since all insectivorous plants are provided with chlorophyll, they surely have acquired this habit not to gain organic compounds of Carbon but more likely Nitrogen and possibly Potassium and phosphoric acid. They can succeed without animal food but its lack decreases production of fruit and seed. Like animals they utilize solid food which has to be rendered fluid by enzymes before it is absorbed. The stomach of animals and the pitchers of insectivorous plants are especially analogous. Most fungi and bacteria physiologically are closer to animals because they gain all their food by the digestion of solid particles while insectivorous plants are at least autotrophic regarding C.

15. Mycorrhiza are fungi associated with the roots of higher plants. Ectotrophic mycorrhiza merely surround the roots, take place of root hairs frequently, and seem to aid in assimilation of raw salts and atmospheric N. Endotrophic mycorrhiza are found within the symbiont. Two types occur: intracellular endotrophic mycorrhiza which are found boring their way into the cell itself and sometimes even coiling around the nucleus. Intercellular endotrophic mycorrhiza are found between the cells usually in intercellular spaces. In certain cases as in orchids and Lyc. gametophytes the intracellular fungus is even partly digested by the higher plant.

Products of Metabolism

1. All of those chemical changes which take place within the body incident to growth and development are commonly included under the term metabolism. These changes may be constructive, or anabolic, and destructive, or katabolic.
2. Many substances produced within a cell are merely temporary. If formaldehyde is one of the intermediate products of photosynthesis it must be temporary because otherwise its poisonous nature would kill the plant.
3. A substance temporary in one plant may be permanent in another.
4. Whenever food manufactured is in excess of that used, it of course becomes a storage product
5. The common stored foods of plants are various sugars.
6. Only rarely does growth take place where foods are being assimilated. Thus the assimilation of CO_2 goes on chiefly in fully grown leaves while the growing points that need that food are more or less distant. Thus the food material must be carried from the part of the plant where it is manufactured to the part where it is needed. This transfer is called translocation
7. Translocation may thus be defined as the transfer of food materials or products of metabolism from one part of the plant to another by osmosis.
8. Starch is formed during photosynthesis in the leaves during the day and then disappears during the night.
9. Starch grains cannot pass through cells nor can colloidal starch escape because colloids cannot osmose through the protoplasmic membrane.
10. Since starch cannot leave the cell as such, it must be transformed into sugar and then it can readily osmose from a cell having a higher concentration to a cell having a lower concentration.

11. The chief avenue of translocation of sugar is through the sieve cells of the phloem.

12. The translocated sugar may then later be stored up in same organ in the form of starch as exemplified by the potato tuber.

13. This naturally leads us to consider the effect of girdling a tree. - - - - - - - - - -

14. What is the relative efficiency of herbaceous annuals and woody perennials? Plants in general use their food to build up body substance while animals employ it for body heat. Thus herbs should be the more efficient and they are developed from the woody type of stem - - - - - - - -.

15. Enzymes: - - - - - Typewritten notes

16. Commonly the large molecules in preparation for translocation are split up by an enzyme into a smaller molecule to which water is added:

a. Diastase + $(C_6H_{10}O_5)_n + n\ H_2O = n\ C_6H_{12}O_6$
starch dextrose

b. Fats found for instance in seeds like castor bean previous to translocation must be decomposed by lipase secreted by cotyledon into fatty acids and glycerine. The fatty acid is capable of passing through the water-saturated cell wall more readily than fat and is thus easily absorbed by embryo.

After translocation the substances are usually changed back into larger molecules again.

Respiration

1. All animals and plants respire but only animals with lungs breathe.

~~2. Respiration in plants and in animals is identical~~

3. When energy is released from chemical compounds, the more completely they are decomposed the more energy is liberated, as a rule.

4. It is commonly thought that O combines directly with carbon and so causes combustion. But this is wrong. Water vapor which yields H and OH ions by dissociation, furnishes the necessary OH ions for facilitating the decomposition of the carbon compounds. ~~and this~~ Proof of this is that decomposition of carbon compounds does not take place in pure O but only in presence of water. The H ion then unites with the O of the air to produce more water.

5. The end products of respiration then are CO_2 and H_2O, the same as were supposed to be formed during the commonly accepted idea of respiration. This probably, however, does not represent the entire ~~end~~ product derived from the molecule we started with. The other is probably merely a simpler carbohydrate or protein which with ~~photosynthesis~~ later addition of material and energy can be rebuilt.

6. Is there any difference between the respiration of animals and plants? No! Why then belief that animal and plant respiration is the exact reverse?

7. Comparison of respiration and photosynthesis

Photosynthesis

$CO_2 + H_2O \rightarrow H_2CO_3$ carbonic acid

$H_2CO_3 \rightarrow CH_2O + O_2$

$6\,CH_2O \rightarrow C_6H_{12}O_6$ sugar

$C_6H_{12}O_6 \rightarrow C_6H_{10}O_5$ starch $+ H_2O$

8. The advantage of respiration is not certainly known, but as the plant in order to do work must expend energy, the inference is that respiration sets free energy by which that work is performed.

9. During respiration usually a certain amount of heat is liberated but this heat does not seem to help the plant in any way. Skunk cabbage flowers about 5°C. – 10°C

4½. ~~Spontaneous calor~~ combustion.
10. The transformation carbohydrates in a plant does not decrease its weight but the resulting loss of CO_2 into the air during respiration does make the plant lighter.

11. The rate of growth influences respiration. The younger and more active the tissue the more rapid the respiration.

12. A plant respires about as much or even more than man if we consider weight of each in contrast to weight of O. 1 gm. O per 24 hours is used by 100 gms of man ~~…~~ young wheat leaves use just as much, opening flowers 4 times as much, and some bacteria 200 times as much.

13. Respiration is increased by wounding

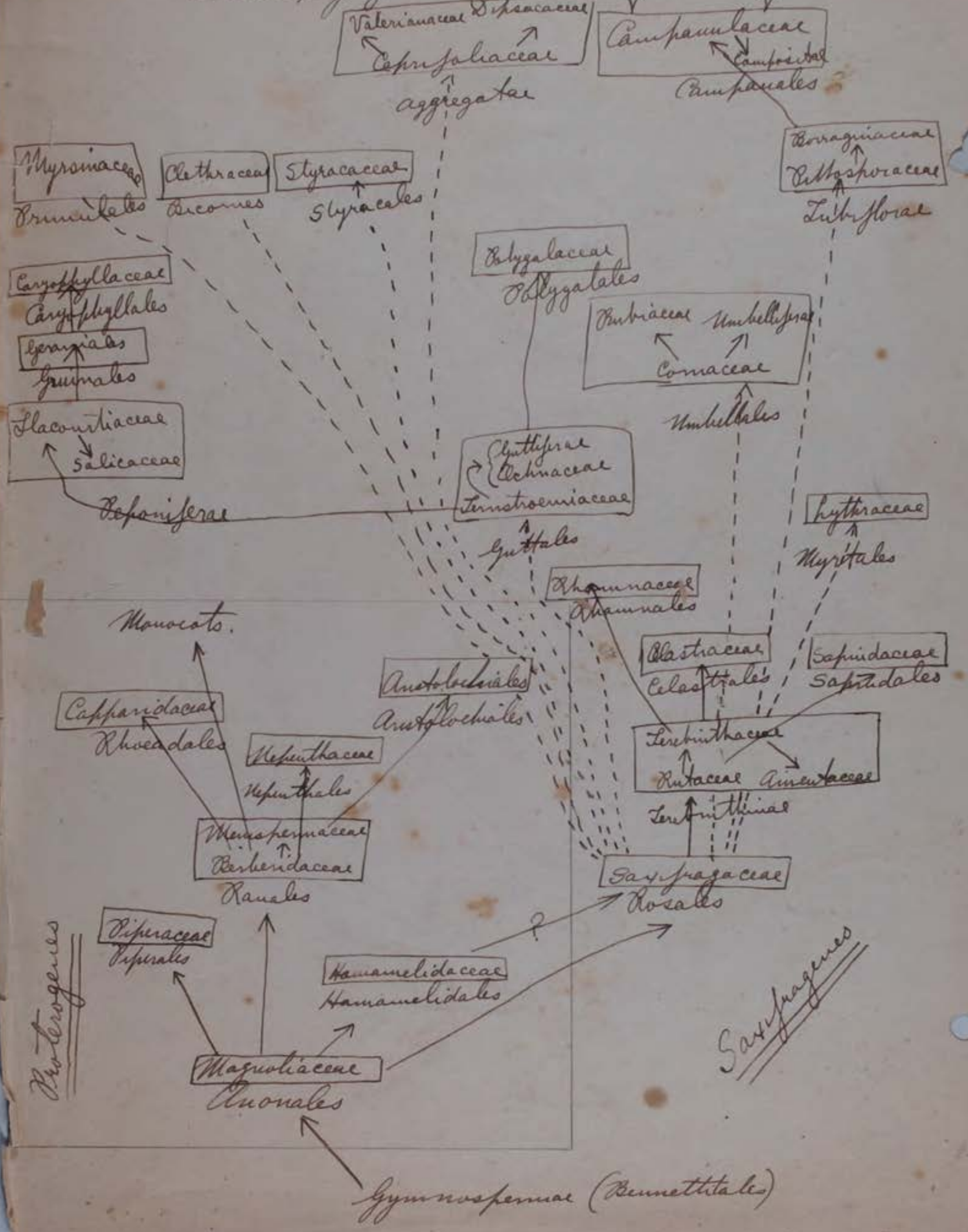
14. If O is with held from a plant, anaerobic or intra-molecular respiration takes place before death ensues. This intramolecular respiration consists of the rearrangement of the complex molecules so as to get O from them to produce CO_2. Such intramolecular respiration frequently occurs in fruits when they are ripening and becoming sweet.

15. Some organisms like bacteria occur which are anaerobic, namely living in absence of air. These do practically same thing as above except that they break down external organic compounds for their supply of O. This breaking down of organic compounds is fermentation, merely a gradual step toward decay.

16. Alcoholic fermentation is produced by various organisms, chiefly yeasts, from sugars which always contain a carbon atom of 3 or a multiple of 3. Reason not known.

17. Fermentation of sugar proceeds very slowly when yeasts are abundantly supplied with O_2. They apparently grow very rapidly and use the sugar as food. But when the supply of O_2 is small so that their vegetative processes are hindered, fermentative action is increased, about 98% of the sugar being used for energy and but 2% for food. Though alcohol is produced at all times, its quantity is in inverse ratio to the favorableness of the conditions for life. When 12% has accumulated in the liquid, action is retarded while at 14% it stops.

Halliers phylogenetic tree according to Lotsy.



(Bessey)


Asterales
Campanulales
Rubiales
Sapindales
Umbellales
Celastrales
Loasales
Myrtales
Cactales
Rosales
Orchidales
Iridales
Graminales
Liliales
Palmales
Arales
Alis.
Ranales
Anonales
Scrophulariales
Lamiales
Polemoniales
Gentianales
Primulales
Ericales
Ebenales
Caryophyllales
Rhoeadales
Guttiferales
Parietales
Geraniales
Malvales
Sarraceniales
Amentiferae

BOTANY 101

1. A plant breeder has been growing two different varieties of orchids. The one is a hybrid whose staminate parent was pure for red flowers and whose pistillate parent was pure for blue flowers. The other is also a hybrid but its pistillate parent was pure for red flowers and its staminate parent was pure for yellow. If the factor red is recessive, compute the different colors of flowers that the grower may expect to see in the next generation of orchids and by letters show their genetic characters.

2. a. Give evolutionary importance of:
   1. Rhodomonas.
   2. Euglena.
   3. Hydrurus.
   4. Vaucheria.
   5. Proterospongia.

   b. Define:
   1. Water bloom.
   2. Spirochaeta.
   3. Manubrium.
   4. Polyphyletic.
   5. Ascus.

3. Indicate to which great group the following plants belong, giving the technical name of the group:
   1. Sphagnum.
   2. Lepidodendron.
   3. Marsilea.
   4. Psilotum.
   5. Cladonia rangiferina.
   6. Saprolegnia.
   7. Nostoc.
   8. Spirochaeta.
   9. Plasmodiophora.
   10. Trypanosoma.

4 & 5. Place the following plants in a sequence that will show the probable evolution of the plant kingdom from most primitive to most complex. (Give pertinent character of each plant briefly.)
   1. Anthoceros
   2. Chlamydomonas
   3. Coniferales
   4. Bidens pilosa
   5. Cycadofilicales
   6. Cycas
   7. Euglena
   8. Fern
   9. Ancient Lycopodium
   10. Marchantia
   11. Mulang, Custard Apple, or Rose
   12. Pleurococcus
   13. Riccia.
   14. Silversword
   15. Tumboa

6. Indicate whether the following structures are sporophytic or gametophytic:
   1. Pseudopodium of Sphagnum.
   2. Embryo of Cycas.
   3. Diploid generation of Marsilea.
   4. Prothallus of fern.
   5. Sperm of Psilotum.
   6. Fertilized egg of Tumboa.
   7. Calyptra of Moss.
   8. Unfertilized egg of Tumboa.
   9. Endosperm of Cycas.
   10. Spore of Selaginella.

7 & 8. Explain with or without drawings the origin of pistil from megasporophyll and origin of stamen from microsporophyll of Cycas.

9 & 10. Now that the entire year's course is ended, reflect upon it and then state conscientiously what changes you would make and the reasons for making them.

PLEDGE.

MID-SEMESTER "FINAL EXAMINATION"

1. Define: Nitella, rhaphe, mannite, Robert Koch, myxamoeba, halofuge, cormophyte, nagana, sarcina, palmella-condition, bog-iron-ore, conceptacle, anaerobic, flowers-of-tan, heterocyst, fomites, Proterospongia, bacterioid, Appert, Beggiatoa, polyhedron, gonidium, hormogoniu, F_2generation, endospore, alimentary-flora. 50%

2. Draw a phylogenetic tree of the Thallophyta (excluding the Fungi) to show relationship of the different great groups, and briefly characterize each great group. 25%

3. a Give method of control for Plasmodiophora

   b Explain the gradual evolution of a multicellular plant from a unicellular one, citing examples to prove your point.

   c Why is the Red Sea red?

   d. How would you clear a reservoir of water bloom?

   e If you had a contaminated food which would spoil if heated above 80°C., how would you sterilize it? Explain principle involved. 25%

PLEDGE

FINAL EXAMINATION.

TAXONOMY.

Answer 10 of the following:

1. How many orders and families of vascular plants exist today and how many species of monocots and dicots?

25. By reduction or degeneration how would you derive the Myristicaceae from the Anonaceae?

50. Describe fully Hill's Theory on the origin of monocotyledony.

75. Define rattan.

100. How do the Berberidaceae differ from the Ranunculaceae?

125. Characterize briefly the Helobiales.

150. To what hypothetical order are the Liliales most probably related?

175. How do the Juncaceae differ from the Liliaceae and how does Juncus differ from Luzula?

200. Describe condition of ovary in Hypoxidaceae and in Agavaceae.

225. Give morphology of filiform structures found in Tacca, and give economic value of plant.

250. Give name of the only economically valuable orchid outside of floricultural values, and give names of the three orchids endemic to the Hawaiian Islands.

MID-SEMESTER "FINAL EXAMINATION"

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PLEDGE

Desk Copy 654

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.

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.

The work of this semester should give you the following:

1. A knowledge of the steps taken in the production of a new seed plant from a seed.

2. A scientific understanding of the naked eye structure of roots, stems, leaves, flowers and fruits.

3. A clear conception of the plant as a living thing with power to adjust itself to all sorts of useful conditions and to protect itself against harmful conditions.

4. An idea of what is meant by evolution from a generalized to a specialized type.

5. Something of what sex means in seed plants and the methods of insuring cross fertilization.

6. A set of technical terms through whose use you can identify plants by means of keys.

7. Some development of your powers of seeing and interpreting common things and also of getting control of your hands in delicate manipulation and drawing.

8. Possibly a set of specimens which shall keep these principles fresh in your mind (if you ever look at them again!) and may well be the foundation of a more extensive collection for which it will serve as an introductory "chapter".

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 INTER-NODES. 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.

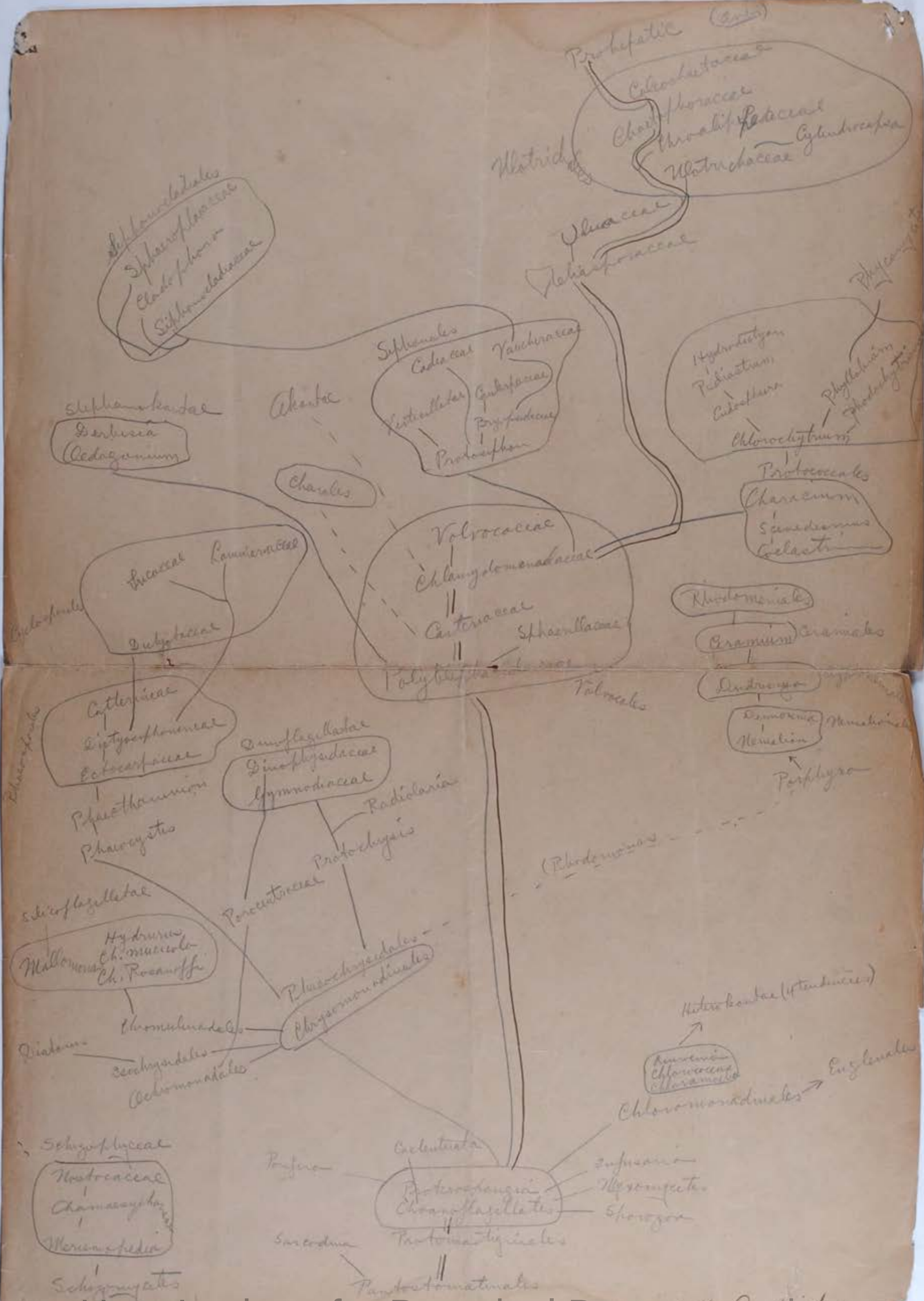
Exercise 2. The seed; its germination and evolution.

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

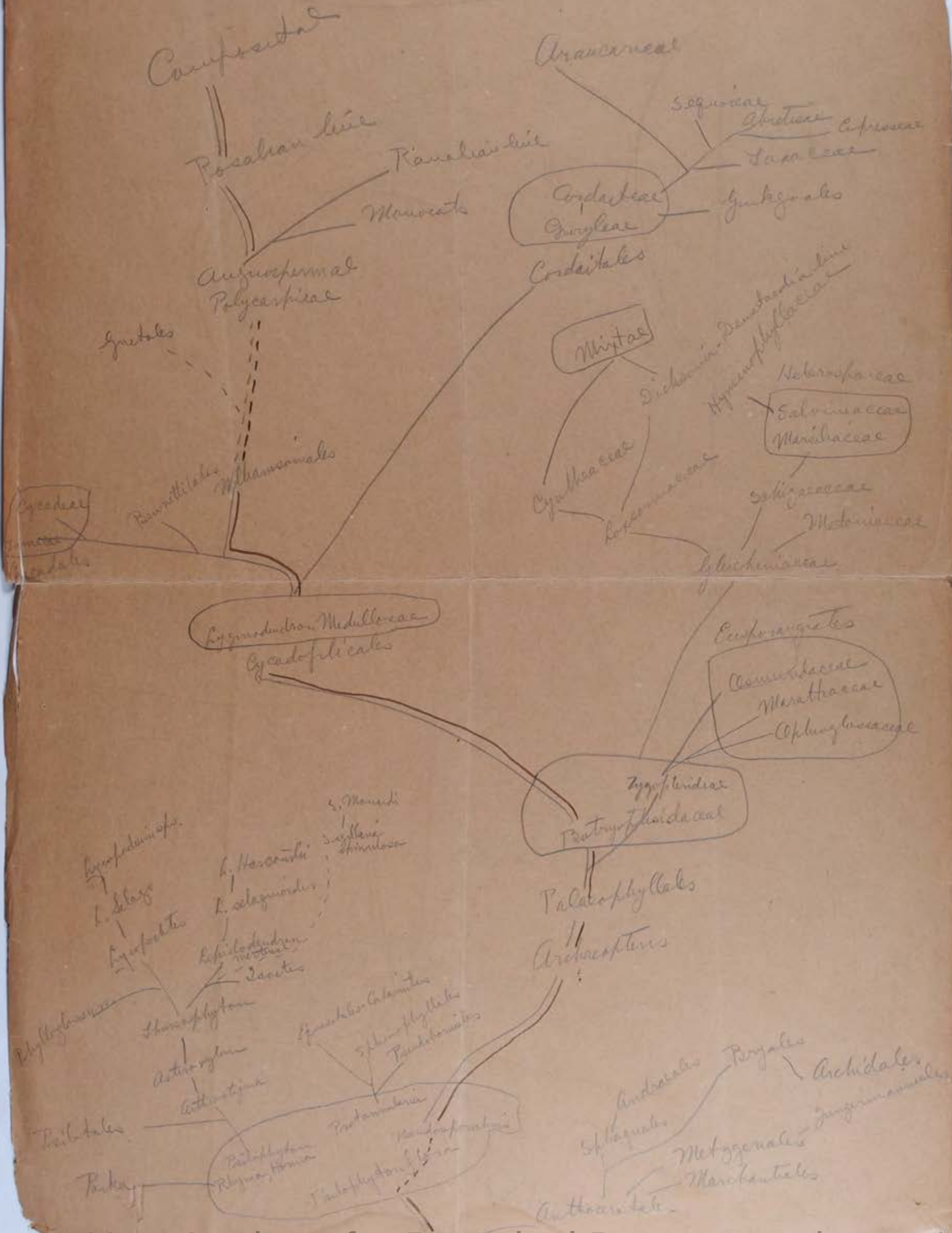
Examine the soaked seeds given you. The hard covering constitutes the TESTA. Can you imagine any possible significance in the odd ornamentation? At one end is seen a curious outgrowth, the CARUNCLE. It is not present on most seeds. More or less hidden by the caruncle is the scar left when the seed fell 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.

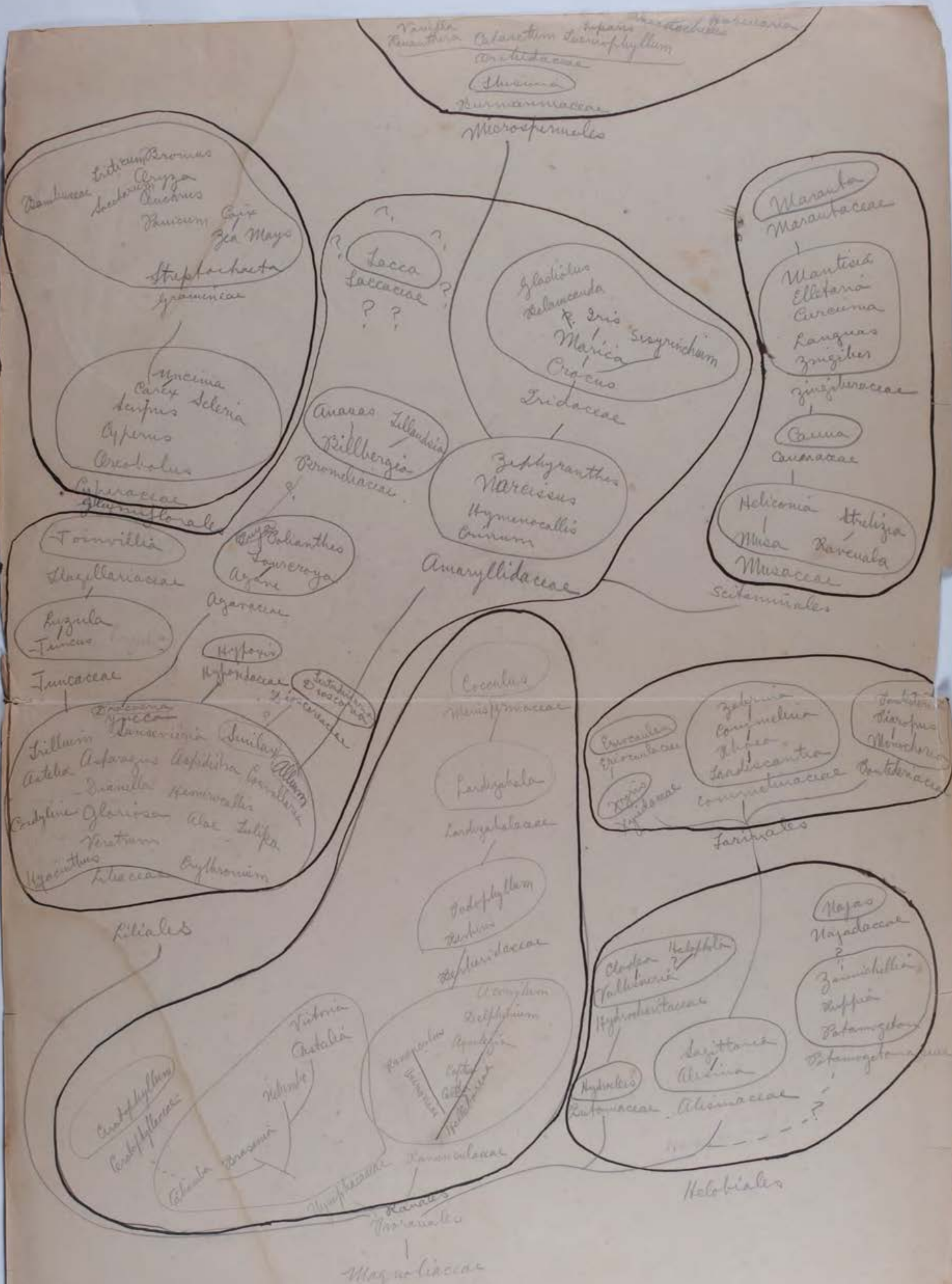
A. Draw the seed 4 cm. long to show these features. Represent markings by shading.

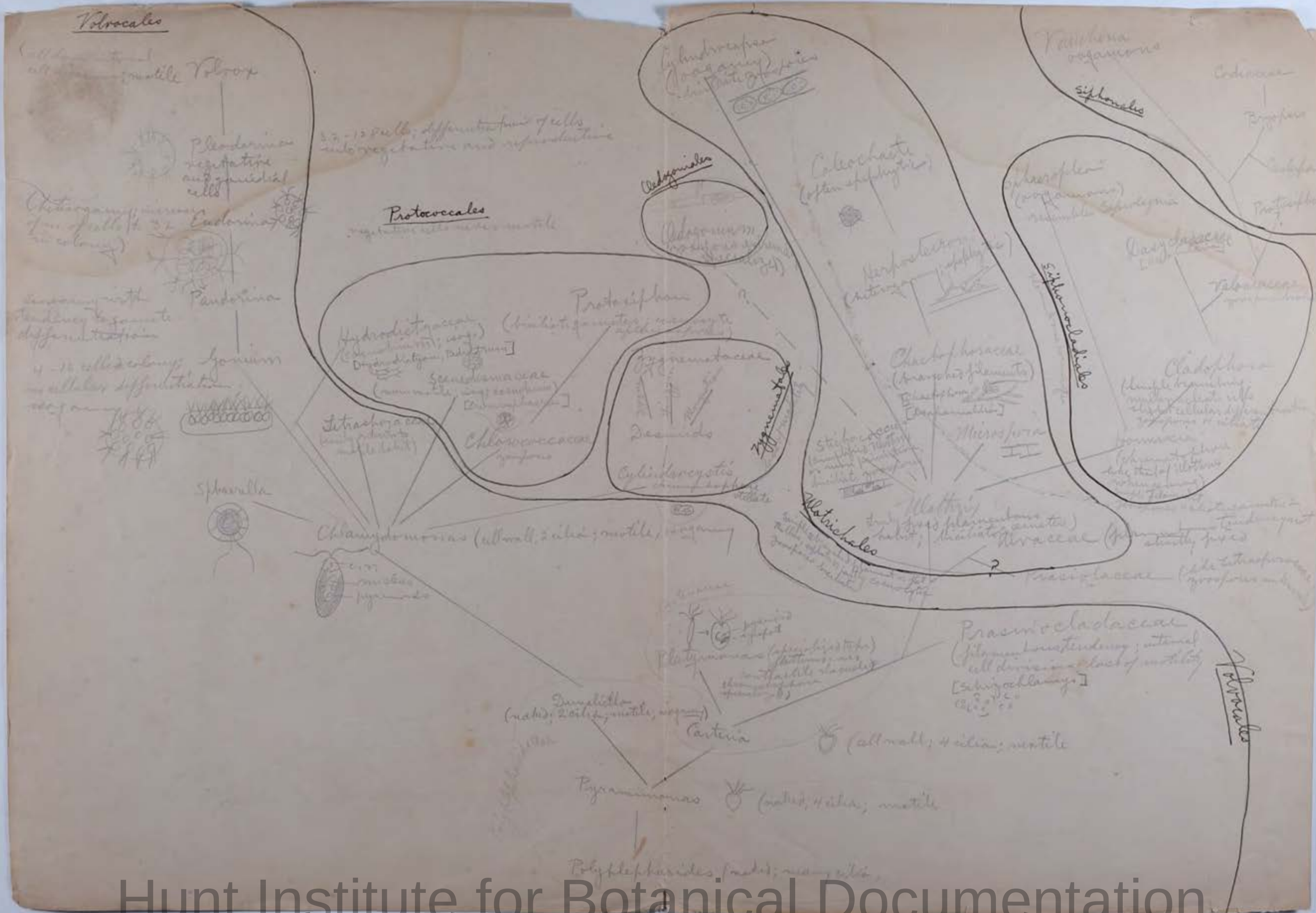
Remove the brittle testa and expose the "meat".
N. B. Do not eat these; they are poisonous.



Ulotrichaceae
Ulvaceae
Siphonales
Vaucheriaceae
Protosiphon
Charales
Hydrodictyon
Pediastrum
Chlorochytrium
Protococcales
Scenedesmus
Volvocaceae
Chlamydomonadaceae
Sphaerellaceae
Volvocales
Derbesia
Oedogonium
Fucaceae
Laminariaceae
Dictyotaceae
Ectocarpaceae
Phaeocystis
Dinoflagellatae
Gymnodiaceae
Radiolaria
Protochrysis
Rhodomonas
Silicoflagellatae
Hydrurus
Mallomonas
Chrysomonadinales
Ceramium
Nemalion
Porphyra
Heterokontae (4 tendencies)
Chloromonadinales
Euglenales
Diatoms
Schizophyceae
Nostocaceae
Merismopedia
Schizomycetes
Coelenterata
Porifera
Choanoflagellates
Sporozoa
Sarcodina
Protomastiginales
Pantostomatinales


Rosalian line
Ranalian line
Monocots
Angiospermae
Polycarpicae
Gnetales
Williamsoniales
Bennettitales
Cycadeae
Araucarieae
Sequoieae
Abietieae
Cupresseae
Taxaceae
Cordaiteae
Poroxyleae
Ginkgoales
Cordaitales
Mixtae
Hymenophyllaceae
Heterosporeae
Salviniaceae
Marsiliaceae
Cyatheaceae
Schizaeaceae
Matoniaceae
Gleicheniaceae
Lyginodendron Medulloseae
Cycadofilicales
Eusporangiates
Osmundaceae
Marattiaceae
Ophioglossaceae
Zygopterideae
Botryopteridaceae
Palaeophyllales
Archaeopteris
L. Selago
L. selaginoides
Lepidodendron
Isoetes
Equisetales-Calamites
Sphenophyllales
Pseudobornales
Protoarticulatae
Psilotales
Bryales
Archidales
Andreaeales
Sphagnales
Jungermanniales
Metzgeriales
Marchantiales
Anthocerotales


Burmanniaceae
Microspermales
Maranta
Marantaceae
Curcuma
Zingiber
Zingiberaceae
Canna
Cannaceae
Heliconia
Musa
Ravenala
Musaceae
Scitamineales
Bromus
Oryza
Avena
Panicum
Coix
Zea Mays
Gramineae
Uncinia
Carex
Scleria
Scirpus
Cyperus
Cyperaceae
Glumiflorales
Tacca
Taccaceae
Gladiolus
Iris
Marica
Sisyrinchium
Crocus
Iridaceae
Ananas
Tillandsia
Billbergia
Bromeliaceae
Zephyranthes
Narcissus
Hymenocallis
Crinum
Amaryllidaceae
Polianthes
Agave
Agavaceae
Flagellariaceae
Luzula
Juncus
Juncaceae
Hypoxis
Hypoxidaceae
Yucca
Trillium
Sansevieria
Smilax
Asparagus
Aspidistra
Allium
Convallaria
Gloriosa
Aloe
Tulipa
Veratrum
Hyacinthus
Liliaceae
Erythronium
Liliales
Cocculus
Menispermaceae
Lardizabala
Lardizabalaceae
Podophyllum
Berberidaceae
Aconitum
Delphinium
Aquilegia
Ranunculus
Ranunculaceae
Victoria
Castalia
Nelumbo
Cabomba
Brasenia
Nymphaeaceae
Ceratophyllum
Ceratophyllaceae
Ranales
Magnoliaceae
Commelina
Tradescantia
Commelinaceae
Pontederiaceae
Eriocaulaceae
Xyris
Xyridaceae
Farinales
Najas
Najadaceae
Zannichellia
Ruppia
Potamogeton
Potamogetonaceae
Elodea
Vallisneria
Hydrocharitaceae
Sagittaria
Alisma
Alismaceae
Butomaceae
Helobiales



Volvocales
Volvox
Pleodorina
Eudorina
Pandorina
Gonium
Protococcales
Protosiphon
Hydrodictyaceae
Scenedesmaceae
Tetrasporaceae
Chlorococcaceae
Sphaerella
Chlamydomonas
Oedogoniales
Oedogonium
Zygnemataceae
Desmids
Cylindrocystis
Zygnematales
Coleochaete
Chaetophoraceae
Microspora
Ulothrix
Ulotrichales
Ulvaceae
Prasiolaceae
Prasiocladaceae
Siphonales
Codiaceae
Siphonocladiales
Dasycladaceae
Cladophora
Dunaliella
Carteria
Pyramimonas
Volvocales