

COURSE CODE:	PCP 202
COURSE TITLE:	Anatomy, Taxonomy and Physiology of Agricultural Plants
NUMBER OF UNITS:	3 Units
COURSE DURATION:	3 hours per week

COURSE DETAILS:

Course Coordinator:	Dr Olalekan Sakariyawo
Email:	sakariyawoos@unaab.edu.ng
Office Location:	
Other Lecturers:	Dr. S.G. Aderibigbe, Dr. (Mrs). J.N. Odedina, Dr. I.O. Lawal, Dr. Akintokun, Dr (Mrs). P.M. Olorunmaye

COURSE CONTENT:

Classification of Agricultural plants: Division, Phyla, Class, Order, Family, Genus, Species.
Microscope and its use; plant cell structures and organelles
Development of cells and tissues; comparative anatomy of major plant organs
Enzymes
Seed germination and dormancy
Respiration and energy balance of crops
Photosynthesis, translocation and assimilate distribution in relation to yield determination
Water relations
Plant growth substances and their role in crop production

COURSE REQUIREMENTS:

Examination: 70%
Practical work: Field and laboratory 30%

READING LIST:

Pandey, S.N. and Sinha, B.K.. In: Plant physiology, 3rd ed. S.N. Pandey and B.K. Sinha (eds). Vikas Publishing House PVT ltd: New Delhi, 1995

Taiz, L. and Zeiger, E. In: Plant Physiology, 3rd ed. Lincoln Taiz and Eduardo Zeiger. (eds). Paniona Publishing Corporation: New Delhi, 2003

Buchanan, B.B. (1980). Role of light in the regulation of chloroplast enzymes. *Annual. Review of Plant Physiology*.31:341-394

Cush, J.C. (2001). Crassulacean Acid Metabolism: A plastic photosynthetic adaptation to arid environments. *Plant Physiology*. 127: 1439 – 1448

Edwards, G.E. and Walker, D. In: C3, C4:Mechanism and cellular and environmental regulation of photosynthesis. University of California Press: Berkeley, 1983

LECTURE NOTES

Classification of agricultural plants

PLANT TAXONOMY

Plant taxonomy is the science that finds, describes, classifies, identifies and names plants. It is thus one of the main branches of taxonomy. Systematics deals with the scientific study of interrelationships, taxonomy, identification, nomenclature, classification, diversity and differences between crops. Taxonomy is one aspect of systematics that is concerned with the study of principles, procedures, rules, regulations and it is the basis of classification. In taxonomic studies the group of any rank is termed as taxon.

Plant taxonomy has two aims:

- a) Identify all kinds of plants; this requires making a complete inventory of all plants. In scientific work it is essential to apply names with precision because the validity of research depends on correct identification of materials involved.
- b) To arrange the kind of plant in a scheme of classification that will show their true relationship.

To be able to achieve this, the taxonomist must utilize the methods and resources of all the major fields of botanical investigation.

- the morphologist gives him an understanding of form and structure.
- The physiologist can point out the requirements for the existence of physiological species that appear identical but differ in their requirements.
- The ecologist can furnish information about the relationship between plants and environment, about how environment may affect form and structure and how the effective action of the environment determines which plants will survive.
- The geneticist and cytologist contribute information concerning inheritance and reproduction as well as chromosome and morphology.
- Biochemistry is used effectively to solve taxonomic riddles.

The nomenclature of plants are sometimes changed. E.g. *Eupatorium odoratum* to *Chromolaena odorata*; *Voandzeia subterranean* to *Vigna subterranean*. Such changes are based on new information that will enable the taxonomist to name and classify plants according to acceptable rules of plant nomenclature.

The science of taxonomy is a synthesis of four interested fields:

- 1.) Systematic botany: includes genetics and cytology as well as other techniques applicable to the fields
- 2.) Taxonomic system: includes taxonomic concepts of plant groups, or taxa; concepts of evolutionary sequence of characteristics; classification and arrangement of taxa, description of taxa or photography.
- 3.) Nomenclature: a method of naming plants based on international rules. This permits only a single valid scientific name for each kind of plant; the discarded name is known as synonym.
- 4.) Documentation: preservation of living or fossil flora in a museum or herbarium, including type, specimen and illustration.

C.) Plant Classification: This is the process of ordering plants into groups which are arranged in hierarchy. Each group termed taxon (plural taxa) contains items or objects with close resemblance which may be natural or artificial. The first classification of plants were based on their economic uses, e.g. cereals, medicinal plants, oil yielding plants etc. or on gross structural resemblances e.g. herbs, shrubs, trees, climbers etc. Agronomic classification: Cereal or grain crops e.g. wheat, rice, maize, oat, sorghum, millet etc., Legumes for seeds (Pulses): e.g. peanut, fieldbean, fieldpea, pigeon pea, cowpea, soybean etc., Forage crops: e.g. grasses, legumes, crucifers etc. Root crops: e.g. sugarbeet, mangel, carrot, turnip, sweetpotato, cassava, yam., Fibre crops: e.g. cotton, kenaf etc. Tuber crops: e.g. potato, yam, etc. Sugar crops: e.g. sugarbeet, sugarcane etc. Vegetable crops: e.g. potato, sweetpotato, carrot, tunip etc.

An ideal system of classification should indicate the actual genetic relationship and also be within a reasonable limit of convenience for practical purpose.

PLANT CLASSIFICATION

Kingdom

Division

Class
Order
Family
Tribe
Genus- Plural: Genera
Species
Varieties, races, lines

All natural classification has a sound scientific basis while artificial classification is based on conveniences. In botany the following are hierarchical classes in descending order. The different hierarchies end with certain recommending letters thus: class-ae; order- ales; family-aceae; subfamily-eae.

From the hierarchical arrangement, there is a relationship between the groups and the division according to the differences between them. Varieties are important for agricultural purposes.

For example, yam has a specific (species) name and a generic name. The classification of of yam according to its hierarchical inter-relationship is as follow:

Species- rotundata
Genus or Generic name-Dioscorea
Tribe- Dioscoreaceae
Family- Dioscoreaceae
Order- Dioscoreales
Class- Dicotyledoneae
Division- Spermatophyta
Kindom- planta

Keys: A key provides several choices of characteristics by which one can identify a plant.

Below is the list of some plant families and their local name

FAMILY	LOCAL EXAMPLES
Agavaceae	Sisal hemp
Alliaceae	<i>Allium cepa</i> , Onion
Amaranthaceae	Amaranthus sp. Greens
Anacardiaceae	<i>Mangifera indica</i> , Mango
Araceae	Colocasia, cocoyam
Bromelaliaceae	Anana – pineapple
Caricaceae	<i>Carica papaya</i> – Pawpaw
Convolvulaceae	Sweet potato
Dioscoreaceae	yams (<i>Dioscorea</i> sp.)
Poaceae	Maize, rice
Fabaceae (Leguminosae)	Cowpea
Malvaceae	Cotton, Okra
Rubiaceae	Coffee
Rutaceae	Citrus (<i>Citrus</i> sp.)
Solanaceae	Tobacco

NOMENCLATURE

1. As the number of plants known to man increased, it became apparent that some form of generally acceptable set of principles had to be adopted in naming them to avoid confusion botanists adopted rules known as the international code of Professional.

2. Nomenclature may be defined as the system of naming plants, animals or other objects. In botanical nomenclature, the names given to plants are either Latin names or Latinized names taken from other languages.

Botanical Nomenclature: these rules deals with the use and application of scientific names.

Binomial Nomenclature:

The Binomial system of nomenclature was started by Carolous Linnaeus (1753). In this system, the plants are given 2 names. One name is given to the genus, called generic name. The other is given to

the species, the specific name. A plant therefore is underlined when printed. For example the scientific name for Yam is *Dioscorea* spp. underlined when written and *Dioscorea spp* italicized in printed form. Based on the International code, there can only be one group of plants in the genus Dioscorea. Within each genus there can only be one group of plants in the genus Dioscorea. Within each genus there can only be one valid specific epithet esculentus, but the same specific epithet way apply to plants of different genus e.g Manihot esculentus., Abelmoscus esculentus etc.

The following terminologies are generally employed in plant taxonomy.

GENERIC NAME:- This is always a noun and it is always written with a capital initial letter. It may be descriptive or the aboriginal name of plants or a name in honour of a person such as Jeffersonia sp after Thomus Jefferson or Linnea sp. For Linnaeus.

SPECIFIC NAME:- This may be any of the following;

(a) An adjective agreeing with the generic name in gender, and usually indicating a distinguishing characteristic of the species or sometimes referring to a locality where the species was first discovered e.g. *Ulmus americana*, *Pennisetum americana* etc.

(b) A noun such as it occurs when the species is named in honour of one or more persons e.g *Carex davissi* after Mr Davis, *Gilia piersonae* after Miss Pierson. Note the ending letters in the two names.

The names of taxa superior to genus, such as orders families and subdivision of such groups are also formed in accordance with generally accepted principles.

ORDER:- Is the major taxa immediately superior to the family. We form the name of the order by adding ales to the stem of an included generic name e.g Poales for Poa for the order including grasses.

FAMILY:- A family consists of a group of related genera. We form its name, except for a few that antedate the standardized system, by adding aceae to the stem of an included generic name e.g Rosaceae for Rosa etc. A few family have long been designated by nauns that predate this system e.g

Family name	Old name	New name
Grass	Gramineae	Poaceae
Mustard	Cruciferae	Brassicaceae
Pea	Leguminouseae	Fabaceae
Sunflower	Compositae	Asteraceae

SUB-FAMILY:- A major subdivision of a family and is sometimes used when the size of the family justifies it and when the included genera may be naturally so grouped. We form the name by adding oideae to the stem of an included generic name e.g Festucoideae, for Festuca and Panicoideae for panicum.

TRIBE:- Is a subdivision of a family, subordinate to the subfamily when the taxon is employed. We form the name by adding eae to the stem of an included generic name, e.g Festuceae from Festuca, for the Fescue tribe of the grass family.

AUTHORITY:- This refers to the name of the person(s) written after the scientific name or taxon. The authors name may be written out, but more commonly it is indicated by a standardized abbreviation. For example *Poa pratensis* (Kentucky blue grass) was first named and described by Linnaeus, he became the authority for that name and it is written as *Poa pratensis*, L., *Erythronium grandiflorum* Pursh.; *Lomatium montanum* C and R. When rank of a plant is changed or when a specie is transferred from one genus to another, the name of the original author is placed in parentheses and it is followed by e.g *Abelmoschus esculentus* (Moend) L., *Medicago zatira* (L) All., *Feruca foeniculacea* (Nutt.) C and R.

Summary of Taxa used in classification for *Poa pretenses*.

1. Kingdom	Plantae, plant kingdom
2. Division	Embryophyta, embryo plant
3. Subdivision	Phanaerogana – seed plants
4. Branch	Angiospermae
5. Class	Monocotyledoneae
6. Order	Poaceae - grass and sedges
7. Family	Poaceae – grass
8. Subfamily	Festucoideae

9. Tribe	Festuceae
10. Genus	Poa
11. Section	Protenses
12. Species	Poa pretenses

TYPE:- Type method is used by taxonomist to achieve stabilization of taxa from species and subdivisions.

The original plant on which the descriptive is based is deposited in a standard herbarium. When the original species is lost by accident, substitutes are provided and placed in the herbarium. The following are the terminologies for the type,

Method

HOLOTYPE: A particular specimen or element designated by the author which automatically fixes the application of this name.

LECTOTYPE: A specimen or element related by a competent worker from the original material studied by the author, to serve as substitute for the holotype if the original material gets missing.

NEOTYPE:- A specimen selected to serve as substitute for the holotype when all material on which the name was based is missing.

ISOTYPE:- A specimen, other than the holotype, which duplicates the holotypes from the same collection, with the same locality, date and number as the holotype.

PARATYPE OR CO-TYPE:- Any specimen, other than the holotype, referred to in the original publication of the taxon.

SYNTYPE:- One of two or more specimen or elements used by the author of a taxon if no holotype was designated.

TOPOTYPE:- A specimen collected at the same locality as the holotype and therefore probably representing the same population.

CLASSIFICATION OF ANGIOSPERM- Flowering plants

The angiosperms belong to the branch – angiospermae and could be divided into 2 classes:- Monocotyledoneae and Dicotyledoneae.

MONOCOTYLEDONEAE: - This class consists of many subclasses and the important ones among them are;

1 Subclass Calyciferae – The agriculturally important orders are :-

(a) Order Bromeliales:- This contains the pineapple family Bromeliaceae which is mainly epiphytic, tropical and subtropical with densely clustered linear and usually spring toothed leaves.

(b) Order Zingiberates – This contains 2 important families;

Musaceae – which is banana and plantain and ginger.

Family – Zingiberaceae.

Subclass - Corolliferae – Agriculturally important orders are;

(a) Order – Liliales which contain lily family Liliaceae which contains onion

(b) Order – Arales which contain Araceae family. Important crops from the family include coconut palm – *Cocos nucifera*, date palm – *Phoenix doctylifera*; Royal palm- *Roystonea regia*; raffia palm – *Raphia pedunculata* etc.

3 Subclass Glumiflorae

This contains grasses and grass-like plants. Important orders include.

(a) Order – Poales – Annual or perennial, mostly grasslike herbs. Two families can be distinguished in this order: Cyperaceae (sedges) and Poaceae (grasses). Members of Cyperaceae are mainly weeds. Poaceae is the most important plant family in the world and it contains all the cereal grains that serve as food for man and his animals. Table 4 shows common members of the family; Table 5 the forage crops:

Members of the Poaceae (grass family)	
Oats	<i>Avena sativa</i>
Barley-	<i>Hordeum vulgare</i>
Wheat	<i>Triticum aestivum</i>
Rice	<i>Oryza sativa</i>
Sugarcane	<i>Saccharum officinarum</i>
Sorghum	<i>Sorghum vulgare</i>
Maize	<i>Zea mays</i>
Millet	<i>Penisetum sp.</i>

Table 5

The forage crops	
<i>Andropogon sp</i>	gamba grass
<i>Panicum maximum</i>	guinea grass
<i>Digitaria sp</i>	crab grass
<i>Cynodon sp</i>	giant star grass etc

DICOTYLEDONEAE

This class contains many subclasses. Important ones among them include.

Sub-class- polypetalae – contain many orders. Such as:-

- (a) Order paparales – contain many families such as Brassicaceae which contain mostly herbs with pungent watery juice. Members of the family include – Cabbage- *Brassica oleracea*, radish- *Rapharues sativa*; turnip – *Brassica rapa*.
- (b) Order Rosales – herbs, shrubs or trees with simple or compound leaves. This is one of the largest order of flowering plant and it include families such as Rosaceae, saxifragaceae, Fabaceae etc. Fabaceae are herbs, shrubs or trees. It is usually divided into three sub families:- Mimosoideae, Ceasalpiniodeae and Iotoideae. Among the three only Iotoideae subfamily contain food crops which include; pea- *Pisium sativum*, sweet peas – *Lathyrus odoratus*, soyabeans- *Glycine sp*. It also contains important species such as clover – *Trofolium sp*, alfalfa – *Medicago sativa*.
- (c) Order geraniales: contains an important family- Rutaceae which contain aromatic trees or shrubs, important crop, include sweet orange – *Citrus sinensis*, Lemon- *Citrus limon*, grapefruit – *Citrus maxima*, citron- *Citrus medica*.
- (d) Order Malvales – contain Tiliaceae and Malvaceae families. Tiliaceae contain corchorus, a popular vegetable. Crops such as cotton – *Gossypium sp.*, okra – *Abelmoscus esculentus*, Rosette- *Hibiscus sabdarifa* etc.
- (e) Order Sapindales – contains an important family such as Anacardiaceae which contain crops such as Anacardiaceae which contain crops such as cashew- *Anacardium occidentale*, Mango – *Mangifera indica*.
- (f) Order Euphorbiales – contains only one family Euphorbiaceae which are herbs, shrubs or trees often with milk juice. Important members of the family are; Rubber – *Hevea brasiliensis*; Cassava- *Manihot sp*, Castor oil- *Ricinus communis*. The family also includes important ornamentals such as Euphorbia pulcherrima- poinsettia.

SUBCLASS – SYMPETALAE

- (a) Order Scrophulariales – contain plant of various habitat but predominantly herbaceous. Important family include solanaceae which contain plants which are chiefly herbaceous, climbing and occasionally woody. Important crops in this family include; potato - *Solanum tuberosum*, tomato – *Lycopersicon esculentum*, tobacco- *Nicotiana tubecum*, peppers – *Capsicum frutescens* etc.
- (b) Order Rubiales : Important family include Rubiaceae – mostly trees or shrubs e.g coffee- *Coffea arabica*.
- (c) Order Cucurbitales – important family is cucurbitaceae and contain such vegetable crops as pumpkin- *Cucurbita pepo*, Water melon – *Citrulus lunatus*, Cucumber – *Cucumis sativus*, calabash – *Lagenaria sp.* etc.

ENZYMOMOLOGY

Enzymes- properties, compositions, Types, Mechanisms of action.

Enzymes are protein compounds that catalyse a specific reaction. Living cells contain thousands of different enzymes that accelerates or decelerates one kind of reaction without itself being changed. In some of these reactions, small organic molecules such as; acids, sugars, nucleotides and lipids are broken down to provide energy for the cell. In other reactions, small molecules are built into complex macromolecules, such as; proteins, DNA, RNA, and polysaccharides, or used to carry signals, or to control cell movement or gene expression. Sometimes the enzyme proteins have non proteins attachment called prosthetic group when bounded by covalent bond, e.g. metals like; Cu, Mg, and Fe, and co-enzyme or co-factors when bonded by loose hydrogen bond, e.g. Vitamins. The co-enzyme and prosthetic group may become attached to several different protein forming different enzymes.

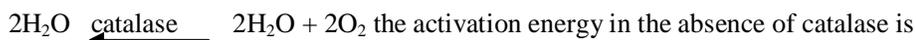
Enzymes exhibit enormous catalytic power, in some cases increasing reaction rates by a factor of over 10¹⁴ (one hundred million). Enzymes dictate the pattern of chemical changes in a cell and without them life as we know it would be impossible.

Properties characteristics of Enzymes

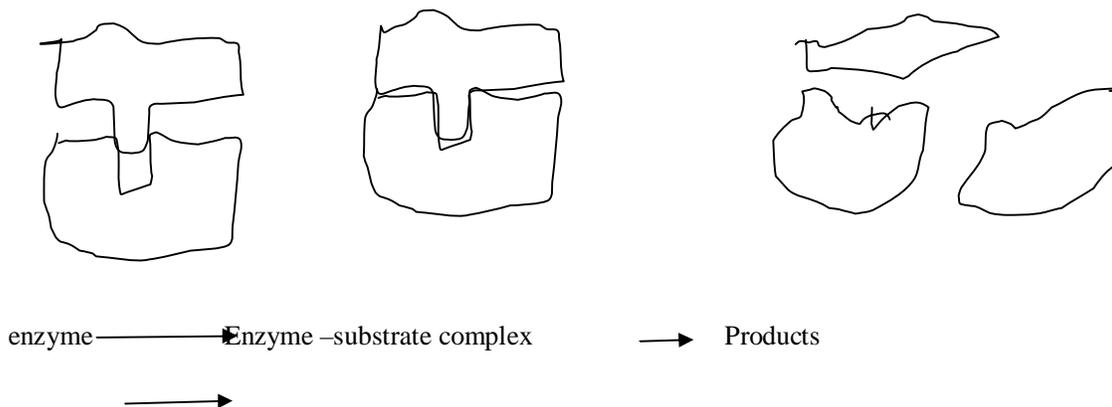
- Small amount of enzymes are needed to convert large amount of substrate into products.
- Same substrate can be utilized by several enzymes. For instance, isomers, phosphoglucumutase and glucose – 6 – phosphate dehydrogenase act on glucose to produce fructose – 6- phosphate, glucose -1- phosphate and 6- phosphoglucolactone respectively.
- Enzymes work at narrow range of temperature. Optimum temp is 40^oc and could be destroyed at 60^oc.
- They work at specific pH. Most function at around neutral pH (5-7). However, pepsin in stomach works at pH 2-3 and trypsin in duodenum works at pH 8.5.
- Catalytic actions of enzymes may be specific. Hence an enzyme which catalyse one reaction may not catalyse another. For instance, invertase works on sucrose to produce glucose while zymase act on glucose and give carbondioxide and ethanol.
- Enzymes are not destroyed by the reactions they catalysed and could be used again.
- Enzymes could be poisoned by chemical compound like; mercury, chloride, silver chloride and hydrogen cyanide. This inactivate the enzymes, for example HCN blocks the enzymes involve in respiration.

Mechanism of Action (working) of Enzymes.

This can be explained by chemical hypothesis A $\xrightarrow{\text{B}}$. Chemical energy needed could be in the form of heat (temperature) to activate passive A by bombarding A's molecules to activate it and later turned into B molecules. The energy that A molecule required to react and be converted into molecule B is the activation energy of reaction. Enzymes are believe to catalyse reaction by lowering the activation energy e.g. in



18,000cal mol. While in the presence of catalase, it is 6,400 cal mol. Lock and Key Hypotheses: the enzyme is believed to be the padlock and substrate the key.



Classification of Enzymes

Enzymes are generally of two types, they are : intracellular enzymes and extracellular enzymes. But specifically, enzymes can be classified as follows:

1 According to substrate they act upon, e.g Arginase that act on arginine, tyrosinase act on tyrosine, lipase acts on lipids while proteinase acts on protein and carbohydases and maltase on carbohydrates and maltose respectively.

2 According to the type of reaction they catalyse. For example: hydrolyses (hydrolytic enzyme), oxidases (oxidation reduction enzymes), phosphorylases (phosphate adding and deleting enzymes).

In both cases above, the suffix-ase is added to the name of the substrate or reaction type.

SPECIFIC ENZYME TYPE

- Hydrolyses (hydrolytic enzymes) they catalyse the addition of the elements of water to specific bond of substrate. $\text{RCO-OR}' + \text{HOH} \rightleftharpoons \text{RCOOH} + \text{R}'\text{OH}$
E.G, lipases, carbohydrates, proteases

- 2 oxidases, (oxidation- reduction enzymes). These catalyse the removal or addition of hydrogen, oxygen or electron from or to substrate, which is thereby oxidised or reduced in the process.

$$\text{RH} + \text{HA} \longrightarrow \text{R} + \text{AH}_2 (\text{removal of H}_2)$$

$$\text{RO} + \frac{1}{2}\text{O}_2 \longrightarrow \text{RO}_2 (\text{addition of O}_2)$$

$$\text{R}^{2+} \longrightarrow \text{R}^{3+} + \text{e} \text{ e.g. dehydrogenases and oxidases}$$
- 3 Phosphoric; these catalyse the addition or removal of elements of phosphoric acids, e.g. glucose + phosphate Hexokinase glucose – 1- phosphate
- 4 Carboxylase; these catalyse ~~the removal~~ or addition of CO₂ e.g. ribulose- 1,5 – diphosphate(5C) carboxydismutase Keto acid (6C)
- 5 Isomers: these catalyse ~~the interconversion~~ of aldose and ketose sugars e.g. Glucose – 6- phosphate Phosphoglucosomerase fructose -6- phosphate
- 6 Lyase; these carry out ~~breaking of double~~ bonds e.g. lysozyme (found in tears, nasal mucus and egg) which dissolve certain airborne cocci (bacteria) by breaking the double bond of polysaccharides in their walls.

ESTIMATION OF RATES OF ENZYME ACTIVITIES

- 1 Use of turnover numbers; this is the number of moles of substrate converted per minute by 1 mole of enzyme. Succine dihydrogenase has turnover number of 1150 while carbonic anhydrase has turnover number 360,000,000.
- 2 Manometric; gases evolve as a result of enzyme activities are measured manometrically, e.g. oxidase, carboxylase.
- 3 Spectrophotometric: uses the fact different quantities of product have different optical density at the same wavelength. The wavelength used depends on the enzyme type involved. E.g. for amylase, the wavelength is 490nm and for protease it is 700nm.
- 4 Colouration Method: works on the basis that the substrate and the product have different colour with dye. The disappearance of the colour with time is taken note of e.g. starch + iodine(blue black) Amylase maltose +iodine + E (iodine colour)
- 5 Chemical Estimation: this involve titration, chromatography and electrophoresis techniques. For instance, lipase are estimated by breaking lipids into fatty acids and glycerol using lipases and the liberated fatty acids quantities determined using titration with NaOH and Phenolphthalein as an indicator.

Enzyme Inhibitors

These are compounds that prevent, limit, or stop enzyme activities; they are divided into competitive inhibitors and non competitive inhibitors.

1. Competitive Inhibitors: have similar shape to the substrate and can fit into the active centre of enzymes. They lower enzyme activities e.g. the inhibition by malonic acid of the enzyme succinic dehydrogenase that catalyse the conversion of succinic acid to fumaric acid. Competitive inhibition can be overcome by increasing the concentration of the substrate.
2. Non Competitive Inhibitor: either undergoes chemical reaction with the enzymes and thereby alter the configuration of the enzymes or form bond with enzymes substrate complex to form inactive compound. They normally stop the working of enzymes and effect cannot be overcome by increasing the concentration of the substrate. Examples are effects of poison, heavy metals (Hg, Au, Ag). Cyanide, and carbon.

COMMERCIAL USES OF ENZYME

- A papain obtained from plants like pawpaw leaves- protease is sold as meat tenderizer (Aldof). It breakdown protein into peptones and make the meat soft.
- B Protein digesting subtilisin(from Bacillus Subtilis) is incorporated into pre-soak laundry agent and detergent for cleaning purposes. It is effective in removing protein- containing stains (chocolate or coffee) from clothes etc.
- C Synthetic amylase is used in beer laundry to break down starch substances into maltose.
- D synthetic cellulase is used in the textile industry to breakdown clothes into pieces of yarns.

Plant-water relations

Water is the most abundant constituent of all physiologically active plant cells. Leaves, for example, have water contents which lie mostly within a range of 55–85% of their fresh weight. Other relatively [succulent](#) parts of plants contain approximately the same proportion of water, and even such largely nonliving tissues as wood may be 30–60% water on a fresh-weight basis. The smallest water contents

in living parts of plants occur mostly in [dormant](#) structures, such as mature seeds and spores. The great bulk of the water in any plant constitutes a unit system. This water is not in a static condition. Rather it is part of a hydrodynamic system, which in terrestrial plants involves absorption of water from the soil, its [translocation](#) throughout the plant, and its loss to the environment, principally in the process known as [transpiration](#).

Cellular water relations

The typical mature, [vacuolate](#) plant cell constitutes a tiny [osmotic](#) system, and this idea is central to any concept of cellular water dynamics. Although the cell walls of most living plant cells are quite freely [permeable](#) to water and solutes, the [cytoplasmic](#) layer that lines the cell wall is more permeable to some substances than to others.

If a plant cell in a [flaccid](#) condition—one in which the [cell sap](#) exerts no pressure against the encompassing cytoplasm and cell wall—is [immersed](#) in pure water, [inward](#) osmosis of water into the cell [sap](#) ensues. This gain of water results in the [exertion](#) of a [turgor pressure](#) against the [protoplasm](#), which in turn is transmitted to the cell wall. This pressure also prevails throughout the mass of solution within the cell. If the cell wall is [elastic](#), some expansion in the volume of the cell occurs as a result of this pressure, although in many kinds of cells this is relatively small.

If a [turgid](#) or partially turgid plant cell is immersed in a solution with a greater [osmotic pressure](#) than the cell sap, a gradual shrinkage in the volume of the cell ensues; the amount of shrinkage depends upon the kind of cell and its initial degree of turgidity. When the lower limit of cell wall [elasticity](#) is reached and there is continued loss of water from the cell sap, the protoplasmic layer begins to recede from the inner surface of the cell wall. Retreat of the protoplasm from the cell wall often continues until it has shrunk toward the center of the cell, the space between the protoplasm and the cell wall becoming occupied by the bathing solution. This phenomenon is called plasmolysis.

In some kinds of plant cells movement of water occurs principally by the process of [imbibition](#) rather than osmosis. The swelling of dry seeds when immersed in water is a familiar example of this process.

Stomatal mechanism

Various gases [diffuse](#) into and out of physiologically active plants. Those gases of greatest physiological significance are [carbon dioxide](#), oxygen, and water vapor. The great bulk of the [gaseous](#) exchanges between a plant and its environment occurs through tiny pores in the [epidermis](#) that are called stomates. Although stomates occur on many aerial parts of plants, they are most characteristic of, and occur in greatest abundance in, leaves.

Transpiration process

The term transpiration is used to designate the process whereby water vapor is lost from plants. Although basically an [evaporation](#) process, transpiration is complicated by other physical and physiological conditions [prevailing](#) in the plant. Whereas loss of water vapor can occur from any part of the plant which is exposed to the atmosphere, the great bulk of all transpiration occurs from the leaves. There are two kinds of [foliar](#) transpiration: (1) stomatal transpiration, in which water vapor loss occurs through the stomates, and (2) cuticular transpiration, which occurs directly from the outside surface of epidermal walls through the [cuticle](#). In most species 90% or more of all foliar transpiration is of the stomatal type.

Transpiration is a necessary consequence of the relation of water to the anatomy of the plant, and especially to the anatomy of the leaves. Terrestrial green plants are dependent upon atmospheric carbon [dioxide](#) for their survival. In terrestrial vascular plants the principal carbon dioxide-absorbing surfaces are the [moist](#) mesophyll cells walls which bound the intercellular spaces in leaves. Ingress of carbon dioxide into these spaces occurs mostly by [diffusion](#) through open stomates. When the stomates are open, outward diffusion of water vapor unavoidably occurs, and such stomatal transpiration accounts for most of the water vapor loss from plants. Although transpiration is thus, in effect, an [incidental](#) phenomenon, it frequently has marked indirect effects on other physiological processes which occur in the plant because of its effects on the internal water relations of the plant.

Water translocation

In terrestrial rooted plants practically all of the water which enters a plant is absorbed from the soil by the roots. The water thus absorbed is [translocated](#) to all parts of the plant. The upward movement of water in plants occurs in the [xylem](#), which, in the larger roots, trunks, and branches of trees and shrubs, is identical with the wood. In the trunks or larger branches of most kinds of trees, however, sap movement is restricted to a few of the [outermost](#) annual layers of wood..

Root pressure is generally considered to be one of the mechanisms of upward transport of water in plants. While it is undoubtedly true that root pressure does account for some upward movement of water in certain species of plants at some seasons, various considerations indicate that it can be only a secondary mechanism of water transport.

Upward translocation of water (actually a very [dilute](#) sap) is engendered by an increase in the negativity of water potential in the cells of [apical](#) organs of plants. Such increases in the negativity of water potentials occur most commonly in the [mesophyll](#) cells of leaves as a result of transpiration.

Water absorption

The successively smaller branches of the root system of any plant terminate ultimately in the root tips, of which there may be thousands and often millions on a single plant. Most absorption of water occurs in the root tip regions, and especially in the root hair zone. Older portions of most roots become covered with cutinized or suberized layers through which only very limited quantities of water can pass.

Whenever the water potential in the peripheral root cells is less than that of the soil water, movement of water from the soil into the root cells occurs. There is some evidence that, under conditions of marked internal water stress, the tension generated in the xylem ducts will be propagated across the root to the peripheral cells. If this occurs, water potentials of greater negativity could develop in peripheral root cells than would otherwise be possible. The absorption mechanism would operate in fundamentally the same way whether or not the water in the root cells passed into a state of tension. The process just described, often called passive absorption, accounts for most of the absorption of water by terrestrial plants.

The phenomenon of root pressure represents another mechanism of the absorption of water. This mechanism is localized in the roots and is often called active absorption. Water absorption of this type only occurs when the rate of transpiration is low and the soil is relatively moist. Although the xylem sap is a relatively dilute solution, its osmotic pressure is usually great enough to [engender](#) a more negative water potential than usually exists in the soil water when the soil is relatively moist. A gradient of water potentials can thus be established, increasing in negativity across the epidermis, cortex, and other root tissues, along which the water can move laterally from the soil to the xylem.

COMPARATIVE ANATOMY OF MAJOR PLANT ORGANS

THE ROOT

The primary functions of the root system are :the attachment of the plant to the soil, the absorption of water and mineral ions from the soil and the transport of materials to and from the shoot system. A secondary, though very common function is storage.

ROOT ANATOMY

The root apex (external features)

The tip of a growing root is always protected by a root cap. This is a conical cap of tissue which protects the apical meristem which lies within. It is easiest to see on aerial roots (e.g. Red Mangroves, epiphytes) and roots of seedlings grown on moist filter paper (e.g. cabbage, cauliflower etc.). The apical meristem lies within the root cap and cannot be seen in the intact root. The bare part of the root is the region of elongation in which cells derived from the apical meristem are increasing in length by vacuolation. Above this region the root is usually covered with root hairs for a short distance. Root hairs usually have a short life and wither away on the older parts of the roots. Above the region of root hairs, lateral roots emerge from within the tissues.

The apical meristem

Within the root cap are the small, thin walled and densely packed cells of promeristem which are actively dividing. The most actively dividing cells are grouped around a quiescent centre in which few cell divisions occur. Cells derived from the promeristem form derived meristems which, together with the promeristem, make up the apical meristem of the root. The outermost layer forms the protoderm, which is one cell thick. Within the protoderm is the ground meristem which is several cells thick. Provascular meristem (procambium) forms the central core. Cells in the three layers differ from each other in shape and in the direction in which they divide. The cells which finally differentiate from them are determined by their planes of division and subsequent vacuolation.

Differentiation of primary tissues

Vacuolation of cells begins before cell division has ceased but is most active after divisions have ceased. This is when the greatest elongation of tissues takes place. Cells from the protoderm form the epidermis (piliferous layer) of the root. Differentiations of epidermal cells involve only elongation and the formation of root hairs from some of them. The ground meristem produces only the parenchyma of the cortex of the root. During the maturation of most of the cortical parenchyma cells, some of the intercellular material softens so that they become rounded and intercellular spaces appear. The layer of cells closest to the epidermis (hypodermis) usually remains more compact and also does the innermost layer of the cortex (endodermis). The endodermis is of special significance in roots. Its cells develop a distinctive thickening of the radial and transverse walls, the casparian strip or band. This thickening involves the impregnation of the middle lamella and primary walls with suberin (a deposit- thin varnishlike layer which helps to seal moisture inside tissue) and sometimes becomes overlaid with cellulose which becomes lignified. The strip is also closely associated with the protoplast of each cell. In some plants (e.g. epiphytic orchids) the cells of the hypodermis also develop casparian strips, after which they are known as the exodermis.

It is in the stele, derived from the procambium that the greatest variety of differentiation occurs. The layer immediately inside the endodermis remains more or less unchanged except for lengthening of the cells during vacuolation. This is the pericycle. The pericycle is usually formed from a single layer of closely packed parenchyma cells but it may be more than one cell thick. The first cells of the vascular system to differentiate are patches of protophloem. Protophloem cells are difficult to recognize with certainty because they are simply narrow, elongated cells without clearly distinguishable features. Sieve tube elements and companion cells (small, slender, living cells) appear only later. The first cells to become lignified are the vessel elements of the protoxylem, formed in groups alternating with the patches of protophloem, immediately inside the pericycle.

Differentiation of both xylem and phloem proceeds towards the centre of the root. The last vessel elements to become lignified after that part of the root has stopped elongating are the largest vessel elements of the metaxylem. There is always a layer of parenchyma left between adjacent groups of primary xylem and primary phloem. There is no cambium at this stage, even in dicots. Dicots usually

have the vascular tissues gathered closely at the centre of the root with the xylem either united by a central mass of metaxylem, or with a small medulla. Monocots usually have thicker roots with more protoxylem groups and larger medulla or pith at the centre. It is in small dicot roots that differentiation of metaxylem extends to the centre of the root, so that the xylem is star-shaped when seen in Transverse Section(TS). Thicken dicot roots and all monocot roots have a central medulla and alternating, but unconnected groups of primary xylem and phloem.

Older roots

Monocots

In monocots, no cambium is formed and the primary structure remains more or less unchanged throughout the life of the root. Changes are restricted to the outer layers of the cortex and the endodermis. Root hairs disintegrate after they have ceased to carry out their absorbing function. The endodermal cells opposite the absorbing the protophloem become covered with a secondary lamella of suberin. These changes in the endodermis are characteristics of monocot roots but also found in dicot roots. Monocot roots do not branch much. The needs of the growing plant are met by the addition of more adventitious roots to the fibrous root system.

Dicots

A dicot root with primary structure has no cambium but a cambium usually forms at an early stage from the parenchyma cells which lie between xylem and phloem and in the pericycle outside the protoxylem.

THE STEM

The primary functions of the stem are to support the leaves in the best position for photosynthesis and to transport materials to and from the leaves.

THE STEM ANATOMY

The primary structure of the stem develops from cells derived from the apical meristem. The apical meristem consists of a promeristem, from which all other cells are derived and three derived meristems (protoderm, ground meristem and provascular strands (procambial strands). The protoderm gives rise to the epidermis of the stem, the ground meristem gives rise to the ground tissues (medullar or pith, cortex) and provascular (procambial) strands gives rise to the vascular bundles.

In dicots, vascular bundles are usually arranged to form a cylinder, with cortex outside, medulla inside and medullary rays between adjacent bundles. In monocots, vascular bundles are usually scattered throughout the ground tissue.

In dicots, a layer of meristematic tissue, the fascicular cambium remains between xylem and phloem and soon divides to give rise to secondary xylem and phloem. There is no cambium in monocots. They can only undergo primary growth - growth in length of shoots (and roots).

THE LEAF

The primary function of the leaf is to carry on photosynthesis which occurs in the mesophyll layer. The other functions includes:

1. it is the main organ for getting rid of excess moisture (i.e. transpiration)
2. it is the main organ for respiration.

LEAF ANATOMY

Parts of the leaf

The leaf base is often slightly swollen. If it is very swollen, it is called pulvinus. A pulvinus is capable of growth movements which turn the leaf so that it is held at right angles to incident light.

The petiole is essentially stem-like in structure. Some petioles are radially symmetrical like a stem. Most are dorsiventral in structure.

The leaf blade consists of midrib which is dorsiventral in structure.

The basic structure of the lamina of the leaf is very constant. There is always an upper (adaxial) and lower (abaxial) epidermis, one or both of which contain stomata. Chlorenchyma forms mesophyll between the adaxial and abaxial epidermis. Vascular bundles, each enclosed in a parenchymateous bundle sheath, lie at about the centre of the mesophyll.

Leaves which are held in a horizontal position have dorsiventral symmetry. Leaves which stand upright, or hang downwards, have isobilateral symmetry. A leaf with isobilateral symmetry has a 'upper' and 'lower' sides and has similar internal structure next to each epidermis. Dorsiventral leaf structure is typical of dicots but is found also in some monocots (e.g. yam). In such leaves, the adaxial epidermis has thicker cuticle and few stomata than the abaxial epidermis. There may be no stomata in the adaxial epidermis. The stomata is formed by the partial separation of two adjoining specialized epidermal cells. Immediately beneath the adaxial epidermis, are one or several layers of palisade mesophyll. The cells of palisade mesophyll are elongated at right angles to the epidermis. Although, these cells appear closely packed, they show abundant air spaces between the cells and contain chloroplasts. Beneath this, is a loose spongy mesophyll composed of chloroplast. The cells are rounded or irregularly shaped and air spaces are very conspicuous. The largest air spaces exist next to where there are stomata in the abaxial epidermis. These are substomatal chambers. The vascular bundles of small veins are located at the junction of palisade and spongy mesophyll. Each vein contains xylem and phloem, surrounded by a layer of parenchyma cells which form a bundle sheath.

Isobilateral leaves are typical of monocots but occur in some dicots (*Eucalyptus* spp). There is no difference in cuticle thickness or stomatal distribution between the adaxial and abaxial epidermis. There is usually little differentiation of the mesophyll in the palisade and spongy layers. In some leaves (e.g. maize), the mesophyll is all more or less of the spongy type. In others (e.g. *Eucalyptus* spp), it is all palisade mesophyll.

DIFFERENCES BETWEEN MONOCOTS AND DICOTS

	Monocots	Dicots
1.	Have one cotyledon	Two cotyledons
2.	Floral parts are in three or multiples of threes	Floral parts are in fours or fives or multiples of fours or fives
3.	Layers (except in yam) are parallel-veined	These are net veined
4.	Have fibrous root system	Typically develop a tap-root system
5.	In monocots e.g. maize, the root usually has a wide, well defined pith area surrounded by a band of conducting tissue containing alternating bundles of xylem and phloem cells	In the root of dicots, there is no pith, xylem and phloem are separated by parenchymateous tissue i.e. center section filled with xylem while phloem occurs outside
6.	Vascular bundles in stems of monocots are scattered through the stem so that there is no pith or very little cortex	Vascular bundles in stems of dicots are well arranged with an extensive pith and a wide cortex
7.	In stems of monocots, there is the absence of cambium between xylem and phloem	Presence of cambium between xylem and phloem

Crop Physiology

Living organisms are built up of molecules and while alive, they are centres of intense and complex chemical activity. Their growth, development, movements and reproductive activities are the outcome of these highly complex and chemical changes. The study of the functioning of living organisms is usually referred to as their physiology and hence the study of the functioning of crop is known as crop physiology.

A TYPICAL PLANT CELL

The early microscopists recognised that living material was built up from, or divided into minute compartment or cells. The cell is the basic unit of living matter. Typical vascular plants consists of hundreds of billions of cells. An average apple leaf is made up of approximately 50 million cells. Many different kinds of cells make up the body of plants. All the various specialized cells, are however, derived from cell division and subsequent enlargement and differentiation from groups of meristematic cells situated at the apices of roots, leaf and stems. Such cells have thin cell walls rich in hemicelluloses and pectin. Within the cell wall, the living material (protoplast) consists of cytoplasm and a large nucleus, the latter occupying two-third to three-quarter of the protoplast volume.

Minute vacuoles (rich in fatty and protein material) are enclosed by a membrane (the tonoplast) which has semi-permeable properties, elasticity and an essential content of lipids.

The lining layer of cytoplasm has a granular appearance due to presence of various inclusions or cellular particles. Some of these: the mitochondria, are spherical or cylindrical bodies, the other is the proplastids. These are the bodies from which develop, during differentiation, the various forms of plastids, most important are the chloroplasts (in photosynthetic parenchyma) and starch-forming amyloplasts (of storage parenchyma). Mitochondria and plastids are centres for metabolic activity and can increase by division and are constant features of the cytoplasmic complex. Cells in tissues are firmly cemented together by the middle lamella. Each protoplast is separated from its neighbouring protoplasts by the two intervening cell walls and the middle lamella between them.

A Plant Cell

STRUCTURE AND FUNCTION OF CELLS

Plant cells are bounded by a membrane. They are also surrounded by a more or less rigid wall. The cell is made up of the cell wall and the protoplast, the living portion of the cell. The protoplast is composed of cytoplasm and minute subcellular bodies, called organelles, that carry on specific functions. Each type of cell and each component have a special structure, chemical composition and function.

CELL WALL: Give protection, support and shape to each cell and form the structural framework of the plant as a whole. The cell wall is non living. Thickness and other physical properties of cell walls vary greatly with age, type and function of the cell. It is composed of three distinct layers: the primary cell wall which is formed during early stages of growth is composed of layers of cellulose, hemicellulose and pectin. This layer is thin and water-permeable and elastic. The secondary cell wall, usually present in mature cells, is laid against the inner surface of the primary cell wall after the cell has achieved its maximum expansion. Lignification occurs in this region and the process makes the cell wall rigid and unstretchable. They provide mechanical support for the plant. The middle lamella, the outermost layer of a mature cell wall, consists of pectin and cements together primary cell walls of adjacent cells.

PROTOPLAST: Is the living portion of a cell inside the cell wall. It is surrounded by the plasma membrane or plasmalemma, a selectively permeable, flexible membrane composed of lipids and

proteins. These membranes regulate the movement of water as well as organic and inorganic materials into and out of the protoplast.

CYTOPLASM: Is a viscous matrix enclosed by the plasma membrane. It contains water, proteins, carbohydrates, lipids and inorganic salts. Suspended in it are the organelles, which carry on all functions necessary to sustain life.

ENDOPLASMIC RECTICULUM: Is a long, membrane network which extends throughout large portions of the cytoplasm. Its function is inter and intracellular transport of cellular products, as a surface for protein synthesis, in separating enzymes and enzyme reactants, in moving cell components during cell division, and in physical support. It often appears to be connected to the nuclear membrane and the plasma membrane in meristematic cell. In differentiated cells, the ER may be less prominent and may be represented only by discontinuous vesicles.

RIBOSOMES: In the cytoplasm and often associated with the endoplasmic reticulum are extremely small dense globular particles called ribosomes. They contain ribonucleic acid (RNA) and proteins and are involved in the synthesis of proteins, including enzymes. Polyribosomes are aggregations of many ribosomes, either on the endoplasmic reticulum or floating free in the cytoplasm, where they also function in protein synthesis.

PLASTIDS: Their function range from photosynthesis to the storage of starches and fats. They are classified by colour. Chloroplasts (green) chromoplast (yellow, red or orange) and leucoplast (colourless). The chloroplast are the dominant plastic in the leaves and other green parts of a plant. In a typical green cell of a leaf, there are 20 to 100 chloroplasts. Chloroplast contain chlorophyll and carotenoid pigments but the yellow and orange carotenoids are masked by chlorophyll and do not become evident until the chlorophyll deteriorates. Chloroplasts also contain the enzyme and intermediate substances required for conversion of radiant energy into chemical energy by photosynthesis. Each chloroplast may have a large number of disk-shaped grana lamellae, highly folded or convoluted layers of the inner membrane of the chloroplast. The grana membranes contain chlorophyll molecules which capture high energy from the sun. Yellow and orange flowers, fruits and seeds lack chlorophyll when mature, owing their colour instead to chromoplasts. These variously shaped plastids synthesize and retain yellow (carotene), red (xanthophylls) and orange (carotenoid) pigments rather than chlorophyll. Leucoplasts are nonpigmented organelles of different shapes which are usually elastic and serve in the synthesis and storage of starch, oils and proteins from smaller molecules. They are located in the colourless leaf cells of variegated leaves, stems, roots and other storage organs, as well as underlying tissues of the plant not exposed to light.

MITOCHONDRIA: Are smaller than most plastids, are pickle shaped. Each mitochondrion contains a semigel stroma of proteins (enzymes) within a two-layered membrane. The mitochondria serve as the cell's power-house and are the major sites for respiration. They are distributed in the matrix of the cytoplasm and are often in contact with the ER or nuclear envelope. The number of mitochondria in a cell is variable but living plant tissues contain 500-800/cell. They contain DNA (deoxyribonucleic acid) and ribosomes and can effect protein synthesis.

DICTYOSOMES: The dictyosomes or golgi bodies, serve as collection centres for complex carbohydrates, they are believed to be involved in cell-wall synthesis and the packaging of cellular products for excretion from the cell. They are characteristics of meristematic cells, and appear to increase in number during cell differentiation. They develop numerous vesicles thought to serve as a source of plasma membrane components. The vesicles may be involved in the transport of polysaccharide material to developing cell walls.

MICROTUBULES: Are proteinaceous structures located in the cytoplasmic matrix of non dividing cells and in the spindle fibers of cells undergoing cell division. They are involved in the growth of cellulose fibers in the cell wall. During cell division, microtubules attach to the chromosomes and appear to draw them to the opposite poles.

LYSOSOMES: These organelles are bounded by a single membrane and contain enzymes capable of digesting various cellular components such as proteins and lipids. Their exact functions are unclear,

but they are believed to be important in the development of those cells which are hollow at maturity. They may also be a defensive mechanism against invasion by pathogens.

VACUOLES: Young meristematic cells have many minute vacuoles within the cytoplasm. As cells grow and mature, these vacuoles fuse into a large central vacuole, which increases in size until it may occupy 80 or 90% of the intracellular volume. The vacuole is filled with cell sap, an aqueous solution of inorganic salts and organic solutes. It is the storage compartment for materials which are no longer needed and may be detrimental to metabolic processes in the cytoplasm. These materials are stored as insoluble crystals in the cell sap. The vacuole is surrounded by a semi permeable membrane known as the tonoplast which regulates the pH of the cytoplasm and controls chemical composition. The vacuole may contain pigments such as the anthocyanins, which are responsible for some colours of flowers, fruits and autumn leaves.

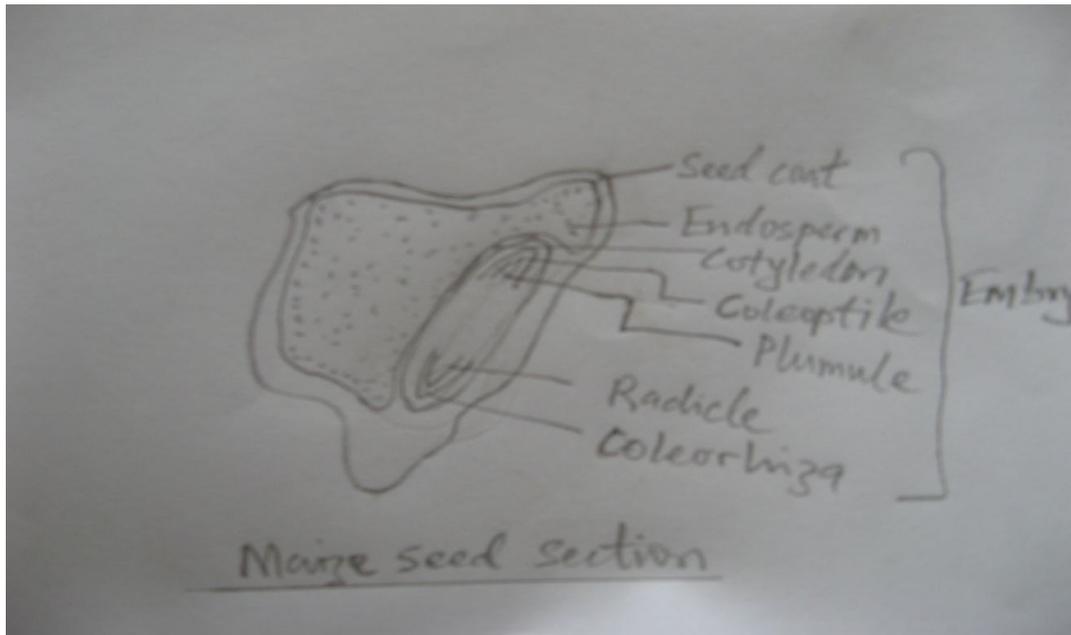
NUCLEUS: The nucleus of mature plant cell is the largest organelle in the cell except for the vacuole. It is usually spherical or disk-shaped, 10 to 20 micrometer (μm) in diameter and surrounded by a double membrane called the nuclear envelope. In young cells, the nucleus is centrally located, but as the vacuole expands to fill most of the cell, the nucleus is pushed into a corner. The nucleus contains a gel-like nucleoplasm, comparable to the cytoplasm of a cell. It contains one or more spherical bodies called nucleoli and is composed of DNA, RNA and proteins, collectively referred to as chromatin. When cell division begins, the chromatin condenses to form microscopically visible bodies called chromosomes. The DNA of the chromosomes contains genetic information and controls the synthesis of specific enzymes on the ribosomes. These enzymes control the metabolic activities of the cell and determine the overall characteristic of the organism. The maintenance of active metabolism in the cytoplasm is dependent upon the presence of the nucleus.

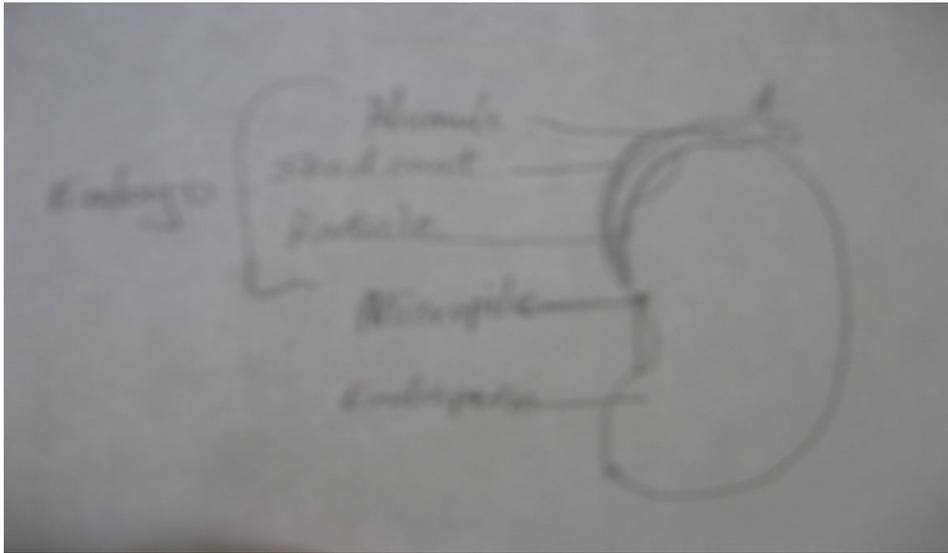
Cells and Tissue

Not only in the cell the basic unit of life, it is also the fundamental morphological unit of the plant body. Cells are in turn organized into groups, whose structure or function, or both are distinct from others. These groups of cells are called tissues.

A plant begins as a fertilized egg or zygote, in the ovary of a flower. The zygote undergoes cell division, and differentiation. The process of growth and morpho-physiological specialization of cells produced by the meristems - giving rise to an embryo

A monocot seed section diagram





A DICOT SEED SECTION DIAGRAM

As the embryo develops into a young seedling and then an adult plant, the embryonic character persists in regions of continued cell division called **meristems** continue to contribute new cells to the plant body as older cells begin to differentiate and mature. Unlike animals where the size and form of the adult is determined in the early stages of embryo formation, meristems give plants their unique character of indeterminate or continuous growth.

The two principal meristems are the “apical meristems located at the apex of the shoot and root. The apical meristems are responsible for adding to the length of the shoot and root axis, called primary growth and the cells and tissues derived from these meristems form the primary plant body. Many plants undergo an increase in girth or thickening of the stems and roots by adding new vascular tissues to the primary body. This lateral growth is called secondary growth and is produced by a lateral meristem called the vascular cambium.

Simple tissue are made up of (one type of cells) Parenchyma, Collenchyma and Sclerenchyma while complex tissues are made up of (several different types cells) xylem, phloem and epidermis.

Parenchyma

Parenchyma cells are found throughout the plant body in the cortical regions of stems and roots and in the mesophyll of leaves and are scattered throughout the vascular tissues. Parenchyma cells serve primarily in photosynthesis (in which case they may be called chlorenchyma), storage and wound healing.

Collenchyma and Sclerenchyma (Supporting tissues)

Collenchyma cells may be considered parenchyma cells that are specialized for support – young tissues. They are commonly found in the cortex of stems and petioles or along the veins in

leaves and are characterized by thickened primary walls. Sclerenchyma cells on the other hand, are scattered throughout the plant in both primary and secondary tissues. There are two types of Sclerenchymas sclerids and fibers are generally very long and slender. Both sclerids and fibers have thick secondary walls that are heavily lignified. For instance, linen thread consists primarily of sclerenchyma fibers from stems of flax plant (*Linum spp*).

Complex tissues

Epidermis: The epidermis is a superficial tissue that forms a continuous layer over the surface of the primary plant body. Cells of the epidermis are usually regular in shape, they are appressed very tightly together and their outer walls are covered with a waxy cuticle. In leaves the integrity of the epidermis is interrupted with pores, which allow for exchange of carbon-dioxide, water and oxygen between the leaf and the ambient air. The pores are surrounded by specialized epidermal cells called. The principal function of the epidermis is to provide mechanical protection and to restrict water loss.

Vascular tissue

The vascular tissues are concerned primarily with the distribution of nutrient, water and products of photosynthesis. There are two types of vascular tissues: Xylem and Phloem.

Xylem is a structurally and functionally complex tissue concerned primarily with water conduction, storage and support. The cells most characteristic of xylem are the principal water conducting elements; tracheids and vessel elements. Xylem tissues also contain parenchyma cells, which function primarily as storage, and mechanical cells (sclerids and fibers) which provide support.

Phloem: This tissue also is both structurally and functionally complex. Phloem is concerned primarily with the distribution of organic molecules between “source” that is photosynthetic or storage tissues, and “sinks” or regions of active growth and metabolism.

The principal conducting elements are sieve cells and sieve tubes phloem also contain parenchyma cells. Some of which are specialized companion cells or transfer cells as well as sclerids and fibers. Vascular tissues are of two origin: primary (Apical meristem) and secondary (Vascular cambium).

Plant Organs

Just as cells are grouped together to form tissues with distinct structures and functions, tissues are also grouped together to form Organs. The following are known as plant organs: Roots, stems, leaves, flowers and fruits. The first 3 organs (roots stems and leaves) are known as the 3 principal vegetative organs.

Topic: Photosynthesis

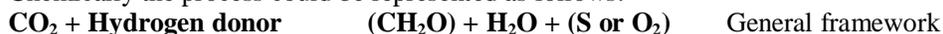
Basic concepts: Metabolism, Anabolic process, quantum yield, photosystems, Emerson effect, pigments, Hill's reaction, assimilatory powers, CAM, C₄ plants, photorespiration, phosphorylation.

Learning objectives:

1. Understanding relationship between photosynthesis and yield
2. Understanding mechanism of photosynthesis
3. Understanding factors affecting photosynthesis
4. Comparative analysis of C₃, C₄ and CAM
5. Photosynthesis, carbon sequestration and environmental health

Theoretical Background: Living systems are thermodynamically open system; such systems exchange energy and matter with the environment. Conceptually, there are two types of such energy transformation in living systems; anabolic and catabolic process. Anabolic process involves the transformation of energy into biological polymer, while catabolic process is breakdown or degradation of biological polymer and the consequent liberation of energy. Photosynthesis is an anabolic process found predominantly in higher plants, whose mode of nutrition is autotrophic. Autotrophic organism are further divided into phototrophic and chemotrophic organism depending on the energy source. All major crops of agronomic values belong to photoautotrophic organism, since they are capable of transforming radiant energy, in the presence of pigments into biological polymers. Chemotropic organism uses other source of energy and they are predominantly found among the lower plants.

Chemically the process could be represented as follows:

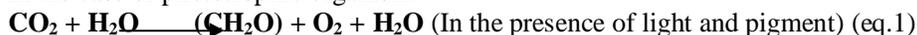


Where:

Hydrogen acceptor = CO₂

Hydrogen donor = H₂O, H₂S (chemolithotroph), organic acid (chemoorganotroph)

In the case of phototrophic organism:



Equations 1 and 2 Energy acquisition process

Equation 3 Carbon assimilation process

Photosynthetic efficiency metrics:

1. Percentage of energy conversion of radiant energy into assimilatory powers (NADPH₂ AND ATP), which is approximately 32 %
2. Quantum yield = O₂/light energy. With increasing wavelength of light there is a reduction in the evolution of O₂, a phenomenon referred to as red drop. (E = hc/λ). It was later observed that in order to enhance photosynthesis there is a need for two light harvesting systems, Emerson effect.
3. Percentage of carbon assimilation; NAR = RGR/ LAR

Tab. 1 Conceptual Framework of Photosynthesis

Parameters for comparison	Photosynthetic stages	
	Light	Dark

Process type	Energetic (Acquisition and conversion of energy)	Metabolic (Assimilation of CO ₂) <ul style="list-style-type: none"> ○ Calvin cycle ○ Hatch+Slack cycle ○ CAM cycle
Organ	Quantasome <ul style="list-style-type: none"> ○ Pigment system (PSI +PSII) ○ Grana 	Stroma (Thylakoid matrix)
Process product	<ul style="list-style-type: none"> ○ ATP ○ NAPH.H₂ ○ Products of photolysis 	<ul style="list-style-type: none"> ○ O₂ ○ (CH₂O)_n

Tab. 2 COMPARATIVE ANALYSIS OF TYPES OF PHOTOPHOSPHORYLATION

	Types of photophosphorylation	
	Non-cyclic	Anoxygenic photosynthesis (cyclic)
Organism	Green plant	Bacteria
Type of photosynthetic unit	PS I and II	PI
Electronic flow	PII→PI→CO ₂ unidirectional	Circular
Wave length	680nm – 700nm	700nm

Types of assimilatory power	NADPH ₂ , ATP	ATP
Capacity for photophosphorylation	Low	High
Photosynthetic efficiency	High	Low

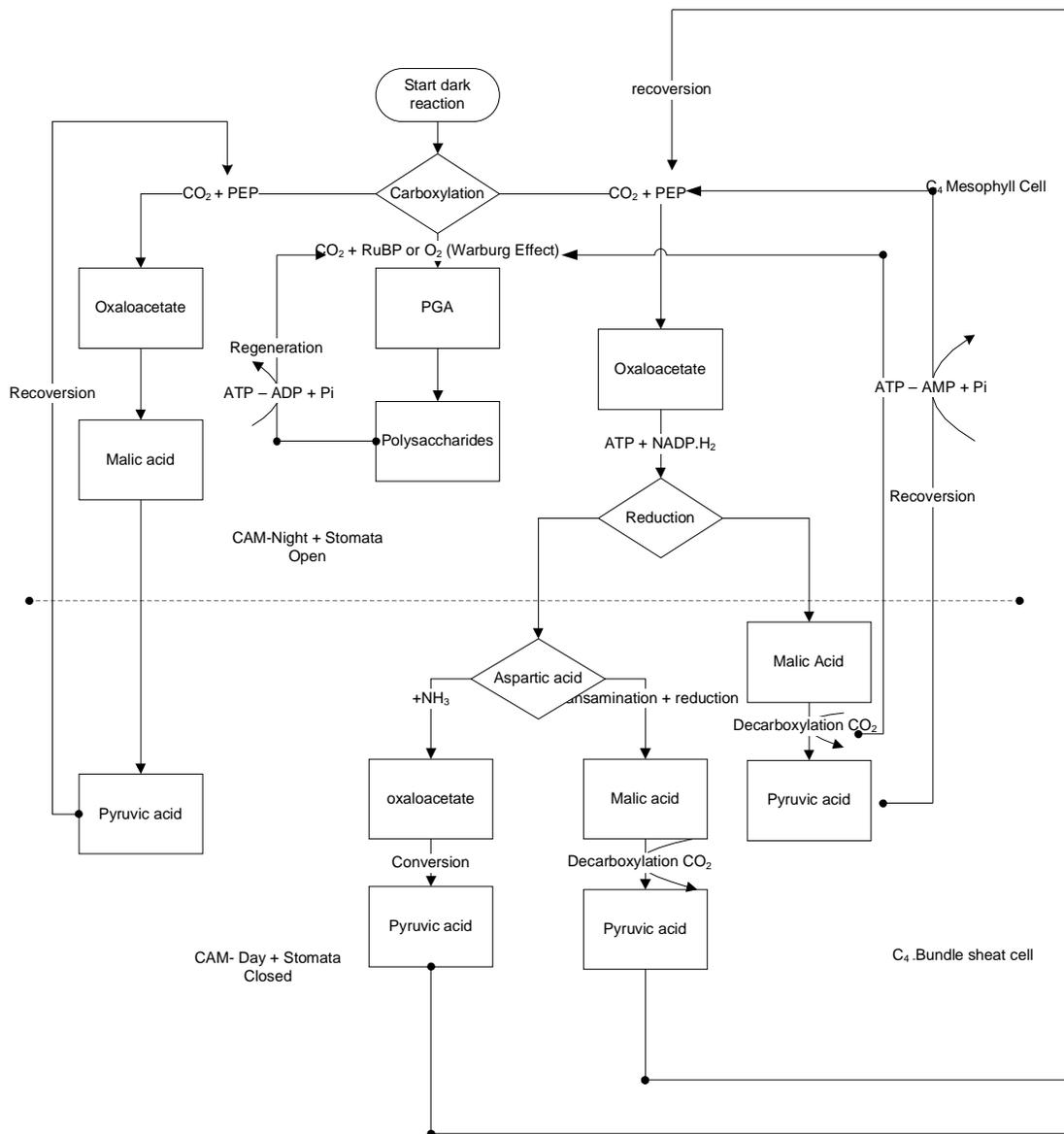
Tab.3 Dimensions of Dark reaction during photosynthesis

Parameters for Comparison	Dark reaction cycle		
	C₃	C₄	CAM
Plant type			
Nomenclature	Calvin cycle or Pentose phosphate reduction cycle	Hatch + slack cycle	CAM cycle
CO₂ acceptor	Ribulose 1,5 Biphosphate (RuBP)	RuBP Dicarboxylic acid Phosphoenolpyruvic acid (PEP)	PEP RuBP
First stage product	Phosphoglyceric acid (PGA)	Oxaloacetic acid/malic acid (Carboxylic acid)	Malic acid and Malate
Compartmentalization of carboxylation	None	Spatial (Mesophyll +Bundle sheath)	Temporal (Diurnal pattern in mesophyll)
Plant habitat	Hydrophytes Mesophytes	Xerophytes	Halophytes
Morphology of the chloroplast	Monomorphic	Dimorphic	Fleshy leaf, stem and petioles
Bundle sheath	Few or no chlorophyll	Chlorophyllous	-
Morphology of chlorophyllous mesophyll	Not distinguishable 5> mesophyll	Kranz anatomy 4-5 mesophyll	-

Photorespiration	More	lesser	-
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Flow chart of Dark reactions of C3, C4 and CAM Plants

Figure 1



Factors affecting photosynthesis are:

1. Light
2. Water
3. Temperature
4. Carbon dioxide concentration
5. Mineral nutrients, most especially, NPK and some micro nutrients

Topic: Translocation and assimilate partitioning in relation to yield determination

Basic concepts: Translocation, transport, assimilate or photosynthates, partitioning, allocation, phloem, xylem, source, sink, sink strength.

Theoretical Background: Product of photosynthesis are transported, allocated and partitioned among various sinks. From the agronomic point of view, it is not only enough to generate adequate photosynthates, but they should be partitioned to organs of great economic returns, this is reflected in the harvest index, indicating the proportion of the economic biomass relative to the general biomass.

Transportation in long distant is referred to as translocation of solute or sap, while short distant movement of molecules and ions is generally accepted as transportation.

A solute **translocation pathway** is the phloem, a living cell compared to the xylem which is dead. The phloem is consisting of:

1. Sieve elements
 - a. Sieve tube element
 - b. Sieve plate pores
2. Sieve cell
3. Companion cell
4. P-protein

Translocation pattern: Source - Sink

The pattern of solute translocation is from the source to sink. The source are organs with assimilate concentrations more than their need; conversely the sink organs are with assimilate concentrations lesser than their needs.

Transported Materials:

1. Inorganic
2. Organic
 - a. Carbohydrates (non-reducing sugars)
 - b. Proteins (Amino acids, amides, P-protein, protein kinase, ubiquitine, chaperones, protease inhibitors)
3. Hormones

Mechanism: The photosynthates produced from the reduction of CO₂ is eventually allocated to various metabolic processes, or partitioned into various organs. The photosynthates could be allocated into the process of RuBP regeneration, storage of transitory starch or synthesis of sucrose for eventual transportation. The decision of whether to store photosynthates as starch or synthesize sucrose depends on the concentration of inorganic phosphorus in cytosol. When it is high sucrose is synthesised and eventually transported, while low concentration of it, leads to storage in the form of starch.

Sucrose is transported to the phloem-companion cell complex through apoplast or symplast path. Loading of sucrose via H⁺/sucrose symport transportation leads to the reduction of water potential, while unloading at sink leads to the increase in water potential. This process in the phloem pathway leads to osmotically **generated pressure gradient**, with the sap moving by **mass pressure** from source to sink. Allocation of photosynthates for storage or differential distribution to various organ is a function of the activities of certain enzymes like *acid invertase*, *starch phosphorylase* and *sucrose synthetase*. Differential distribution (partitioning) of photosynthates among sink organs is dependent on various factors. There are different models proposed to explain assimilate partitioning in crop plant. Please see the matrix below for comparative analysis. We shall be focusing our attention on functional equilibrium model. The basic assumptions of this model are:

1. Assimilate is constant at a given period in time.
2. Partitioning is a proportional process and involves a trade-off at any given period in time

3. Changes in partitioning during ontogeny (developmental stages) reflect changes in plant's priority – phenotypic plasticity
4. Differential distribution is to process that is limiting at that point in time

Functional equilibrium model:

Dry matter allocation = $W_r/W_s \propto A_s/A_r$

Where:

W_r – Weight of root

W_s – Weight of shoot

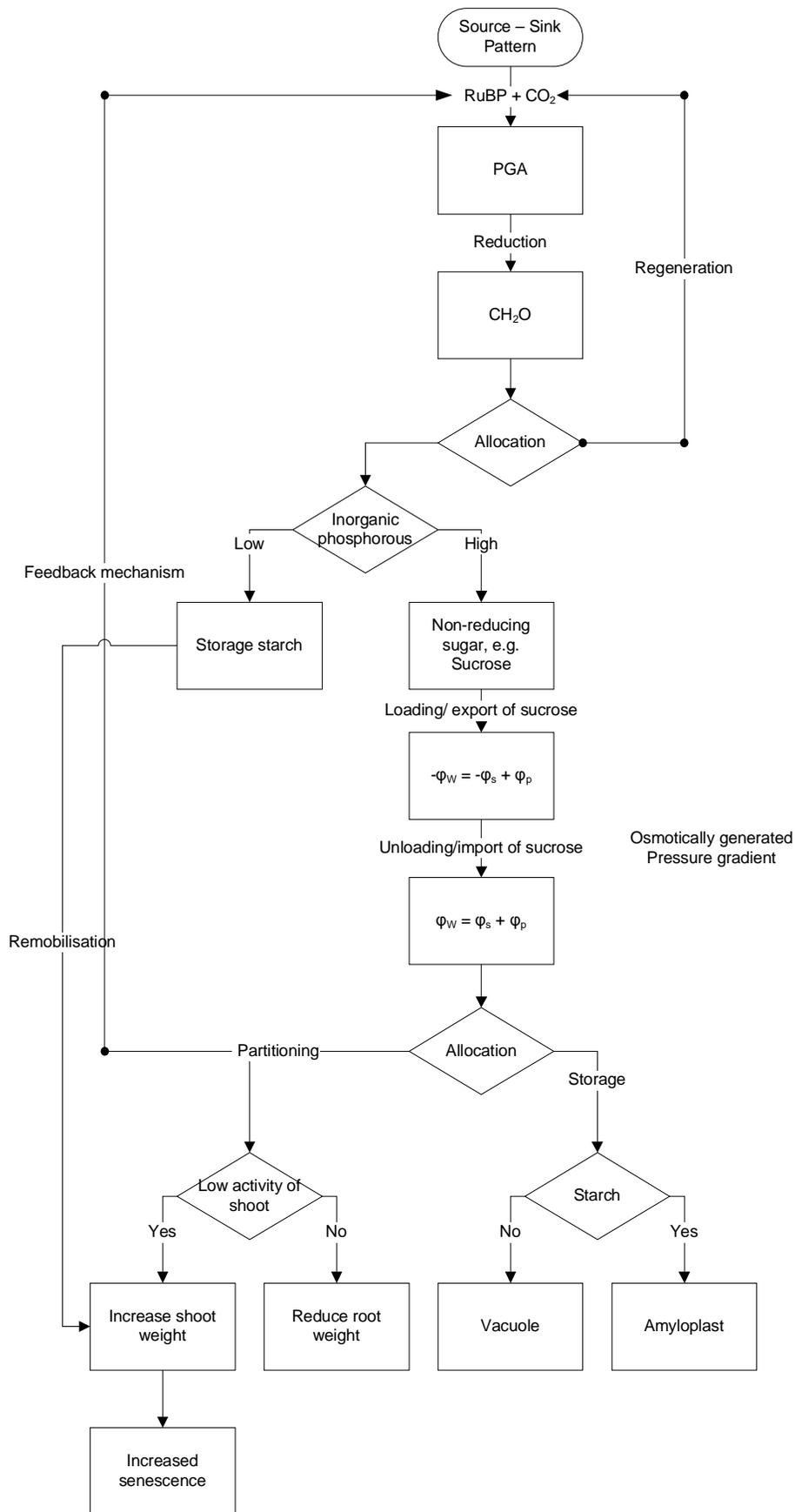
A_s – Activity of shoot (carbon assimilation)

A_r – Activity of root (nutrient and water uptake)

With respect to yield, high yield is recorded when there is a there is functional balance of physiological activities, contrary to which assimilates could be partitioned to other sinks indicating priority process, which may not be of economic value to the farmer.

COMPARATIVE ANALYSIS OF MODEL S OF ASSIMILATE PARTITIONING

Models name	Assumptions	Model	Deficiency of the model
Descriptive Allometry	Predetermined RGR among organs	Allometric pattern = $f\{\text{genotype} \times \text{environment} \times \text{dev}\}$	Fluctuation in dry matter allocation could not be explained by the model
Functional Equilibrium (Teleonomic model)	Existence of functional balance among the plant organs (Shoot and Root)	1. Dry Matter Allocation = $W_r/W_s \propto A_s/A_r$ 2. Or Carbon/Nitrogen	Not applicable to other organ aside from shoot and root
Canonical Model	Interrelationship of parts	1. Non linear, dynamical process 2. Numerical analysis	Too quantitative
Sink Strength	Commonality of assimilate pool	1. DMA = $f\{\text{sink strength} - (\text{source strength} + \text{transport resistance})\}$ 2. $f_i = s_i/\Sigma S$	Sink strength is conceptual, not measurable
Transport Resistance		DMA = $f\{\text{pressure gradient} \times \text{differences in labile carbon}\}$	Complexity in computing resistance transport parameters



The above Conceptual Model according to Sakariyawo 2009