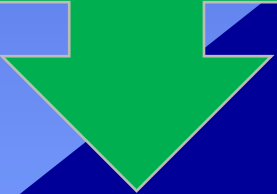


Introduction: A reminder of the basics

Introduction of vegetal physiology

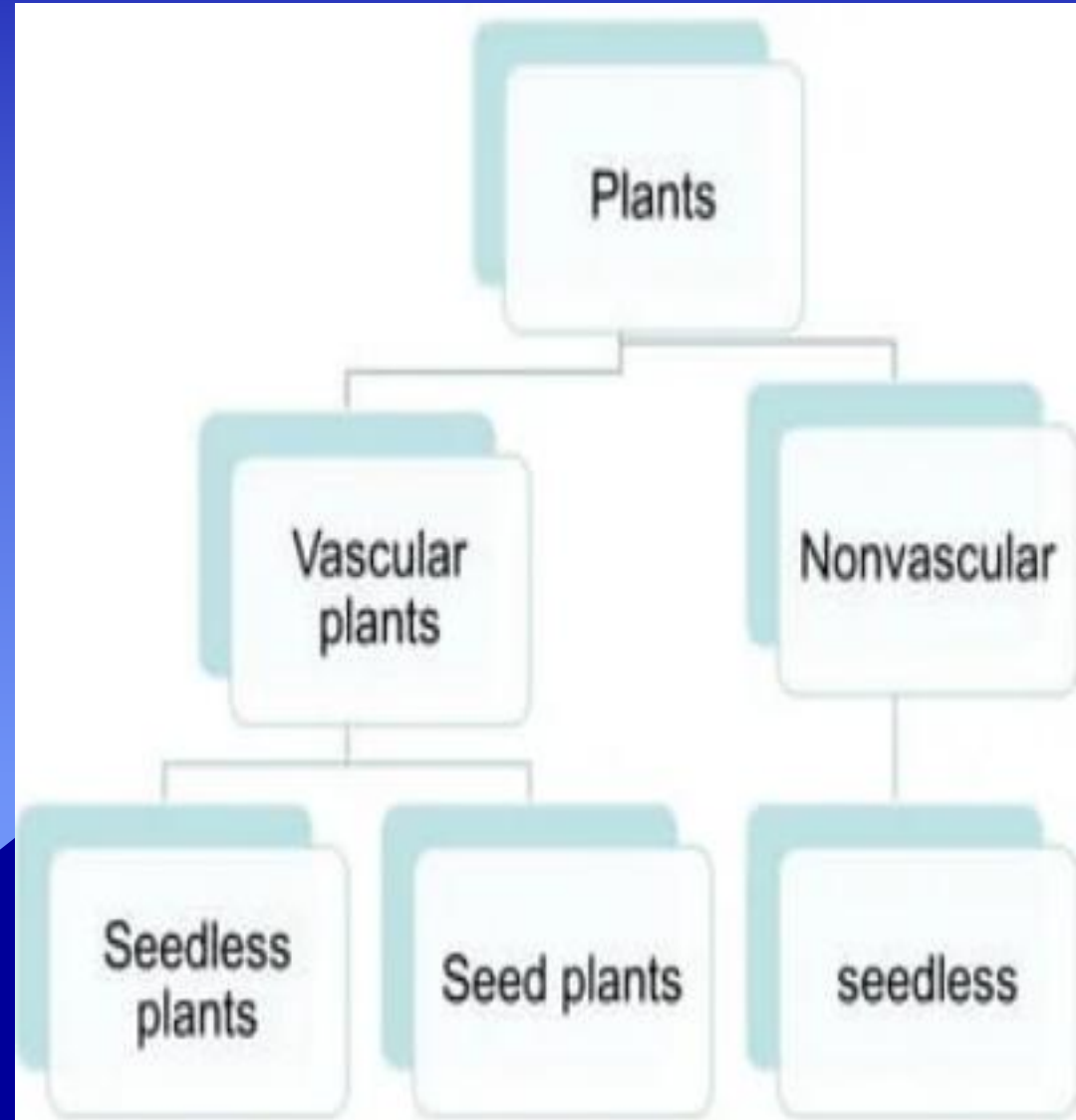


I. Plant organisation:

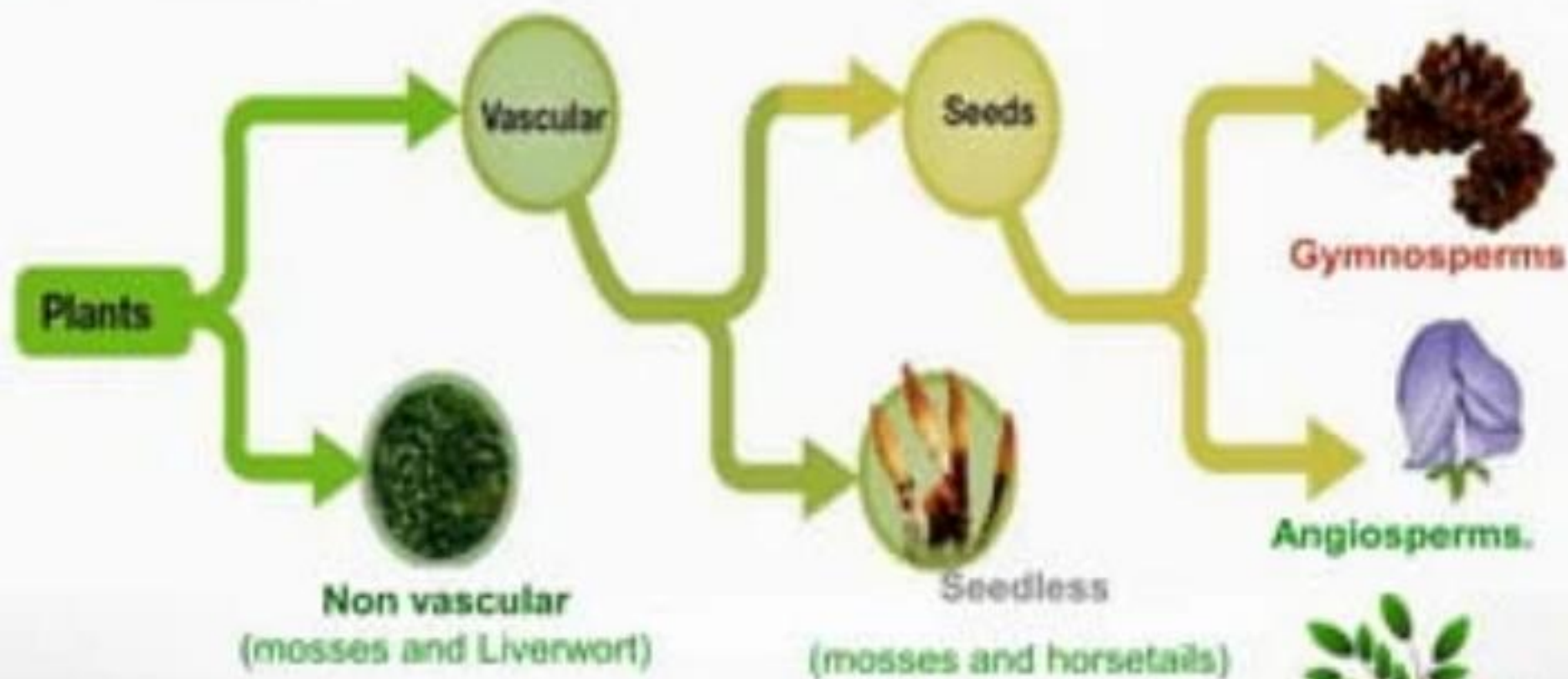
General characteristics of plants:

Characteristics of Plants

1. Made of cells (with DNA, cell wall, chloroplasts)
2. Multicellular – no single celled plants
3. Producers – make own food (Photosynthesis)
4. Body plan (cells to organ systems)



Plant Characteristics

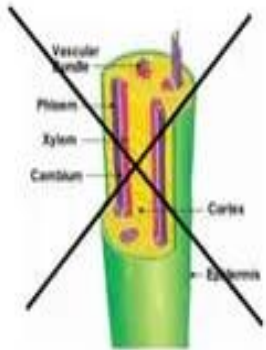


Tutor

Mains divisions

Types of Plants

1. Nonvascular Plants – do not have roots, stems or leaves
 - a. NO Vascular tissue and NO seeds!



Nonvascular Plants are Simple Plants.

- They are small.
- No vascular tissue means water has to move by osmosis from the ground through the plant.
- This means they must live in moist places.
- They produce spores for reproduction.

Examples of Nonvascular Plants :

- Mosses



- Liverworts

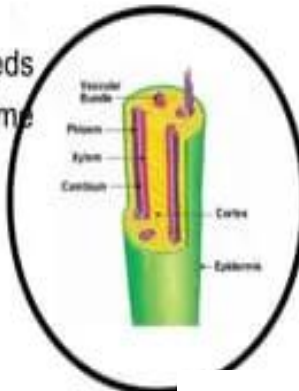


Vascular plants

Types of Plants

2. Vascular Plants – contain vascular tissue (transports food and water)

- a. Some contain seeds
- b. Some don't contain seeds
- c. Some have flowers, some don't have flowers



a. seedless vascular plants

- 1. Vascular tissue
- 2. No seeds, still have spores
- 3. Examples: horsetails and ferns



Spores



b. Vascular seed plants

- **Gymnosperm**- produce seeds on the scales on of female cones.
 - They do not produce flowers
 - Have needlelike or scale like leaves
 - Examples: conifers, evergreens

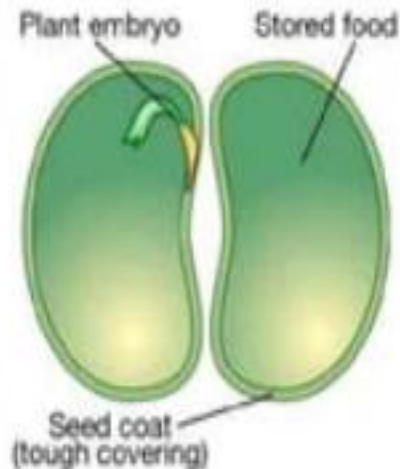


Flowering Plants



- **Angiosperm**- their seeds are inside.
 - All produce flowers
 - most common plants on earth

Vascular plants with Seed



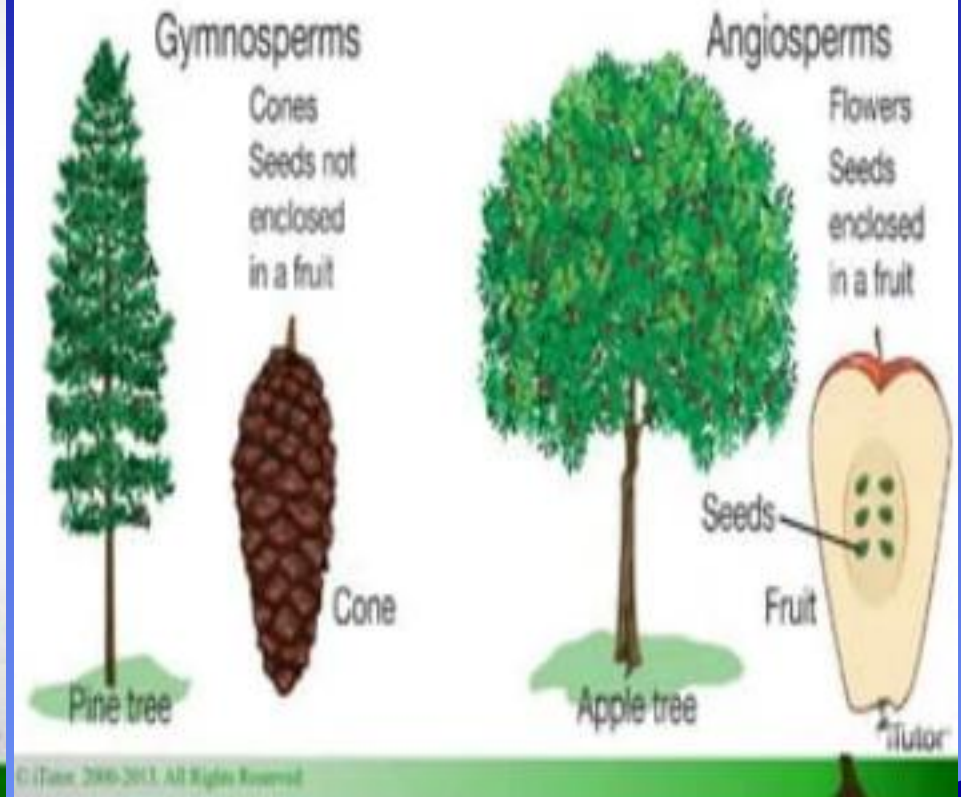
❖ A **seed** is a structure that contains a plant embryo and a supply of food inside a protective covering.



Vascular plants with Seed

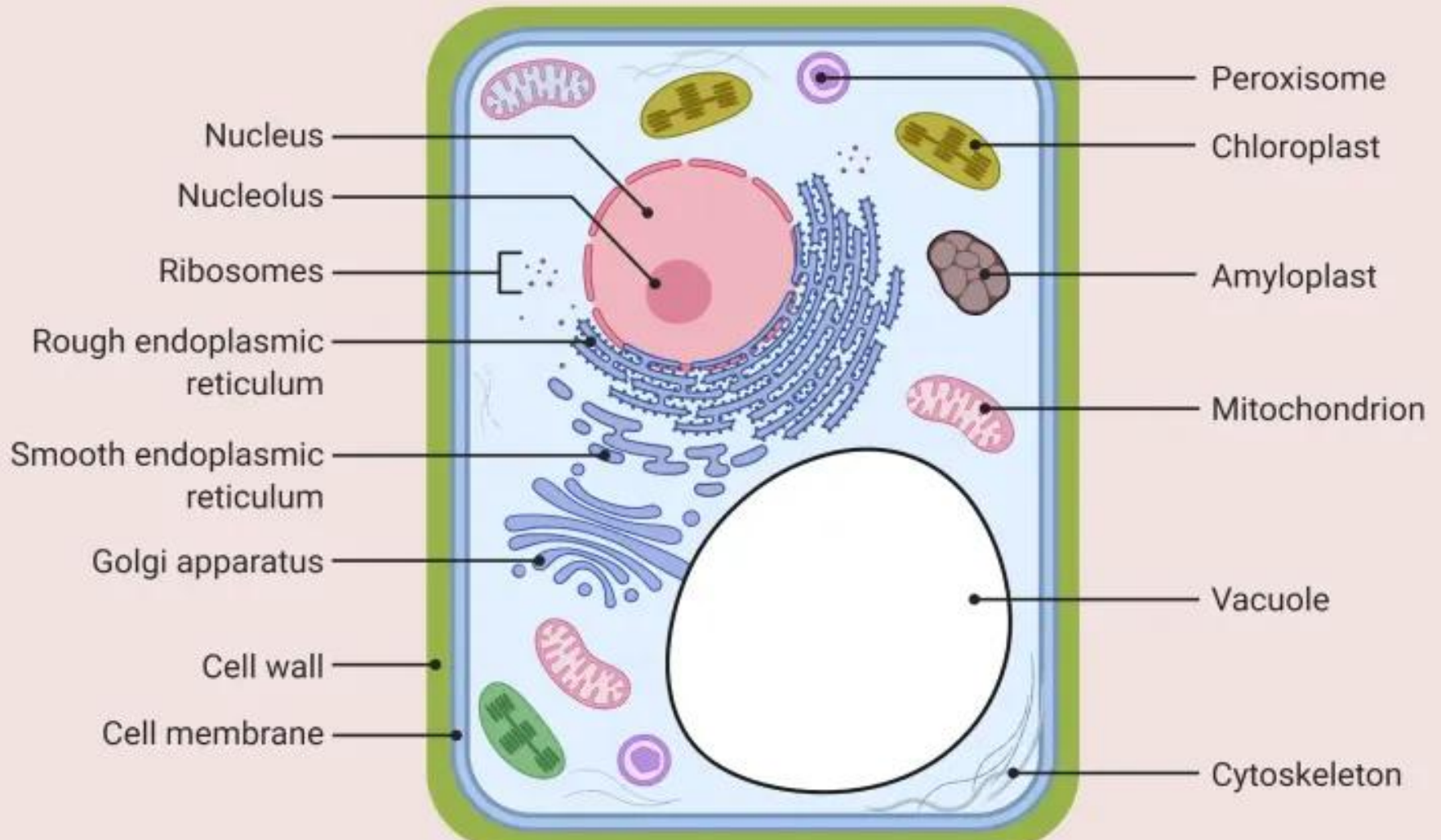


Vascular plants with Seed

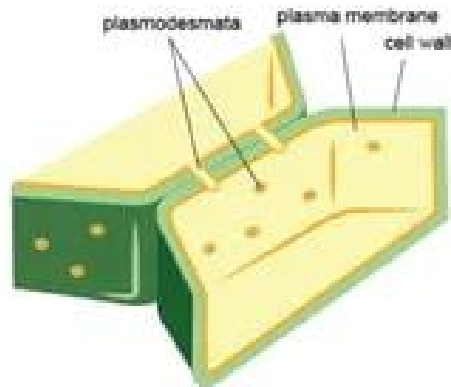


II. Organisation of Plant cells

Plant Cell



The Cell Wall



TEM image of cell wall structure in plant roots

Cell Walls

- Cellulose cell walls help distinguish plants from other organisms
- The main component of a cell wall is cellulose arranged in microfibrils
- The cellulose framework is interpenetrated by a cross-linked matrix of non-cellulose molecules - primarily hemicelluloses and pectin
- Cell walls are layered - there is a primary cell wall, a middle lamella between two cells and sometimes a secondary cell wall

Cell Wall

- Provides support
- Double layered
- Made from cellulose

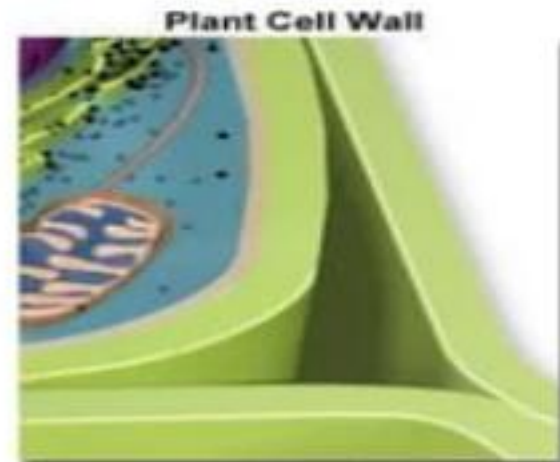
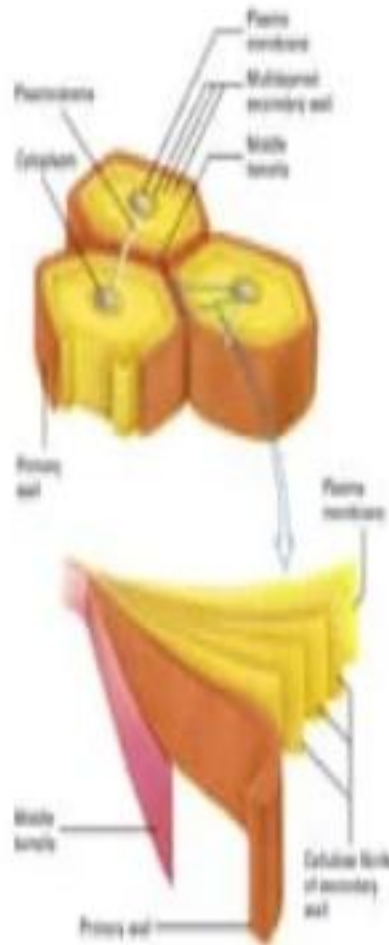


Figure 1

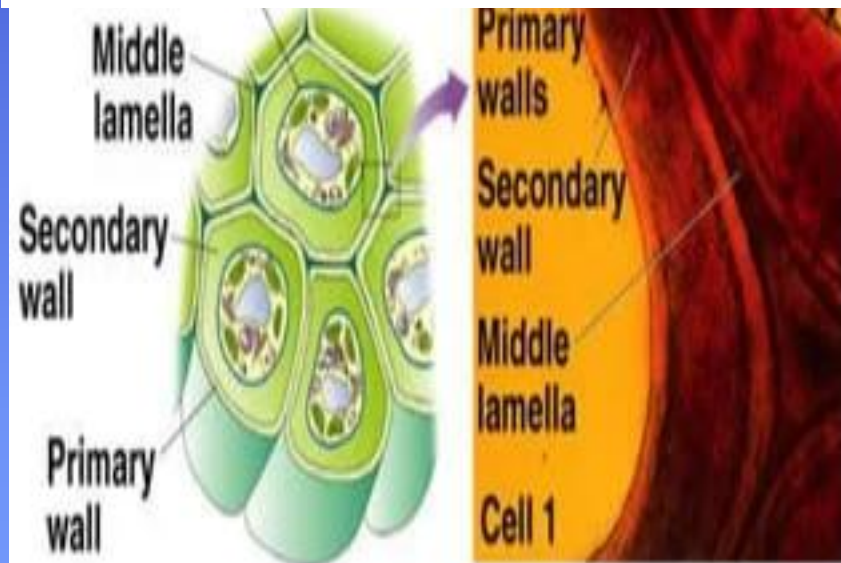
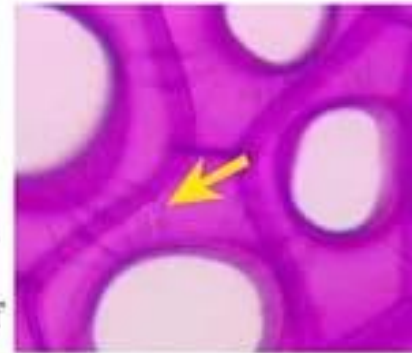
Cell Walls

- The primary cell wall is deposited before and during growth of the cell
- Actively dividing cells typically only have primary cell walls
- Secondary cell walls are usually formed after the cell has stopped growing and the primary cell wall is no longer increasing in surface area
- The secondary cell wall forms between the primary cell wall and the protoplast



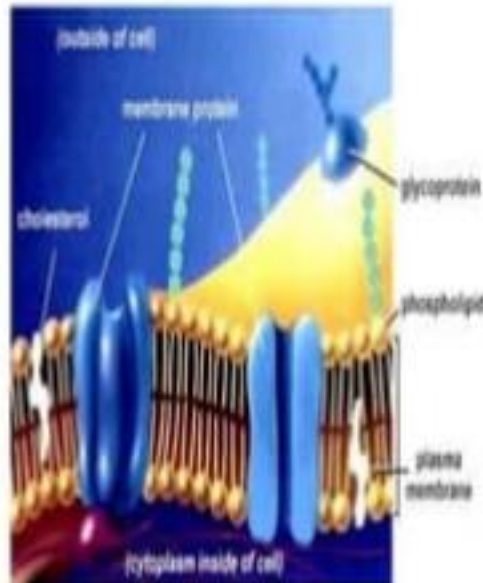
Plasmodesmata

- Plasmodesmata allow the transport of substances from one cell to the next
- They are cytoplasmic threads which connect the living protoplasts of adjoining cells



Cell Membrane

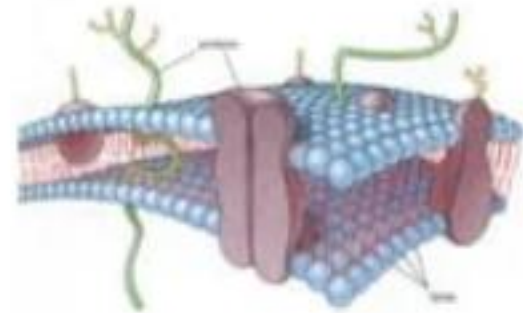
- Controls what enters and leaves the cell
- Found in ALL cells
- Phospholipid bilayer with transport proteins, and **cholesterol** (for flexibility)



Plasma Membrane

The plasma membrane has several functions

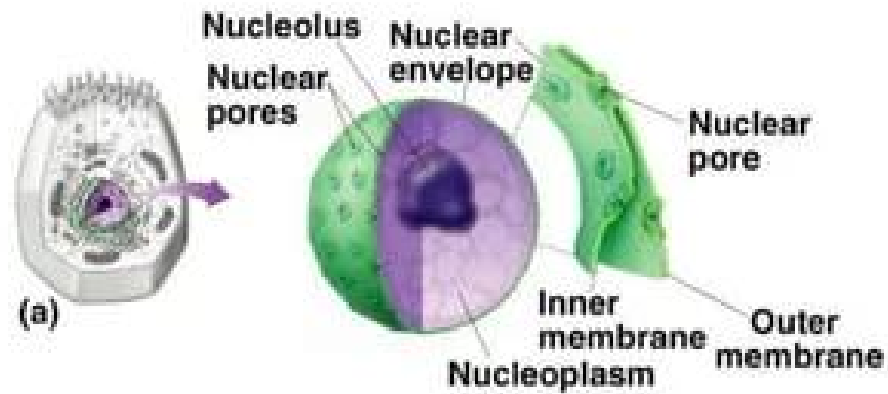
1. It mediates the transport of substances into and out of the protoplasm
2. It coordinates the synthesis and assembly of cellulose microfibrils
3. It relays hormonal and environmental signals involved in the control of cell growth and



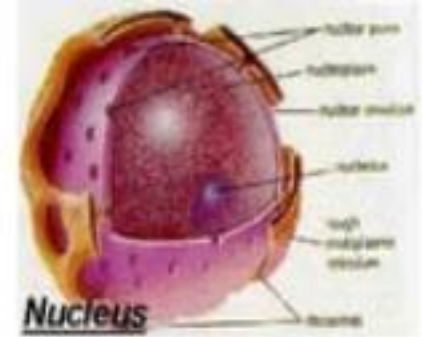
Cell Organelles

- Nucleus
- Ribosomes
- Endoplasmic reticulum
- Golgi apparatus
- Lysosomes
- Vacuole
- Organelles with DNA (mitochondria and chloroplasts)
- Cytoskeleton

Nucleus

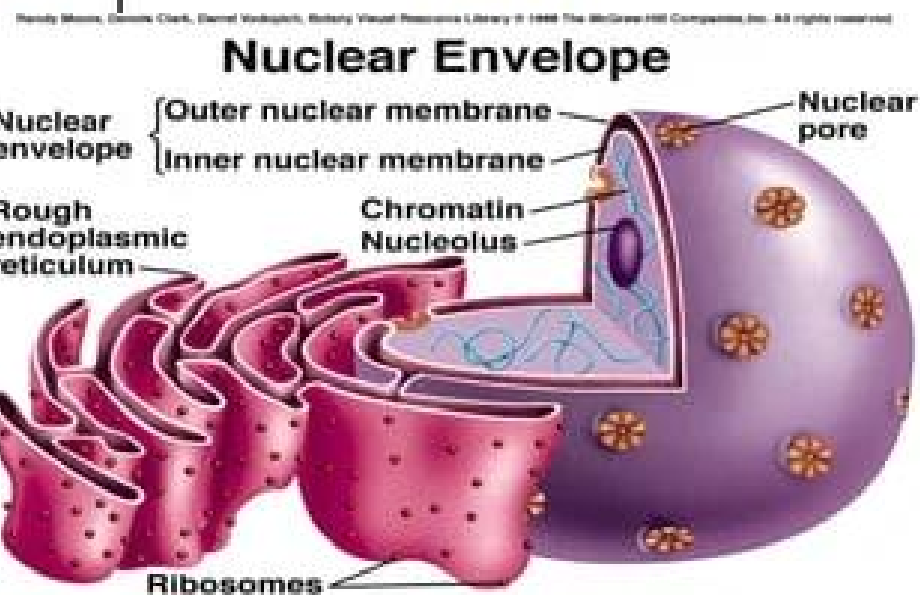


Nucleus



- Stores genetic material
- Contains DNA
- *Nucleolus*: site where RNA is made
- Chromatin and ribosomal subunits present
- *Nuclear envelope*:
 - Double membrane with pores
- Largest organelle
- BRAIN of the cell – controls protein synthesis

Nucleus



Nucleus

The nucleus is usually the most prominent structure in the protoplast of eukaryote cells

1. It controls the ongoing activities of the cell by determining which protein molecules are produced by the cell and when they are produced
2. It stores genetic information, passing it onto daughter cells during cell division

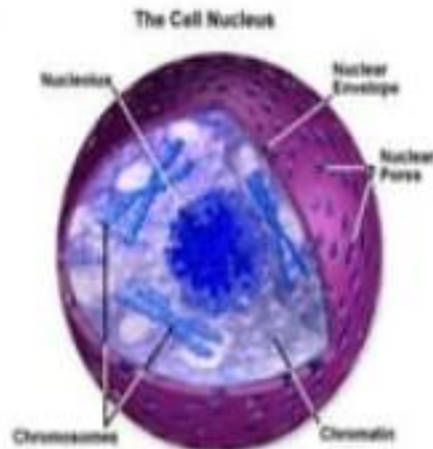


Figure 1

Ribosomes

- Ribosomes(80s) are RNA-protein complexes composed of two subunits(50s & 30s) that join and attach to messenger RNA.
 - site of protein synthesis
 - assembled in nucleolus

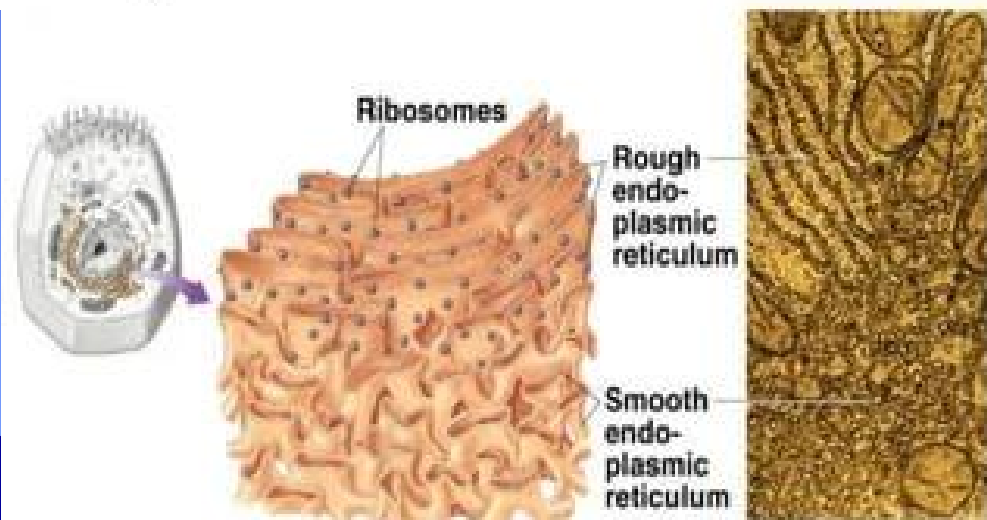


Figure 1

Endoplasmic reticulum

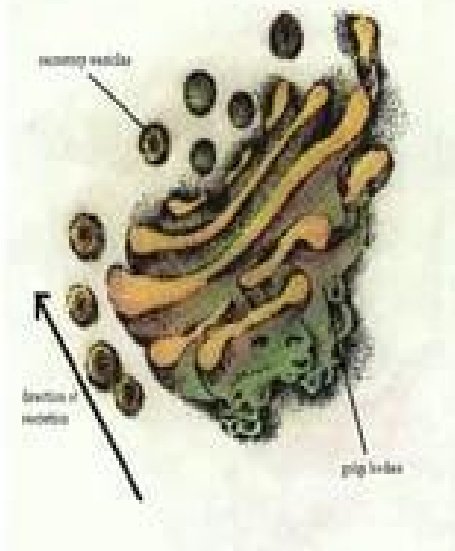
- Transports materials through the cell
- 2 types:- (i) Rough ER
(ii) Smooth ER
 - Rough ER - studded with ribosomes
 - Attached to nuclear membrane
 - site of protein synthesis and processing
 - Smooth ER - lacks ribosomes
 - site of synthesis of phospholipids and the packaging of proteins into vesicles

Endoplasmic reticulum



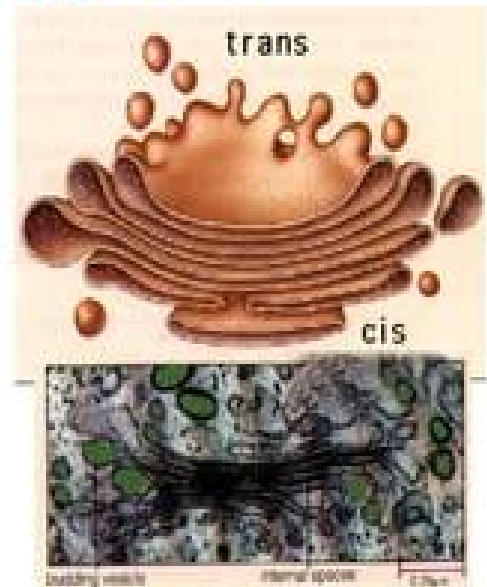
Golgi apparatus

- Collection of Golgi bodies
 - Stacked flattened sacks
 - Site where cell products are packaged for export
 - Proteins are modified by being combined with fats or carbohydrates



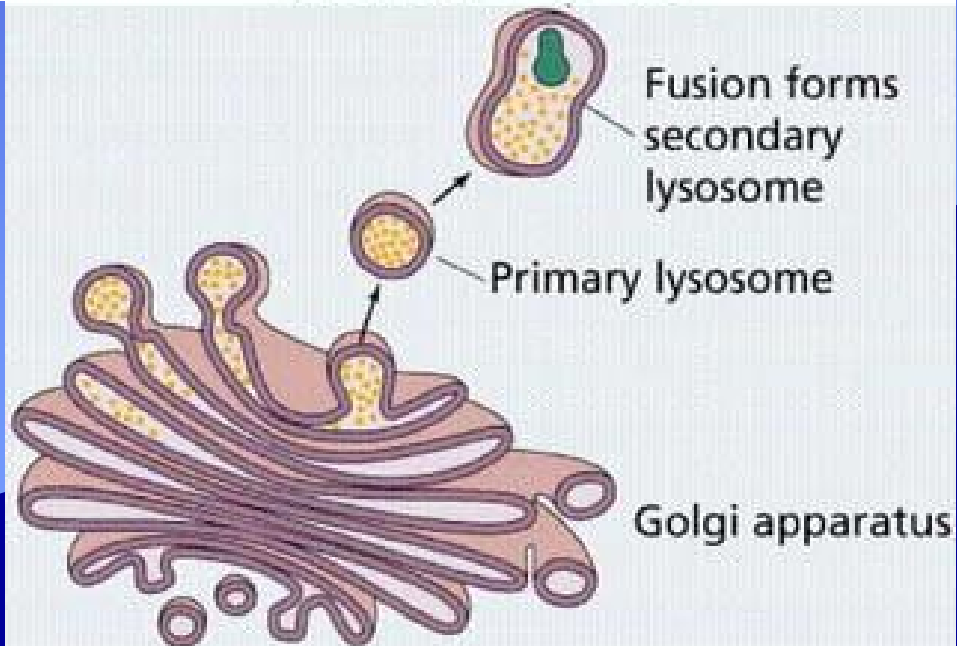
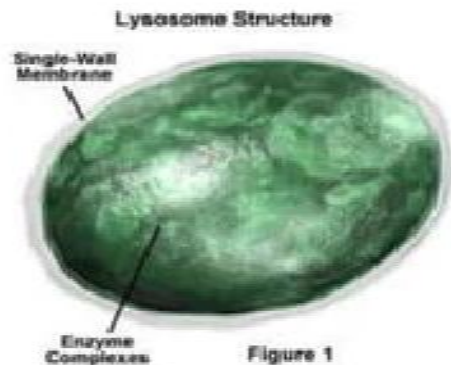
Golgi apparatus

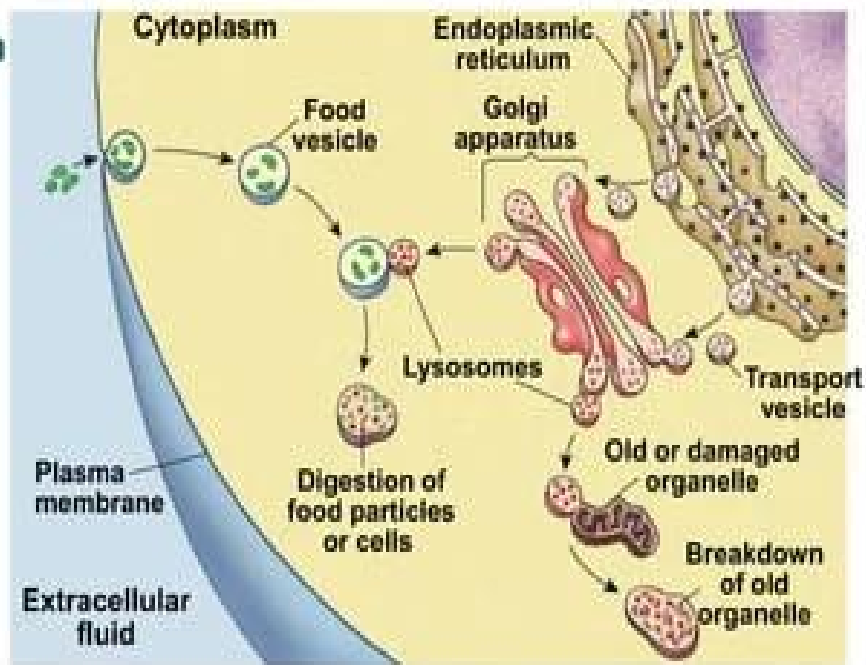
- Vesicles then pinch off from the Golgi body to be secreted (outside the cell)
- Involved in the production of lysosomes



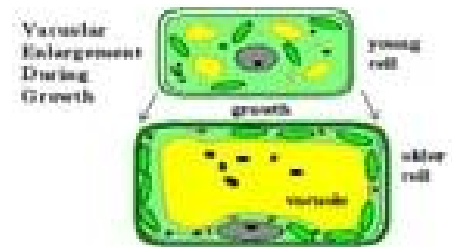
Lysosomes

- Vesicles produced by the Golgi apparatus.
- Lysosomes contain digestive enzymes and are involved in intracellular digestion of food particles, disease causing bacteria and worn out cell parts
- They are known as the "suicidal bags of the cell"





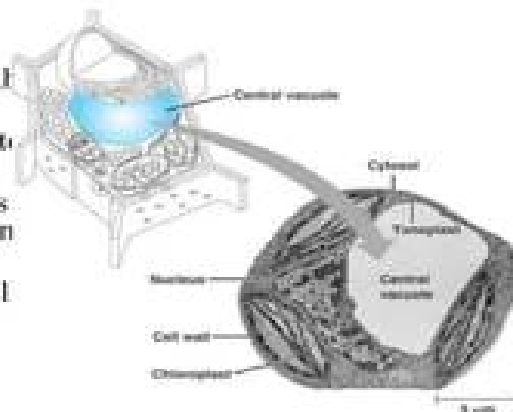
Vacuoles



- Found in **PLANT** and **ANIMAL** cells
- The vacuole acts a container, storing water and dissolved particles
- Plants have a large central vacuole for water storage
- Unicellular animals can use contractile vacuoles for movement

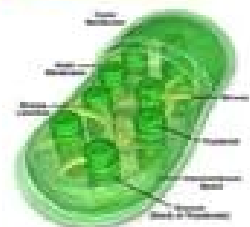
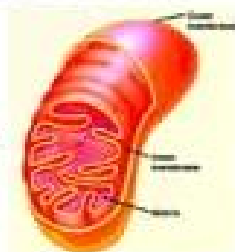
Vacuoles

- Vacuoles are membrane bound organelles filled with cell sap
- The membrane is referred to as the tonoplast
- Different kinds of vacuoles may have different function within the same cell
- Along with water based cell sap, vacuoles typically contain salts, sugars and some dissolved proteins



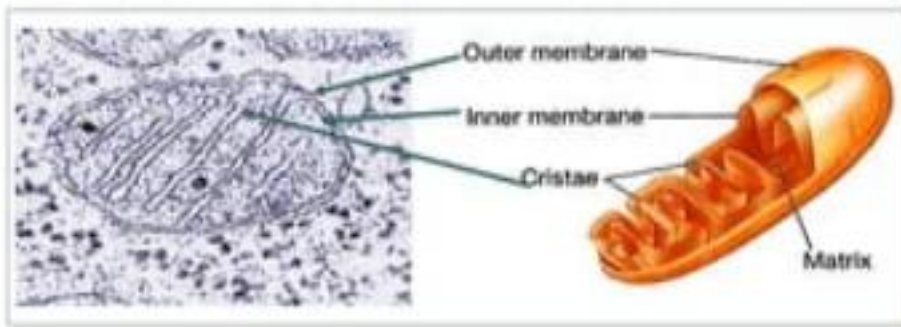
Organelles With DNA

- Mitochondria
 - site of cell respiration
- Chloroplasts
 - site of photosynthesis



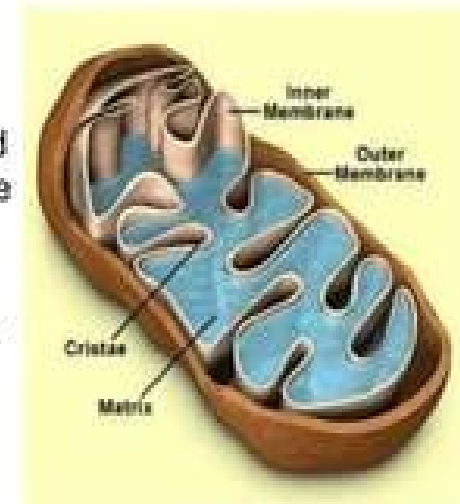
Mitochondria

- "Powerhouse of the cell" - cellular metabolism
- Structure- outer and inner membranes, cristae
- Found in both plant and animal cells
- Very active cells have more mitochondria



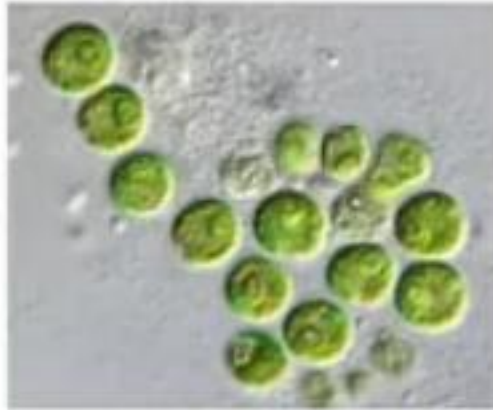
Mitochondria

- Mitochondria are another organelle bounded by two membranes
- The inner membrane is folded into many pleats called cristae
- Mitochondria are the sites of cellular respiration - converting organic molecules to ATP the main immediate energy source for living eukaryote cells - plant cells may have hundreds to thousands of mitochondria



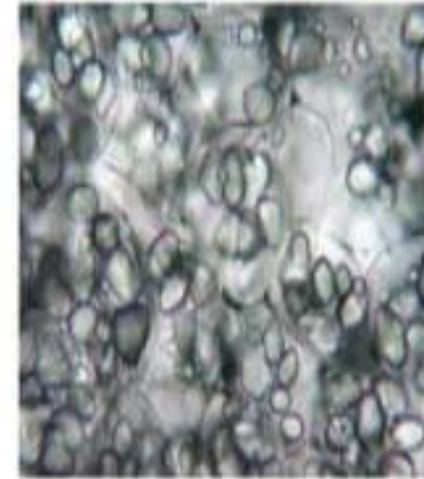
Chloroplasts

Plant Cell Chloroplast Structure



Leucoplasts

- Leucoplasts are non-pigmented plastids some of which synthesize starch while others produce oils or proteins
- Upon exposure to light they may develop into chloroplasts



Chromoplasts

- Chromoplasts lack chlorophyll but synthesize and retain carotenoid pigments which are responsible for the yellow, orange or red colors of many flowers, old leaves, some fruits and some roots



Part 01: Growth and development



There are three phases of growth:

- meristematic,
- elongation
- maturation

The plant life cycle consists of four stages

- seed
- sprout
- small plant
- adult plant

In biology, growth can be classified into two main types:

- **Determinate Growth:** In determinate growth, an organism grows only until it reaches a certain size. Most animals and some plants exhibit this type of growth. ...
- **Indeterminate Growth:** In indeterminate growth, an organism continues to grow throughout its life.
- Plant growth could be defined as the increasing of plant volume and/or mass with or without formation of new structures such as organs, tissues, cells or cell organelles. Growth is usually associated with development (cell and tissue specialization) and reproduction (production of new individuals).

- Plant life cycle describes the various stages of plant life. The main stages in the life cycle of a plant are seed germination, seedling formation, growth, development and differentiation
- Plant growth and development relies on water for transpiration, photosynthesis, and respiration.

Stage 3: Stem Elongation Or Rosette Growth And Shoot Development.

there are two types of growth in plants:

- The increase in length of the stem and the root is referred to as primary growth, and is the result of cell division in the stem apical meristem. Secondary growth is characterized by an increase in thickness or girth of the plant, and is caused by cell division in the lateral meristem.

the different plant growth forms:

- We defined nine plant growth forms based on woodiness (woody or non-woody), shoot structure (self-supporting or not self-supporting), and root traits (rooted in soil, not rooted in soil, parasitic or aquatic): Epiphyte, Liana, Vine, Herb, Shrub, Tree, Parasite, or Aquatic.

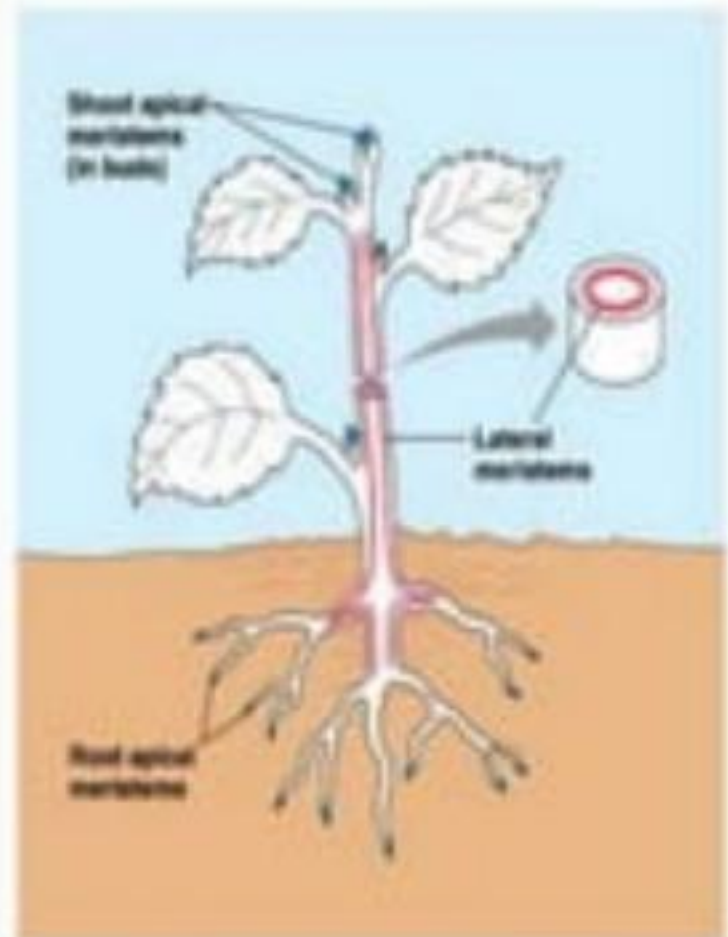
Types of Growth- Classified by Developmental Stages

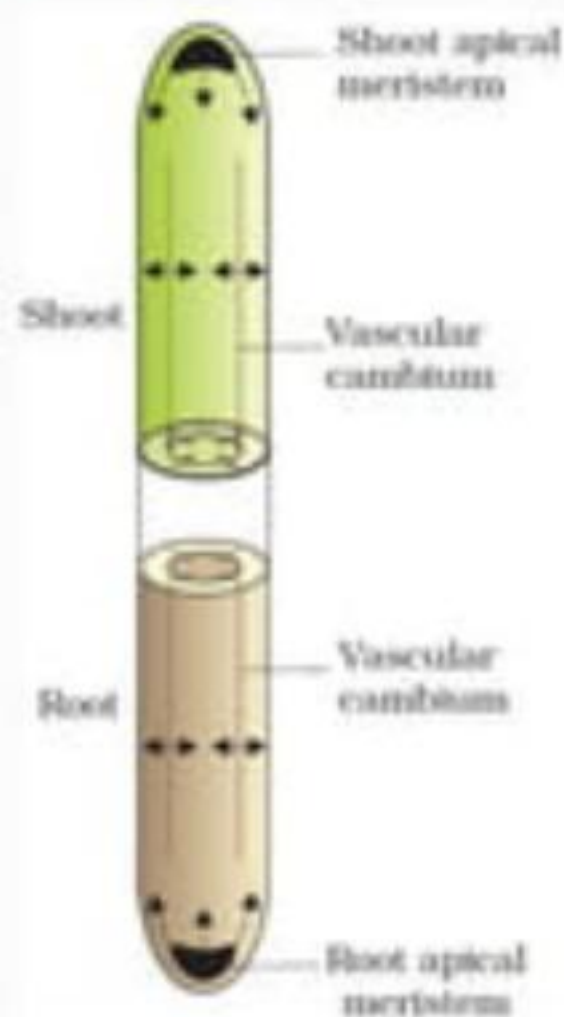
Primary growth:

Apical meristems extend roots and shoots by giving rise to the primary plant body

Secondary growth:

Lateral meristems add girth by producing secondary vascular tissue and periderm.





Diagrammatic representation of locations of root apical meristem, shoot apical meristem and vascular cambium. Arrows exhibit the direction of growth of cells and organ

MEASUREMENT OF GROWTH

It can be measured in terms of:

- Increase in length or growth – in case of stem and root.
- Increase in area or volume – in case of leaves and fruits.
- Increase in the number of cells – in algae, yeast and bacteria.

Types of Growth & Development

- Vegetative Phase
 - Carbohydrate Utilization
- Reproductive Phase
 - Accumulation or storage of carbohydrates

Factor

Factor is a substance that takes part in a biochemical reaction or a biological process or A component in the environment that influence other components of the environment.

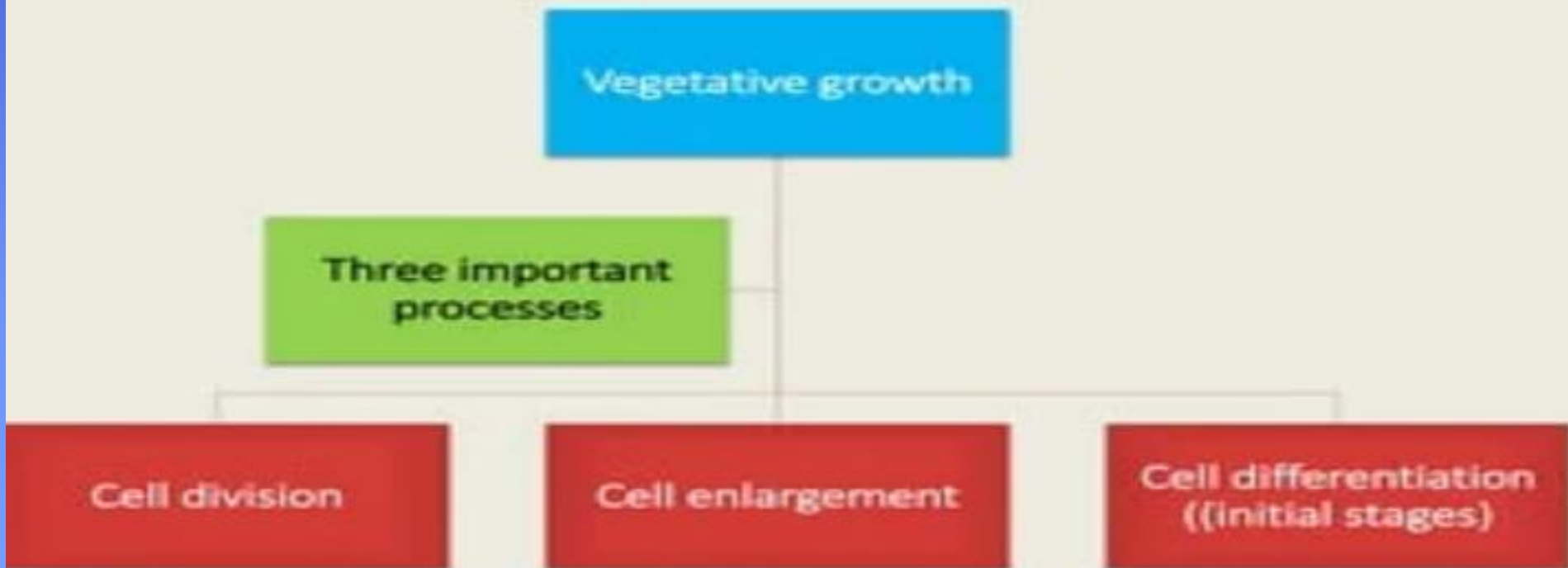
Environmental Factors

Environmental factor or ecological factor is any factor, abiotic or biotic, that influences living organisms.

Abiotic Factors

Abiotic factors are non-living chemical and physical parts of the environment that affect living organisms and the functioning of ecosystems.

Abiotic components include physical conditions and non-living resources that affect living organisms in terms of growth, maintenance, and reproduction. Resources are distinguished as substances or objects in the environment required by one organism and consumed or otherwise made unavailable for use by other organisms.



Reproductive Growth Phase

1. Maturation of tissues manufactured during vegetative phase

2. Production of growth regulators

3. Development of flower buds, flowers, fruit and seed, or the development of storage organs

4. Relatively little cell division occurs

5. Most of the carbohydrates are accumulated in the fruit, seed or storage organs

Phases of growth

1.

- Cell division/
meristematic

2.

- Elongation

3.

- Differentiation/
Maturation

Meristematic: both at the root apex and the shoot apex represent the meristematic phase of growth.

Meristematic Cells
(Stem Cells)

Primary

Shoot Apical Meristem
(SAM)

Root Apical Meristem
(RAM)

Secondary

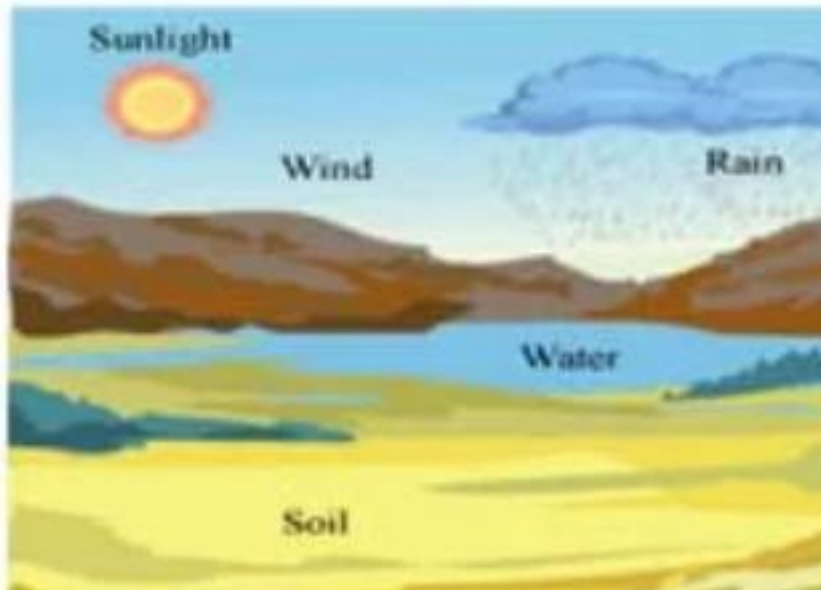
Axillary Buds

Cork Cambium

Vascular Cambium

Pericycle (root)

Abiotic Factors



Water

Water (H_2O) is a very important abiotic factor – it is often said that “water is life.” All living organisms need water. Plants must have water to grow. Even plants that live in the desert need a little bit of water to grow. Without water, animals become weak and confused, and they can die if they do not rehydrate.



Sunlight

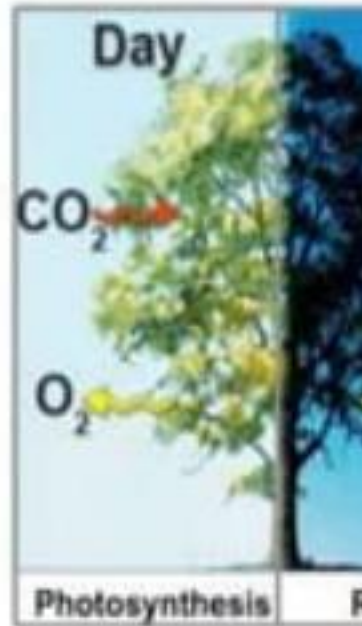
Sunlight is the main source of energy on Earth, which makes it an extremely important abiotic factor. Sunlight is necessary for photosynthesis, the process by which plants convert carbon dioxide (CO_2) and water to oxygen (O_2) and sugar – food for the plants that later becomes food for animals. Without the sun, plants could not live, and without plants, animals could not live! The sun's heat is also extremely important – see the section on Temperature below.



Oxygen And Carbon Dioxide

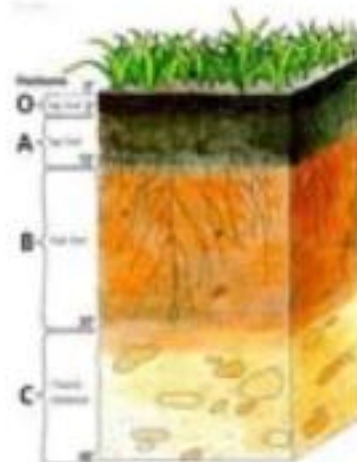
Oxygen (O_2) is another important abiotic factor for many living organisms. Without oxygen, **Respiration** is not possible for living organisms.

Carbon Dioxide (CO_2) is another important abiotic factor for many living organisms. The green plants make their food by **Photosynthesis** that must need carbon dioxide (CO_2).



Soil

Soil is often considered an abiotic factor since it is mostly made up of small particles of rock (sand and clay) mixed with decomposed plants and animals. Plants use their roots to get water and nutrients from the soil. Soils are different from place to place – this can be a big factor in which plants grow in a certain area.



Topography

Topography is a non-living factor that refers to the "lay of the land". It includes the physical factors of the earth such as the land elevation, slope, terrain (flat, rolling, hilly, etc.), mountains, ranges, and bodies of water. The altitude or elevation of the land with respect to the level of the sea surface influences plant growth & development primarily through temperature effects.

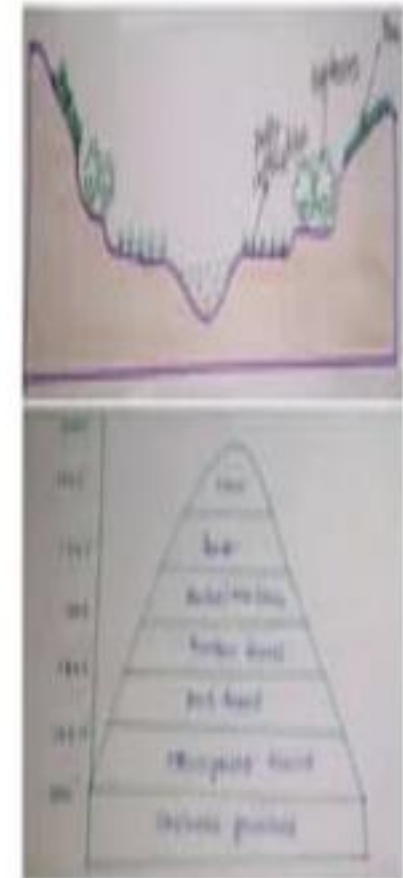


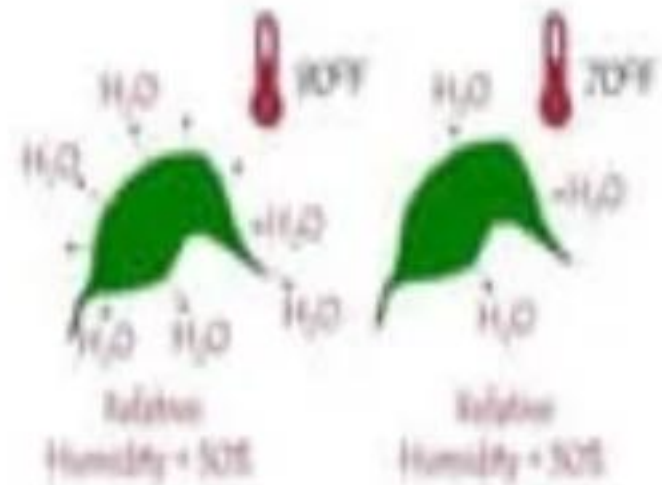
Figure: Topography

Temperature

This abiotic factor influences all the plant growth processes such as photosynthesis, respiration, transpiration, breaking of seed dormancy, seed germination, protein synthesis.

"Plants survive within a temperature range of 0° to 50°C" (Poincelot 1980).

The favorable or optimum day & night temperature range for plant growth and maximum yields varies crop species.



1. Minimum Temperature: 5.5°C
2. Maximum Temperature: 55°C
3. Optimum Temperature: 23-28°C

Biotic Factors

Biotic factors are all of the living things in an ecosystem, such as plants and animals. These living things interact with one another in many ways. Biotic factors and their interactions can be broken down into three groups:

1. Producers. All plants, such as grass and trees, are producers. These organisms absorb the sun's energy and convert the energy into food for themselves, allowing them to grow larger, make flowers and seeds, etc.

Oxygen

Carbon dioxide



2. Consumers: These organisms, mostly animals, eat producers and/or other animals. They may also be divided into two groups: herbivores (eat plants) and carnivores (eat animals).



3. Decomposers. These organisms break down dead material (such as a fallen tree) into soil and return nutrients to the soil so they can be re-used by producers to create food. An example of a decomposer is a mushroom.



Worm

Mushroom

Insects

Bacteria

Phytohormones and their roles

• Plant Growth Regulators (Hormones)

• The organic compounds, other than water, that regulate the morphological structure and physiological concentrations are known as **Plant Growth regulators or plant hormones**.

• Plant hormones control the complete process of germination, rooting, growth, flowering, and death.

• They induced native and synthetic active regulators are as :

1. Auxins
2. Gibberellins
3. Cytokinins
4. Abscissic acid

• Functions of auxin

- Stimulates **internode elongation**.
- Stimulates leaf growth.
- Stimulates initiation of vascular tissue.
- Inhibition of root growth.
- **Differentiation of vascular tissue** (IAA).
- Auxin stimulates **root initiation** on cuttings.
- Stimulates **lateral root development** (rooting).
- Auxin mediates the **tropic response of bending to gravity and light**.

1. Auxins

- Auxins were the first plant hormones discovered.
- Auxin is a general term used to indicate substances that promote elongation of tissues.

• Indole acetic acid (IAA) is an auxin that occurs naturally in plants.

• **Natural auxins –**

• Indole-3-acetonitrile (IAN)

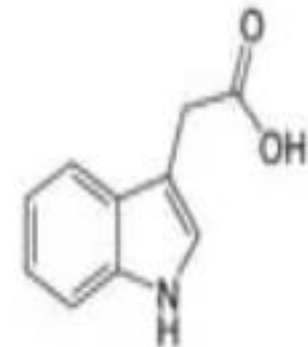
• Phenyl acetic acid

• **Synthetic auxins -**

• Indole-3-Butyric Acid (IBA),

• α -Naphthyl Acetic Acid (NAA),

• 1-naphthyl acetamide (NAD)



2. Gibberellins :

- gibberellins occur in green plants, fungi and bacteria.
- According to a research carried out in Japan, USA and Britain has shown that Gibberellins A – isolated in 1938 – is actually a mixture of at least six gibberellins named as – GA_1 , GA_2 , GA_3 , GA_4 , GA_5 and GA_6 .
- The gibberellins are named GA_1 , GA_2 in order of discovery.
- GA_1 is termed as **Gibberellic acid**.

3. Cytokinins :

- Cytokinins are compounds with a **structure resembling adenine**.
- Cytokinins have been found in almost all higher plants as well as mosses, fungi, bacteria, and also in many prokaryotes and eukaryotes.
- There are more than 200 natural and synthetic cytokinins identified.
- The first naturally occurring cytokinin was **isolated from corn** in 1961 by Miller and it was later called **zeatin**.
- The naturally occurring cytokinins are **zeatin**, N^6 dimethyl amino purine, isopentenyl aminopurine.
- The synthetic cytokinins are **kineatin**, adenine, 6-benzyl adenine, benzimidazole and N , N' -diphenyl urea.

Functions of Gibberellins :

- Stimulates **stem elongation** by stimulating cell division and elongation.
- GA controls **internode elongation** in the mature regions of plants.
- Dwarf plants do not make enough active forms of GA .
- **Flowering in biennial plants is controlled by GA** . Biennials grow one year as a rosette and after the winter, they bolt (rapid expansion of internodes and formation of flowers)
- **Breaks seed dormancy** in some plants.
- Stimulates α -amylase and other hydrolytic enzymes during germination of monocot seeds.
- Stimulates germination of pollen and growth of pollen tubes.

Functions of Cytokinins :

- **Stimulate cell division** (cytokinesis).
- Stimulate **morphogenesis** (shoot initiation/bud formation) in tissue culture.
- Stimulate the **growth of lateral** (or adventitious) roots.
- **Stimulate leaf expansion** resulting from cell enlargement.
- **May enhance stomatal opening** in some species.
- Promotes the conversion of **etioplasts into chloroplasts**.

4. Ethylene :

- It is a **simple organic molecule present in the form of volatile gas** - in ripening fruits, flowers, stem, roots, tubers, seeds.
- It is present in very small quantity, but its **quantity increases during the time of growth and development.**
- Ethylene is responsible for
 - fruit ripening,
 - leaf abscission,
 - stem swelling,
 - leaf bending,
 - flower petal discoloration and
 - **inhibition of stem and root growth,**
- It is commercially used for promotion of flowering and fruit ripening, and stimulation of latex flow in rubber trees.

5. Absciscic acid (ABA) :

- The physiological activities in plants like retaining or shedding of different organs such as leaves, flowers and fruits requires a natural growth inhibitor.
- Other synthetic ABA are **Maleic hydrazide, Daminozide, Glyphosine, Chlorophonium chloride.**
- It inhibits the gibberellins induced synthesis of **amylase** and other hydrolytic enzymes.
- ABA accumulates in many seeds and helps in **seed dormancy.**
- ABA serves as potential anti-transpirant by closing the stomata, when applied to leaves.

GERMINATION



What is Germination

- **Germination** is the process by which a plant grows from a seed.
- **Germination** is emergence of normal seedlings from the seeds under ideal conditions of light, temperature, moisture, oxygen and nutrients.
- **Germination** is emergence of radicle and plumule through Seed Coat

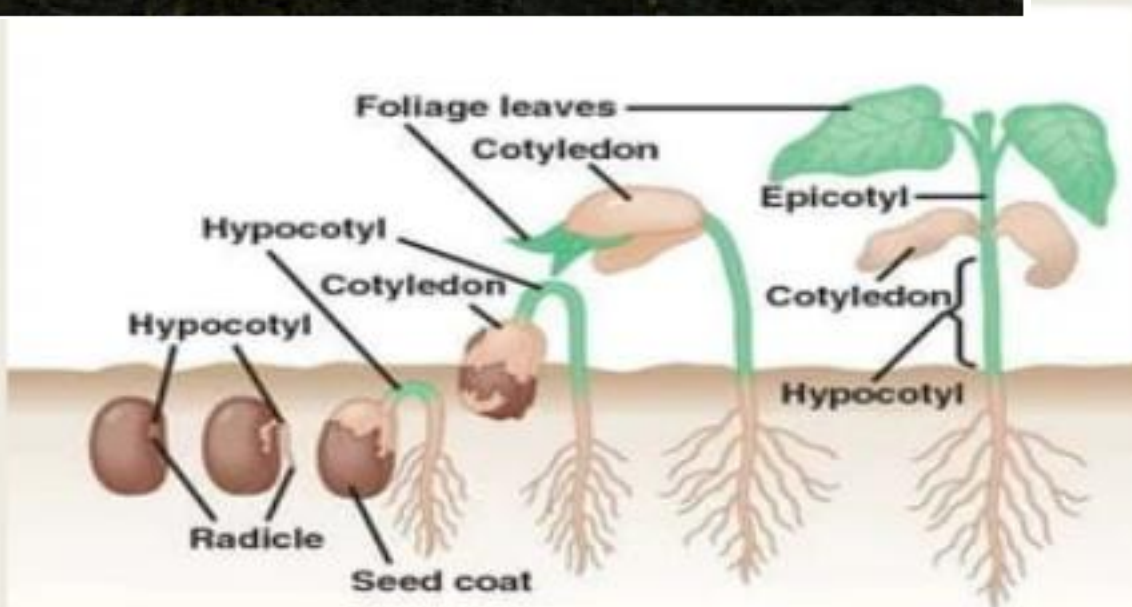


Fig.: Germination of Common bean



Requirements for Germination

External factors:

- ✓ Water,
- ✓ Temperature,
- ✓ Oxygen or aeration,
- ✓ Light or darkness,

Internal factors:

- ✓ Seed vitality,
- ✓ Genotype,
- ✓ Seed maturation,
- ✓ Seed dormancy.

Often this depends on the individual seed variety and is closely linked to the ecological conditions of a plant's natural habitat



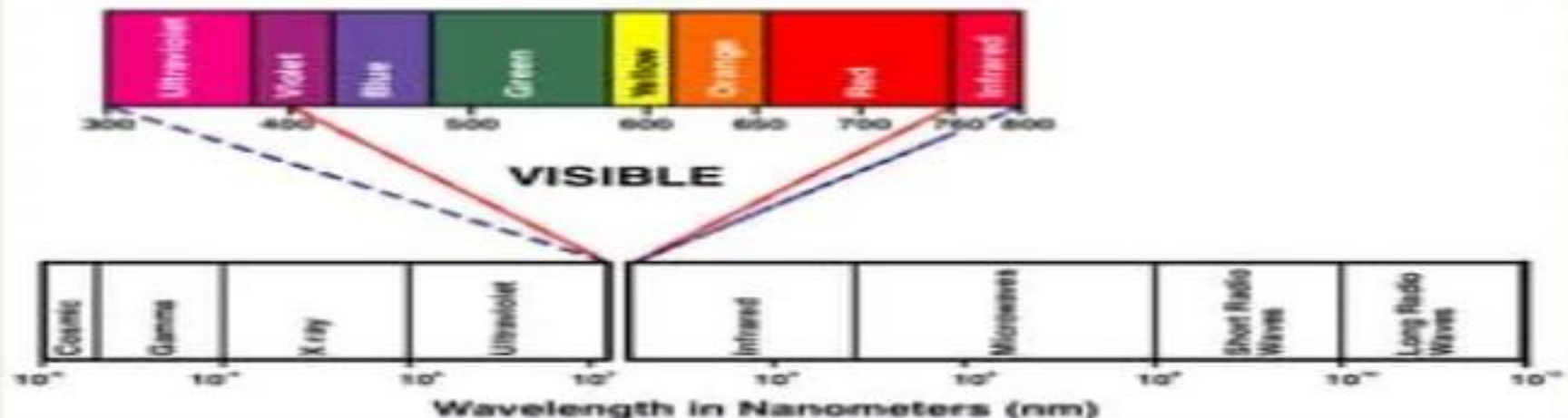
Requirements for Germination

Light

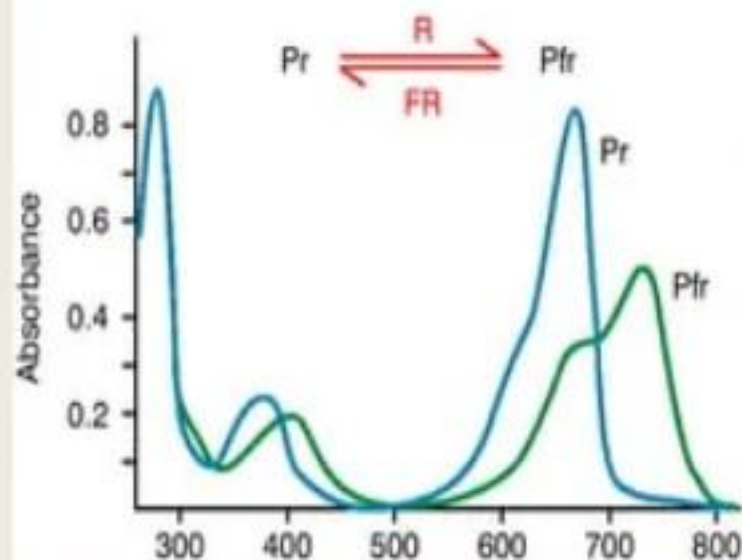


- Phytochrome is a plant pigment found in cytoplasm that senses the presence of red light.
- Phytochrome absorbs light in two inter-convertible forms.
 - 1) Pr is metabolically inactive & absorbs red light (660 nm.)
 - 2) Pfr is metabolically active and gets transformed from Pr. The latter promotes germination and other phytochrome-controlled processes in plants. Pfr reverts back to Pr after absorbing far-red (730 nm.).

LIGHT SPECTRUM



PHYTOCHROME ABSORBANCE



Factors for Germination

Seed Factor for Germination	Field factor for Germination
➤ Viability	➤ Good tilth
➤ Vigor	➤ Optimum soil moisture
➤ Seed age	➤ Optimum soil temperature
➤ Free from Dormancy	➤ Aeration
➤ Free from injury	➤ Free from obstacle

Stages of Seed Germination

STAGE	EVENTS
PREGERMINATION	(a) Rehydration – imbibitions of water. (b) RNA & protein synthesis stimulated. (c) Increased metabolism – increased respiration. (d) Hydrolysis (digestion) of food reserves by enzymes. (e) Changes in cell ultrastructure. (f) Induction of cell division & cell growth.
GERMINATION	(a) Rupture of seed coat. (b) Emergence of seedling, usually radicle first.
POST GERMINATION	(a) Controlled growth of root and shoot axis. (b) Controlled transport of materials from food stores to growing axis. (c) Senescence (aging) of food storage tissues.

Dormancy

INTRODUCTION

- ❖ Dormancy :
- During the developmental cycle of the plant, at some phase certain structures like buds, tubers, seeds, go through a period of temporary suspension of growth activity or slow down for a period of time or deep sleep, such a state is called **Dormancy**.
- This minimizes metabolic activity and therefore helps an organism to conserve energy.
- **Dormant** = not active or growing but able to become active later.

TYPES OF DORMANCY

- ❖ According to Wareing (1969) the dormancy may be two types :
- 1) **Imposed dormancy or quiescence** :
 - The dormancy due to unfavourable environmental conditions is called **imposed dormancy or quiescence**.
- 2) **Innate dormancy or rest** :
 - The dormancy due to conditions within the dormant plant or organ is called **innate dormancy or rest**.
 - It is a condition in which germination or growth fails to occur even though the external environmental conditions are favourable.

- ❖ During the entire process, there may be following three phases of dormancy :

1) Pre-dormancy or early rest :

- During these phase, the dormant organ has capacity to resume growth by various treatments i.e., capacity of germination or growth is not completely lost. It is called **predormancy**.

2) Full dormancy or mid rest :

- When a seed or organ becomes completely dormant and germination or growth cannot be induced by changes in environmental conditions, it is called **full dormancy or mid rest**.



3) Post dormancy or after rest :

- When a dormant seed or organ gradually emerges from full dormancy and in it the germination or growth can be induced by changing environmental conditions, it is called **post-dormancy** or **after rest**.

- ❖ The dormancy may be true, relative or secondary :

1) True dormancy :

- When in a seed or organ, the germination or growth cannot be induced under any set of environmental conditions. it is called **true**

2) Relative dormancy :

- When in a seed, the germination can be induced under specific conditions even at the time of its deepest dormancy, it is called **relative dormancy**.

3) Secondary dormancy :

- When a seed has not fully emerged from dormancy and is again thrown back into full dormancy by certain environmental conditions, e.g., temperature etc., it is called **secondary**

TYPES OF SEED DORMANCY

- ❖ Crocker (1916) divided seed dormancy into two types :

1) Seed coat induced dormancy :

- The dormancy of seeds due to extreme hardness of seed coat is called **seed coat induced dormancy**.

2) Embryo induced dormancy :

- The dormancy of seeds due to rudimentary or complete dormant embryo is called **embryo induced dormancy**.

- ❖ Other types of dormancy may be –

3) Secondary dormancy :

- When the seed become dormant again after breaking the dormancy, it is called **secondary dormancy**.
- It may be due to combination of different kinds of dormancy in a single seed, e.g., *Xanthium pennsylvanicum*.

4) Special type of dormancy :

- The failure of seedling development is not always traceable due to dormancy of seed itself.

classification system which include five classes of seed dormancy –

- (1) Physiological dormancy
- (2) Morphological dormancy
- (3) Morpho-physiological dormancy
- (4) Physical dormancy
- (5) Combinational dormancy

INTRODUCTION

- **Vernalization** word derived (from Latin *vernus*, "of the spring")
- Literal meaning of vernalisation is bringing to spring condition.

"Vernalization is the induction of a plant's flowering process by exposure to the prolonged cold of winter, or by an artificial equivalent".

- For some plants , vernalization is an absolute requirement or in some cases it simply assists in flowering.
- The duration of low temperature treatment required varies from four days to three months.

TYPES OF VERNALIZATION

1. FACULTATIVE VERNALIZATION

Flowering will appear earlier once exposed to low temperature
Eg., Winter annual Triticale (fig 1)

2. OBLIGATE VERNALIZATION

Must expose to low temperature to a desired period of time
Eg., Biennial plants (Cabbage) fig 2



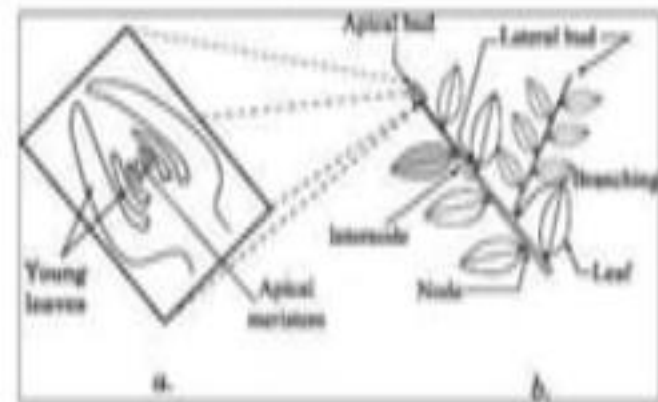
(fig 1)



(fig 2)

SITE OF VERNALIZATION

- Metabolic active **apical meristem** is the site of temperature perception for flower initiation.
- **Younger leaves** are more susceptible to vernalization.
- The low temperature stimulus is received by the **shoot apex** of a mature stem or embryo of the seed.





FACTORS AFFECTING VERNALIZATION

1. Water and Oxygen

- Seed need to imbibe 10-20 % water, dry seed cannot be vernalized.
- Similarly oxygen is also necessary for vernalization. Oxygen is used during respiration. A germinating seed need energy. This energy is provided by respiration. The inhibition of respiration blocks the process of vernalization.

2. Temperature

- The seeds are exposed to low temperature during vernalization.
- Temperature lower than 4°C is not effective. Similarly, temperature above 12°C does not cause vernalization, the duration of vernalization varies in different species.

3. Devernalization

The exposing of vernalized seed to high temperature (30 -35°C) , lose the effect of vernalization called as Devernalization.

4. Effect of light

- The seed of a plant can be vernalized by light.
- But many plants like carrot require vernalization. They must be first vernalized before flowering.

5. Effect of hormones

Many species like carrot and Hyacinth require vernalization. These plants show rapid flowering both bolting and flowering.

REQUIREMENTS OF VERNALIZATION

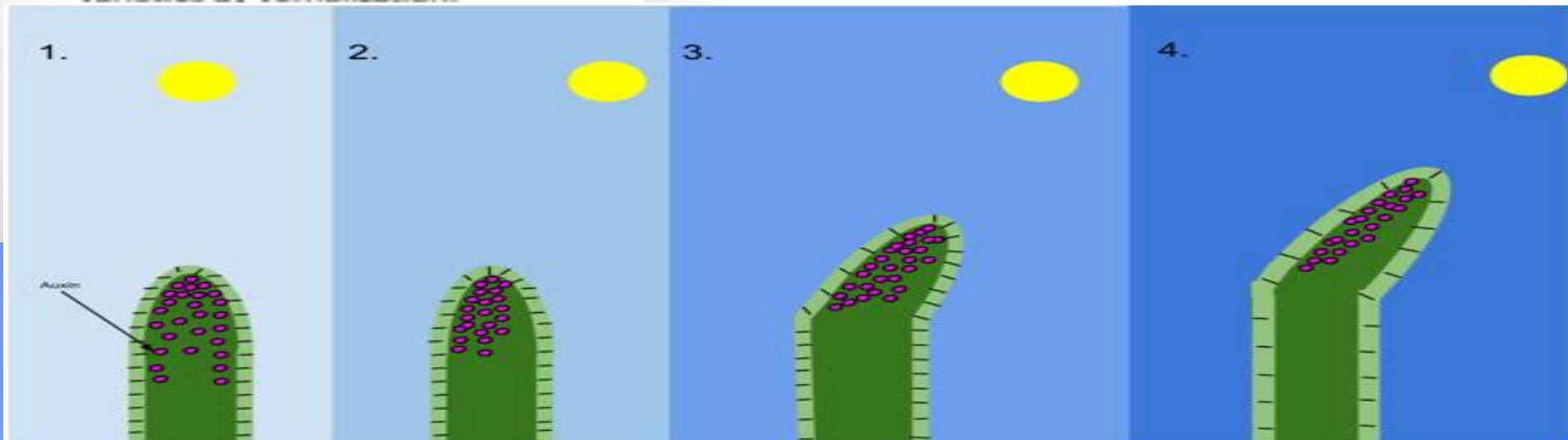
- I. **Low Temperature** : Low temperature required for vernalization is usually 0° - 5°C .
- II. **Period of Low Temperature Treatment** : It varies from a few hours to a few days.
- III. **Actively Dividing Cells**
- IV. **Oxygen** : The vernalization is an aerobic process and requires metabolic energy. In the absence of O_2 , cold treatment becomes completely ineffective.
- V. **Water** : Sufficient amount of water is also essential for vernalization. Vernalization of the dry seed is not possible.
- VI. **Proper Nourishment**

Importance of vernalization

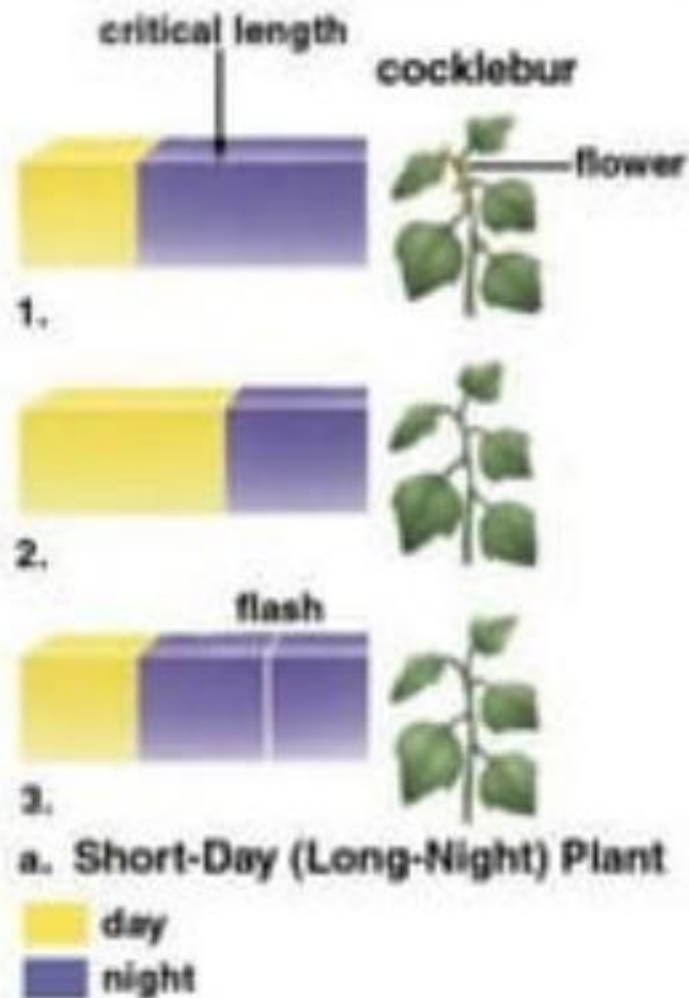
- Vernalization shortens the vegetative period.
- It increases cold resistance of the plant.
- Vernalization increases the resistance to frost.
- In biennials, vernalization induces flowering.
- A non vernalized shoot apex can be converted to a vernalized plant.
- Winter varieties of crop plants can be converted to summer varieties by vernalization.

PHOTOPERIODISM

- Photoperiodism is the phenomenon of physiological changes that occur in plants in response to relative length of day and night (i.e. photoperiod).
- Plant in order to flower require a particular day length or light period called **photoperiod** and response of plants to photoperiod in terms of flowering is called photoperiodism.
- It influences plant development such as leaf fall, dormancy and tuber formation but its major effect is on control of flowering.



Photoperiodism



CLASSIFICATION OF PLANTS BASED ON PHOTOPERIODIC RESPONSES

Garner and Allard classified the plants into **5 types** based on their photoperiod response of flowering:

1. Short day plants (SDP)
2. Long day plants (LDP)
3. Day neutral plants (DNP)
4. Short-long-day plants (SLDP)
5. Long-short-day plants (LSDP)

1. Short day plants

- These plants require a relatively short day light period (usually 8-10 hours) and a continuous dark period of about 14-16 hours for subsequent flowering.
- In short day plants, the dark period is critical and must be continuous. If this dark period is interrupted with a brief exposure of red light (660-665 nm wavelength), the short day plant will not flower.
- On the other hand, a brief period of darkness during day time had no effect on flowering.
- Because of the importance of dark period in flowering, these are also called as **Long Night Plants**.
- **E.g. Rice, Coffee, Soybean, Tobacco, Chrysanthemum, Xanthium and Morning glory (*Ipomoea purpurea*)**

2. Long day plants

- These plants require longer day light period (usually 14-16 hours) in a 24 hours cycle for subsequent flowering.
- These plants are also called as **short night plants**.
- In long day plants, light period is critical and a brief exposure of red light in the dark period or the prolongation of light period stimulates flowering in long day plants
- **E.g. Barley (winter barley), Wheat, Henbane (*Hyoscyamus Niger*), Radish, Cabbage, Sugar beet, Spinach, carrot, lettuce and onion**

3. Day neutral plants

- Indeterminate or DNP flowers readily over a wide range of day length from relatively SDL to continuous illumination.
- **E.g. Tomato, Chilly, Potato, Cotton, Sunflower, Cucumber, Peas, Balsam and Maize**

4. Short-long day plants

- These are long day plants but must be exposed to short day during early periods of growth for subsequent flowering.
- These plants require first short photoperiod and then long photoperiod for flowering.
- **E.g. Winter rye , Candy tuft**

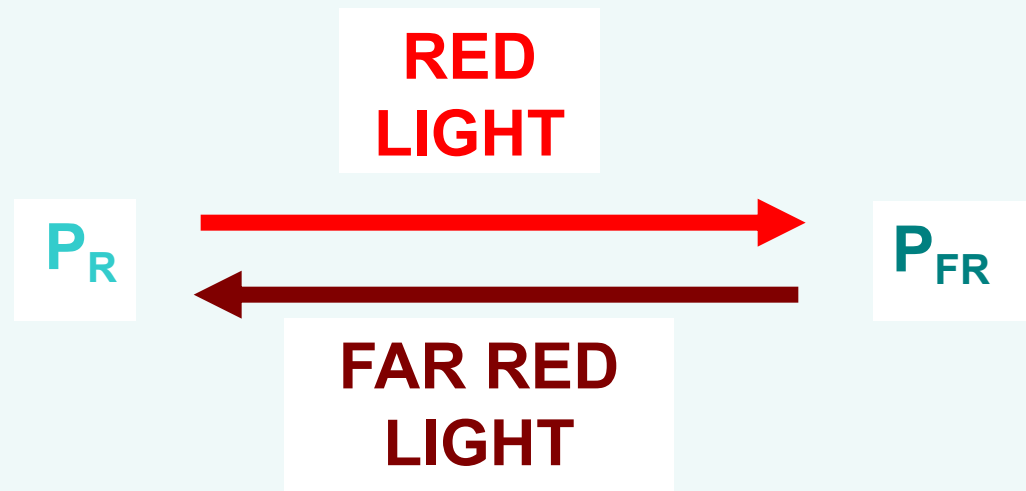
5. Long-short day plants

- These are short day plants but must be exposed to long days during early periods of growth for subsequent flowering.
- These plants require first long days and then short photoperiod for flowering.
- These plants do not flower when exposed to either SD or LD and need both LD and SD for its flowering.
- **E.g. Bryophilum , Cestrum Nocturnum (Night blooming Jasmine)**

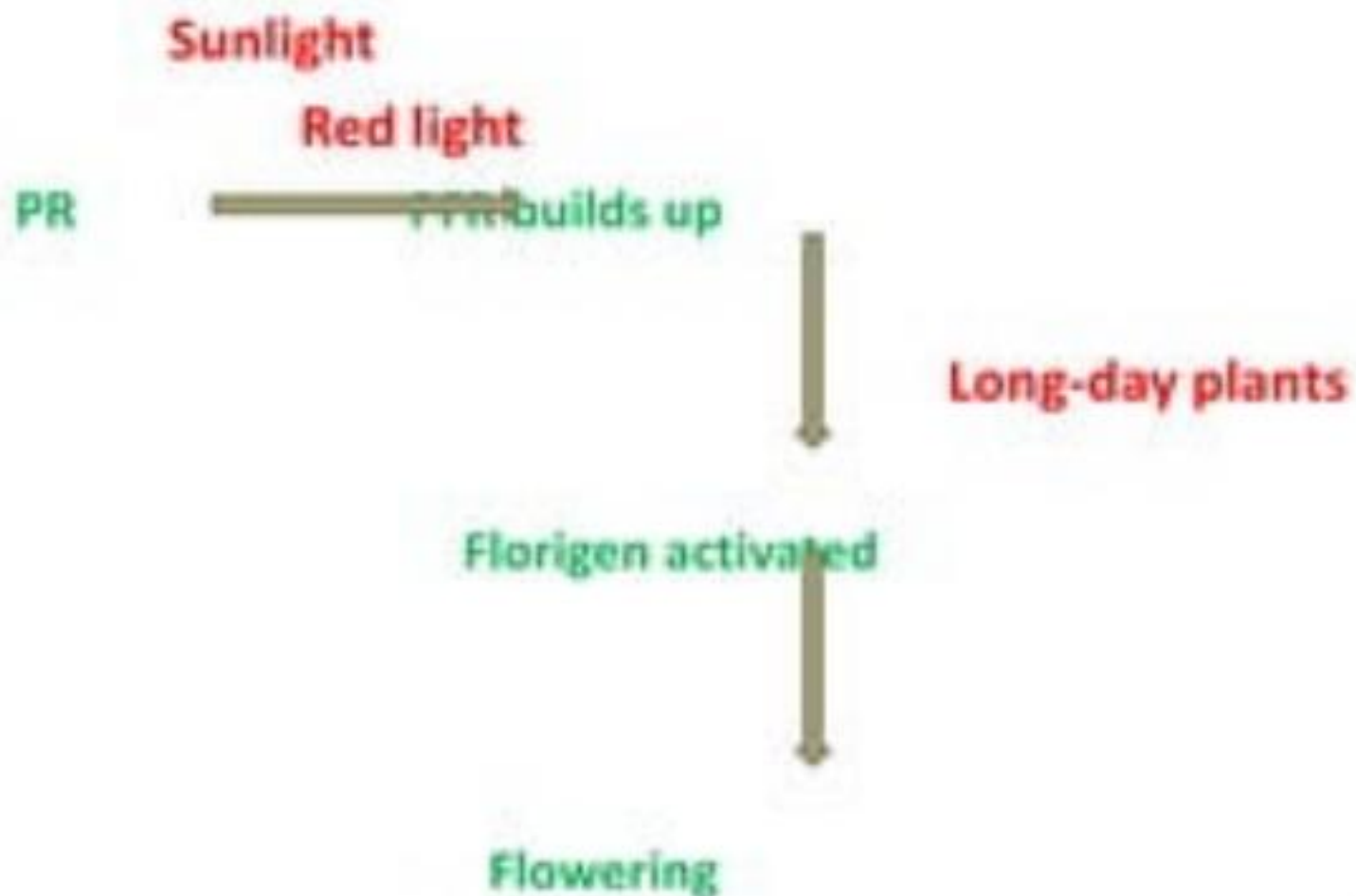
LDP	SDP	DNP
Long Day Plant	Short Day Plant	Day Neutral Plants
Flowering is induced under Long Day Length conditions	Flowering is induced under Short Day Length condition	Flowering is not dependent upon Day Length conditions
Long Day length	Short Day length	Independent of light
Short Night Length or Short Night Plants	Long Night Length or Long Night Plants	Throughout the year
Summer Variety's	Winter Variety's	All time available
Eg. Spinach, Wheat, Raddish , Beet, lettuce	Eg. Cosmos, Dahlia Chrysanthemum, Marigold	Eg. Tomato, Cucumber, Sunflower

The photoperiod mechanism

- Phytochrome exists in two versions which are inter-convertible
- P_R that absorbs red light
- P_{FR} that absorbs far red light



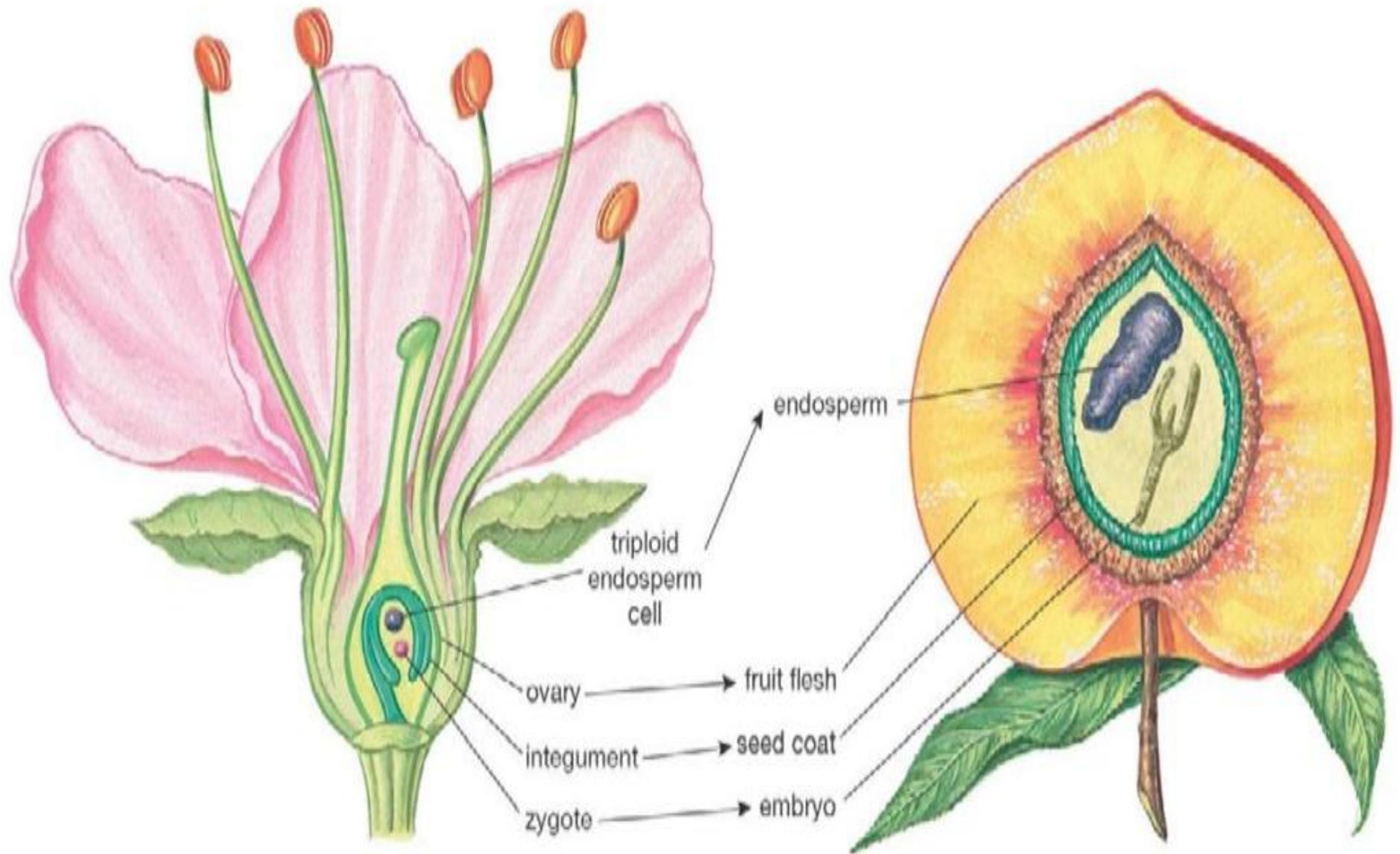
In the long-day plant



§ 3:

fructification

Development of flower



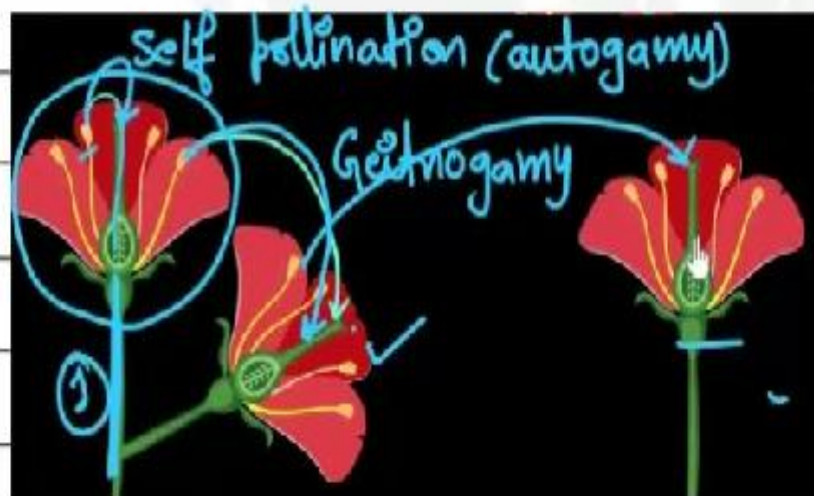
key concept = Pollination

transfer of pollen grain
from anther to stigma

self
① Autogamy
transfer of pollen grain from same flower anther to stigma.

② Geitonogamy
Transfer of pollen grain from different flower of same plant

③ Xenogamy
transfer of pollen grain from different plant of different flower

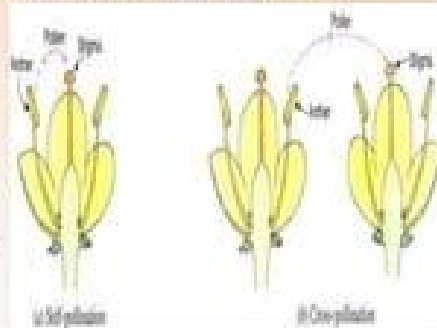


Mode of pollination

• 1) Autogamy

- Development of seed by self pollination.
- Several mechanism that promotes self pollination

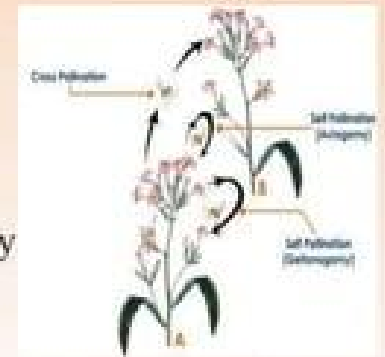
- I. Bisexuality
- II. Homogamy
- III. Cleistogamy
- IV. chasmogamy



• 2) Allogamy

- Development of seed by cross pollination
- Mechanisms which promotes autogamy

- I. Dicliny
- II. Dichogamy
- III. Heterostyly
- IV. Herkogamy
- V. Self incompatibility
- VI. Male sterility



• Mode of Pollination

The process by which pollen grains are transferred from anthers to stigma is referred as **pollination**. Pollination is of two types: viz. 1) Autogamy or self pollination and 2) Allogamy or cross pollination.

• I. Autogamy/ Self pollination

Transfer of pollen grains from the anther to the stigma of same flower is known as autogamy or self pollination. Autogamy is the closest form of inbreeding. Autogamy leads to **homozygosity**.



Mechanism promoting self-pollination

1. **Bisexuality**- Presence of male and female organs in the same flower is known as bisexuality. The presence of bisexual flowers is a must for self pollination. All the self pollinated plants have **hermaphrodite** flowers.
2. **Homogamy**- Maturation of anthers and stigma of a flower at the same time is called **homogamy**. As a rule, homogamy is essential for self-pollination.
3. **Cleistogamy**- When pollination and fertilization occur in unopened flower bud, it is known as **cleistogamy**. It ensures self pollination and prevents cross pollination. some varieties of wheat, barley, oats and several other grass species.

4. **Chasmogamy**- Opening of flowers only after the completion of pollination is known as chasmogamy. This also promotes self pollination and is found in crops like wheat, barley, rice and oats.

5. **Position of Anthers**- In some species, stigmas are surrounded by anthers in such a way that self pollination is ensured. Such situation is found in tomato and brinjal. In some legumes, the stamens and stigma are enclosed by the petals in such a way that self pollination is ensured. Examples are green gram, black gram, soybean, chickpea and pea.

II. **Allogamy/ Cross pollination:**

- Transfer of pollen grains from the anther of one plant to the stigma of another plant is called **allogamy or cross pollination**.
- This is the common form of out breeding. Allogamy leads to heterozygosity.



2. **Dichogamy**. (from the Greek *dikho*-apart and *gamous*-marriage) It refers to maturation of anthers and stigma of the same flowers at different times. Dichogamy promotes cross pollination even in the hermaphrodite species. Dichogamy is of two types: viz. i) **protogyny** and ii) **protandry**.

Protogyny -When pistil matures before anthers, it is called **protogyny**. pearl millet.



Protandry- When anthers mature before pistil, it is known as **protandry**. Maize, sugarbeet and several other species.

3. **Heterostyly**. When styles and filaments in a flower are of different lengths, it is called **heterostyly**. It promotes cross pollination, such as linseed.

4. **Herkogamy**. Hinderance to self-pollination due to some physical barriers such as presence of hyline membrane around the anther is known as herkogamy. Such membrane does not allow the dehiscence of pollen and prevents self-pollination such as in alfalfa.



5. **Self incompatibility**: The inability of fertile pollens to fertilize the same flower is referred to as self incompatibility. It prevents self-pollination and promotes cross pollination. Self incompatibility is found in several crop species like *Brassica*, *Radish*, *Nicotiana*, and many grass species. It is of two types **sporophytic** and **gametophytic**.

Mechanism promoting cross-pollination

1. **Dicliny**. It refers to unisexual flowers. This is of two types: viz. i) monoecy and ii) dioecy. When male and female flowers are separate but present in the same plants, it is known as **monoecy**.

❖ In some crops, the male and female flowers are present in the same inflorescence such as in mango, castor and banana. In some cases, they are on separate inflorescence as in maize. Other examples are cucurbits, grapes, strawberry, cassava and rubber.

❖ When staminate and pistillate flowers are present on different plants, it is called **dioecy**. It includes papaya, date palm, spinach, hemp and asparagus.

- Study of **floral biology** and aforesaid mechanisms is essential for determining the mode of pollination of various crop species.
- Moreover, if selfing has adverse effects on seed setting and general vigour, it indicates that the species is cross pollinated. If selfing does not have any adverse effect on these characters, it suggests that the species is self-pollinated.

6. **Male sterility**: In some species, the pollen grains are non functional. Such condition is known as **male sterility**. It prevents self-pollination and promotes cross pollination. It is of three types: viz. **genetic**, **cytoplasmic** and **cytoplasmic genetic**. It is a useful tool in hybrid seed production.

Pollinators

- Wind
- Water
- Animals
 - insects
 - mammals
 - spiders
 - kangaroos
 - humans
 - + others

birds
monkeys
bats
mites



Types of Pollination

- Self pollination
- Wind pollination
- Water pollination
- Animal pollination



Fertilisation

- ▶ Fertilisation is the fusion of the male (n) and female (n) gametes to produce a zygote (2n)
- ▶ The pollen grain produces the male gametes
- ▶ Embryo sac produces an egg cell and polar nuclei

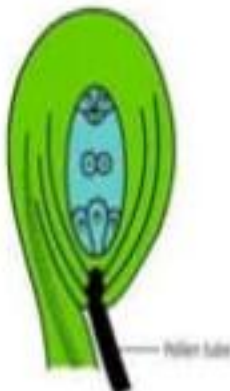
Fertilisation

- ▶ Entry of pollen tube is 3 types
- ▶ A. Porogamy
- ▶ B. Mesogamy
- ▶ C. Chalazogamy

Fertilisation

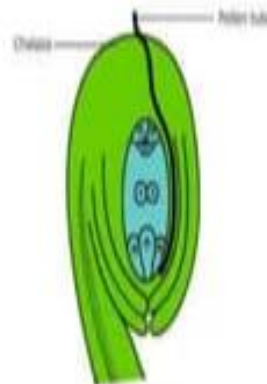
Fertilisation

- ▶ **Porogamy**: enters through micropyl

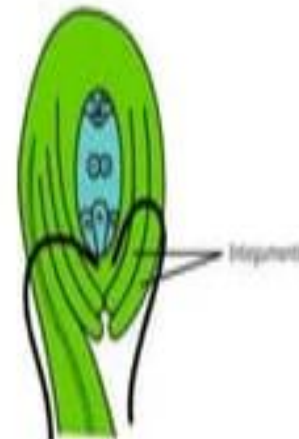


Fertilisation

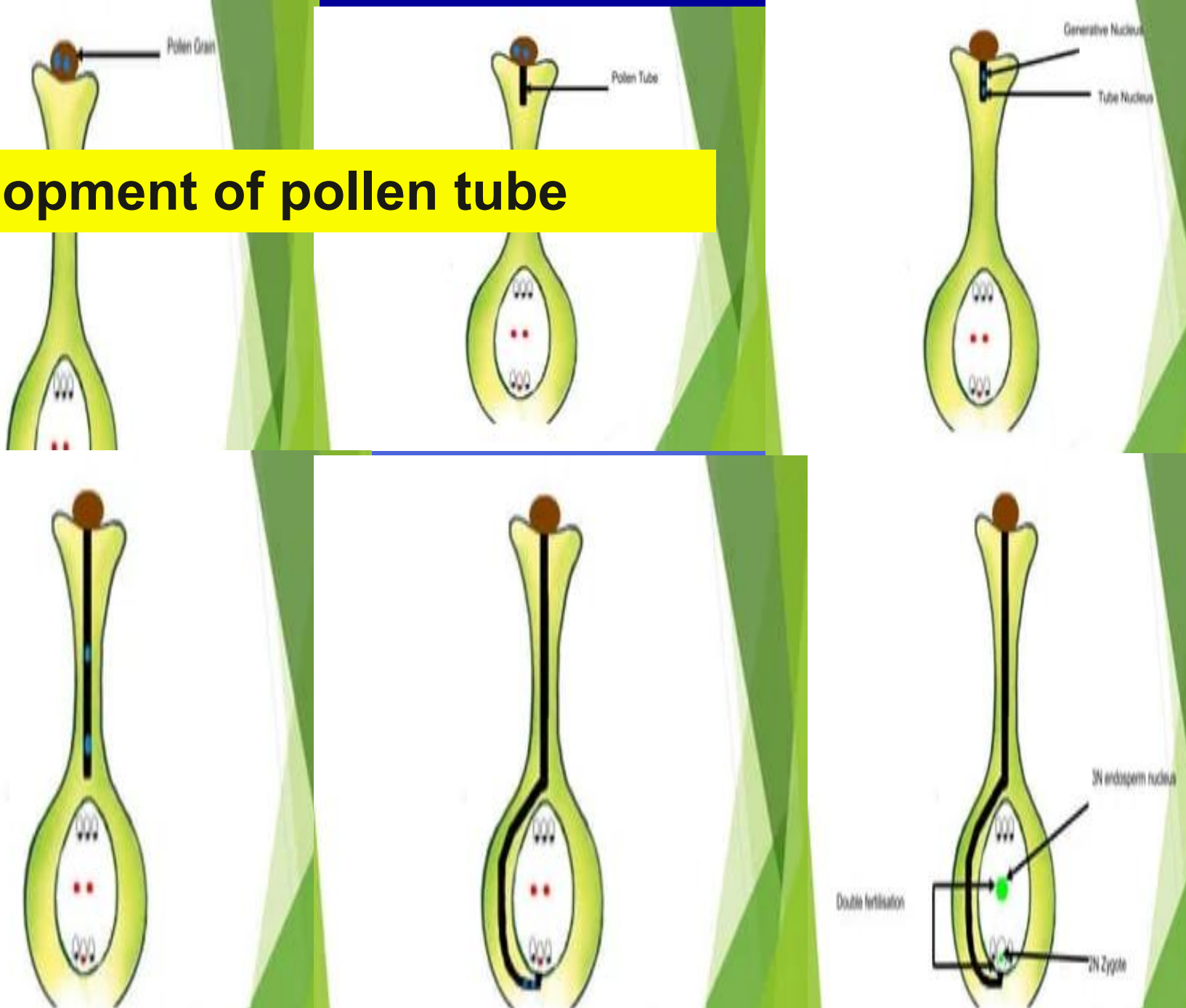
- ▶ **Chalazogamy**: enters through Chalaza.



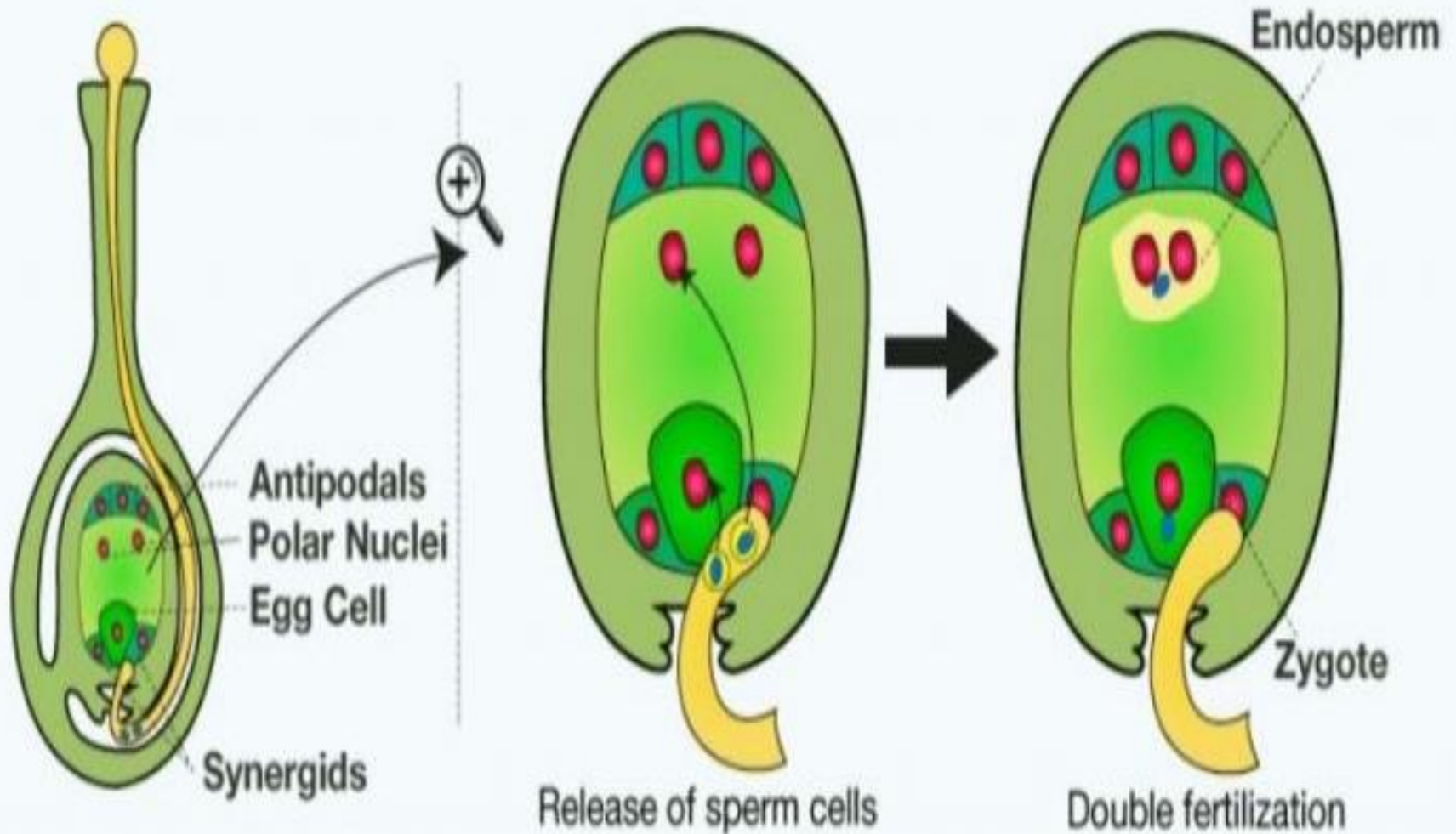
- ▶ **Mesogamy**: enters through integuments.



Development of pollen tube



WHAT IS DOUBLE FERTILIZATION?

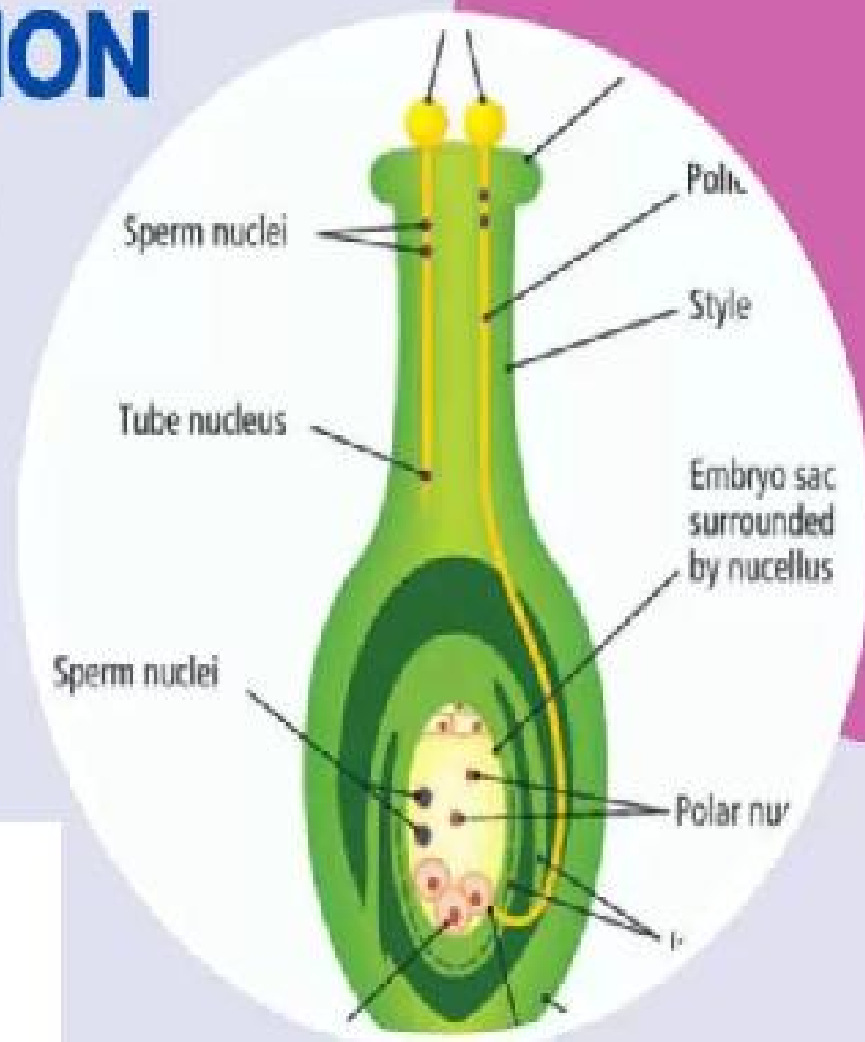


Seed Growth

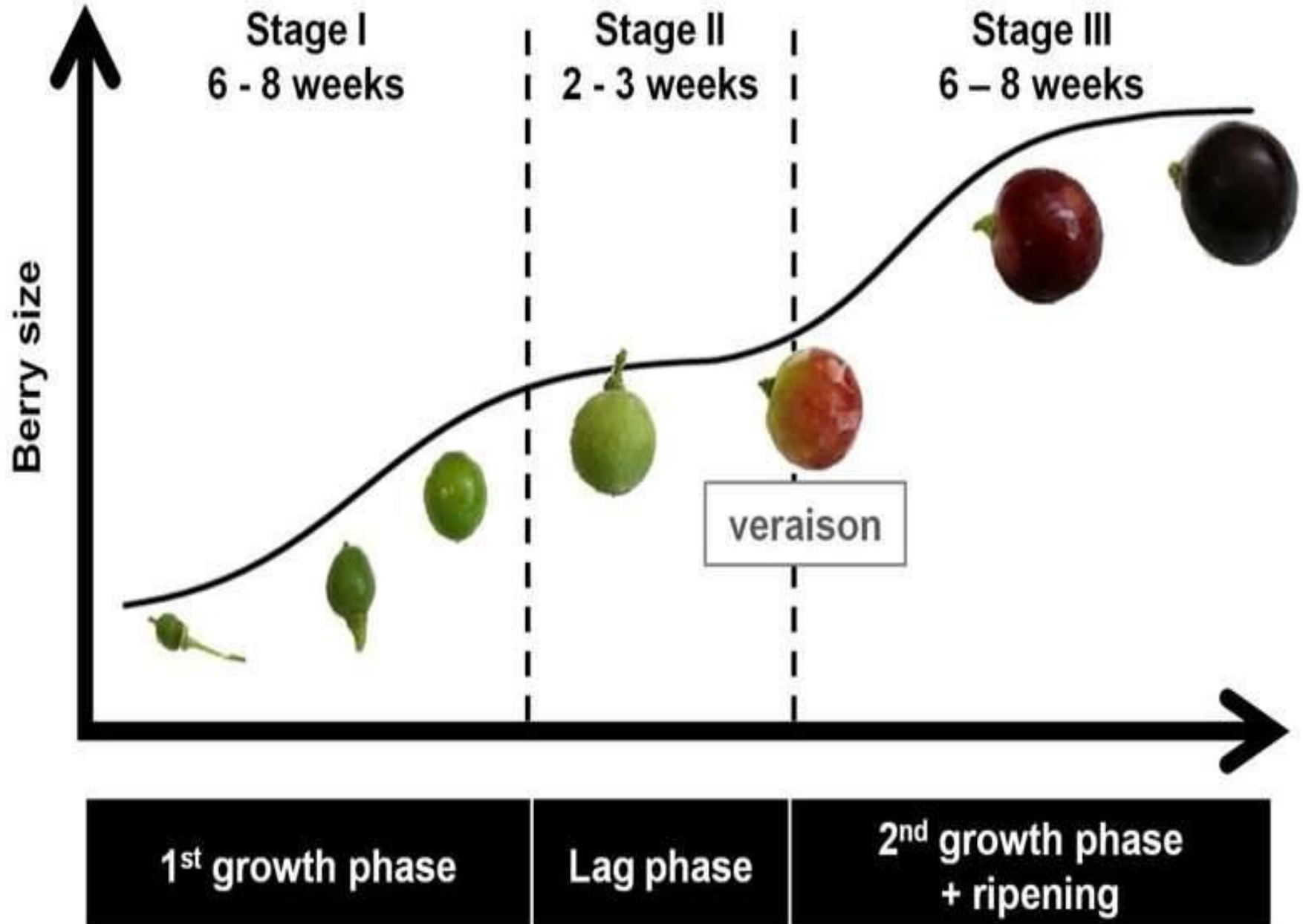
In angiosperms, the seed development involves double fertilization, the fusion of the egg nuclei into a zygote. As part of this process, one of the polar nuclei and a sperm cell nucleus fuse to form a primary endosperm.

DOUBLE FERTILIZATION

Double fertilization is a unique process in flowering plants where two sperm cells fertilize distinct female gametes.

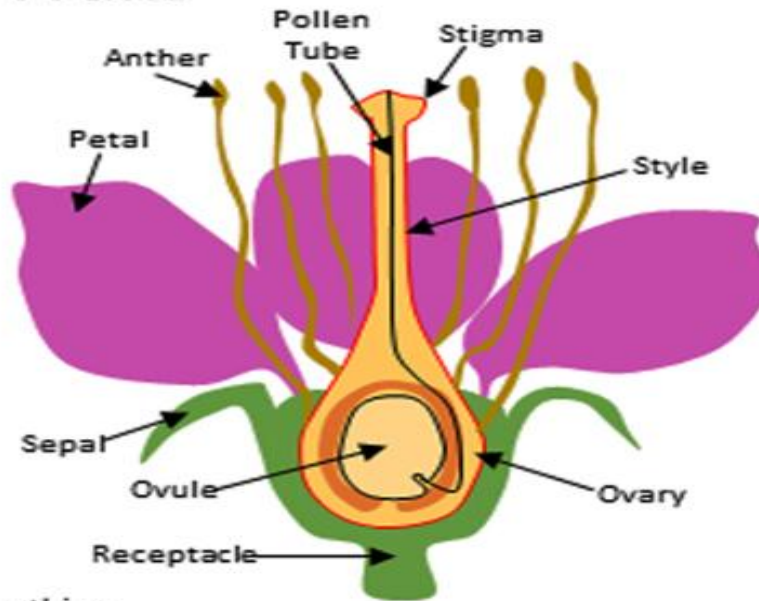
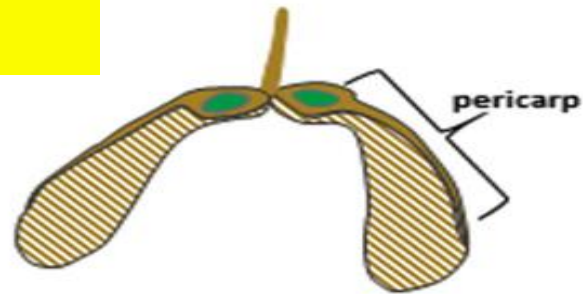


growth of fruits

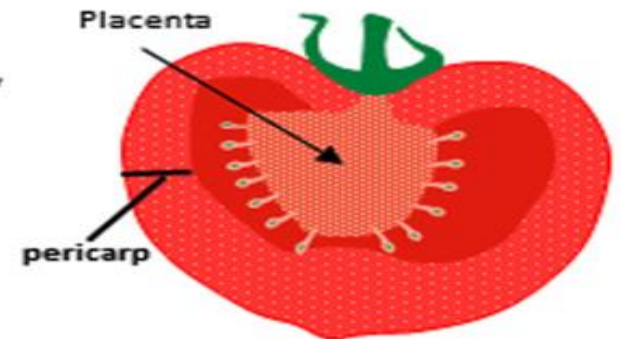
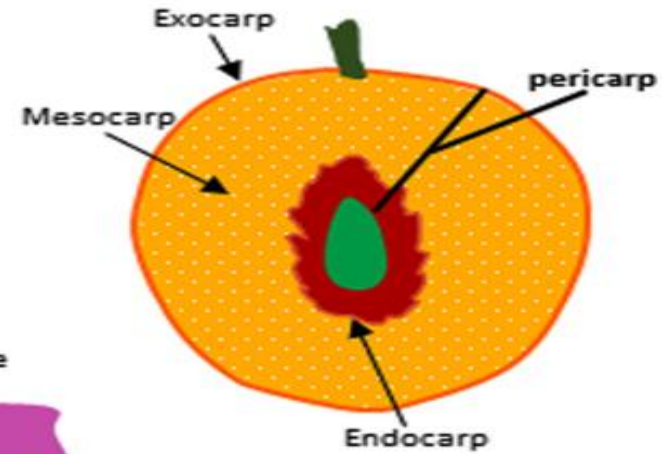


Types of fruits

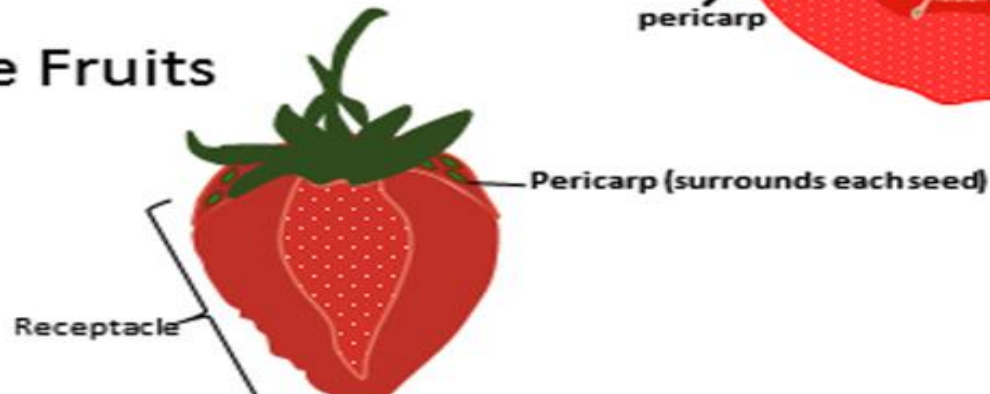
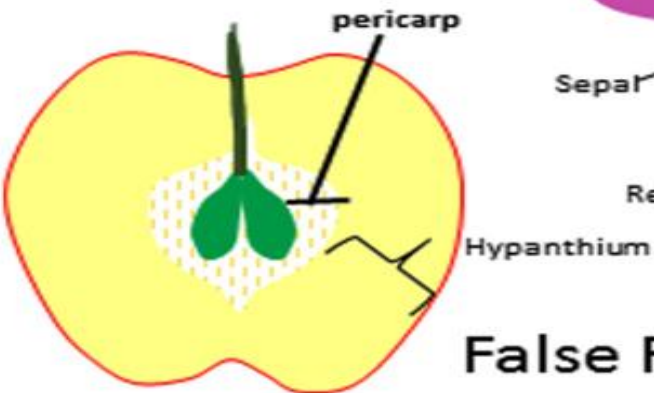
Dry Fruits



Fleshy Fruits



False Fruits



Types of Fruits

1. Simple
2. Aggregate
3. Composite

These fruits develop from the monocarpellary ovary or multicarpellary syncarpous ovary. Only one fruit is formed by the gynoecium. Simple fruits are of two types:

- **Fleshy Fruits:** In fleshy fruits, the fruit wall is differentiated into epicarp, mesocarp, and endocarp. These fruits develop from superior or inferior syncarpous gynoecium.
- **Dry Fruits:** The pericarp of simple dry fruits is usually quite dry and hard. It is not differentiated into the three layers of epicarp, mesocarp and endocarp. In some dry fruits, this pericarp is broken down and the seeds are scattered or dispersed. These fruits are dehiscent fruits.
- In some fruits, the pericarp is further arranged into one or more seeded segments. Such fruits are schizocarpic fruits. In some fruits, the pericarp is not observed to be dehiscent even after maturing/ripening. Such fruits are indehiscent Fruits.

Part 2: Nutrition

§ 1: water nutrition

- Water is an essential nutrient for plants and comprises up to 95% of a plant's tissue.
- It is required for a seed to sprout, and as the plant grows, water carries nutrients throughout the plant.
- Water is responsible for several important functions within plant tissues.
- Plants are about 80-95% water and need water for multiple reasons as they grow including for photosynthesis, for cooling, and to transport minerals and nutrients from the soil and into the plant.
- Water is the transport medium for nutrients absorbed by plant roots and transported throughout the plant tissues (transpiration). Water evaporation (transpiration) from the plant leaves helps cool the plant,
- The structure of plant roots, stems, and leaves facilitates the transport of water, nutrients, and products of photosynthesis throughout the plant.
- The phloem is the tissue primarily responsible for movement of nutrients and photosynthetic produces, and xylem is the tissue primarily responsible for movement of water.

5 properties of water

These properties include:

- high boiling
- melting points
- high specific heat
- high surface tension
- the ability to dissolve many substances

These properties allow water to regulate temperature, transport nutrients, and provide a suitable environment for biological processes to occur

The characteristics of water can be classified into three broad categories:

- ✓ Physical Characteristics: temperature, color, odor, turbidity and solids.
- ✓ Chemical Characteristics: pH, conductivity, salinity, hardness,
- ✓ Biological Characteristics: counts of specific organisms and groups of organisms. ... **movement of water in plants**

Transpiration is the loss of water from a plant in the form of water vapor. Water is absorbed by roots from the soil and transported as a liquid to the leaves via xylem. In the leaves, small pores allow water to escape as a vapor and CO_2 to enter the leaf for photosynthesis.

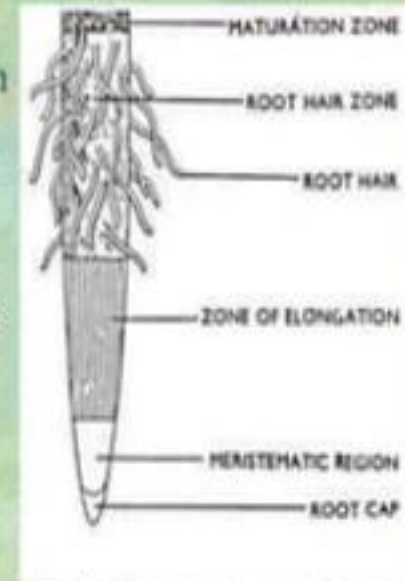
ABSORPTION OF WATER

- ✓ Uptake of water by plant is called **absorption** of water.
- Plant **absorb** water from the soil through the **root hairs**.
- Water is said to be the liquid gold of life.
- Plant are capable of absorbing water from soil solution.
- Mainly absorb capillary water.
- Plant also absorb dissolved nutrients along with water.

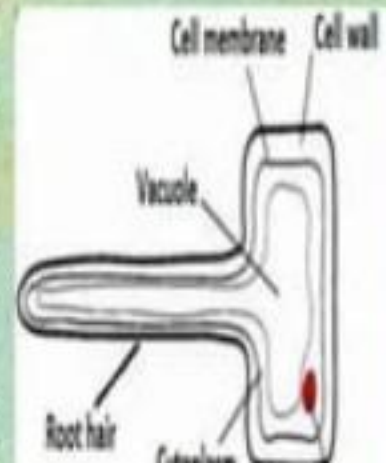


Site of Water Absorption

- ✓ Water is mainly absorption of root hairs.
- ✓ Located in a group just above the root cap.
- ✓ This area rich in root hairs is called **root hair zone**.



- Root hair is modified epidermal cell
- The wall of the root is permeable to water it is made up of cellulose and pectic substances which are strongly hydrophilic (water loving in nature)
- Next cell wall there is plasma membrane enclosing cytoplasm, nucleus and vacuole.
- Vacuole is filled with cell sap whose water potential is more negative than



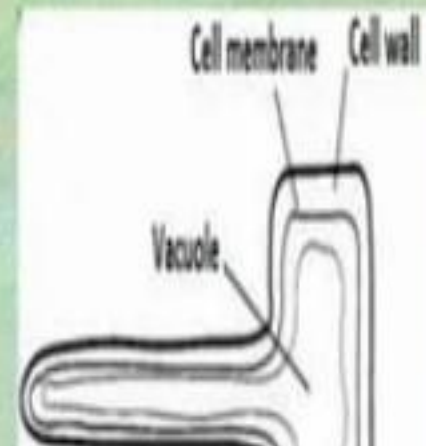
Typical Root Hair

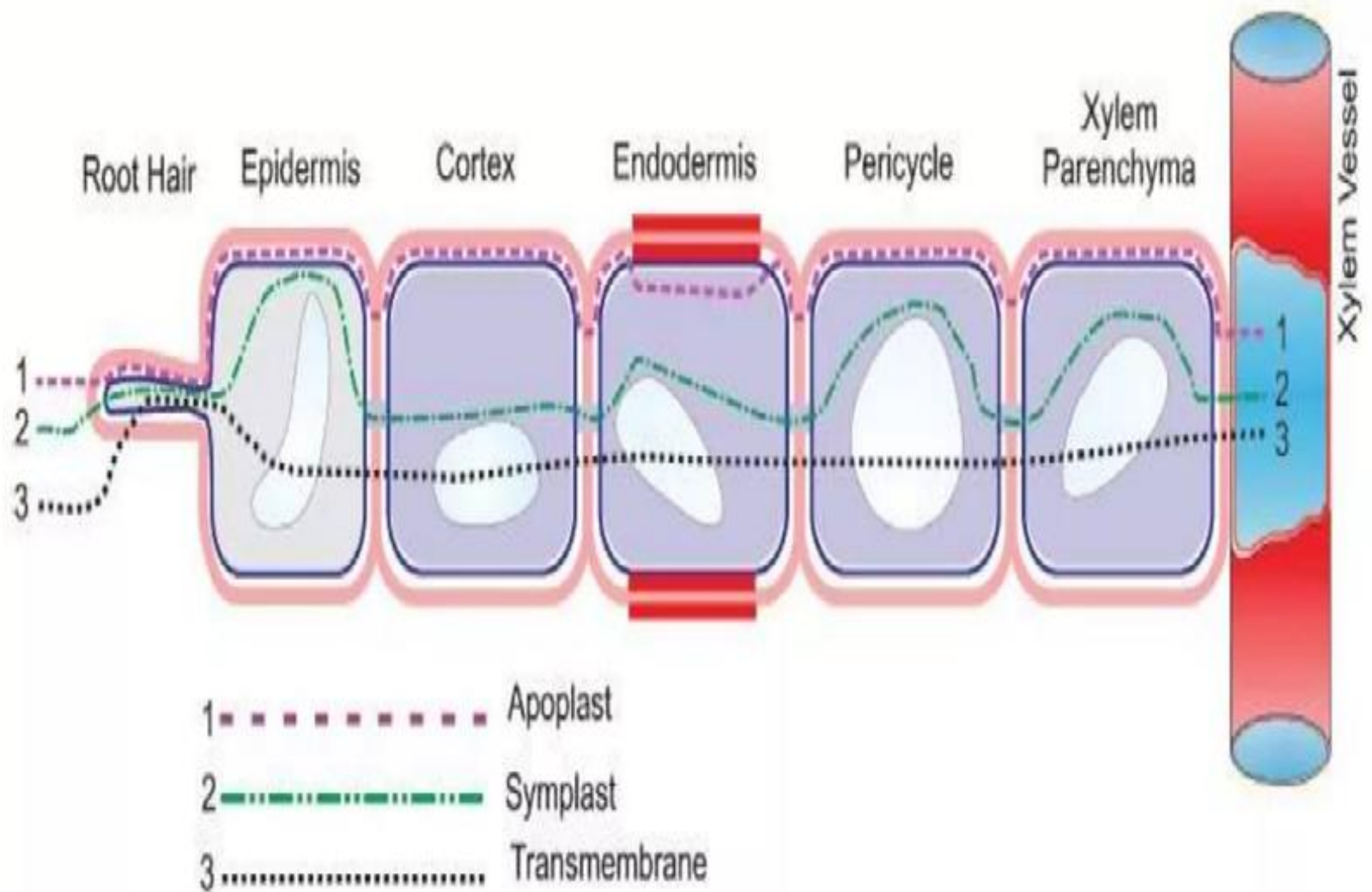
Billions of root hairs in the root system of a plant.

Root hairs are tubular hair like projections of the epidermal cells.

Each root hair is single cell.

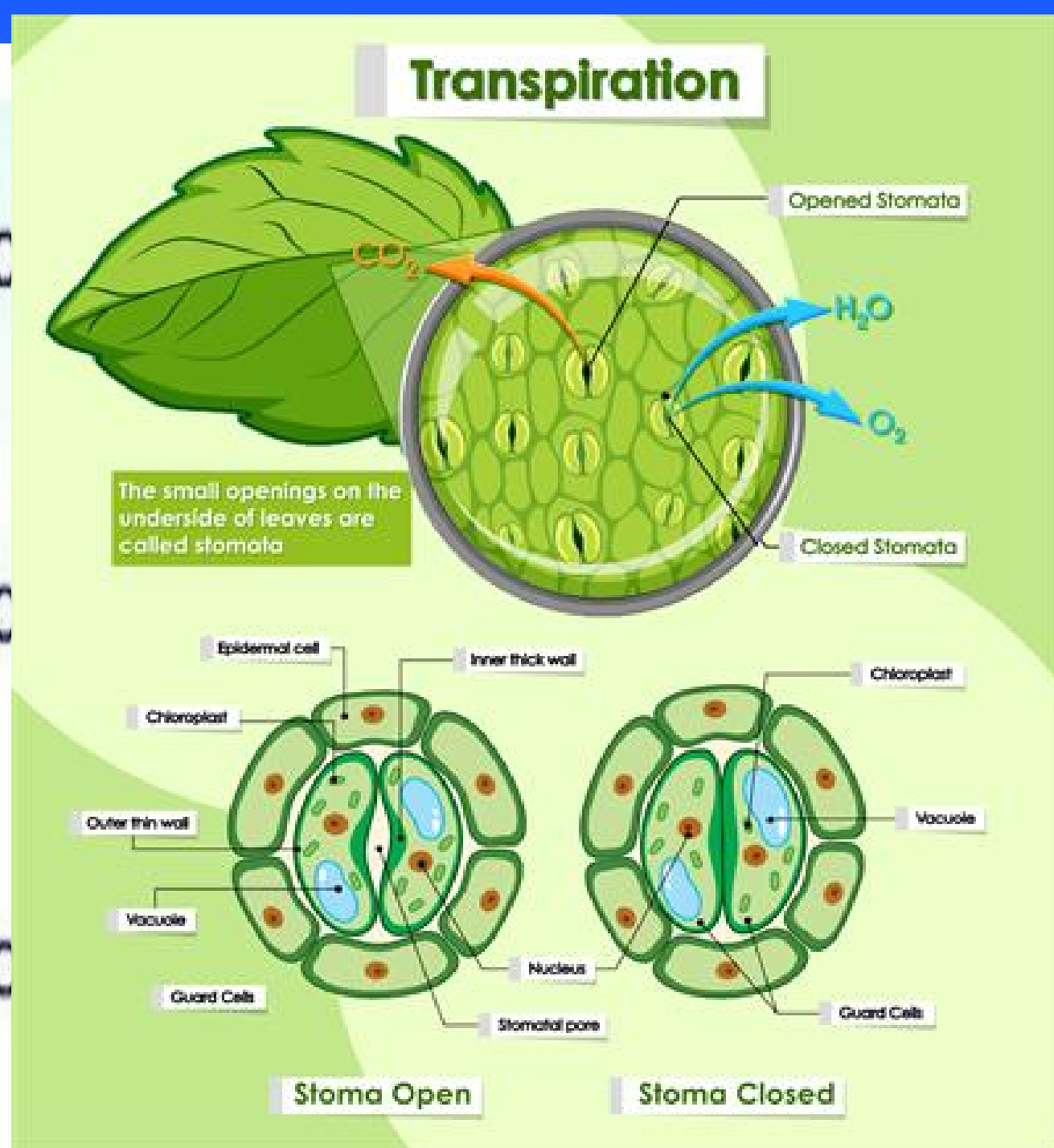
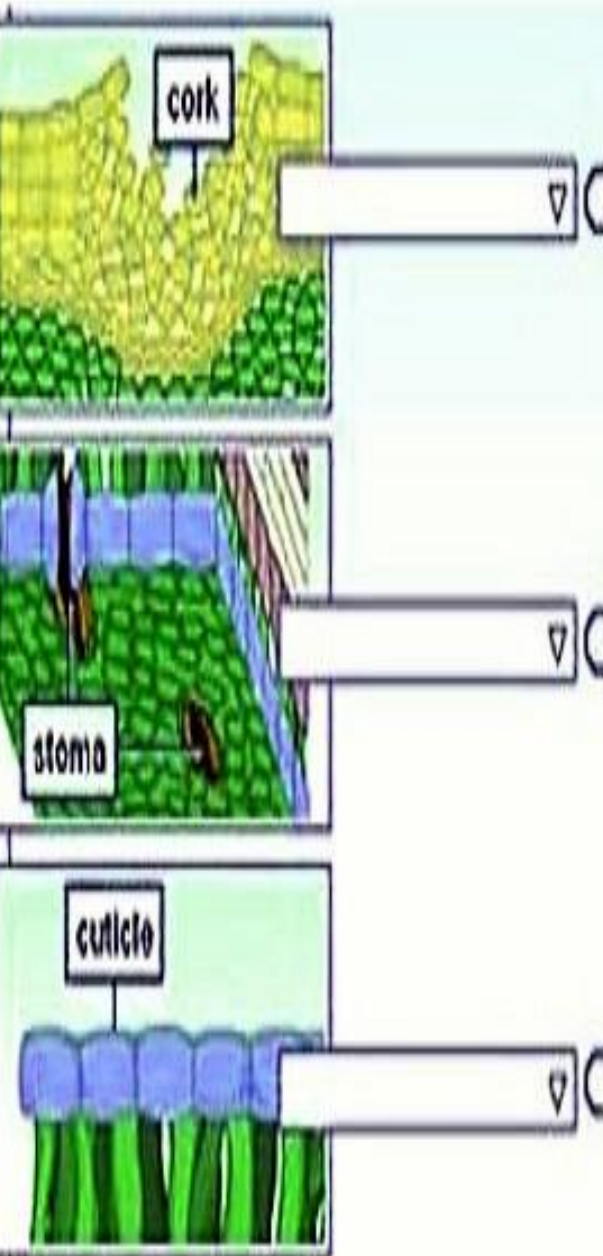
Root hairs are 0.5 to 1.0 cm in





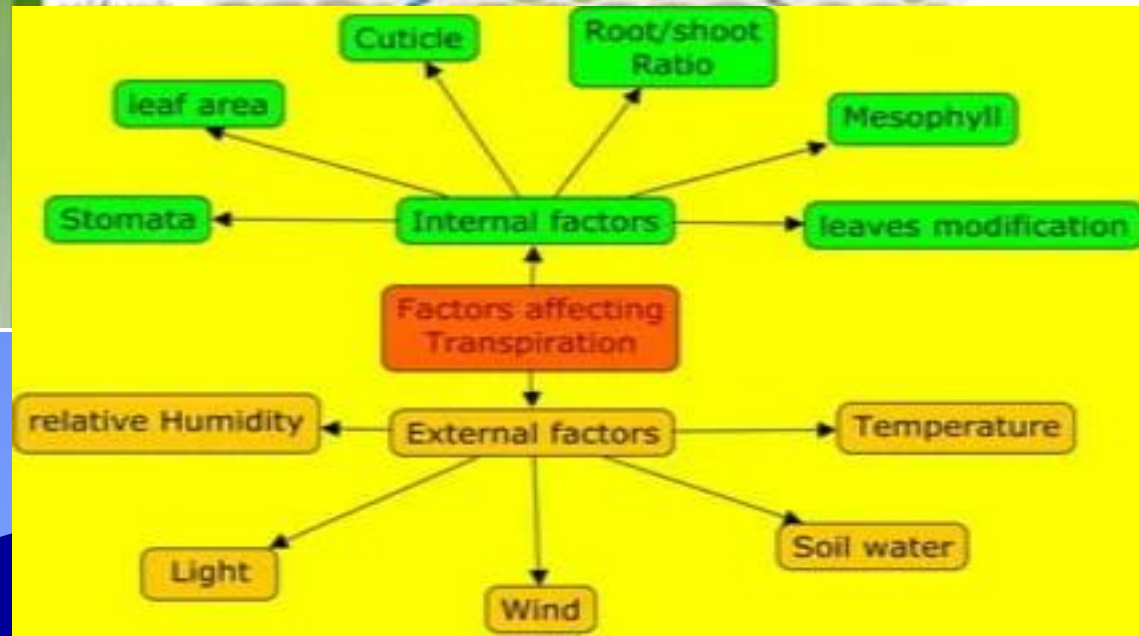
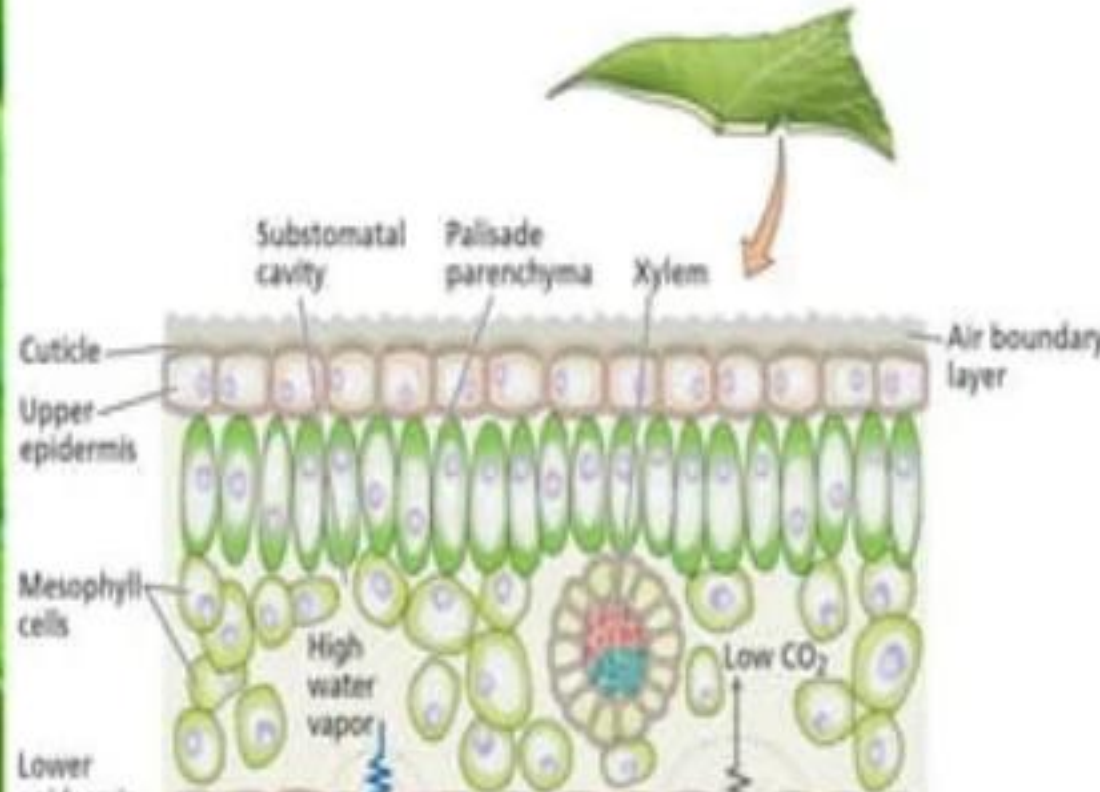
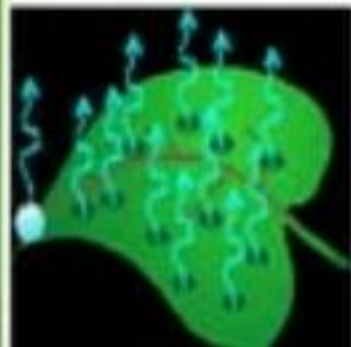
Path of water across root cells

Transpiration

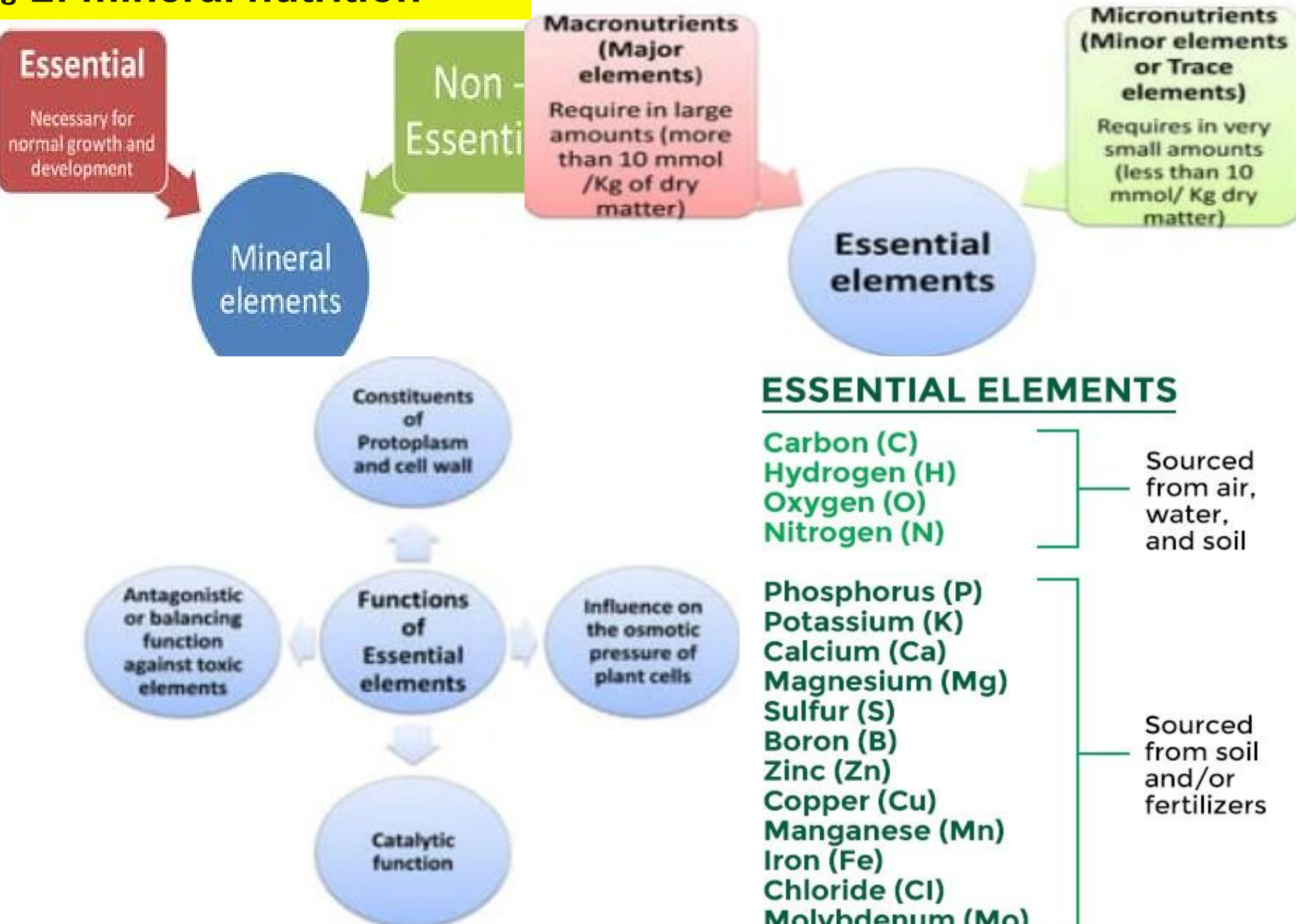


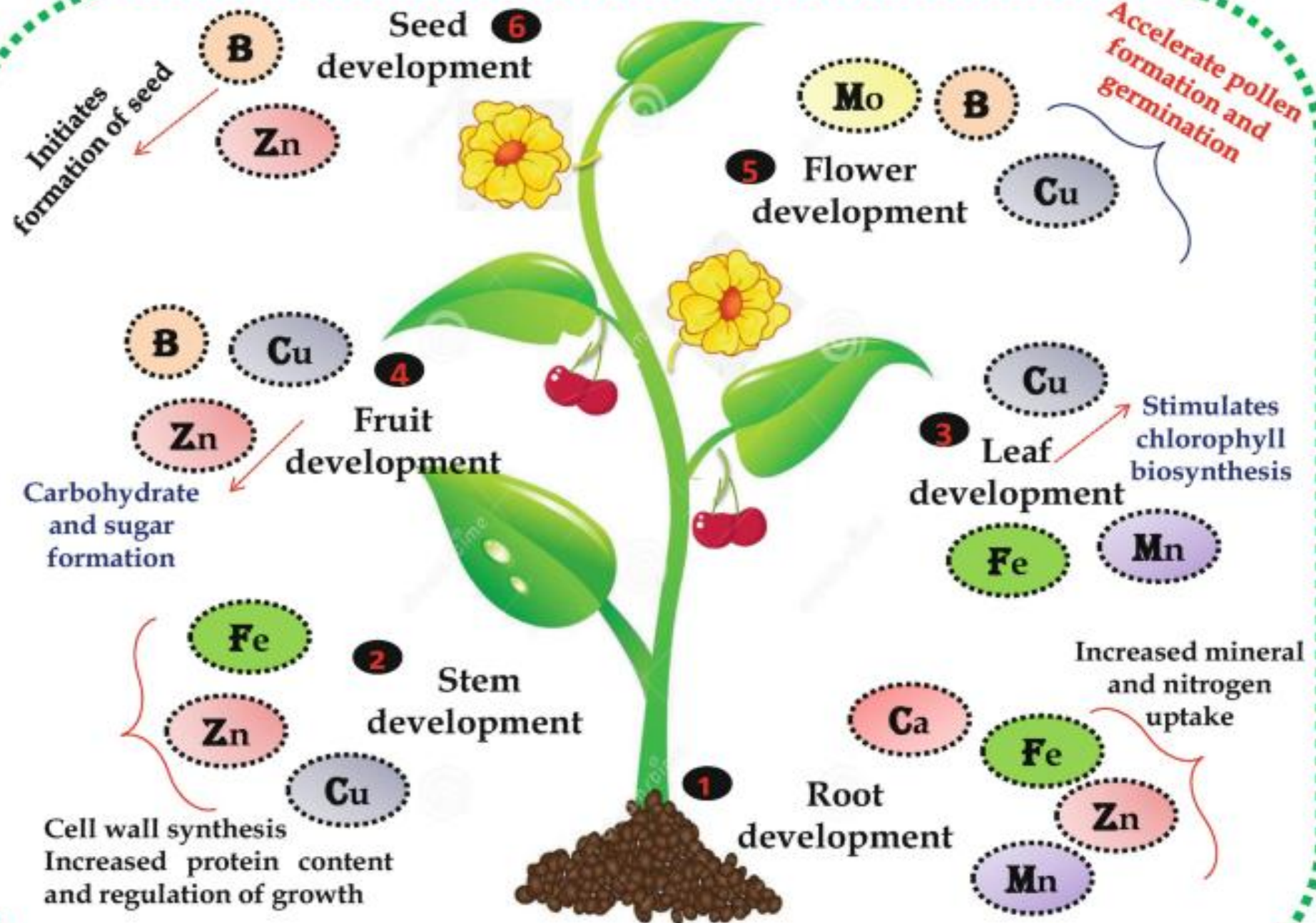
So mechanism of transpiration steps:

- Absorption at the roots
- Capillary action in the xylem
- Evaporation at the leaves



§ 2: mineral nutrition





Morphological responses triggered by micro and macro elements

Simple plant deficiency

Mineral deficiency and excess

Calcium

New leaves misshapen or stunted.
Existing leaves remain green.

Iron

Young leaves are yellow and white with green veins. Mature leaves are normal.

new growth

old growth

Nitrogen

Upper leaves are light green where lower leaves are yellow. Bottom or older leaves are yellow and shrivelled.

Potassium

Yellowing at the tips and edges, usually in younger leaves. Dead or yellow patches develop on leaves.

Carbon Dioxide

White deposits on leaves. Stunted growth, and plant die back

Manganese

Yellow spots and or elongated holes between veins.

Phosphate

Leaves are darker than normal and loss of leaves.

Magnesium

Lower leaves turn yellow from outside going in, veins remain green



§ 3: carbon nutrition

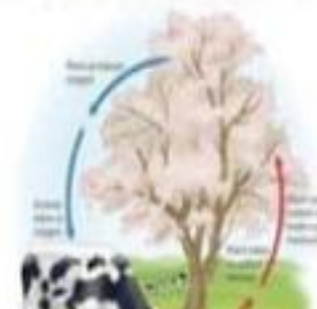
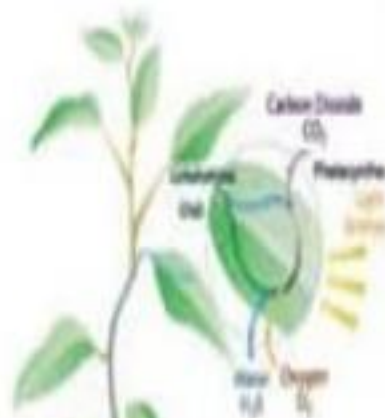
Heterotrophic Nutrition –

The word Heterotrophic is the combination of two words i.e. Hetero + Trophos. Hetero means 'others' and 'trophos' means nourishment. If organisms depend on others for their food, it is called the Heterotrophic Nutrition.

Animals cannot make their food themselves. They depend for food upon plants. Therefore, nutrition in animals is called Heterotrophic Nutrition. Animals are known as Heterotrophs.

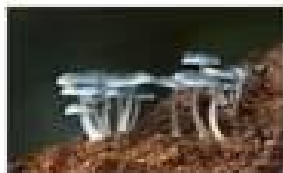
Autotrophic Nutrition -

Auto means self and trophos means nourishment. Plants are called autotrophs because they make their food themselves. The making of food for themselves is called the Autotrophic nutrition. Autotrophic nutrition is



Saprotrophic Nutrition –

The taking of nutrients by organism from dead and decaying matter in the form of solution is called the saprotrophic nutrition. The organisms which use saprotrophic mode of nutrition are called saprotrophs. For example: fungi.



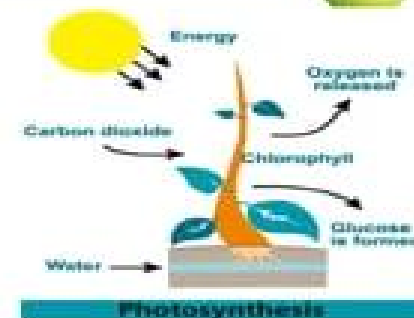
Photosynthesis - Food Making Process in Plants

The process of making of food by green plants in the presence of sunlight and chlorophyll is known as photosynthesis.

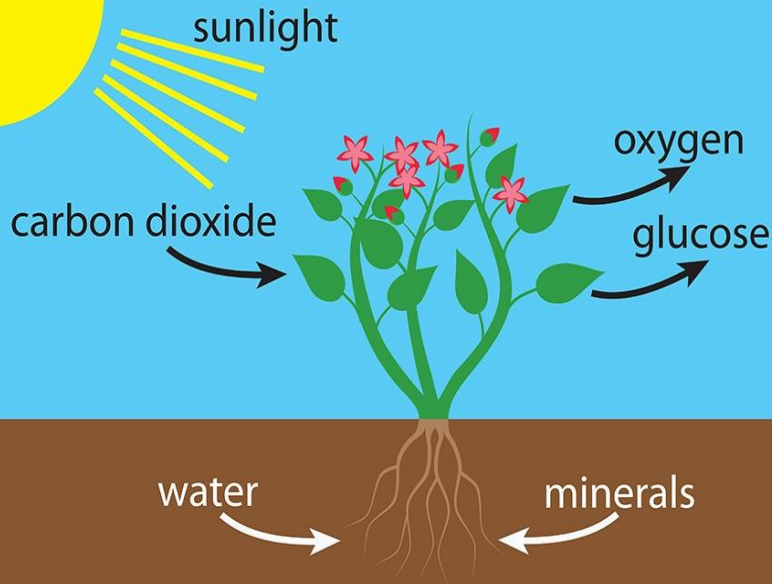
Photosynthesis is the combination of two words- Photo + Synthesis. 'Photo' means light and 'Synthesis' means to make.

Process of food making in green plants:
Green plants make their food themselves. Green leaves make food from Carbon dioxide and water in the presence of sunlight and chlorophyll.

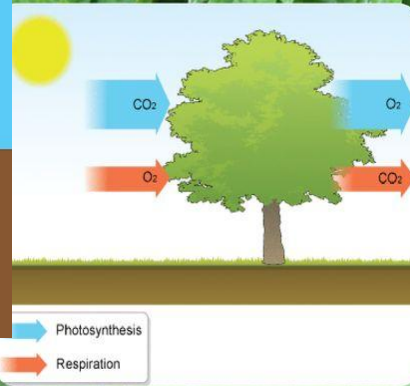
Hence, for taking place of photosynthesis carbon dioxide, water and sunlight must be reached at the green leaves in addition to presence of chlorophyll.



Photosynthesis



Photosynthesis takes carbon dioxide from the air, water and sunlight to create sugar. After this happens, oxygen is released back into the air.

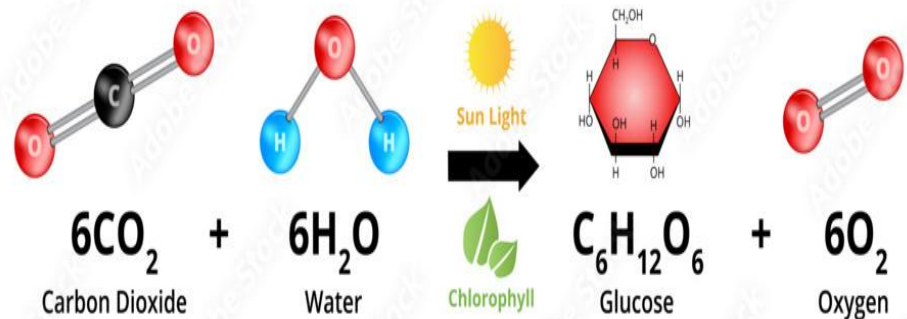


Cellular respiration takes the sugars and combines them with oxygen to release the energy as ATP. Carbon dioxide and water are released.

Using more of the light energy, hydrogen (H) left from the water molecule combines with the carbon dioxide (CO₂) to make glucose (C₆H₁₂O₆).



Photosynthesis



pigments of photosynthesis

PIGMENTS IN PLANTS:-

The Principal pigments in plants are:-

1. Chlorophyll
2. Carotenoids
3. Xanthophylls
4. Anthocyanins
5. Betalins



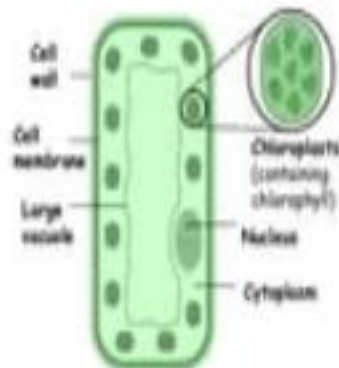
CHLOROPHYLL

- Primary pigment in plant.
- Chlorin absorbs yellow and blue wavelengths.
- Reflecting green.
- All land plants and green algae have two types of chlorophyll.
- Chlorophyll a and Chlorophyll b.
- Kelps and photosynthetic heterokonts contain Chlorophyll c.
- Chlorophyll serve as fuel to photosynthesis

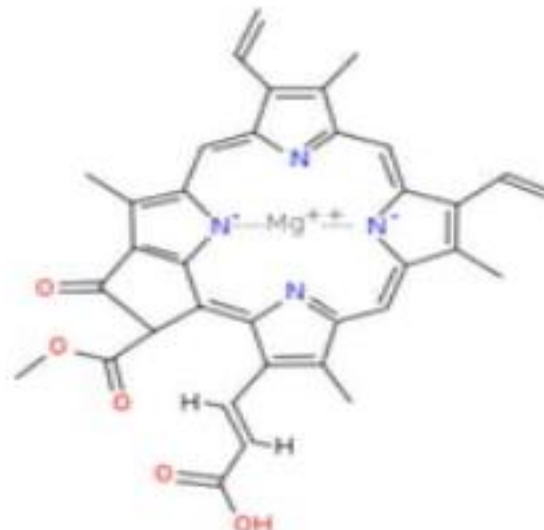
WHERE ARE THESE PHOTOSYNTHETIC PIGMENTS FOUND?



<u>PIGMENTS</u>	<u>LOCATED IN</u>
Chlorophyll	Chloroplast
Carotenoids	Chloroplast
Anthocyanin	Cell vacuole
Xanthophyll	Chloroplast



STRUCTURE OF CHLOROPHYLL





ANTHOCYANINS:

- Literally "Flower blue"
- Water soluble flavanoid pigments
- Colour appear as red to blue, acc to pH.
- Occur in all tissues of higher plants but colour not noticeable.
- Have purple colour and are present in:
- vegetables
- (onions, cabbage, potatoes), red, blue & purple berries, black beans



BETALINS

- Red or yellow pigments.
- Water soluble.
- Synthesized from tyrosine.
- Never co-occur in plants having anthocyanins.
- Occur in:
- beets (red and yellow), chard, spinach, fruit of prickly-pear cactus.



XANTHOPHYLLS

- Fourth common class of pigments
- Essentially oxidized carotenes
- Usually red and yellow
- Do not absorb energy as well as carotenoids.



CAROTENOIDS:

- Red, orange or yellow pigments.
- Function as accessory pigments in plants.
- Absorb wavelength not readily absorbed by chlorophyll.
- Ex: Carotene (Found in Carrots)
- Lutein (Yellow pigment found in fruits and vegetables).
- Lycopene (Red pigment in tomatoes)



photosynthesis

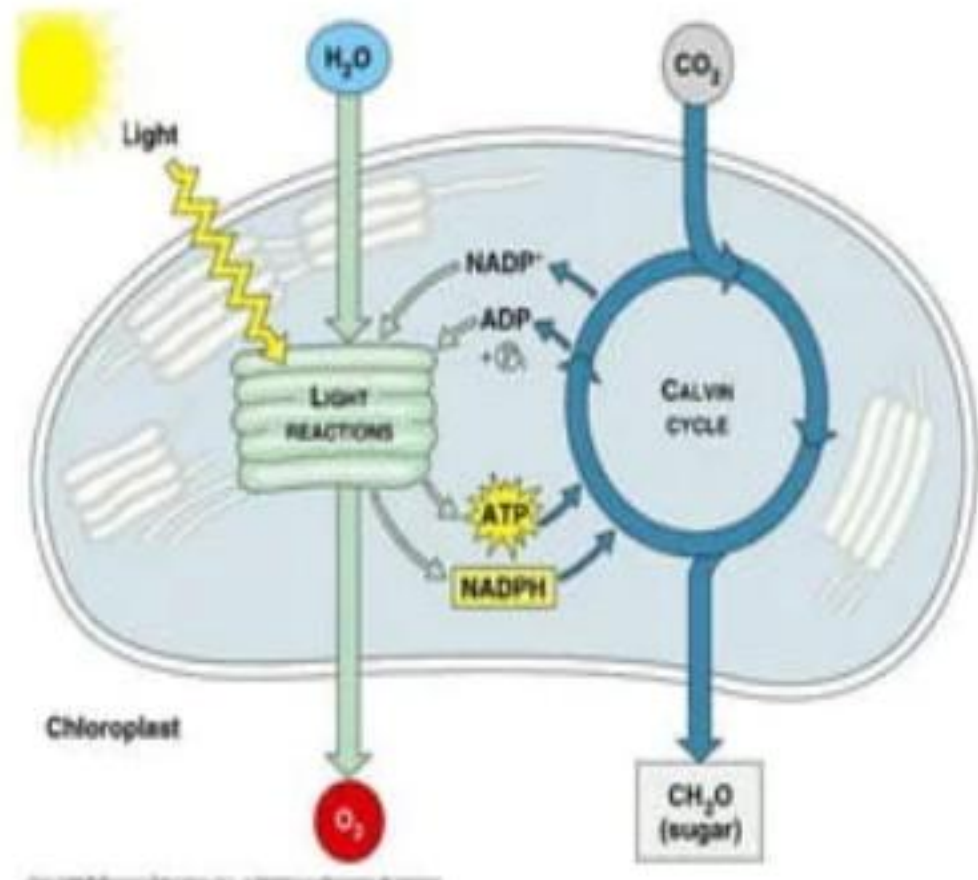
PHASE 2, DARK REACTION

- Other names :
 - Calvin Cycle
 - Light Independent Reaction
 - Carbon Fixation or C3 Fixation
- Does not require light
- Location Occurs in stroma of chloroplast
- Requirements
 - ATP and NADPH as a fuel
 - CO₂ (air)
- Product glucose sugar
- Step
 - CO₂ fixation in glucose sugar
- The Chemical Energy Stored in ATP and NADPH powers the formation of Organic Compound glucose (Sugar) using CO₂



PHASE 1. LIGHT REACTION

- Also called Light Dependent Reaction which contain Photosystem I



DEFINITION

In the process of photosynthesis, the phosphorylation of ADP using the energy of sunlight is called

light energy is used to create a higher and a lower energy state. Electrons then move spontaneously from the higher energy state through an electron transport chain.

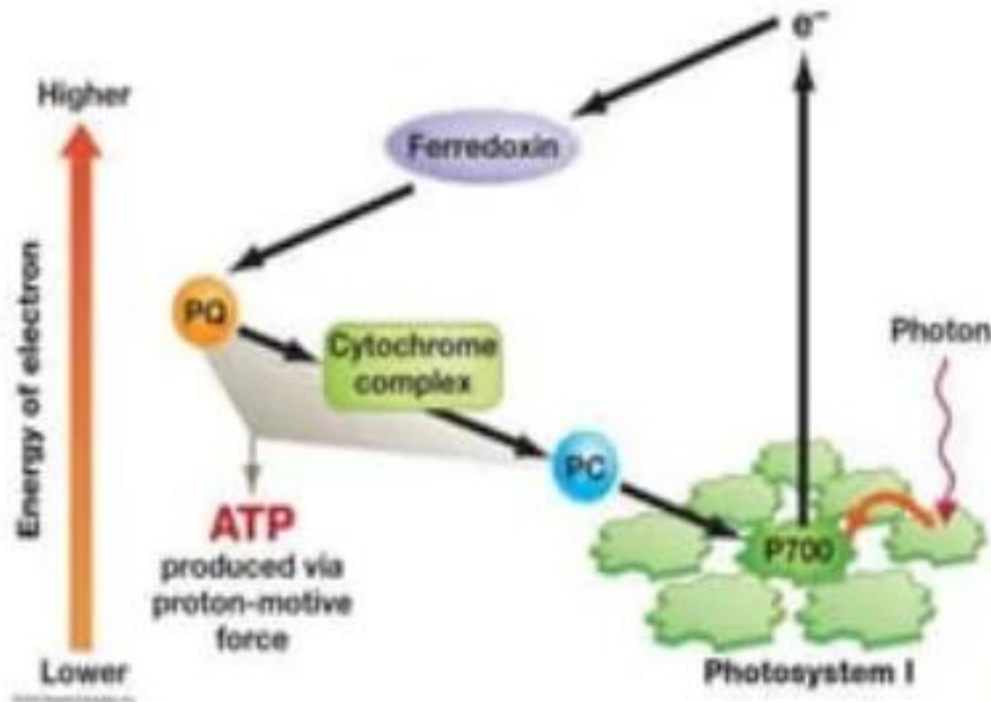
PHOTOPHOSPHORYLATION

Photophosphorylation

is the

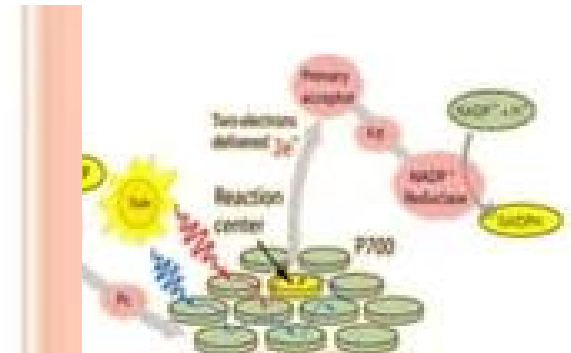
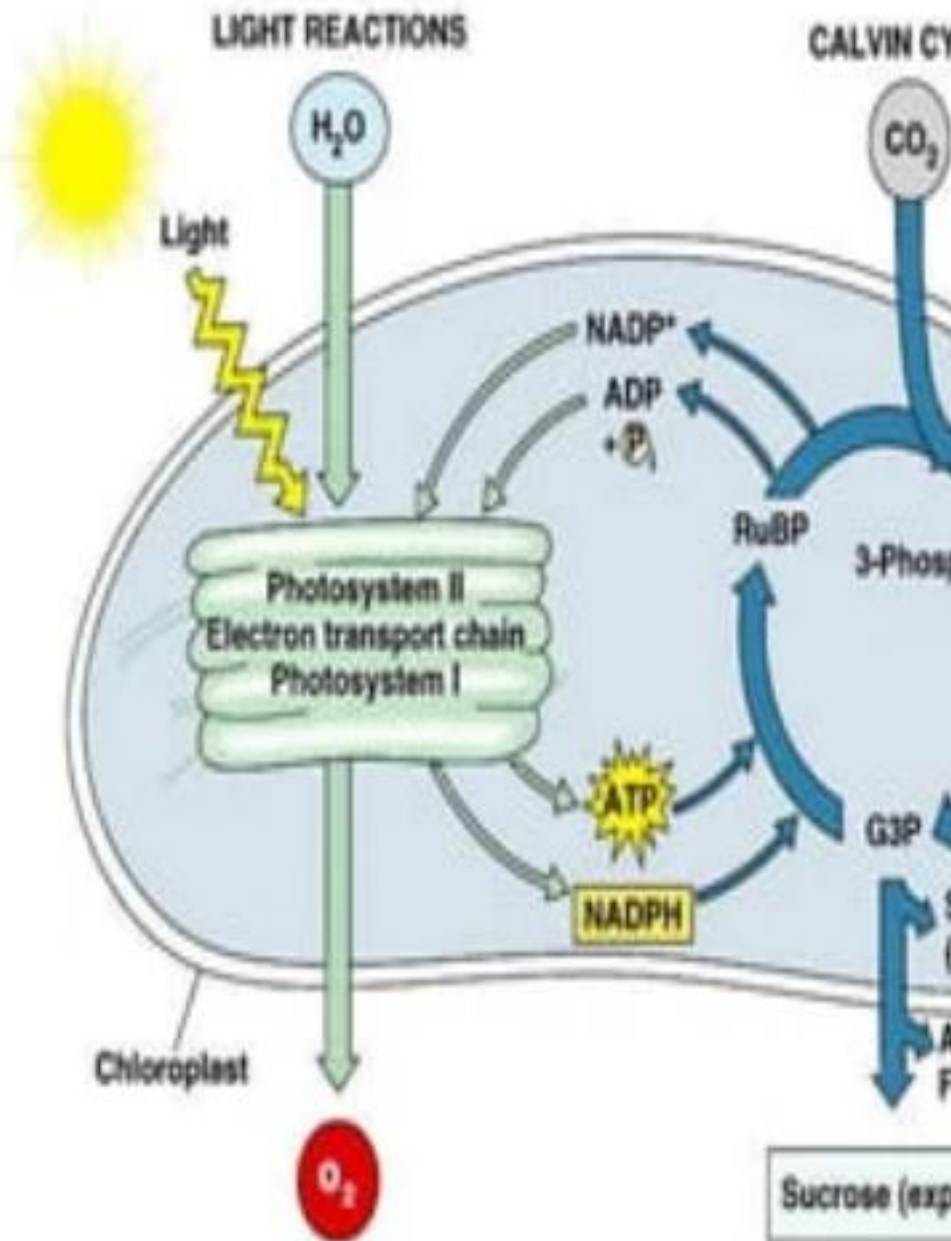
phosphorylation

CYCLIC



NON-CYCLIC

NON-CYCLIC

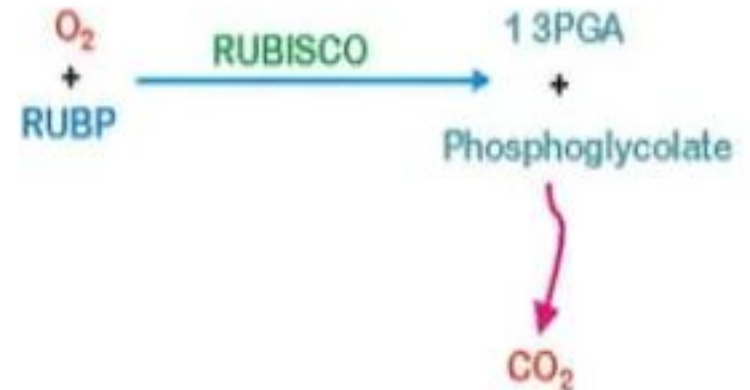
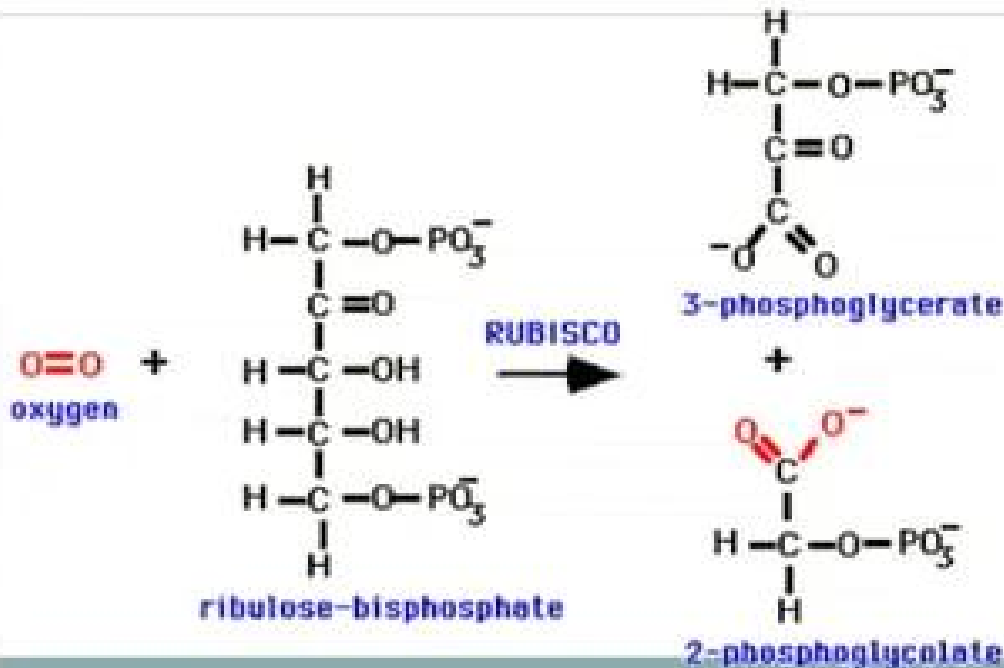
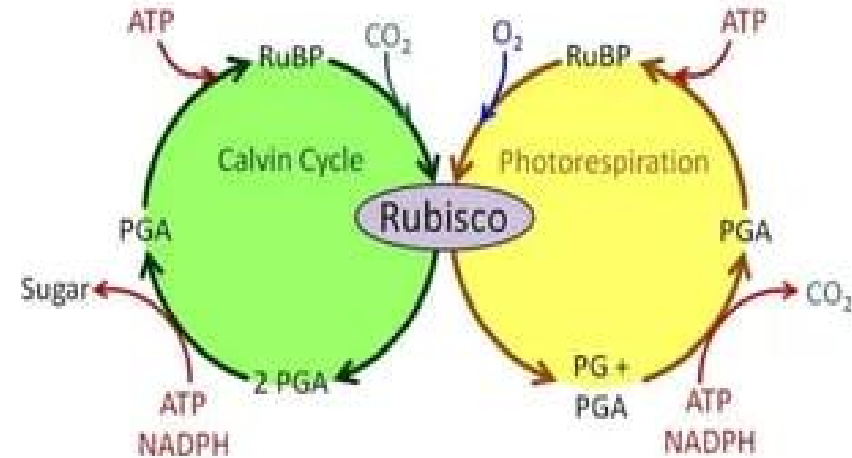


- the free energy of cleavage of ~P bonds of ATP, and reducing power of NADPH, are used to fix and reduce CO₂ to form carbohydrate.
- Carbon atoms from CO₂ are bonded, or fixed, into organic compounds = carbon fixation.
- THIS OCCURS IN THE STROMA

Photorespiration - Introduction

Dark reactions

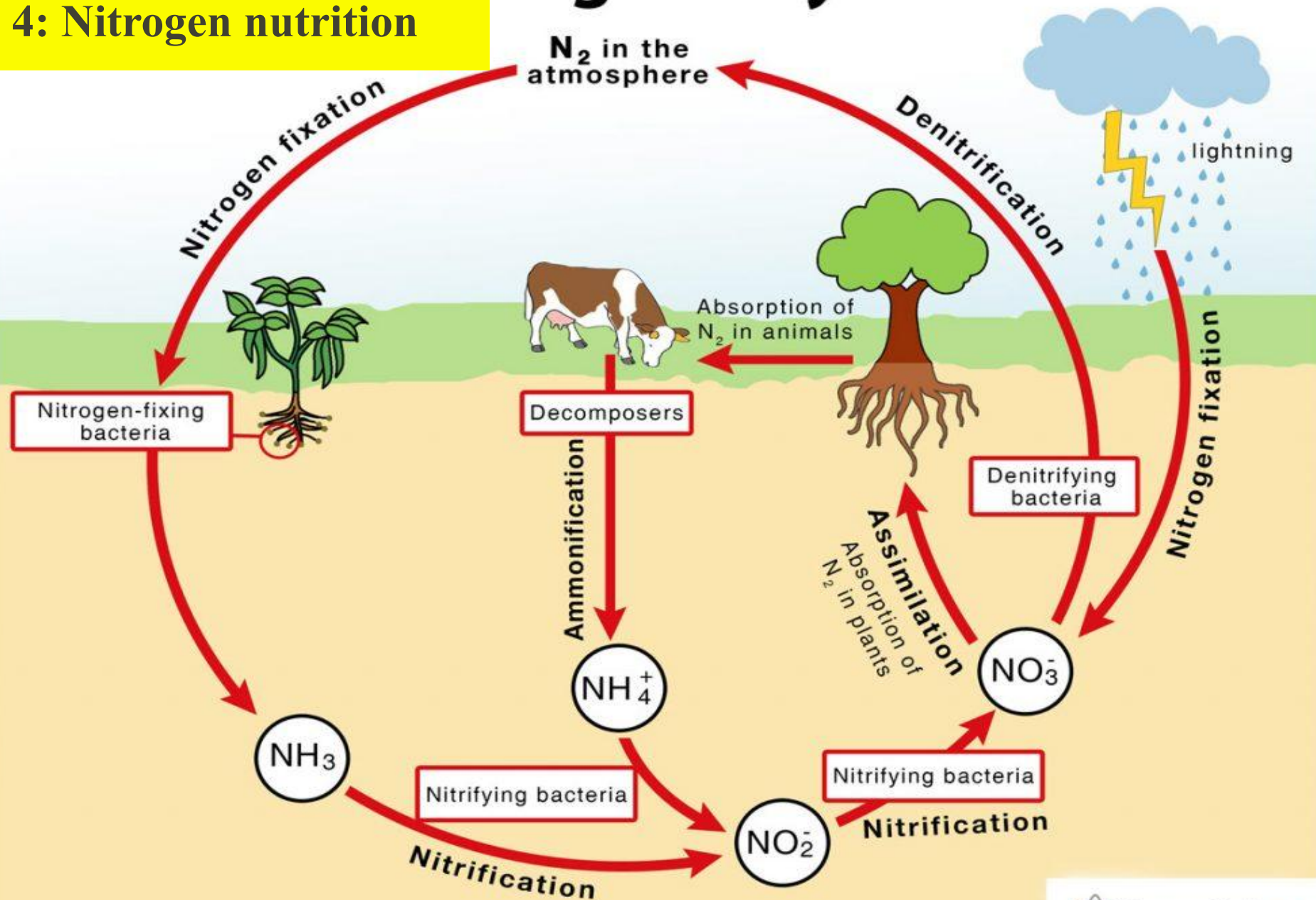
- ❖ Photorespiration is a **metabolic pathway** that occurs in photosynthetic organisms and releases carbon dioxide, **consumes oxygen**, and **produces no chemical energy or food**.
- ❖ This process **limits the growth rates of plants**.
- ❖ Photorespiration generally **occurs on hot, dry, sunny days** causing plants to close their stomata and the **oxygen (O₂) concentration in the leaf to be higher** than the carbon dioxide (CO₂) concentration.



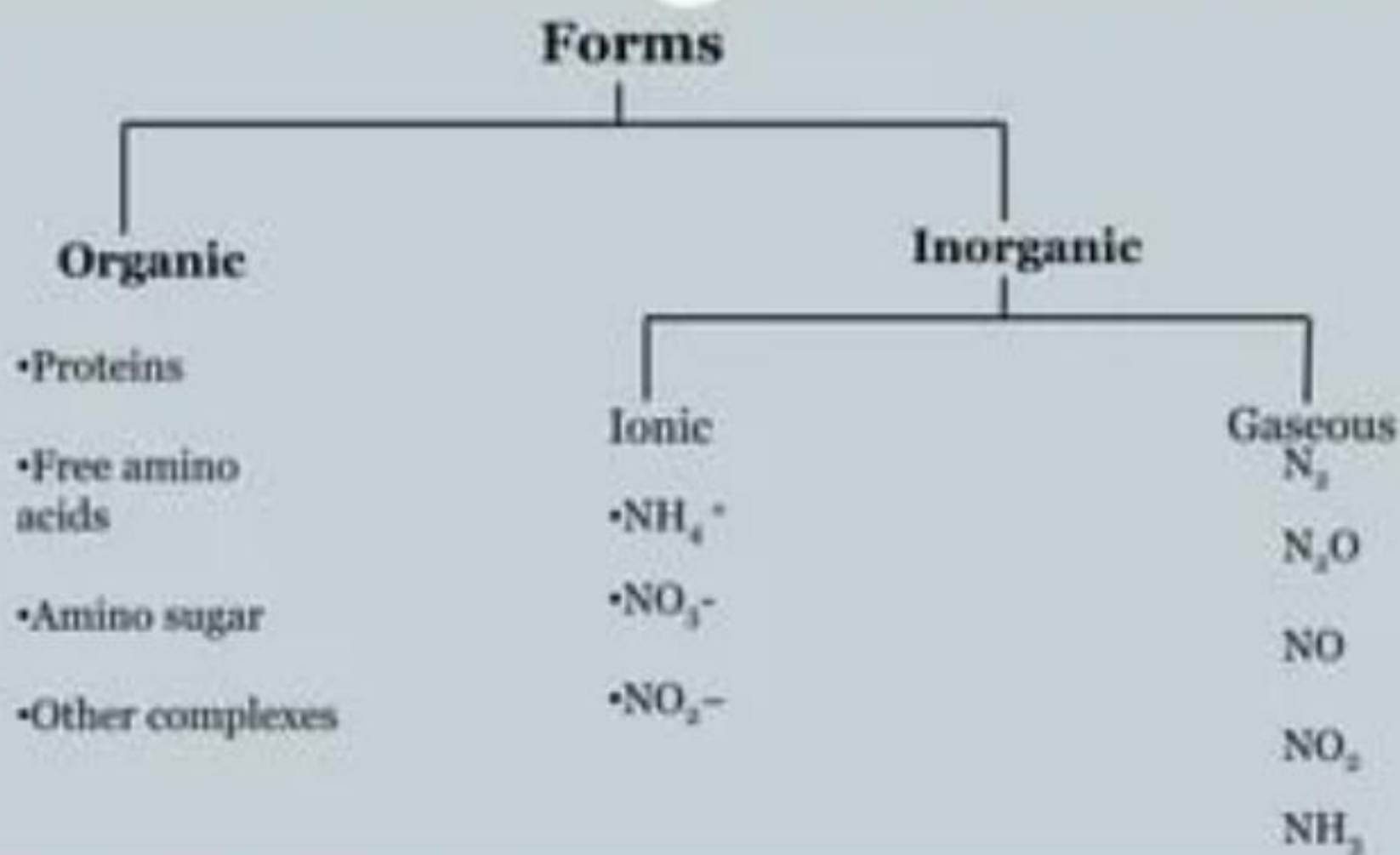
In the process called **photorespiration**, O₂ replaces CO₂ in a non-productive, wasteful reaction.

Nitrogen Cycle

§ 4: Nitrogen nutrition



Forms of Nitrogen in soil



Name ^a	Species	Oxidation State
Organic N	R_{NH_3}	-3
Ammonium	NH_4^+	-3
Ammonia (g)	NH_3	-3
Dinitrogen (g)	N_2	0
Nitrous oxide (g)	N_2O	+1
Nitric oxide (g)	NO	+2
Nitrite	NO_2^-	+3
Nitrogen dioxide (g)	NO_2	+4
Nitrate	NO_3^-	+5

^a (g) indicates gas at STP.

Nitrogen mineral types

Nitrogen-bearing minerals are fairly uncommon and include **nitratine** (sodium nitrate: NaNO_3), **nitrammite** (ammonium nitrate: NH_4NO_3), **nitrobarite** (barium nitrate: BaNO_3), **nitrocalcite**: Ca_3N_2 and **nitromagnesite**: Mg_3N_2 .

Forms of N absorbed by plants

- NO_3^- :- predominated in warm & well-aerated soil. Hence, plants grown in well-aerated soil absorb nitrate ion.
- NH_4^+ :- urea $\text{CO}(\text{NH}_2)_2$, urea is absorbed through leaf epidermis, when urea solution is spread over the foliage, & usually not absorbed by root.
- NO_2^- :- plants absorb nitrite ions, they are toxic. However they accumulate in soil in small quantities.
- **Amino acid & nucleic acid** :- absorbed by higher plants, accumulated in soil in small quantities.

Mineralization

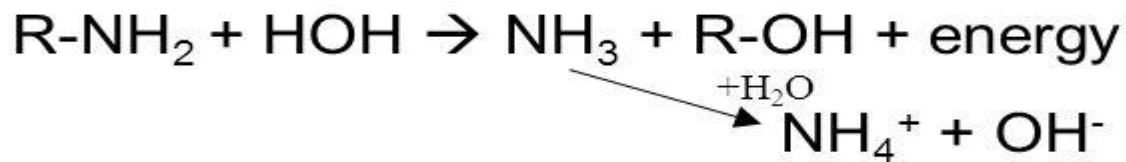


- Mineralization is the conversion of organic form of the element to inorganic form or mineral form
- In case of nitrogen NH_4^+ , NO_3^- , NO_2^- the inorganic forms
- It takes place in three steps as follows :-
 1. Aminization
 2. Ammonification
 3. Nitrification

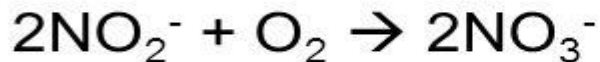
Aminization: Decomposition of proteins and the release of amines and amino acids



Ammonification:



Nitrification: biological oxidation of ammonia to nitrate



Symbiotic nitrogen fixation

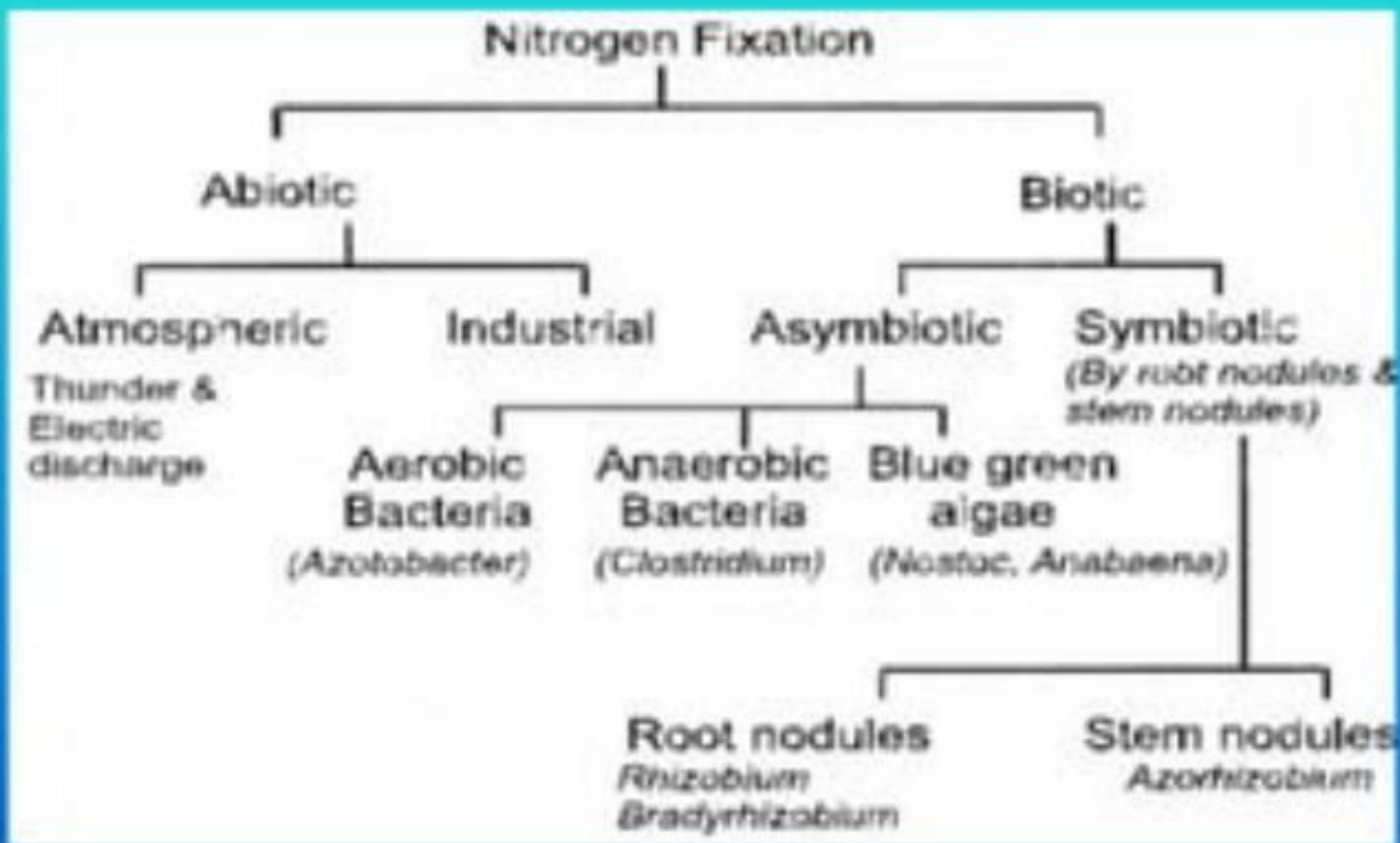
Symbiotic nitrogen fixation is part of a mutualistic relationship in which plants provide a niche and fixed carbon to bacteria in exchange for fixed nitrogen.

Symbiotic nitrogen fixing bacteria usually fix nitrogen in a symbiotic association with the host plant like Rhizobium in the root nodules of leguminous plants. Non-symbiotic or free living nitrogen fixing bacteria fix nitrogen without the host living freely and convert atmospheric nitrogen to nitrites and nitrates.

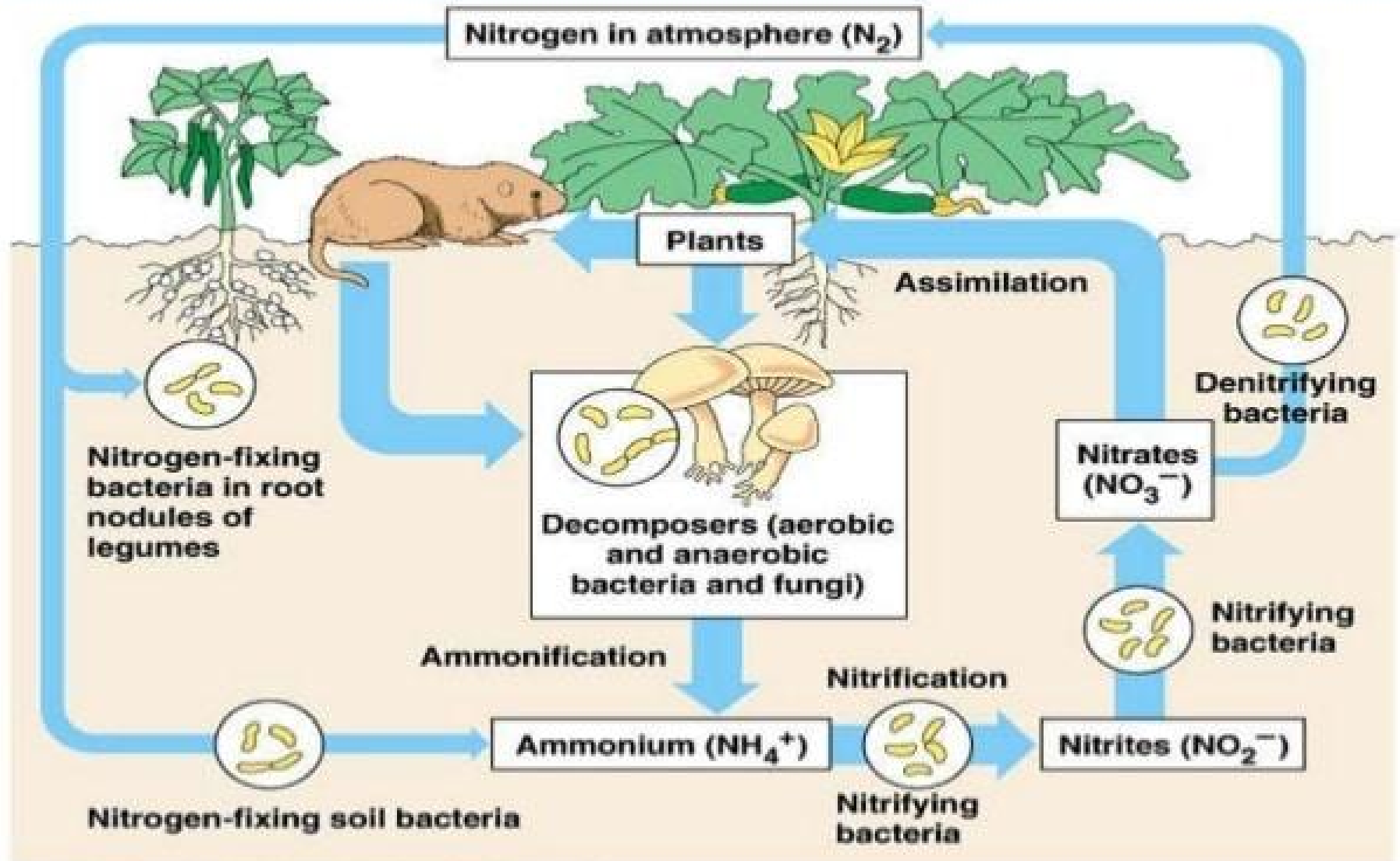
Legumes are able to form a symbiotic relationship with nitrogen-fixing soil bacteria called rhizobia. The result of this symbiosis is to form nodules on the plant root, within which the bacteria can convert atmospheric nitrogen into ammonia that can be used by the plant.

Symbiotic bacteria include Rhizobium, Bradyrhizobium, Sinorhizobium, Mesorhizobium, and Azorhizobium

Types of Nitrogen Fixation



Biological nitrogen Fixation



Symbiotic nitrogen fixation :

- Symbiotic nitrogen fixation occurs in plants that fix bacteria within their tissues
- The best-studied example is the symbiotic association of legumes and bacteria of the genus *Rhizobium*
- This association results from the root nodules in
- Root nodules - it is an enlarged multicellular structure
- Legume - rhizobium association will fix 25 - 60 kg of nitrogen annually



Asymbiotic nitrogen fixation:

- The free living nitrogen fixing organisms are called are asymbiotic - organisms.
- It includes Aerobic bacteria, anaerobic bacteria and blue green algae
- Bacteria: types -
 - Free living aerobic : *Azotobacter*
 - Free living anaerobic : *Clostridium*
- Blue green algae: types -
 - Filamentous (non heterocystous) - *Oscillatoria*
 - Filamentous (heterocystous) - *Nostoc*, *Anabaena*

Legume plant	Nodulating bacteria
Alfalfa	<i>Sinorhizobium meliloti</i>
Beans	<i>Rhizobium biovar</i>
Clover	<i>R. trifolii</i>
Lotus	<i>Mesorhizobium loti</i>
Pae	<i>R.viciae</i>
Soybean	<i>Bradyrhizobium japonicum</i>



Nitrogen Fixation: Mechanism

- The reaction for Biological nitrogen fixation is:
$$\text{N}_2 + 8 \text{H}^+ + 8 \text{e}^- \rightarrow 2 \text{NH}_3 + \text{H}_2.$$
- The enzymatic reduction of N_2 to ammonia requires an input of chemical energy, released from ATP hydrolysis, to overcome the activation energy barrier.
- This is a reduction reaction since electrons are added to the N_2 to reduce it to NH_4 .

Through Nodule formation in non-legume plants

- ◆ Some non-legume plants involve in nodule formation.
- ◆ The best known plant is Alder associated with actinomycete, *Frankia* sp.
- ◆ Other plants are Casuarina and Hippophae.



Alder nodule



Hippophae nodule

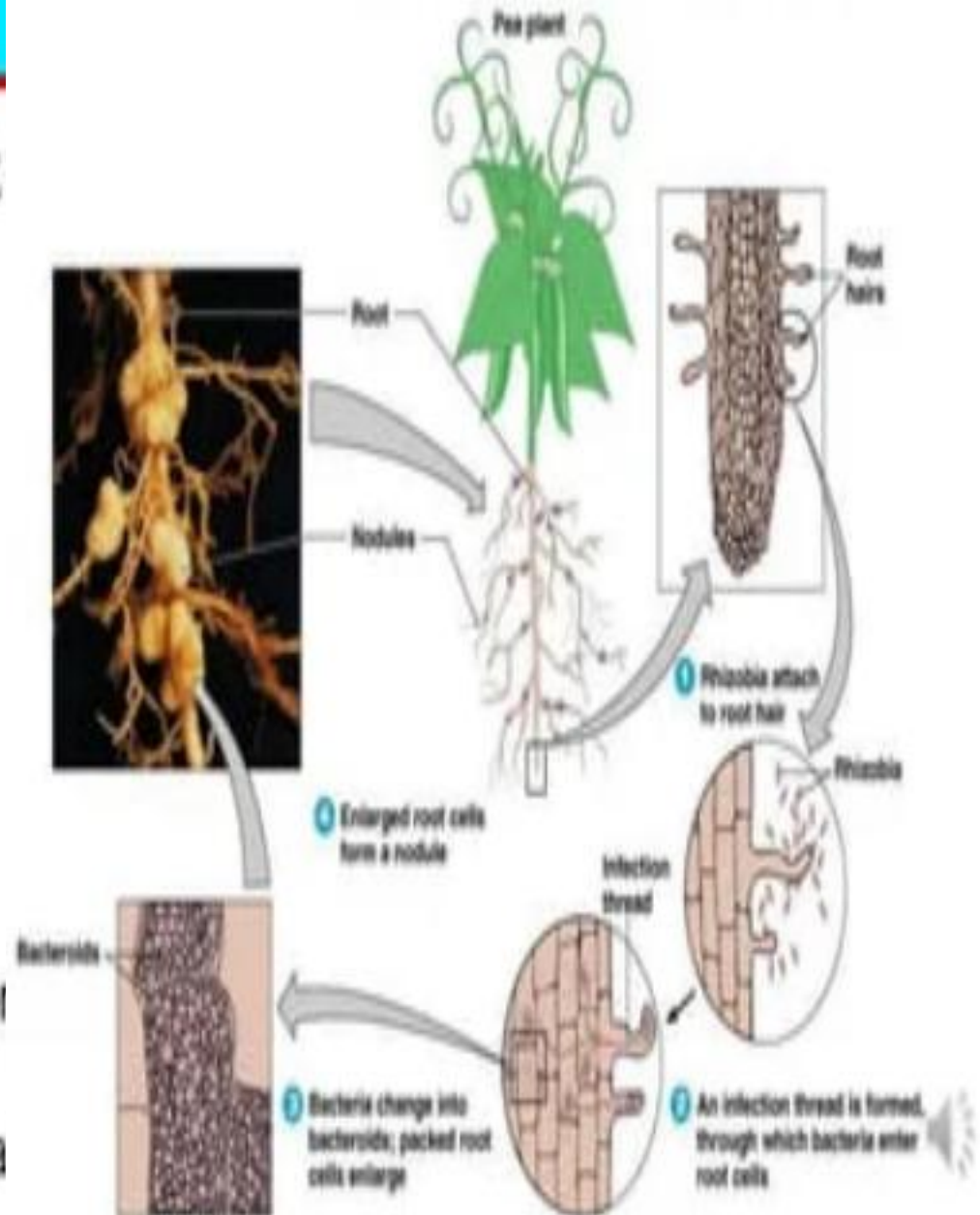


3. NODULES FORMATION IN RHIZOBIUM ASSOCIATION

NODULES FORMATION TAKES PLACE FOLLOWING STAGES :

- (a) Recognition
- (b) Attachment
- (c) penetration
- (d) Travel
- (e) Bacteroid formation
- (f) Development of ma

Formation of a Root Nodule



Assimilation of nitrates by plants

