HARAMAYA UNIVERSITY

Building the Basis for Development

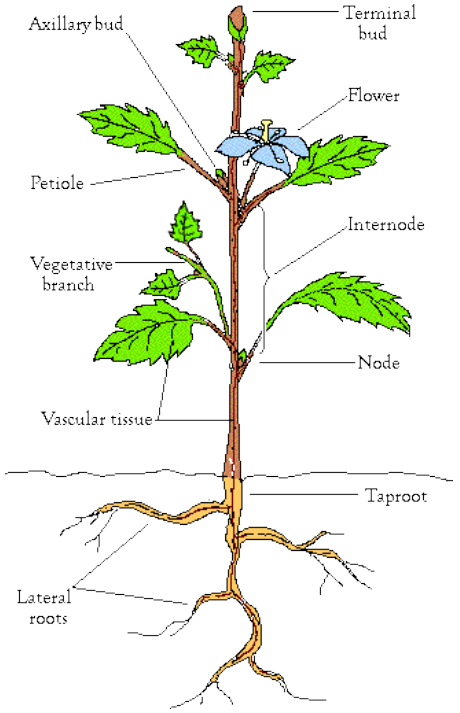
Course Title: **Remedial Biology**

Unit 9. Food making and growth in plants

CNCS, SBBT, Department of Biology

Today…

- **Plant Anatomy**
  - Cells
  - Tissues
  - Organs
- **Plant Physiology**
  - Water & sugar transport
  - Plant hormones



What is plant anatomy?

- **ANATOMY:** study of the **structure** of organisms… looking at cells, tissues (Morphology: Study of form)

What is plant physiology?

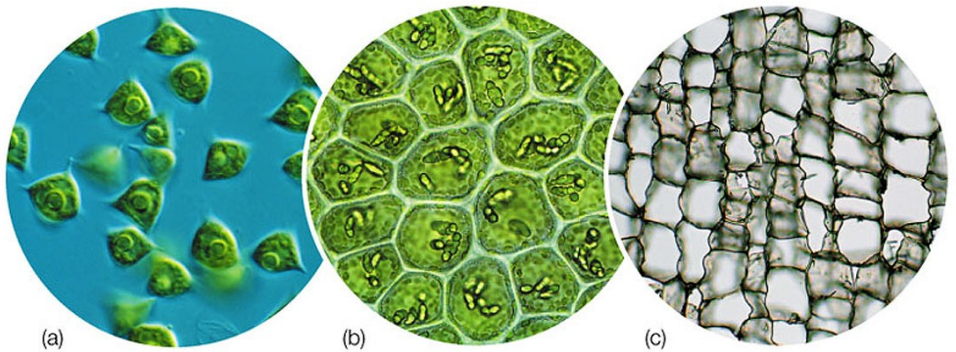
- **PHYSIOLOGY:** study of the **function** of cells, tissues, organs of living things;

  and the physics/chemistry of these functions…

Plant Anatomy: Cells

- Plant cells are basic building blocks
- Can specialize in form and function
- By working together, forming tissues, they can support each other and survive
- Levels of organization

atoms > molecules > cells > **tissues** > **organs** > whole plant > pop.



Plant Tissues Types

All plant organs (roots, stems, leaves) are composed of the same tissue types.

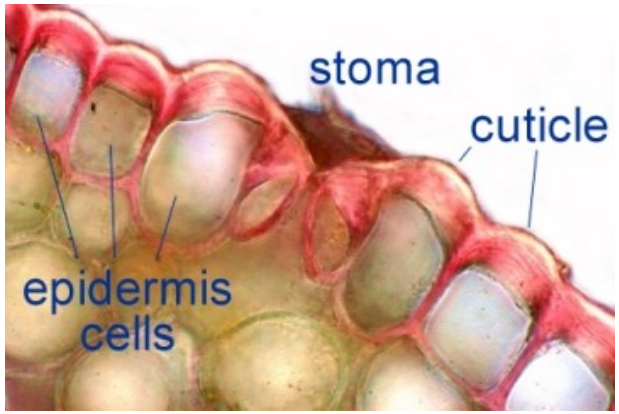
There are three types of tissue:

- **1. Dermal** – outermost layer
- **2. Vascular** – conducting tissue, transport
- **3. Ground** – bulk of inner layers

1. Dermal tissue

❖**Epidermis** is the outermost layer of cells

- Like the “skin” of animals
- In stems and leaves, epidermis has **cuticle**, a waxy layer that prevents water loss.



- Some have **trichomes,** hairs.
- Root epidermis has **root hairs,** for water and nutrient absorption

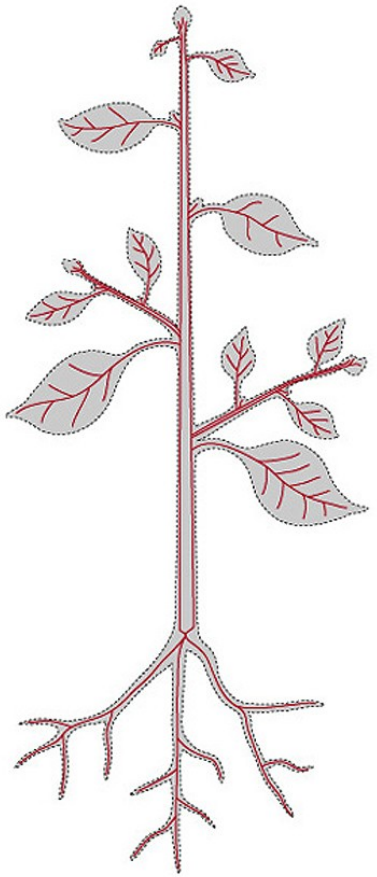


2. Vascular tissue

❖Transports water and organic materials (sugars) throughout the plant

- **Xylem** – transports water and dissolved ions from the root to the stem and leaves.

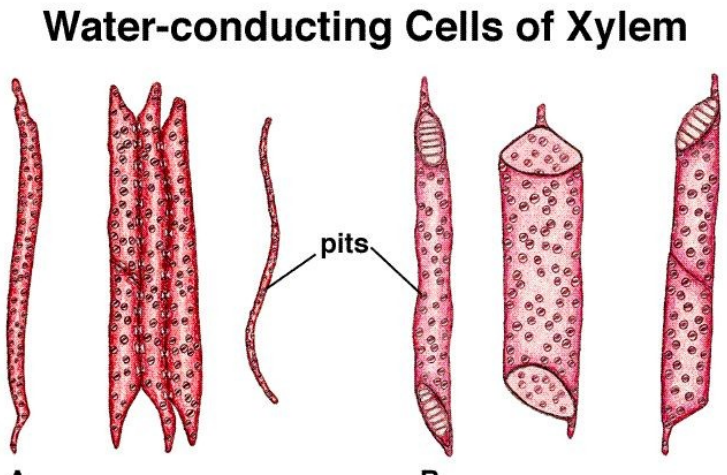
- **Phloem** – carries dissolved sugars from leaves to rest of the plant



Xylem

- Transports water and dissolved minerals
- **Tracheids**: long, thin tube like structures without perforations at the ends
- **Vessel elements**: short, wide tubes perforated at the ends (together form a pipe, called vessel).
- Both cells have **pits** (thin sections) on the walls

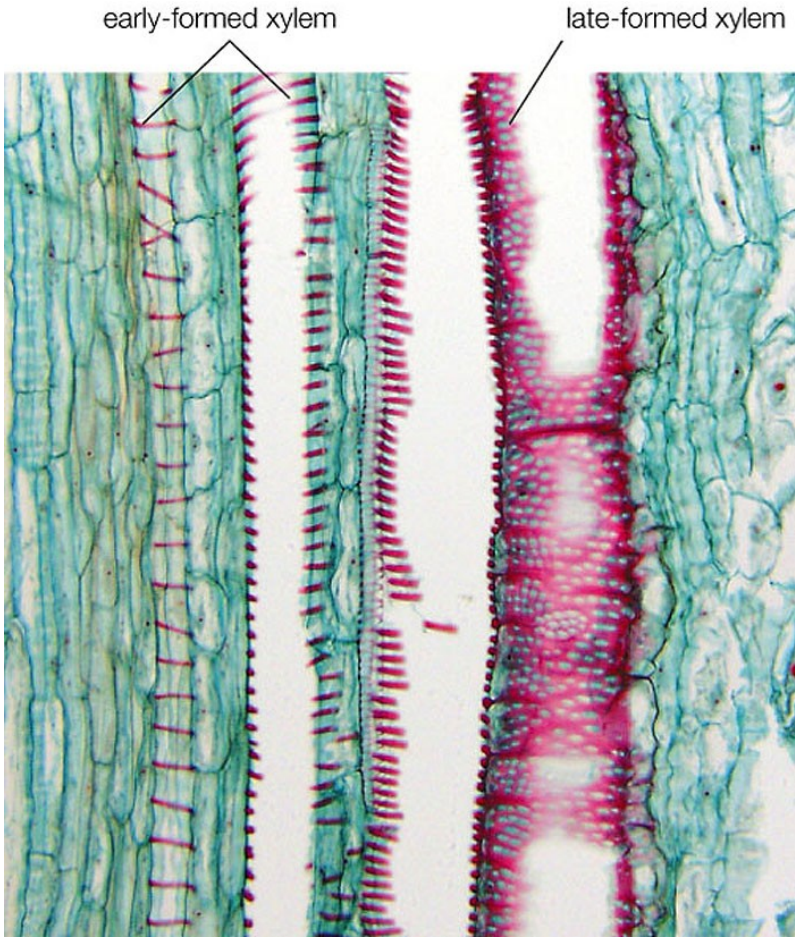
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Tracheids Vessel elements

Xylem cells

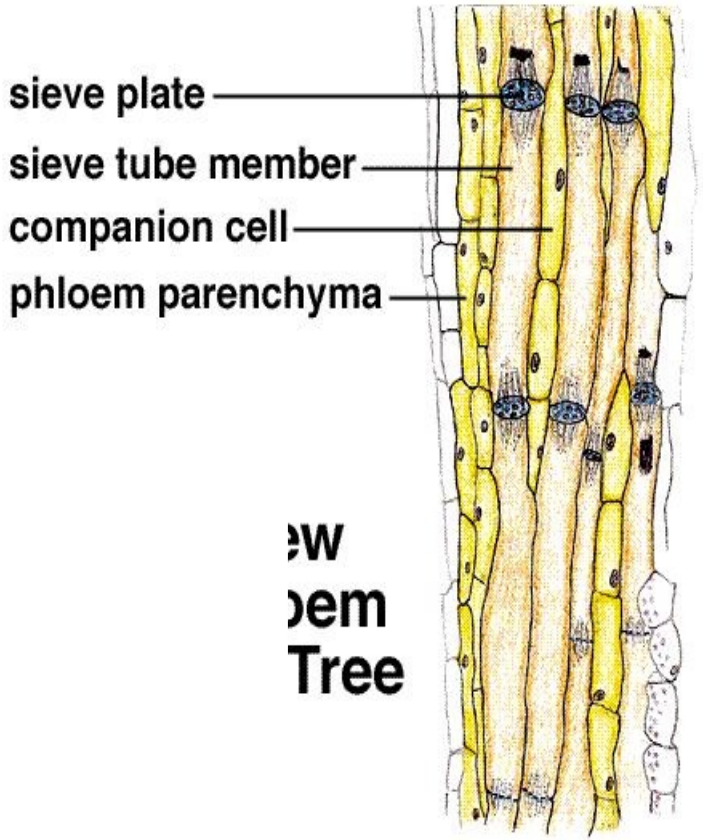
- **Xylem** cells are dead!
- They are hollow cells and consist only of <u>cell wall</u>



Phloem

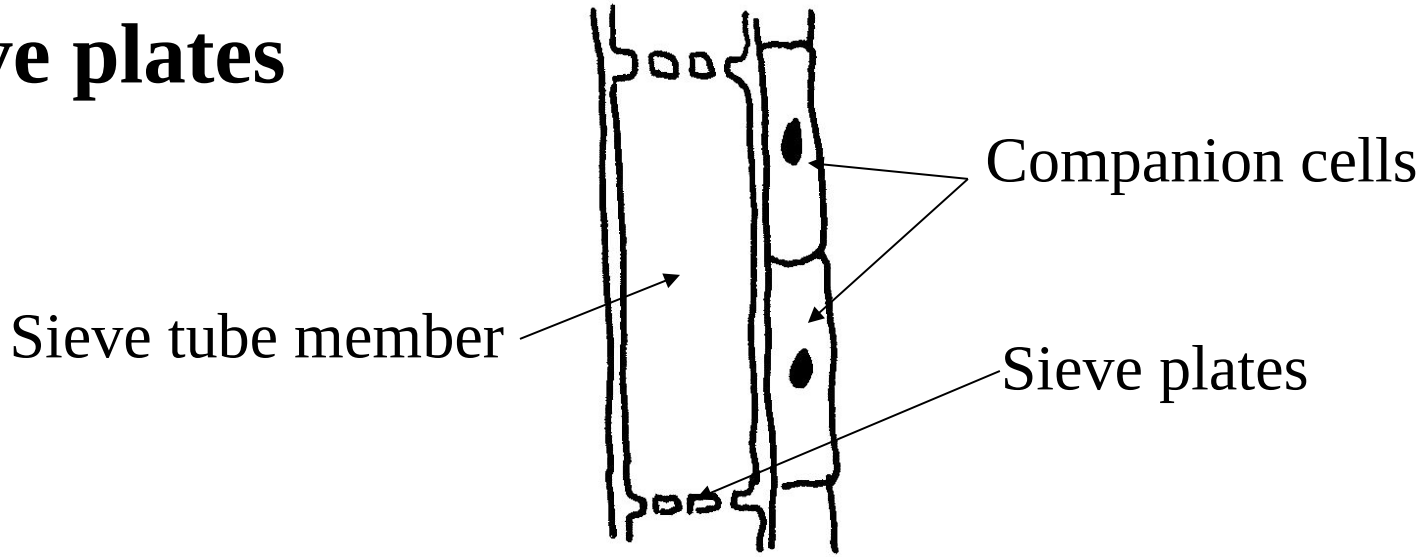
- Cells that transport organic materials (sugars)
- Phloem cells are ALIVE! (unlike xylem)
- However, they lack **nucleus and organelles**

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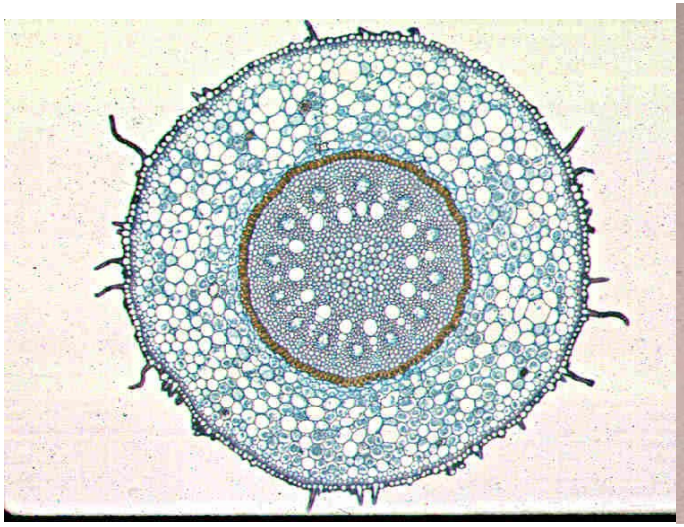
Phloem: transports sugars

- Phloem composed of cells called **sieve tube members (STM)**
- **Companion cells** join sieve tube members, are related, and help to load materials into STM
- End walls of STM have large pores called **sieve plates**

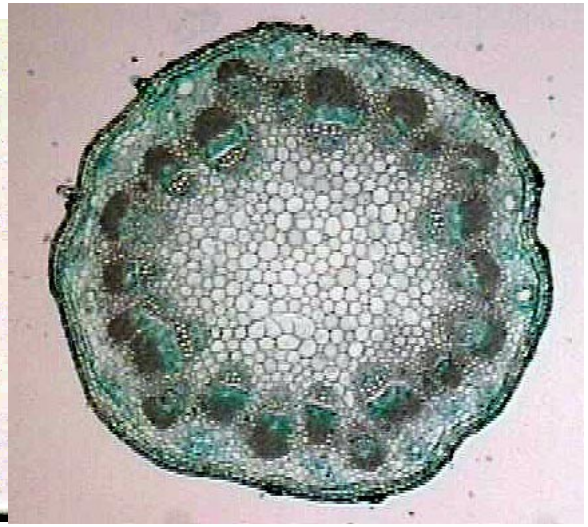


3. Ground tissue

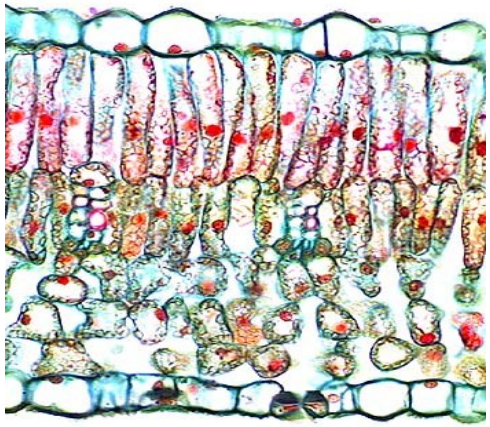
- Makes up the bulk of plant organs.
- **Functions:** Metabolism, storage and support.



Root



Stem

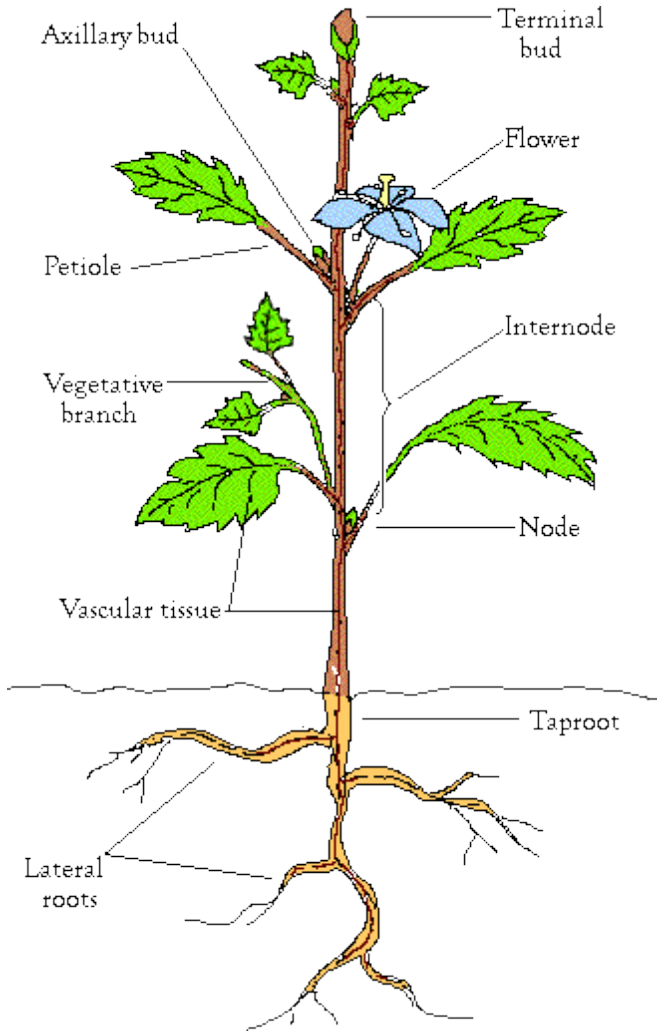


Leaf

Plant Organs

- **Organs:** tissues that act together to serve a specific function

- Roots
  - Dermal
  - Vascular
  - Ground
- Stems
  - Dermal
  - Vascular
  - Ground
- Leaves
  - Dermal
  - Vascular
  - Ground

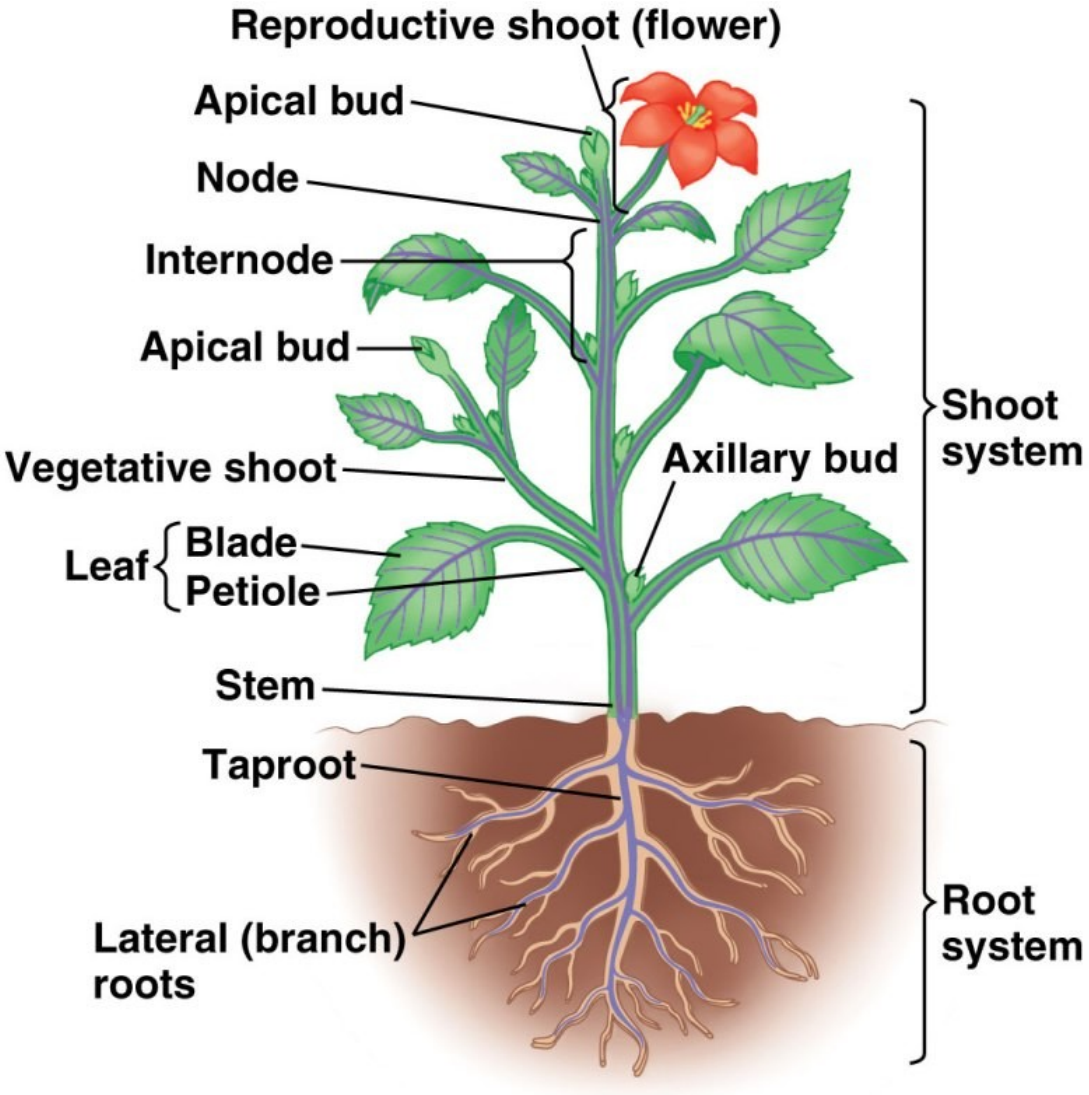


Functions of plant organs:

- **ROOTS:** Anchorage, water/nutrient absorption from soil, storage, water/nutrient transport

- **STEMS:** Support, water/nutrient transport

- **LEAVES:** Photosynthesis (food production)

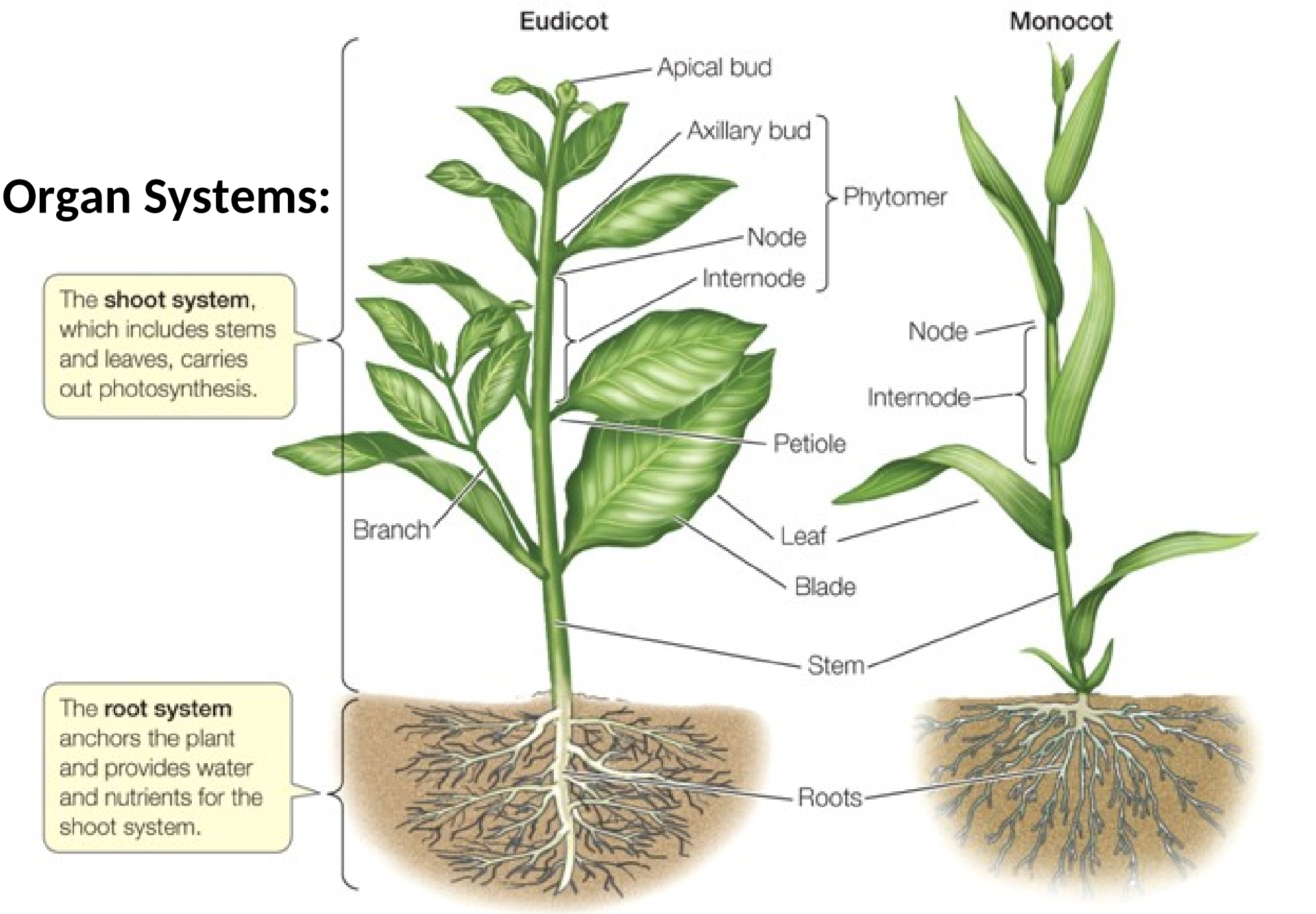


Systems - root and shoot

Organs – roots, stems, and leaves

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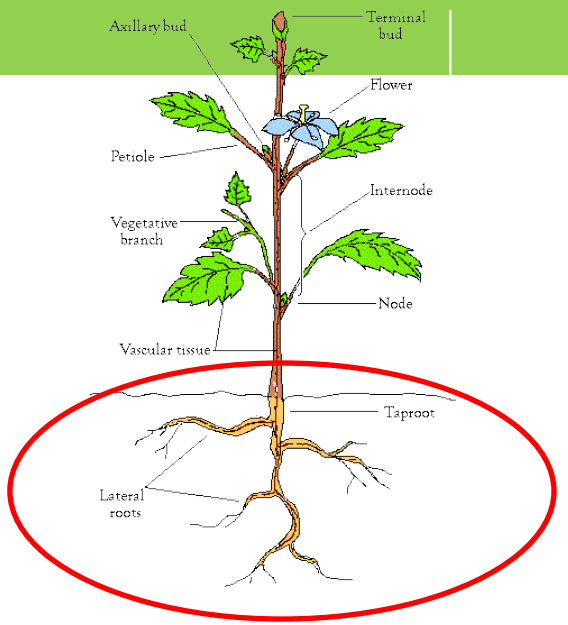
Organ Systems:



***PRINCIPLES OF LIFE*, Figure 24.1**

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ROOTS



❖**ROOTS** "the hidden half"

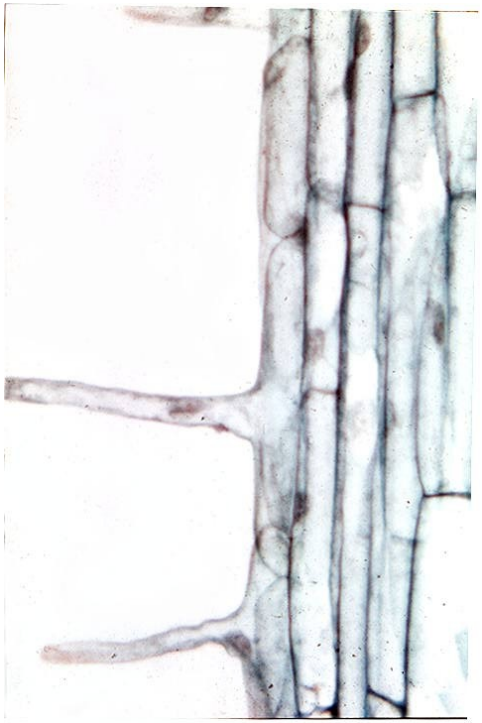
- Functions of roots:
- Anchorage
- Absorption of water & dissolved minerals
- Storage (surplus sugars, starch)
- Conduction water/nutrients

Root Epidermis



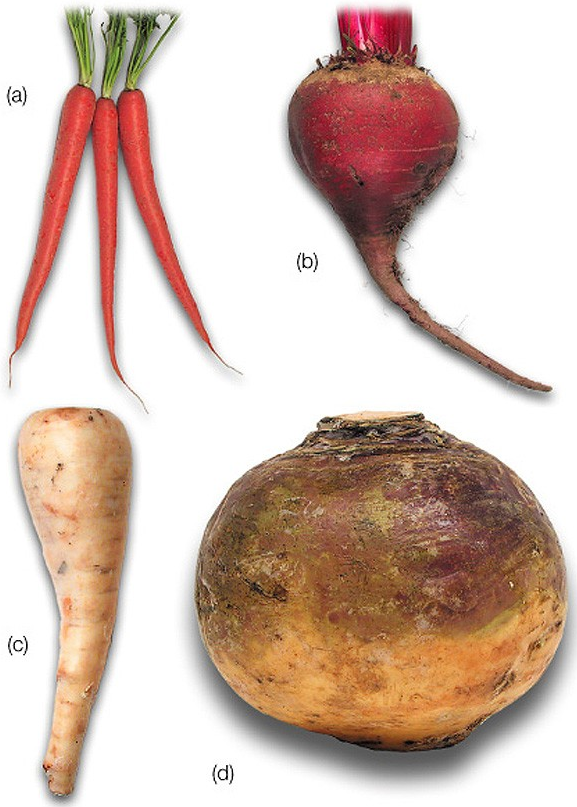
- Outermost, single layer of cells that:
  - Protects (from diseases)
  - Absorbs water and nutrients

- **ROOT HAIRS**: tubular extensions of epidermal cells.
- <u>Increase surface</u> area of root, for better water/nutrient absorption



Root Cortex

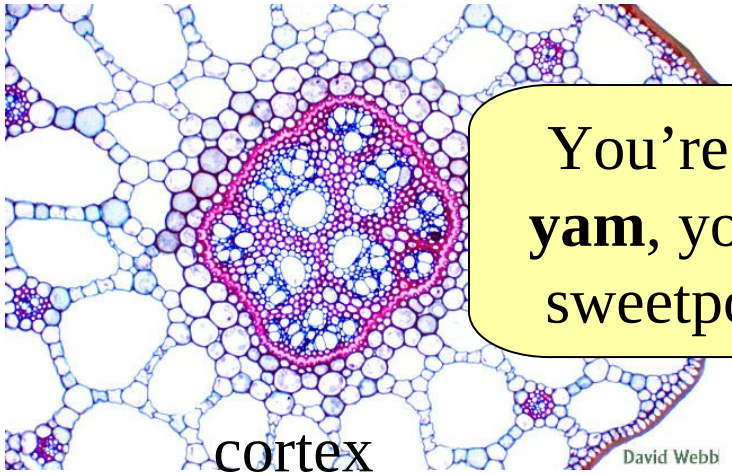
- Stores starch, sugars and other substances

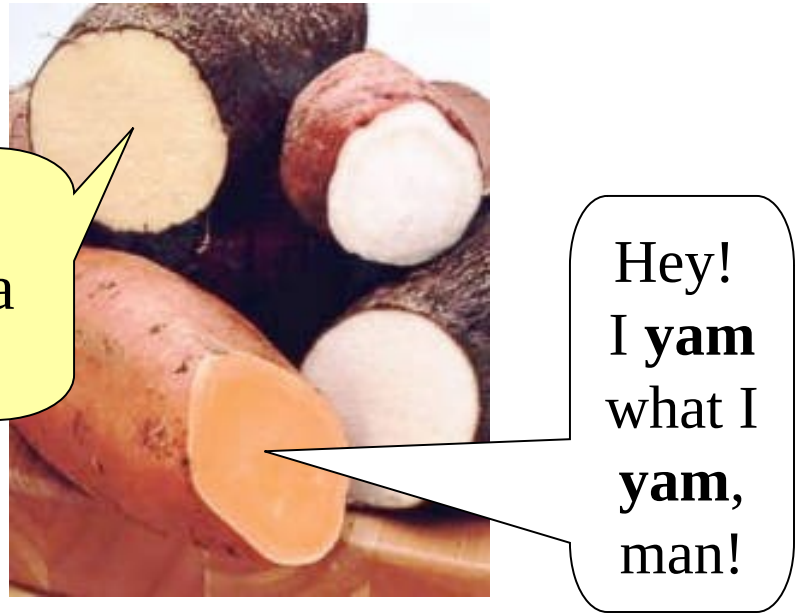


Root Ground tissue

- In roots, ground tissue (a.k.a. cortex) provides support, and often stores sugars and starch

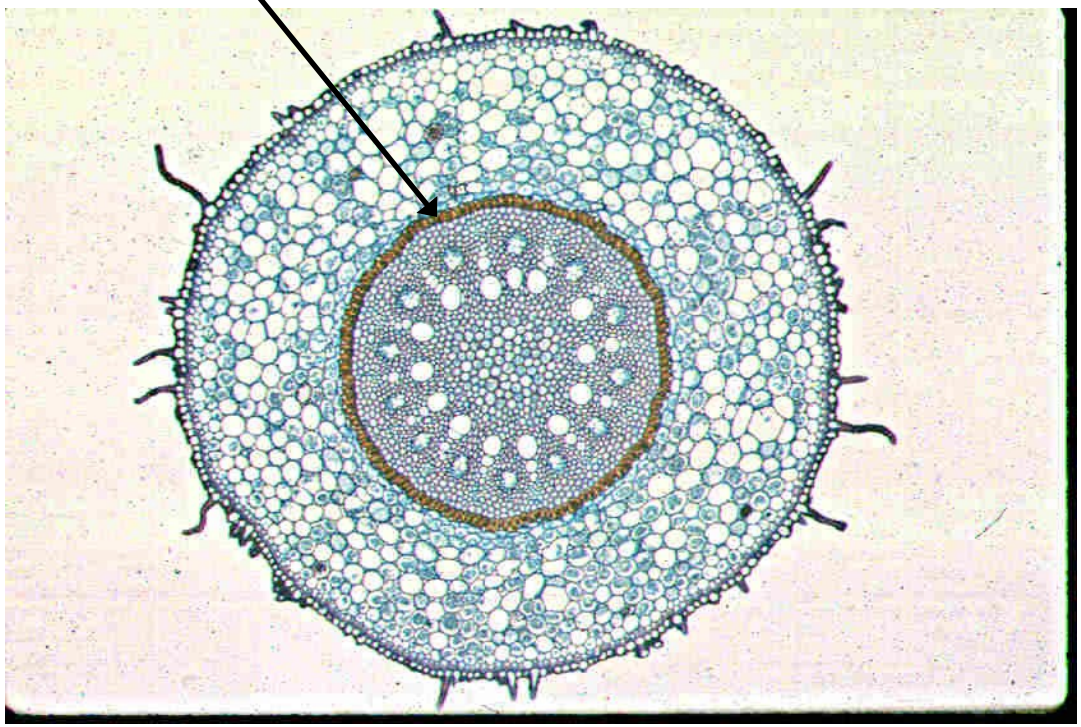
  (for example: yams, sweet potato, etc.)





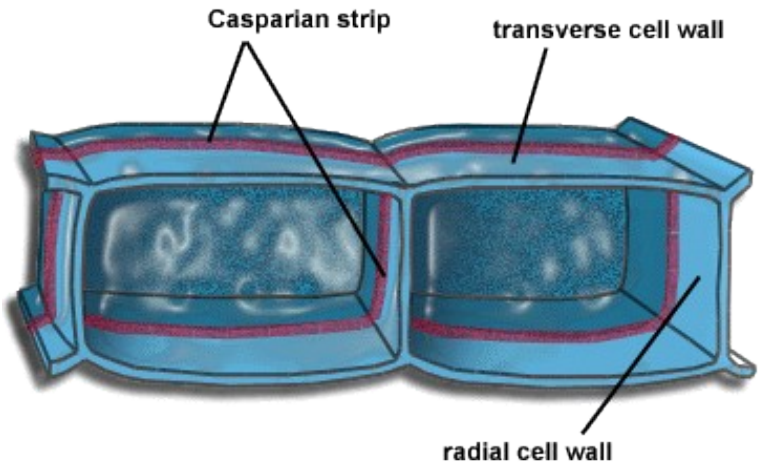
Root Cortex: Endodermis

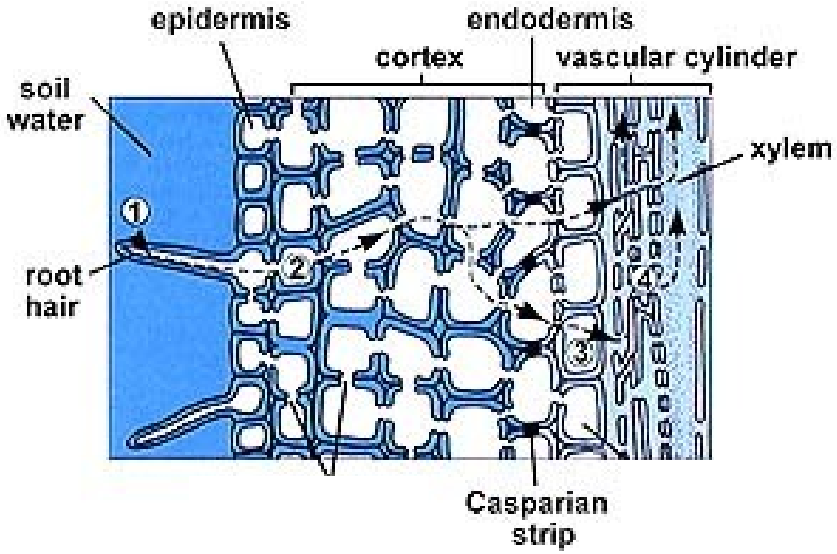
- **Endodermis**: the innermost layer of the cortex



Root cortex: Casparian strip

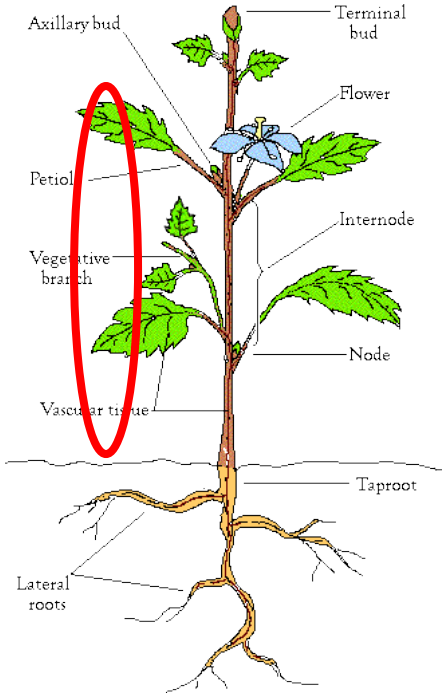
- The **Casparian strip** is a water-impermeable strip of waxy material found in the **endodermis** (innermost layer of the cortex).
- The **Casparian strip** helps to control the uptake of minerals into the xylem: they have to go through the cytoplasm of the cell!





STEMS

- Above-ground organs (usually)
- Support leaves and fruits
- Conduct water and sugars throughout plant (xylem and phloem)

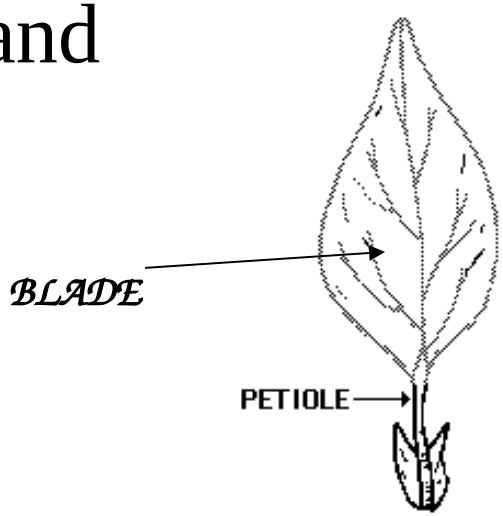


LEAVES:

❖‘Photosynthetic factories’ of the plant…



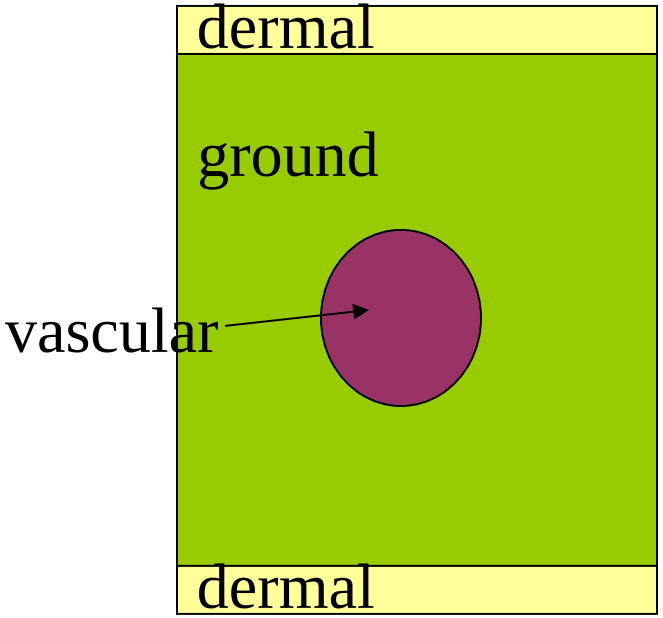
- **Function:** Photosynthesis – food production for the whole plant
- **Blade**: Flat expanded area
- **Petiole**: stalk that connects leaf blade to stem, and transports materials

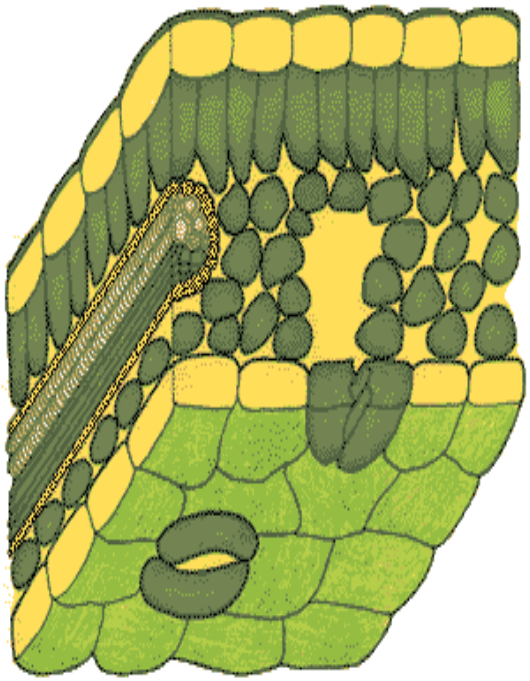


Leaf Anatomy

- Leaf anatomy is correlated to photosynthesis:

  Carbon dioxide + Water → sugars + oxygen

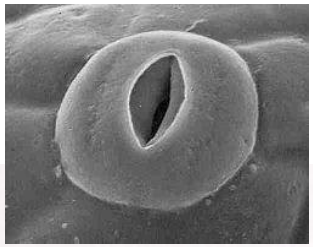




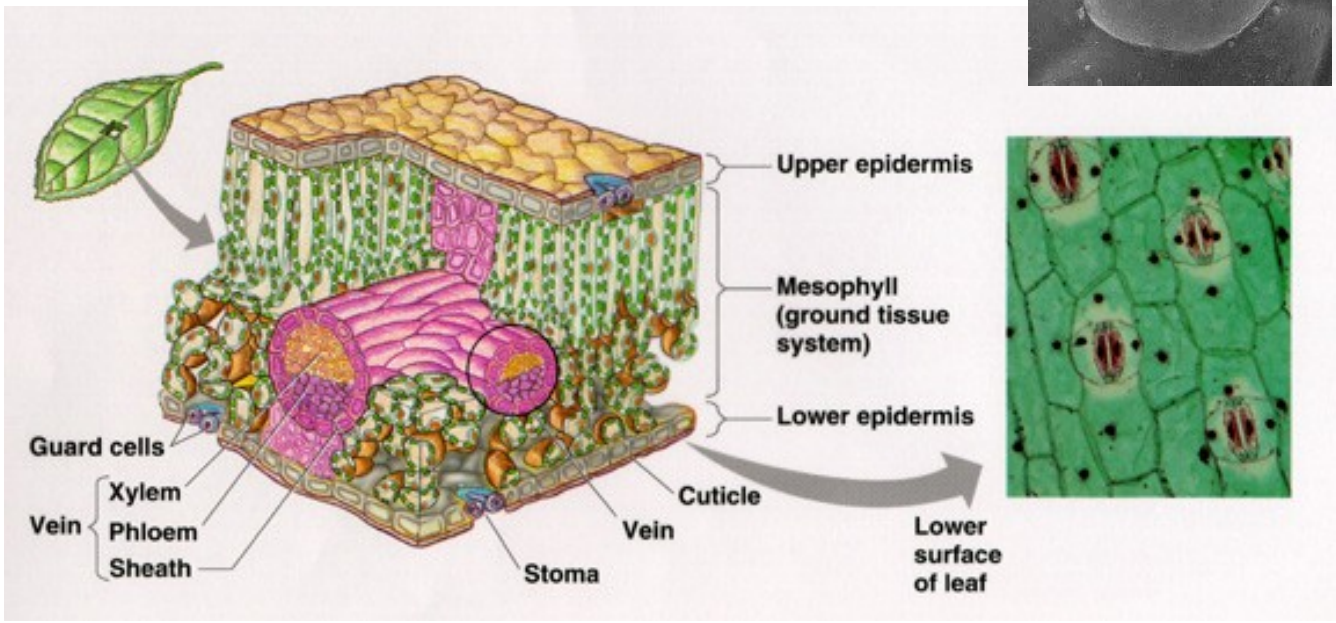


Leaf epidermis

- Is transparent – so that sun light can go through.
- Waxy cuticle protects against drying out
- Lower epidermis: **stomata** with **guard cells** – for gas exchange (CO_2, H_2O in; O_2 out)



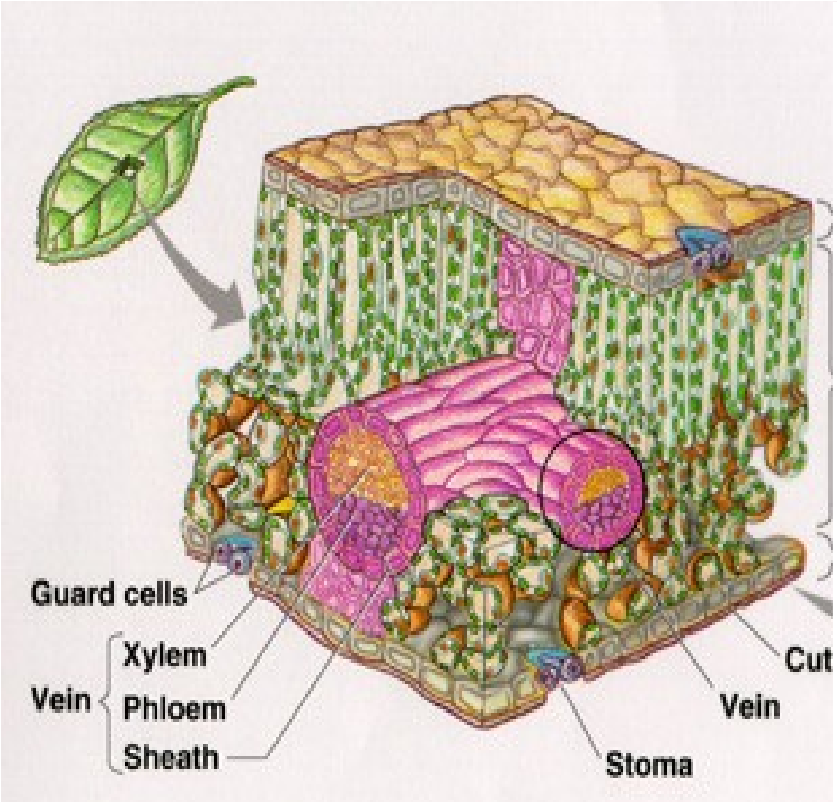




Leaf vascular tissue

❖**VEINS** → vascular tissue of leaves.

- Veins are composed of **xylem** (water transport) **phloem** (food transport) and **bundle sheaths**, cells surrounding the xylem/phloem for strength & support



Leaf Mesophyll

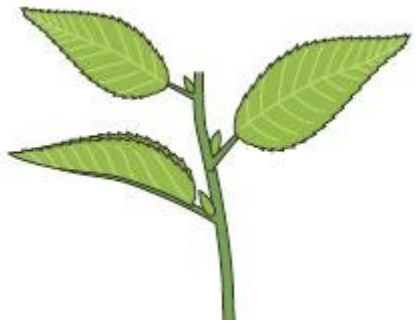
- Middle of the leaf (meso-phyll)
- Composed of photosynthetic ground cells:
- **Palisade** parenchyma
  (long columns below epidermis;
  have lots chloroplasts for
  photosynthesis)

Spongy parenchyma
(spherical cells)
with **air spaces** around,
(for gas exchange)



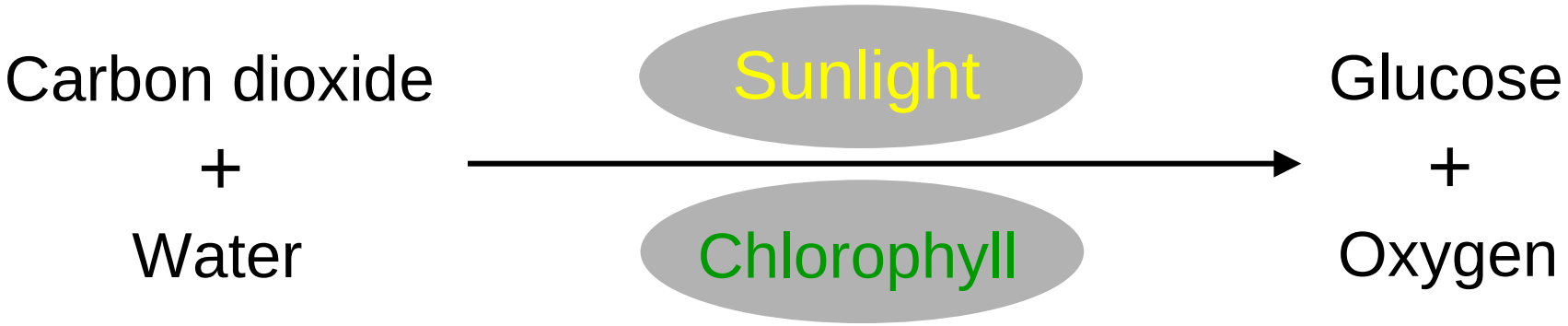
Photosynthesis

- Photosynthesis:
  - is the way in which green plants make food
  - converts solar (sun) energy into chemical energy in food
  - takes place in the green parts of plants, mostly in the leaves
  - is one of the main differences between plants and animals.



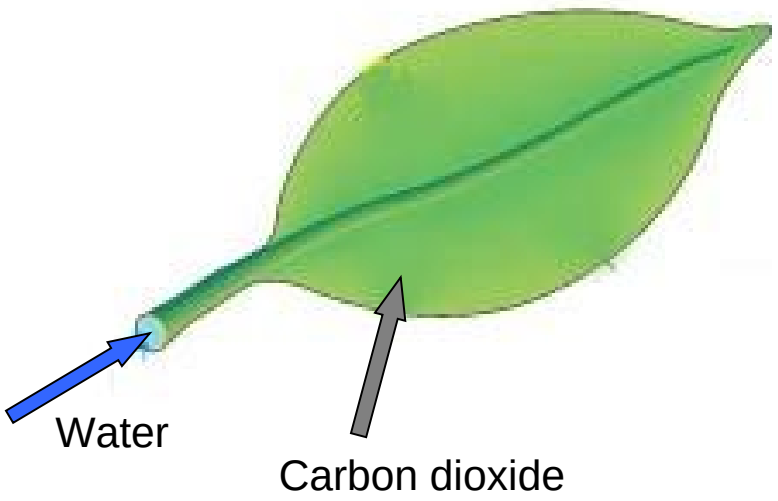
Equation for photosynthesis

Photosynthesis can be summarised as:

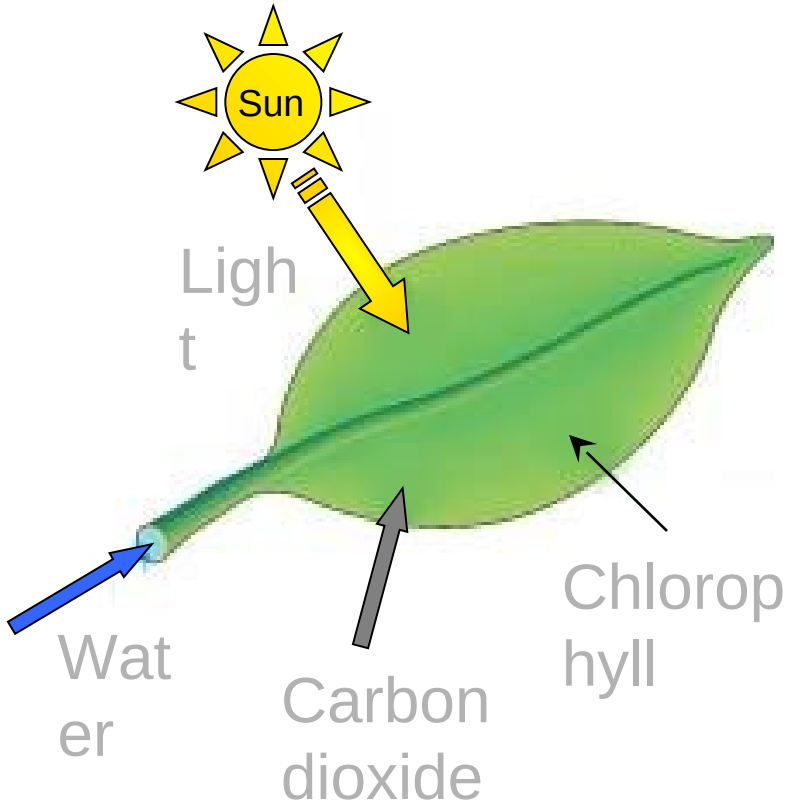


Factors needed for photosynthesis

- **Carbon dioxide (a gas)**
  - passes into the leaves from the air
  - enters the under-surface of leaves through tiny openings called stomata.
- **Water**
  - enters the roots from the soil
  - passes up through the stem
  - enters the leaves in the veins.



- **Light**
  - in the form of sunlight, provides the energy for photosynthesis.
- **Chlorophyll**
  - is a green pigment or dye made by plants
  - acts as a catalyst for photosynthesis.

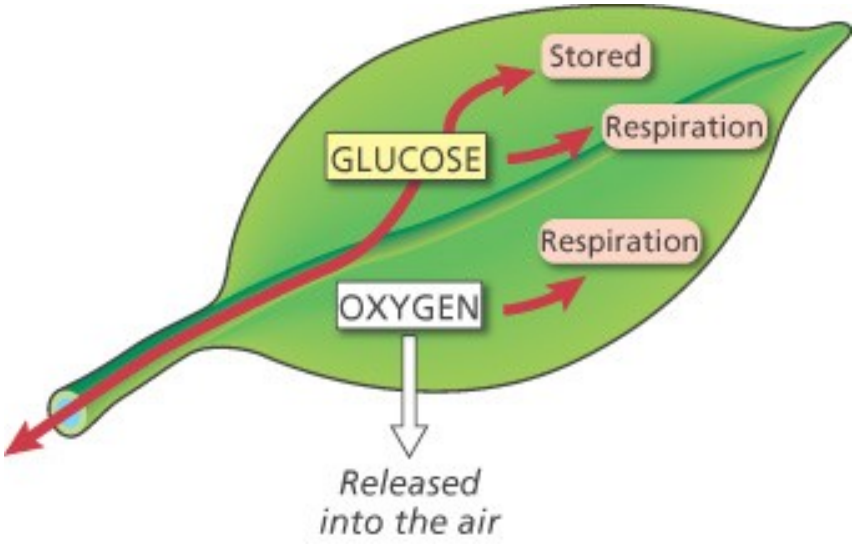


Products of photosynthesis

- **Glucose**
  - is a sugar or carbohydrate
  - may be used in the plant for:
    - respiration (i.e. it is broken down to release energy)
    - storage in the form of starch
    - making cell walls (i.e. it is converted to cellulose).

Products of photosynthesis

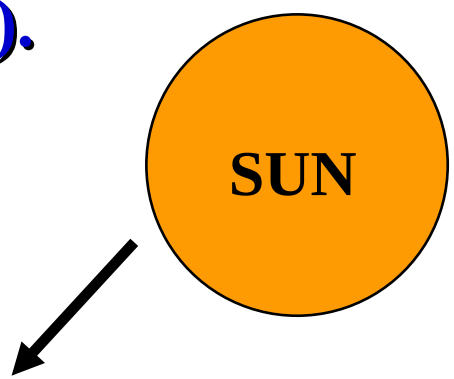
- **Oxygen**
  - is a gas
  - may be used in the plant for respiration
  - mostly passes out of the stomata into the air.



PHOTOSYNTHESIS

Photosynthesis

- An **anabolic, endergonic, carbon dioxide (CO_2)** requiring process that uses **light energy (photons)** and **water (H_2O)** to produce **organic macromolecules (glucose).**



$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

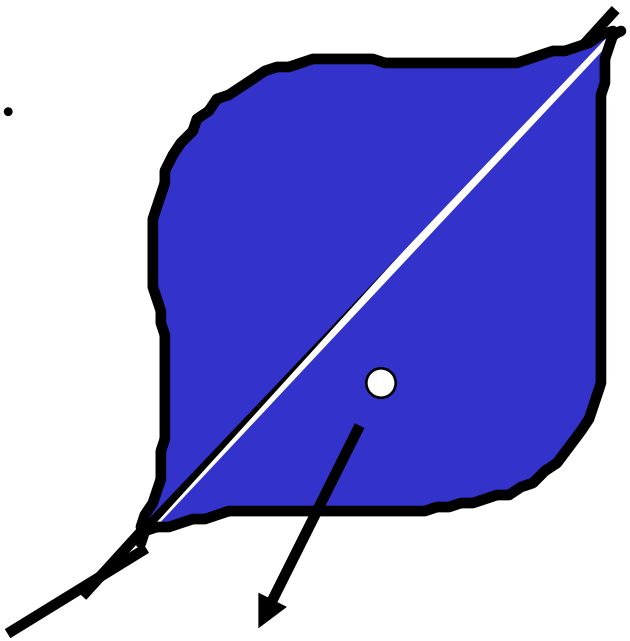
glucose

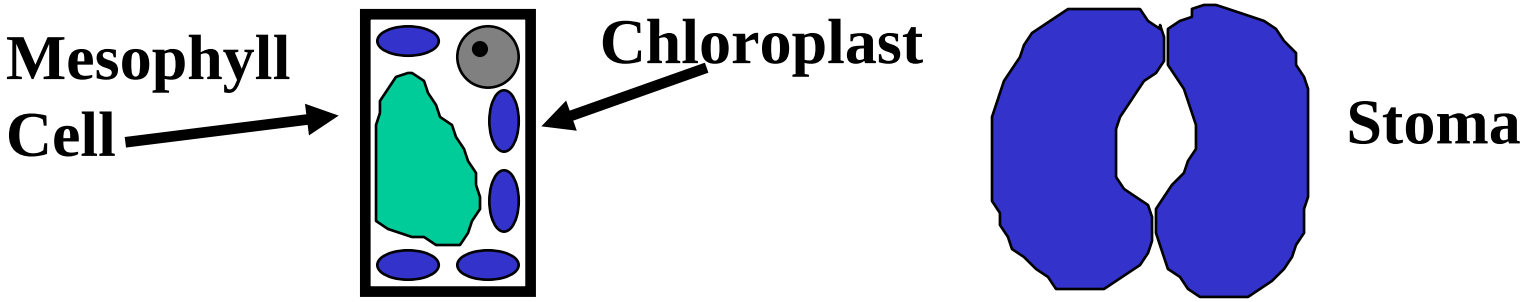
Question:

- **Where does photosynthesis take place?**

Plants

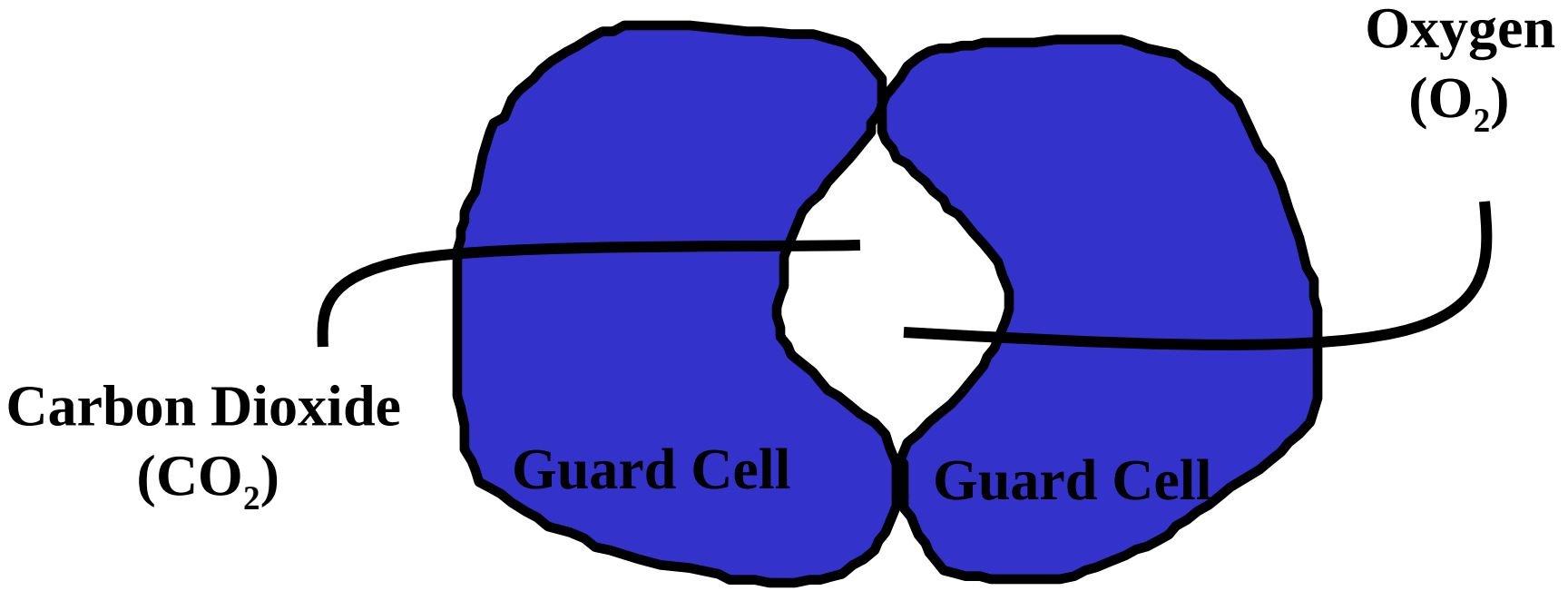
- **Autotrophs:** self-producers.
- Location:
  1. Leaves
     a. **stoma**
     b. **mesophyll cells**



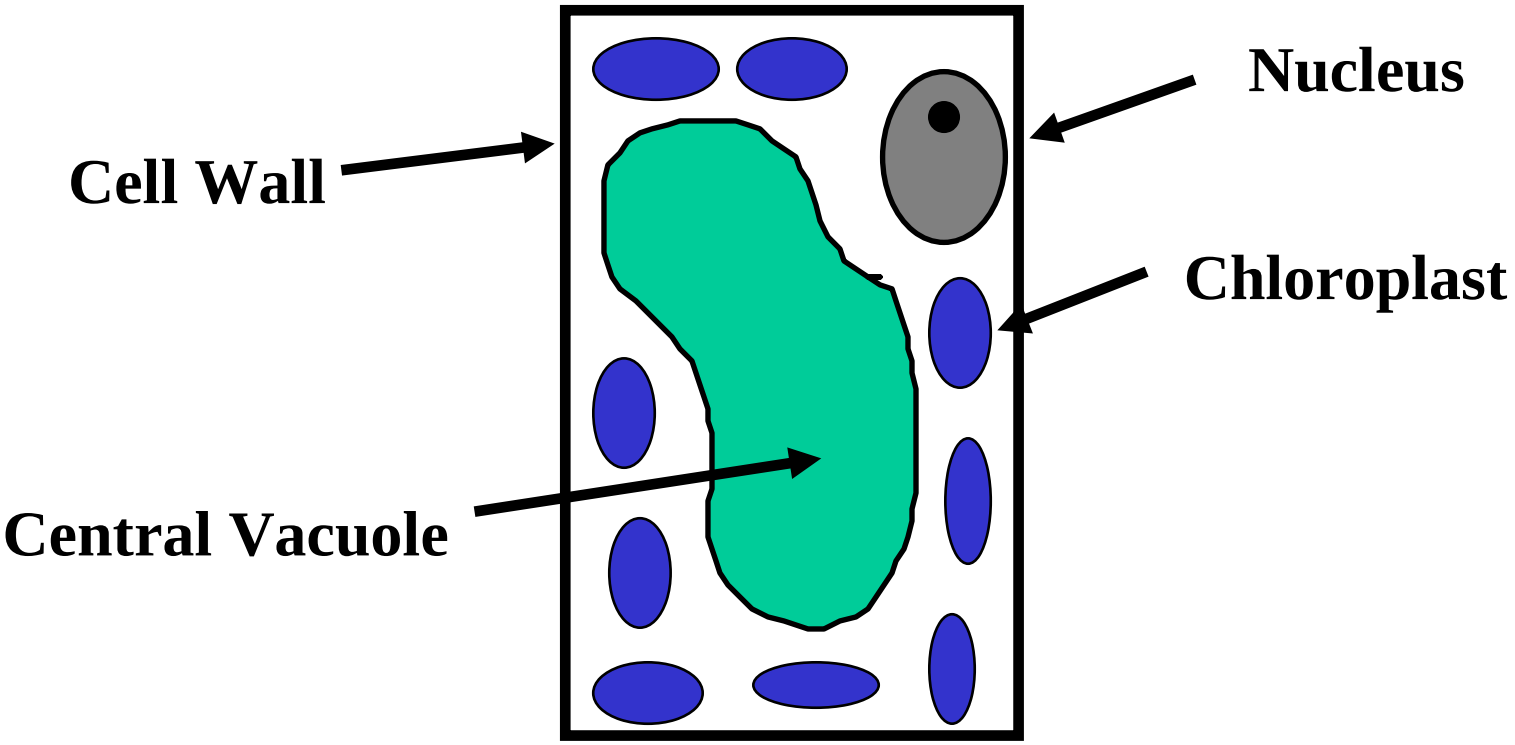


Stomata (stroma)

- **Pores** in a plant's cuticle through which **water** and **gases** are exchanged between the plant and the atmosphere.

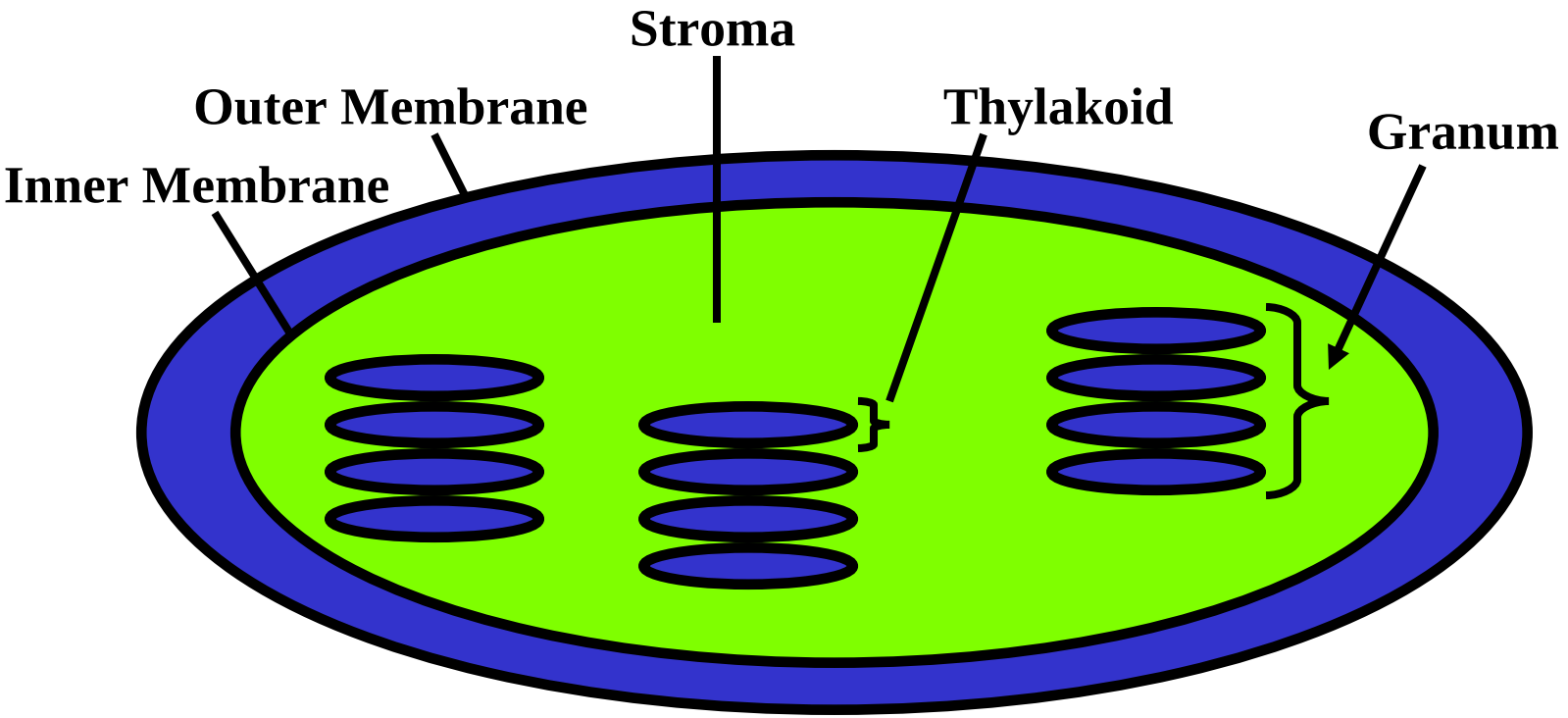


Mesophyll Cell

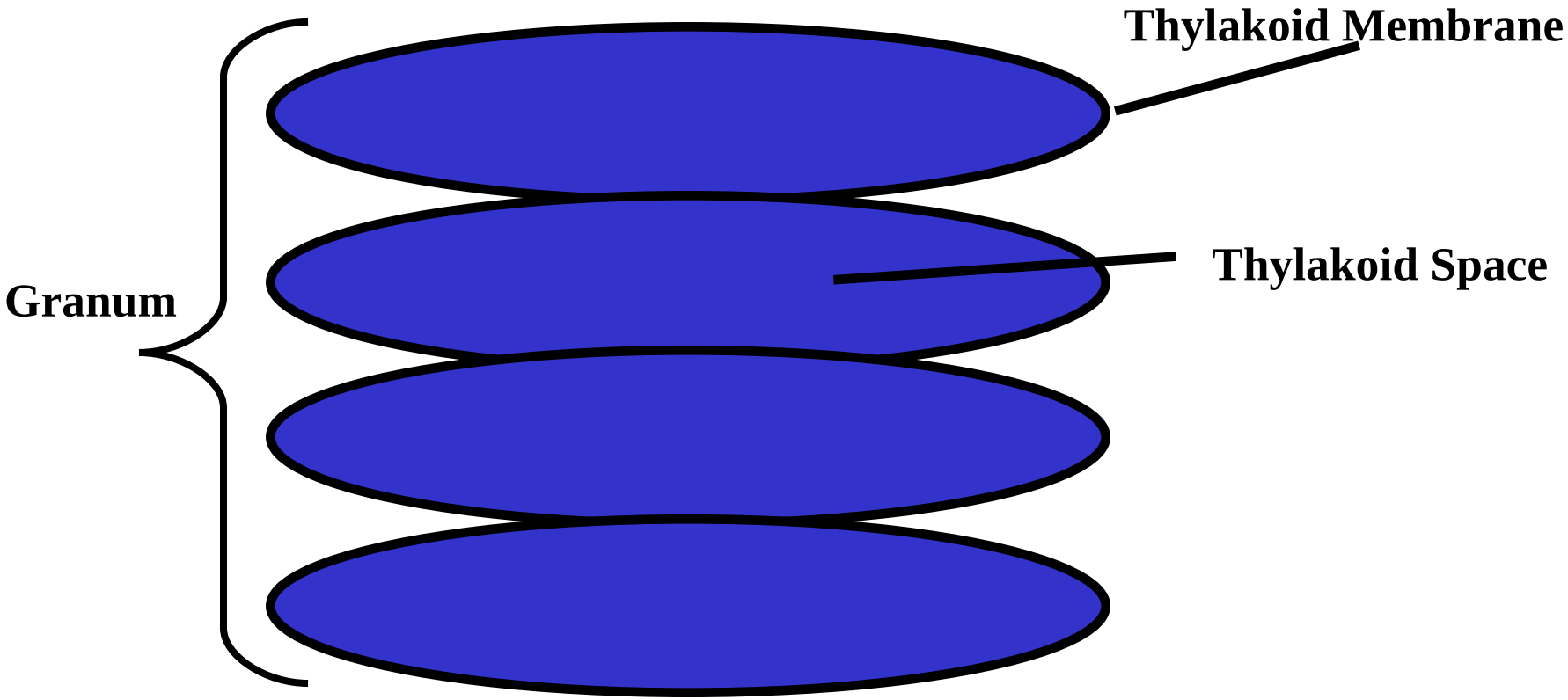


Chloroplast

- **Organelle** where **photosynthesis** takes place.



Thylakoid



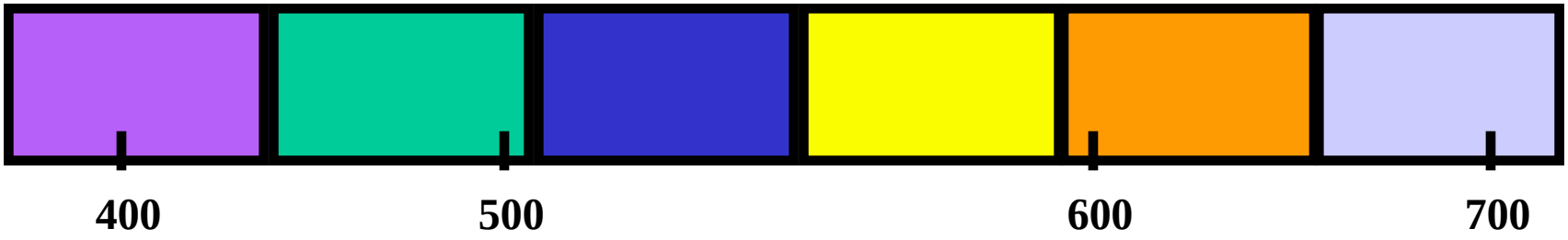
Question:

- **Why are plants green?**

Chlorophyll Molecules

- Located in the **thylakoid membranes**.
- Chlorophyll have **Mg^{+}** in the center.
- **Chlorophyll pigments** harvest energy (photons) by **absorbing** certain **wavelengths** (**blue-420 nm** and **red-660 nm** are most important).
- **Plants** are **green** because the **green wavelength** is **reflected**, not absorbed.

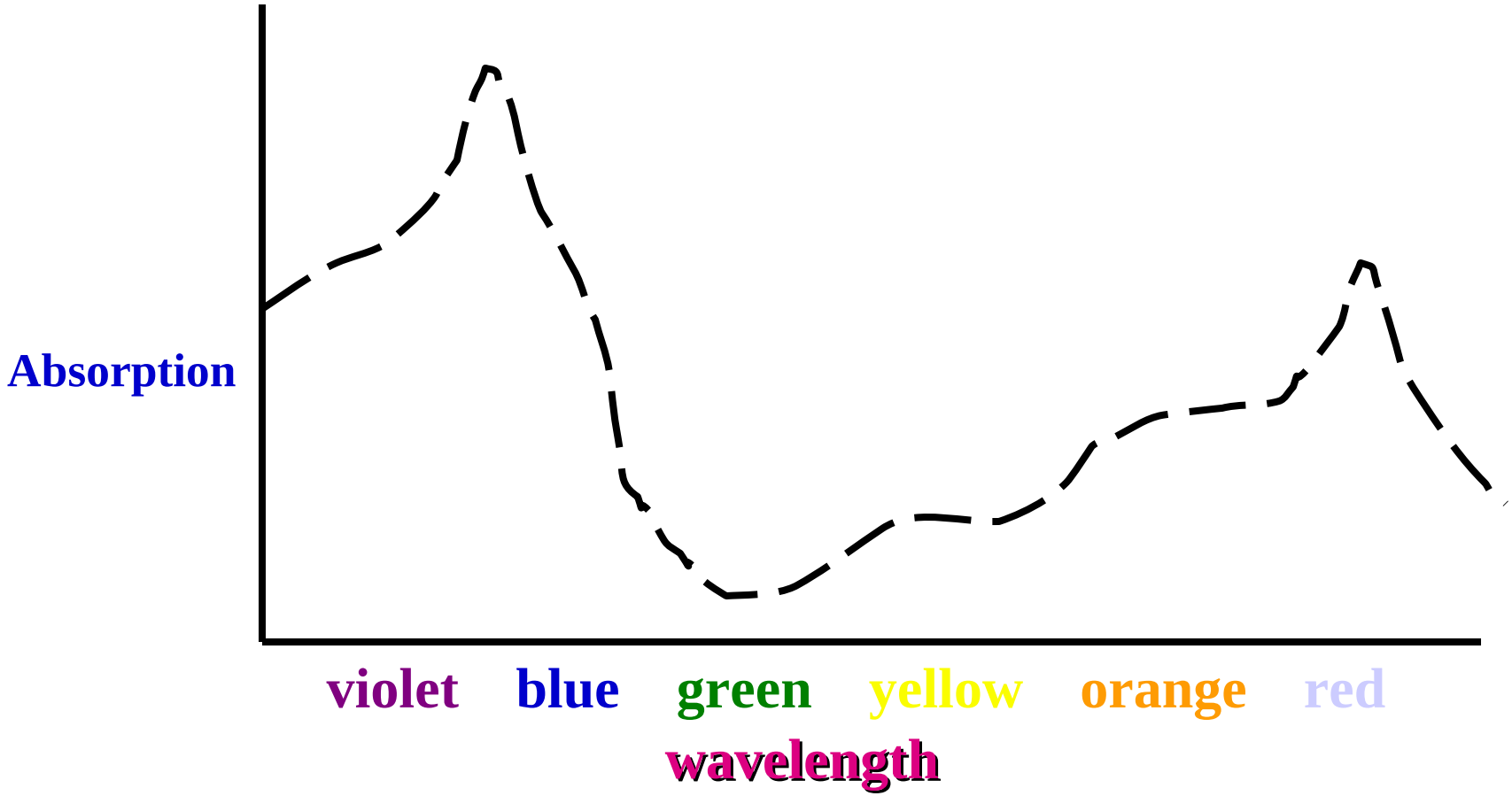
Wavelength of Light (nm)



Short wave
(more energy)

Long wave
(less energy)

Absorption of Chlorophyll



Question:

- **During the fall, what causes the leaves to change colors?**

Fall Colors

- In addition to the chlorophyll pigments, there are other **pigments** present.

- During the fall, the **green chlorophyll** pigments are greatly reduced revealing the other **pigments**.

- Carotenoids are pigments that are either red **or** yellow.

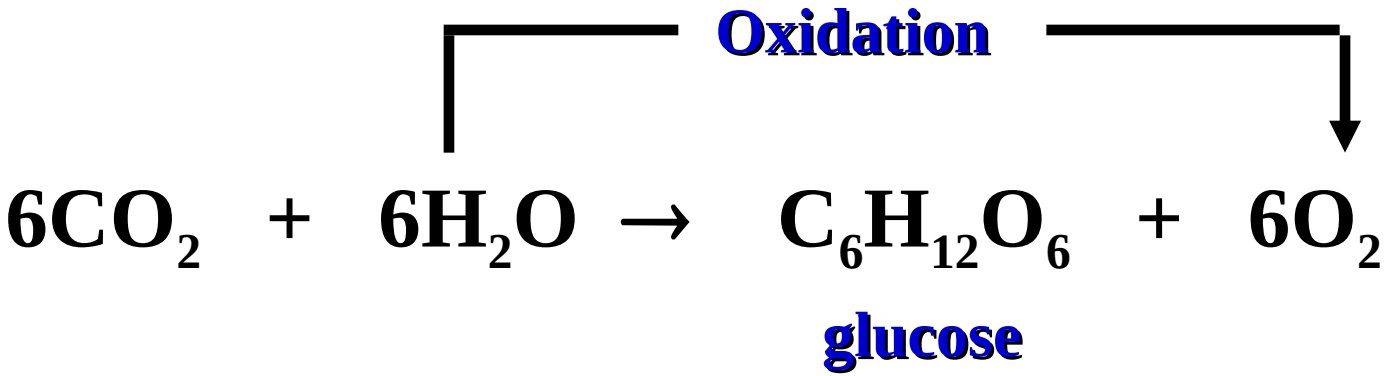
Redox Reaction

- The **transfer** of **one** or **more electrons** from **one reactant** to **another**.

- Two types:
  1. **Oxidation**
  2. **Reduction**

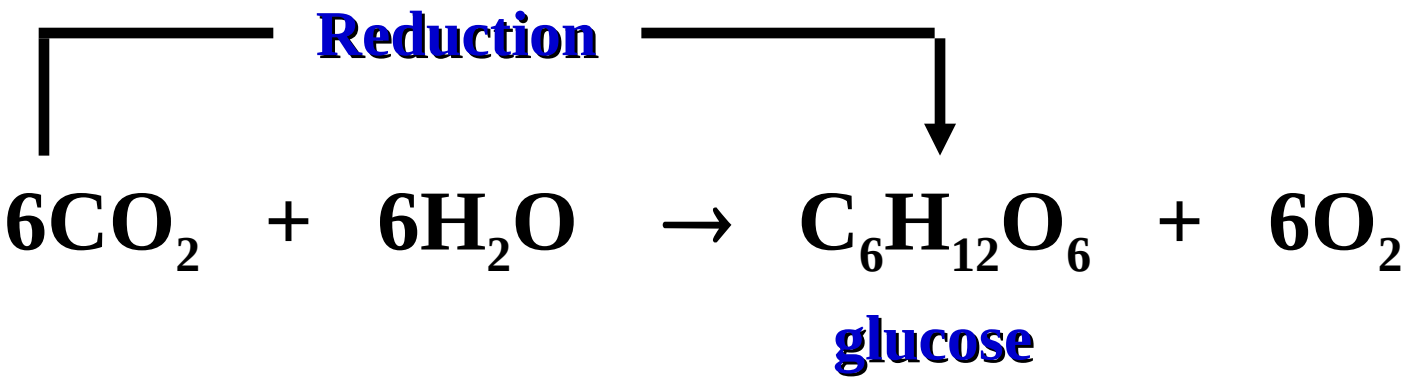
Oxidation Reaction

- The loss of **electrons** from a **substance**.
- Or the **gain** of **oxygen**.



Reduction Reaction

- The **gain** of **electrons** to a **substance**.
- Or the **loss** of **oxygen**.



Breakdown of Photosynthesis

- **Two main parts (reactions).**

1. **Light Reaction or**
   Light Dependent Reaction

Produces **energy** from **solar power (photons)** in the form of **ATP** and **NADPH**.

Breakdown of Photosynthesis

2. **Calvin Cycle or**
Light Independent Reaction or
Carbon Fixation or
C_3 Fixation

Uses **energy (ATP and NADPH)** from **light rxn** to make **sugar (glucose).**

1. Light Reaction (Electron Flow)

- Occurs in the **Thylakoid membranes**
- During the **light reaction**, there are two possible routes for **electron flow**.

A. Cyclic Electron Flow

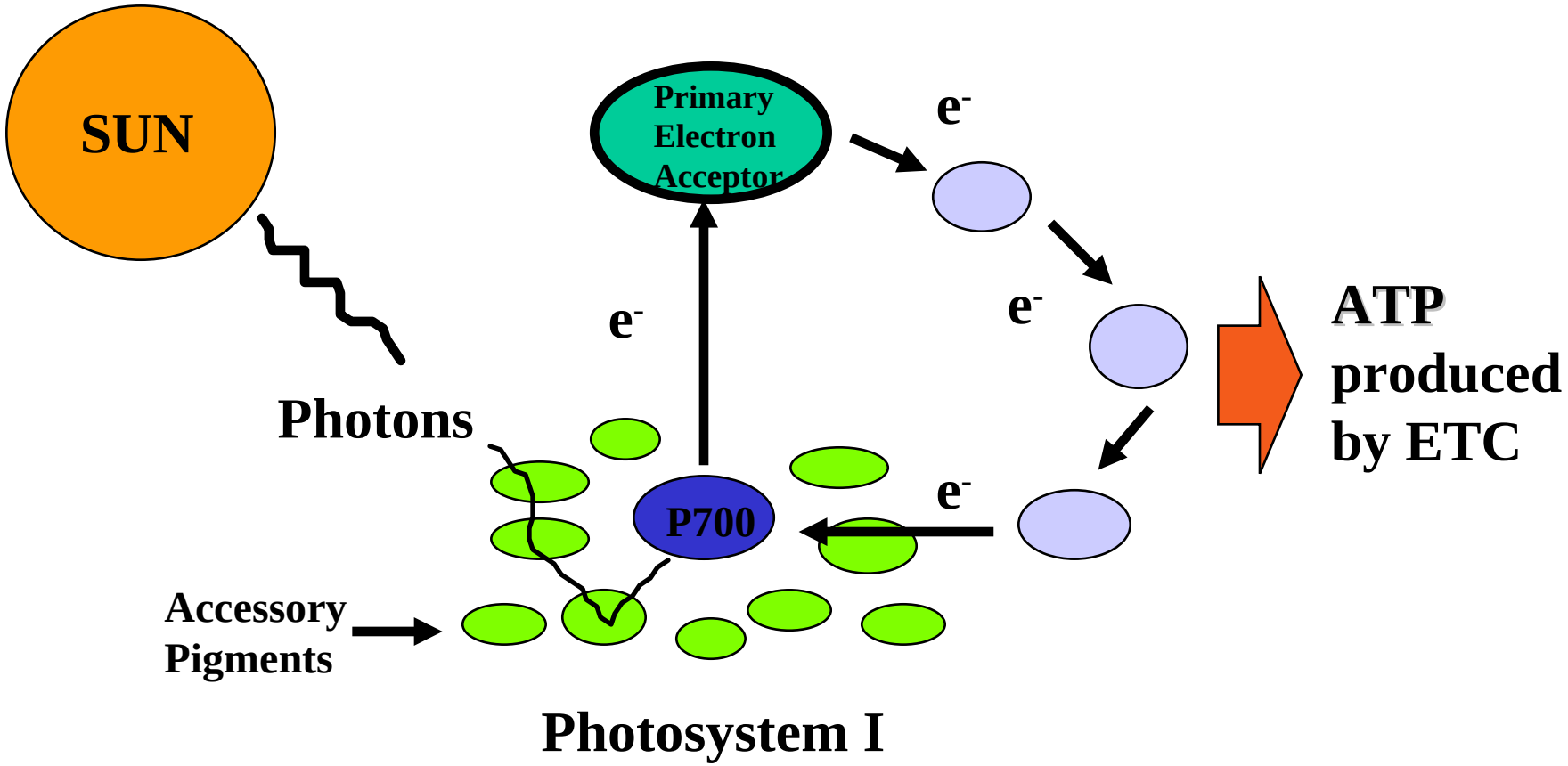
B. Noncyclic Electron Flow

A. Cyclic Electron Flow

- Occurs in the **thylakoid membrane**.
- Uses **Photosystem I only**
- P700 reaction center- chlorophyll a
- Uses **Electron Transport Chain (ETC)**
- Generates ATP only



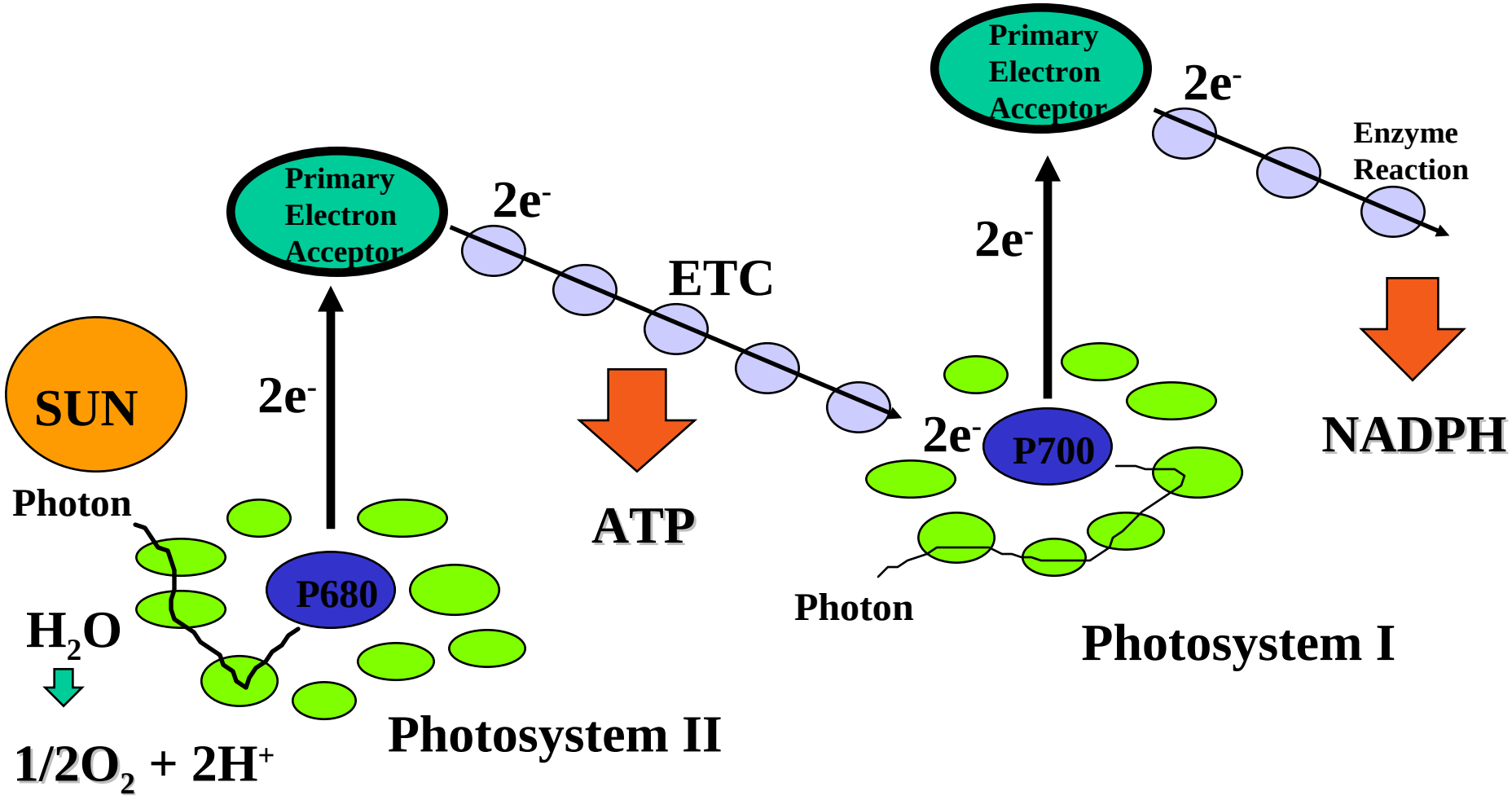
A. Cyclic Electron Flow



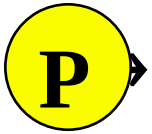
B. Noncyclic Electron Flow

- Occurs in the **thylakoid membrane**
- Uses **PS II** and **PS I**
- P680 rxn center (PSII) - chlorophyll a
- P700 rxn center (PS I) - chlorophyll a
- Uses **Electron Transport Chain (ETC)**
- Generates O_2, ATP and NADPH

B. Noncyclic Electron Flow



B. Noncyclic Electron Flow

- **ADP +**  **ATP**

  (Reduced)

- **$NADP^+$ + H → NADPH**

  (Reduced)

- Oxygen comes from the splitting of **H_2O**, not **CO_2**

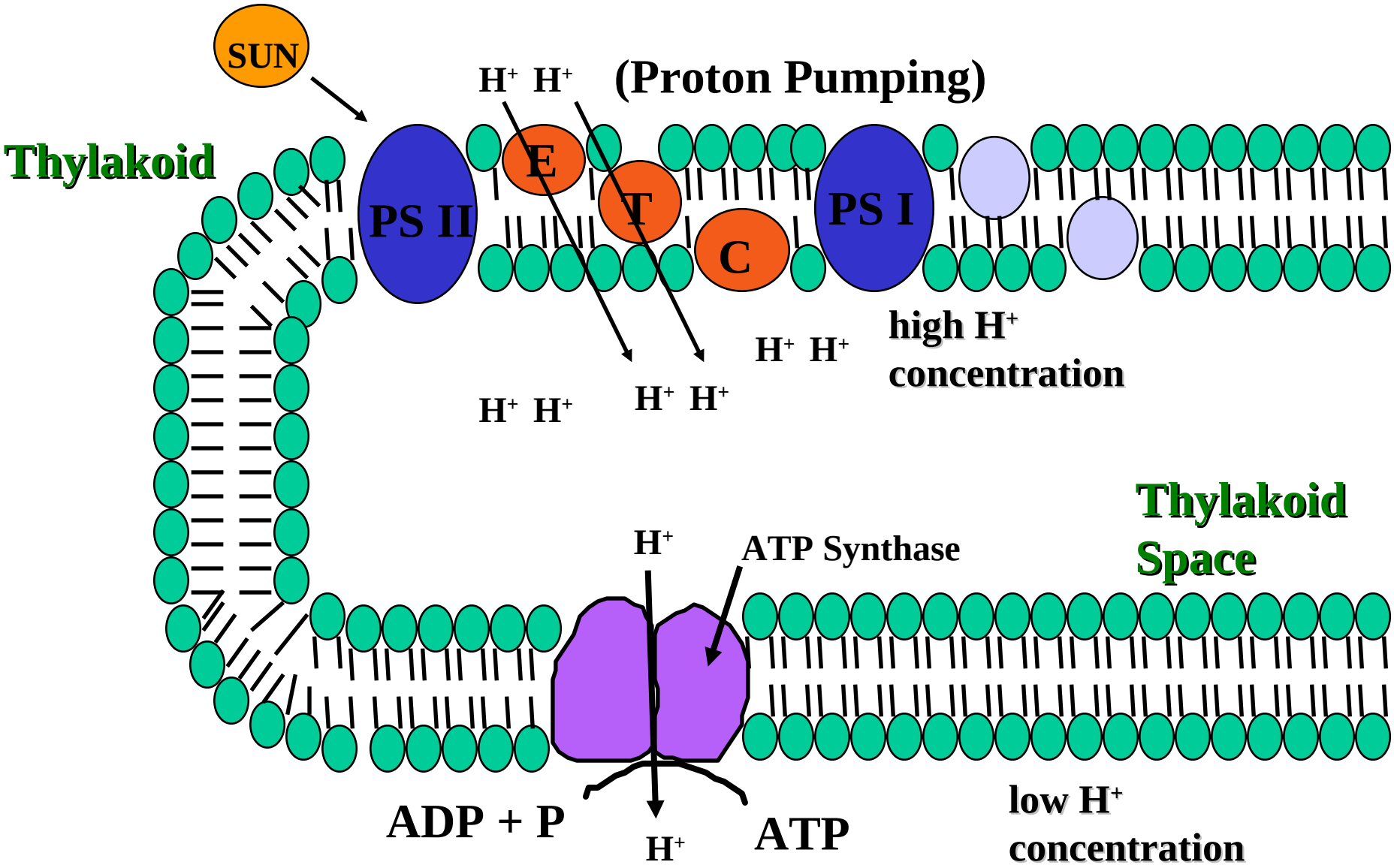
$H_2O \rightarrow 1/2\ O_2 + 2H^+$

(Oxidized)

Chemiosmosis

- **Powers ATP synthesis.**
- Located in the **thylakoid membranes**.
- Uses **ETC** and **ATP synthase (enzyme)** to **make ATP**.
- **Photophosphorylation:** addition of **phosphate** to **ADP** to make **ATP**.

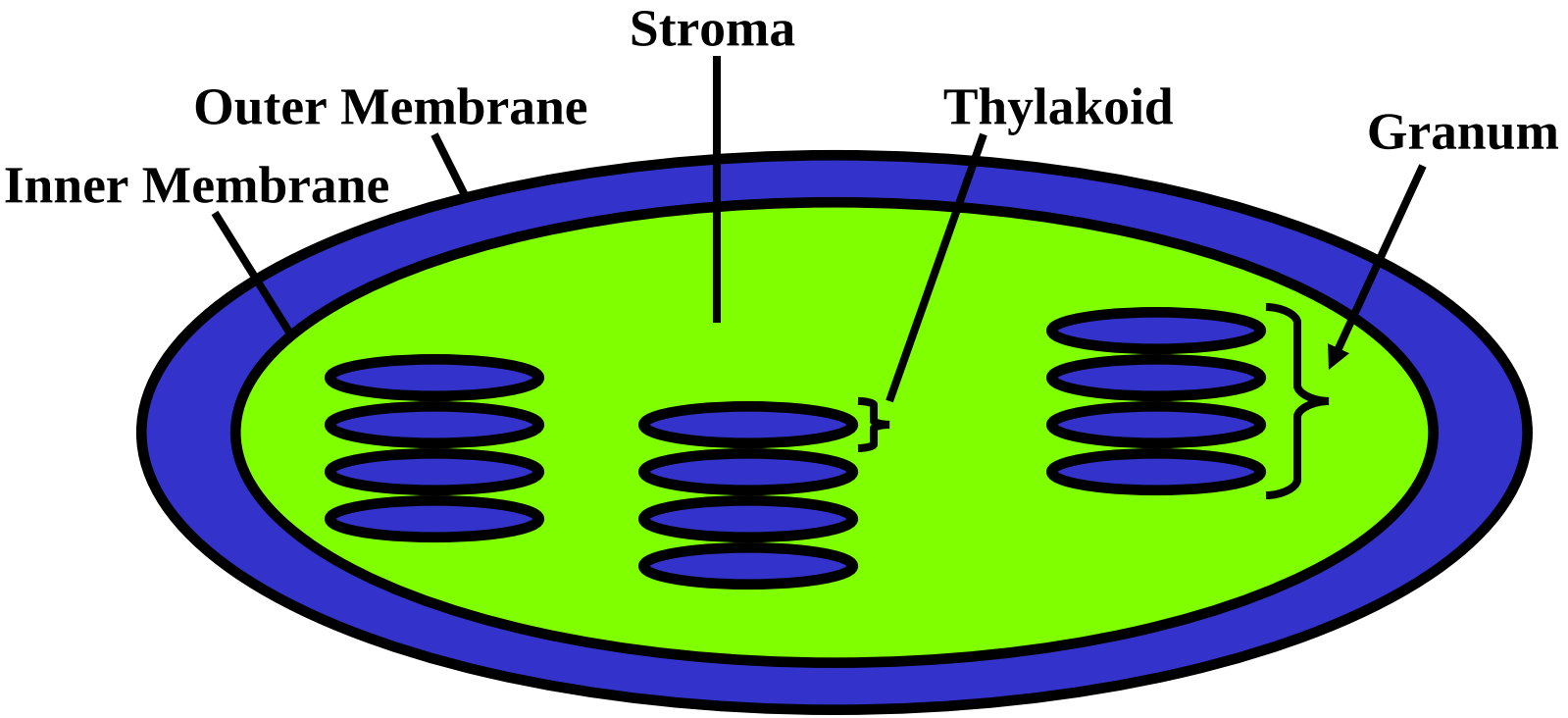
Chemiosmosis



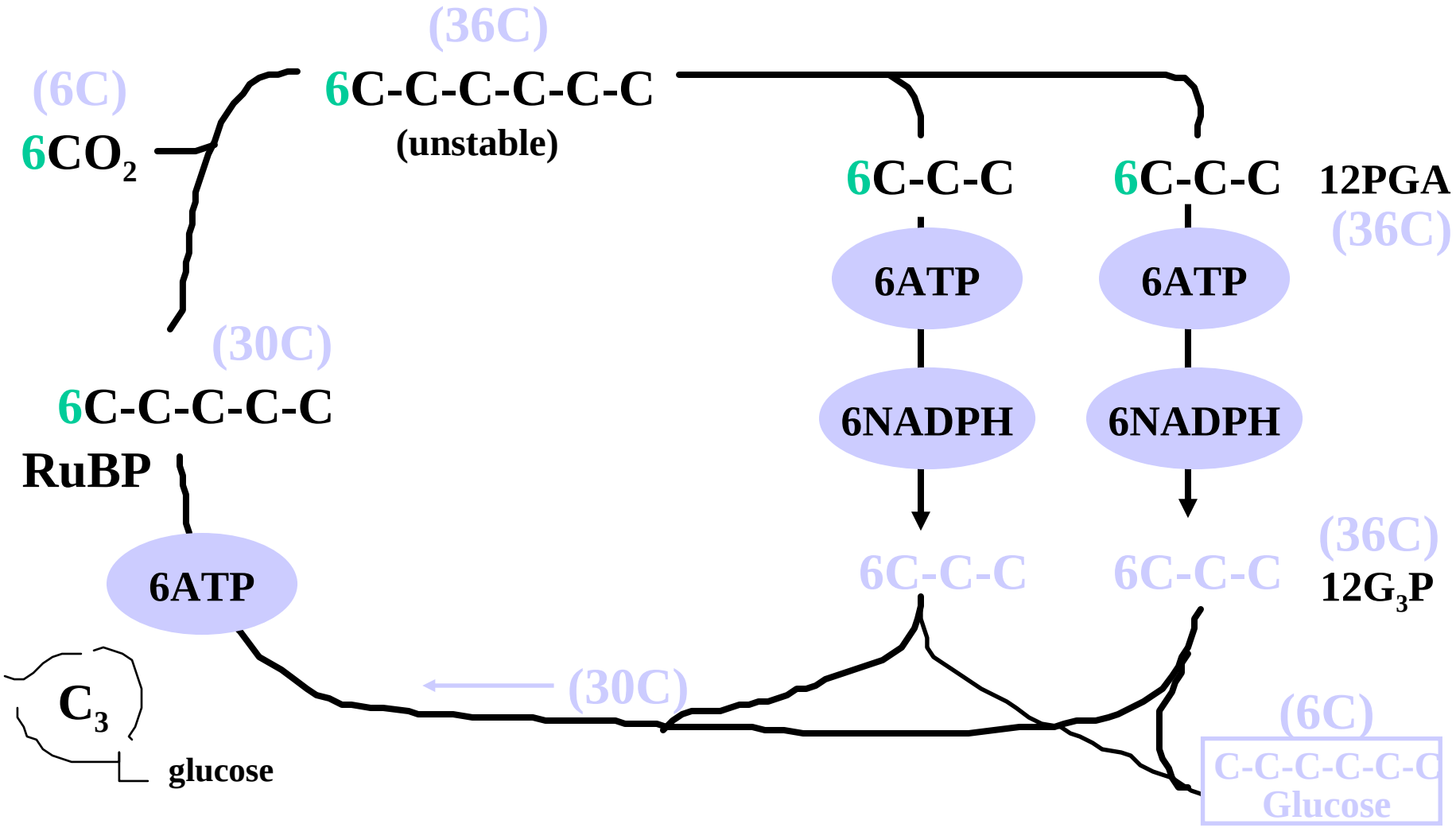
Calvin Cycle

- **Carbon Fixation (light independent rxn).**
- **C_3 plants** (80% of plants on earth).
- Occurs in the **stroma**.
- Uses **ATP** and **NADPH** from light rxn.
- Uses **CO_2**.
- To produce **glucose**: it takes **6 turns** and **uses 18 ATP and 12 NADPH**.

Chloroplast

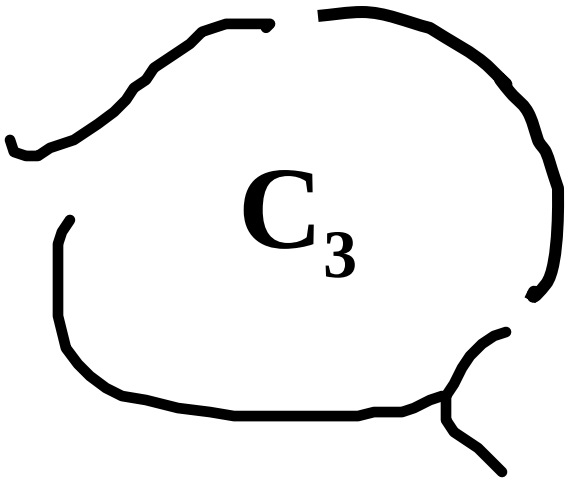


Calvin Cycle (C_3 fixation)



Calvin Cycle

- **Remember: C3 = Calvin Cycle**



Glucose

Photorespiration

- Occurs on **hot, dry, bright days**.
- **Stomates close.**
- Fixation of **O_2 instead of CO_2**.
- Produces **2-C molecules** instead of **3-C sugar molecules**.
- Produces **no sugar molecules or no ATP.**

Photorespiration

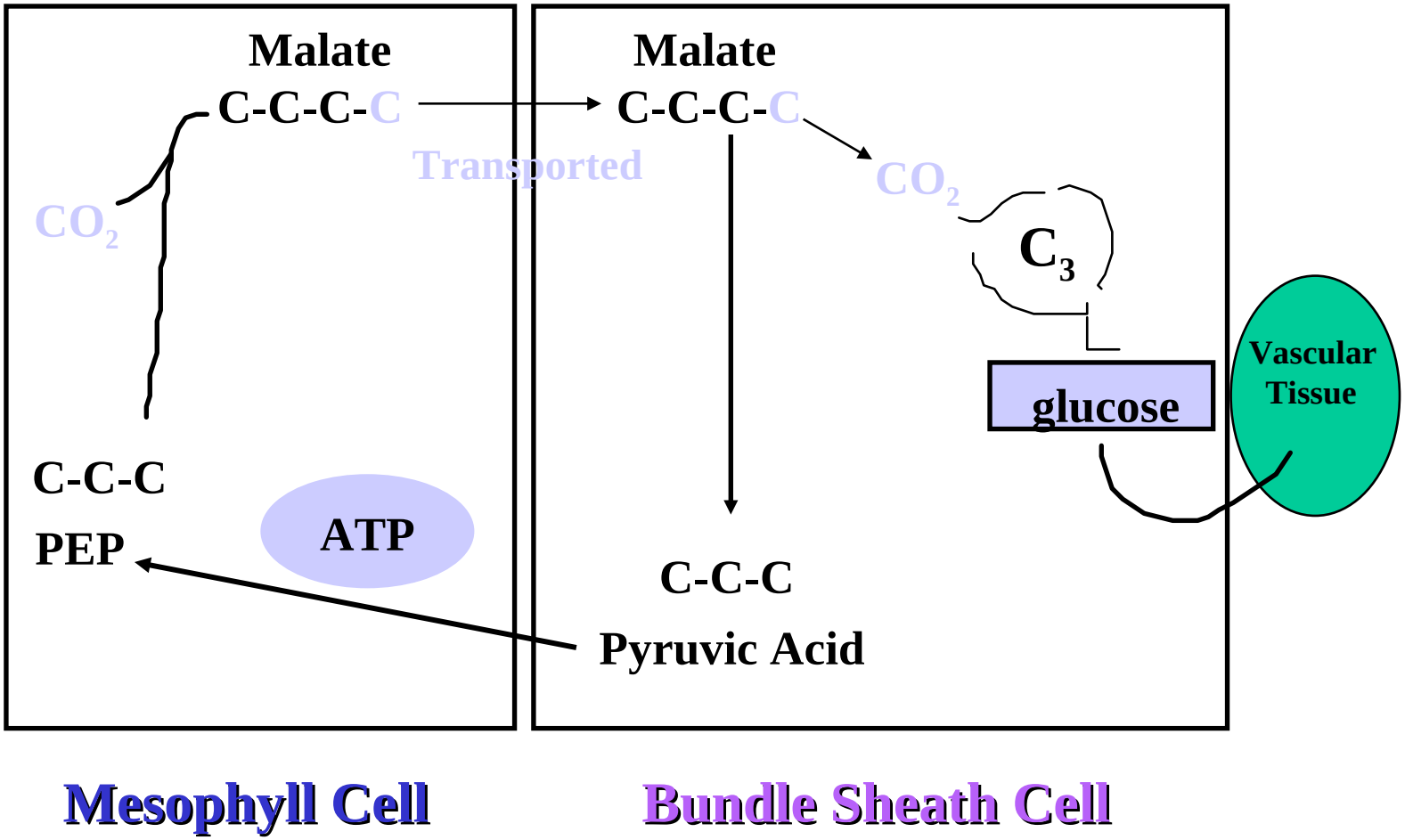
- Because of photorespiration: **Plants** have **special adaptations** to limit the effect of **photorespiration**.

1. **C4 plants**
2. **CAM plants**

C4 Plants

- Hot, moist environments.
- **15% of plants (grasses, corn, sugarcane).**
- **Divides photosynthesis spatially.**
- Light rxn - mesophyll cells.
- Calvin cycle - bundle sheath cells.

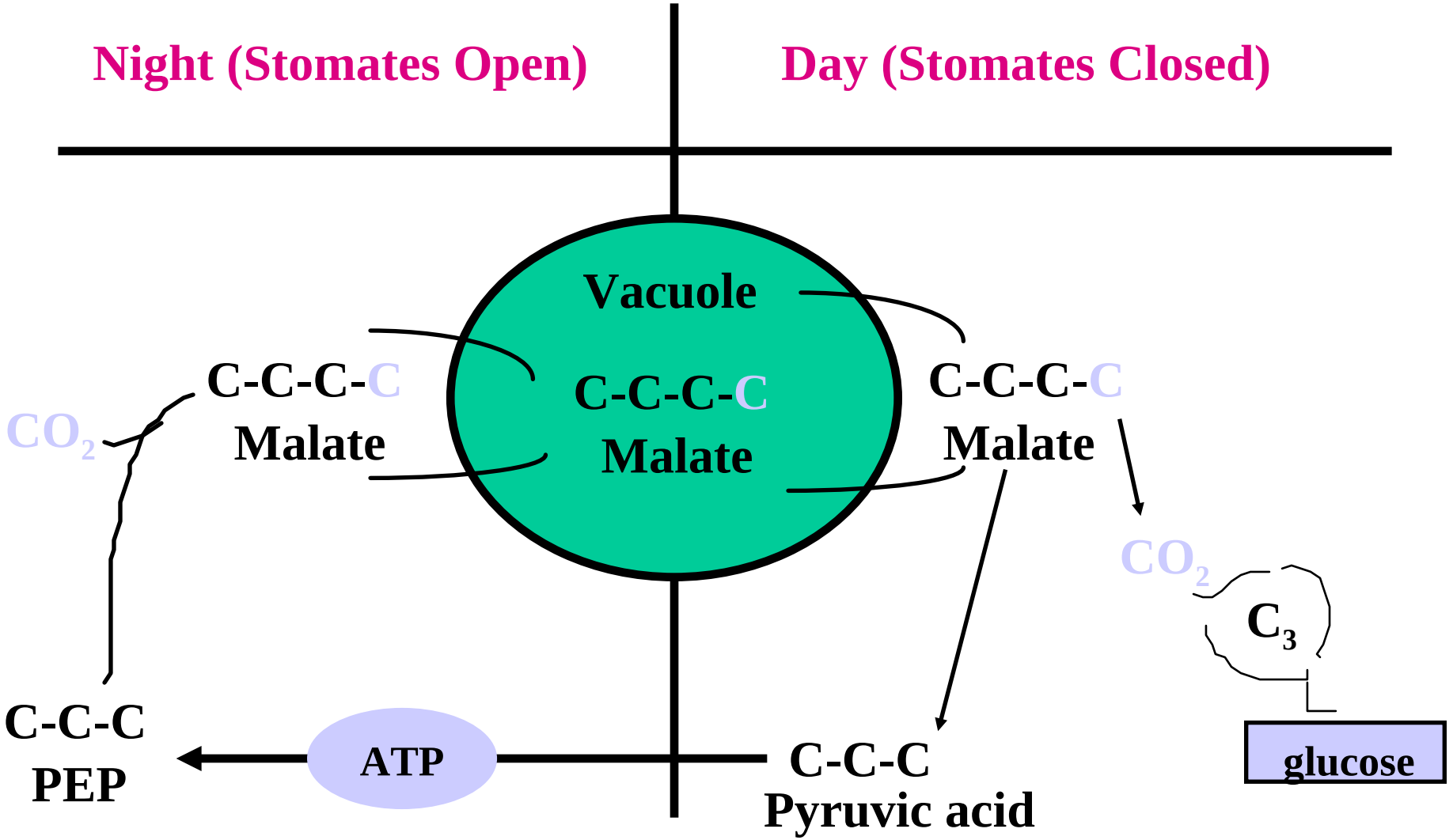
C4 Plants


Malate
C-C-C-C
Transported
Malate
C-C-C-C
CO_2
CO_2
C_3
Vascular Tissue
glucose
C-C-C
PEP
ATP
C-C-C
Pyruvic Acid
Mesophyll Cell
Bundle Sheath Cell

CAM Plants

- Hot, dry environments.
- **5% of plants (cactus and ice plants).**
- **Stomates <u>closed during day</u>.**
- **Stomates <u>open during the night</u>.**
- Light rxn - occurs during the **day**.
- Calvin Cycle - occurs when CO_2 is present.

CAM Plants


Night (Stomates Open)
Day (Stomates Closed)
Vacuole
C-C-C-C
Malate
C-C-C-C
Malate
C-C-C-C
Malate
CO_2
CO_2
C_3
C-C-C
PEP
ATP
C-C-C
Pyruvic acid
glucose

Question:

- **Why would CAM plants close their stomates during the day?**

Plant water transport

- How can water move from the ground all the way to the top of a 100 m tall redwood tree?

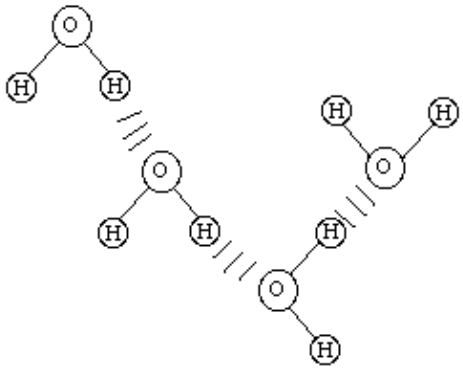


Water transport in plants:



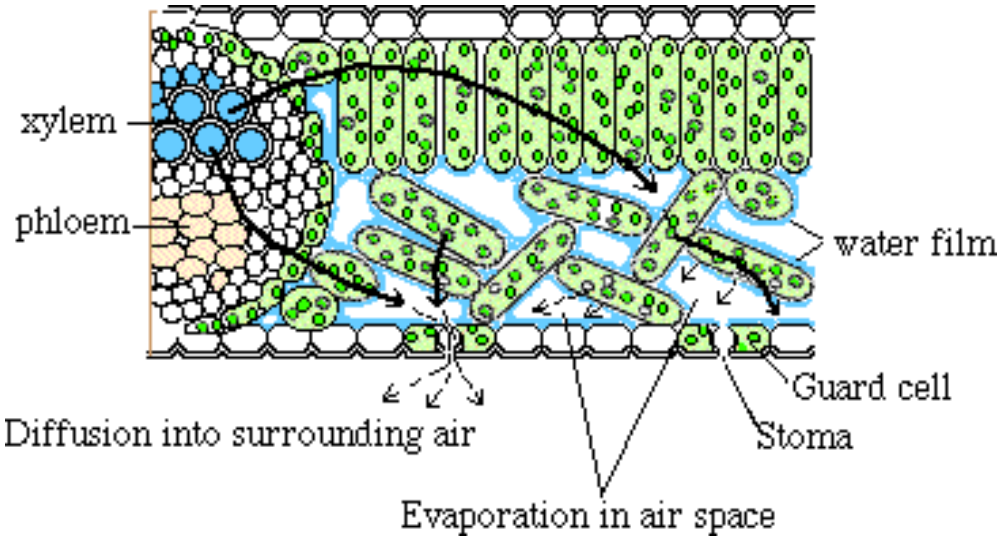
❖The same way we drink soda from a straw!

- Water's great **cohesive forces** (molecules sticking to each other) and **adhesive forces** (attaching to walls of xylem cells)



Transpiration-cohesion Theory
for water transport in the xylem

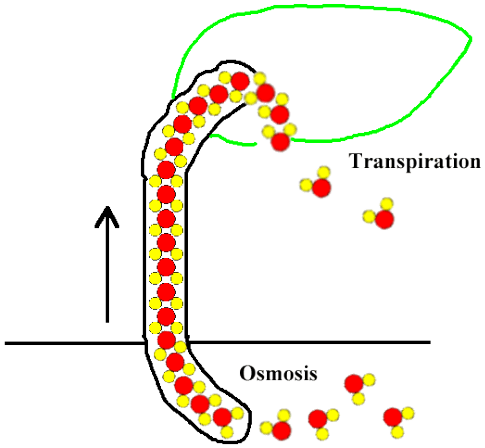
- **Evaporation** of water in the leaves (through stomates) generates the 'sucking force' that pulls adjacent water molecules up the leaf surface



Water transport (cont.)

- Like a long chain, water molecules pull each other up the column.
- The column goes from roots → leaves.

❖What's amazing is that the water moves up by using the sun's evaporative energy…



- Plants control transpiration by opening/closing stomata

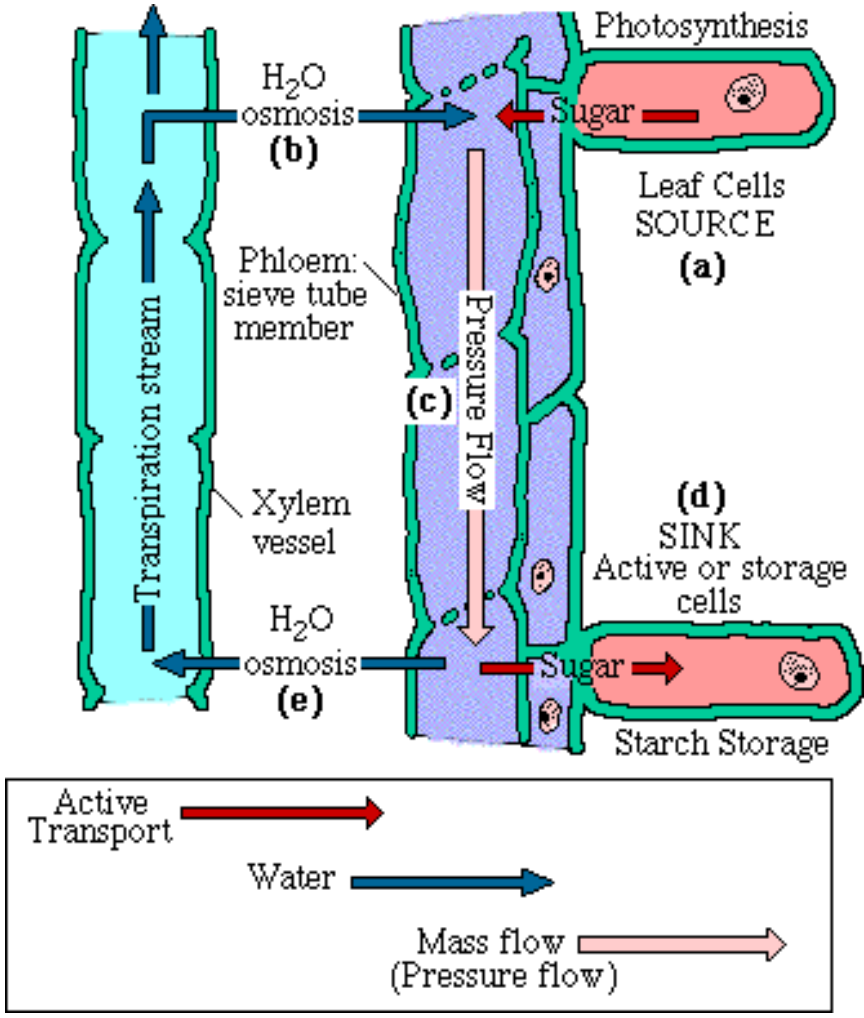
Sugar translocation

- 1. Sugars made in **leaf mesophyll** cells (source) diffuse to phloem cells in the vascular bundles.
- 2. **Companion cells** load dissolved sugars into the phloem STM using energy (ATP).
- 3. Water moves into cells with high sugar concentration.
- 4. Osmotic water flow generates a high hydraulic pressure that moves dissolved sugars through the phloem to the rest of the plant (sink).

Pressure flow in phloem

- Sugars made in the leaves are loaded into companion cells and into phloem STM.

- Water (from xylem) moves in by osmosis, creating **pressure flow** down the phloem.



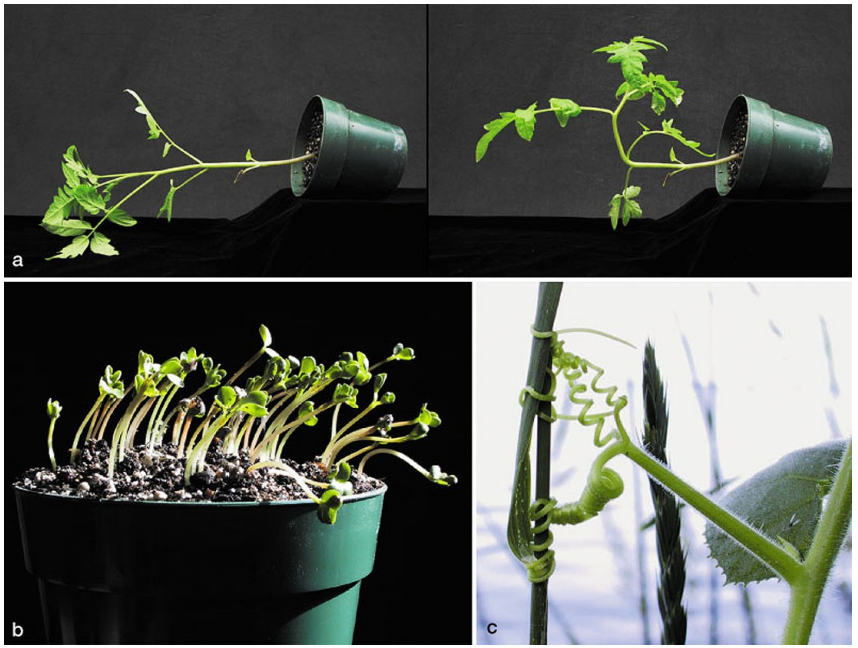
Plant Hormones

- Chemical compounds produced by plants
- Effective at very low concentrations
- Five major hormone groups are:

1. Auxins
2. Gibberellins
3. Cytokinins
4. Abscisic Acid
5. Ethylene

1. AUXINS

- Promote cell growth
- Involved in gravitropism



and phototropism

- Control fruit development



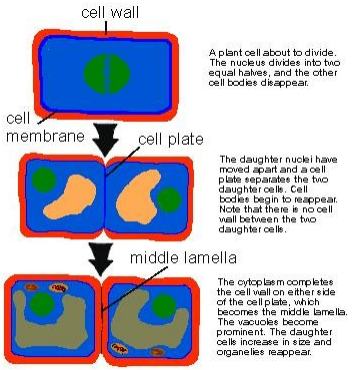
2. Gibberellins

- Promote stem elongation



3. Cytokinins

- Promote cell division and organ differentiation



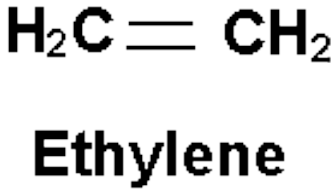
4. Abscisic Acid

- Promotes seed dormancy
- Causes stomata closing



5. ETHYLENE

- Gaseous hormone,
  very simple formula (C_2H_4)



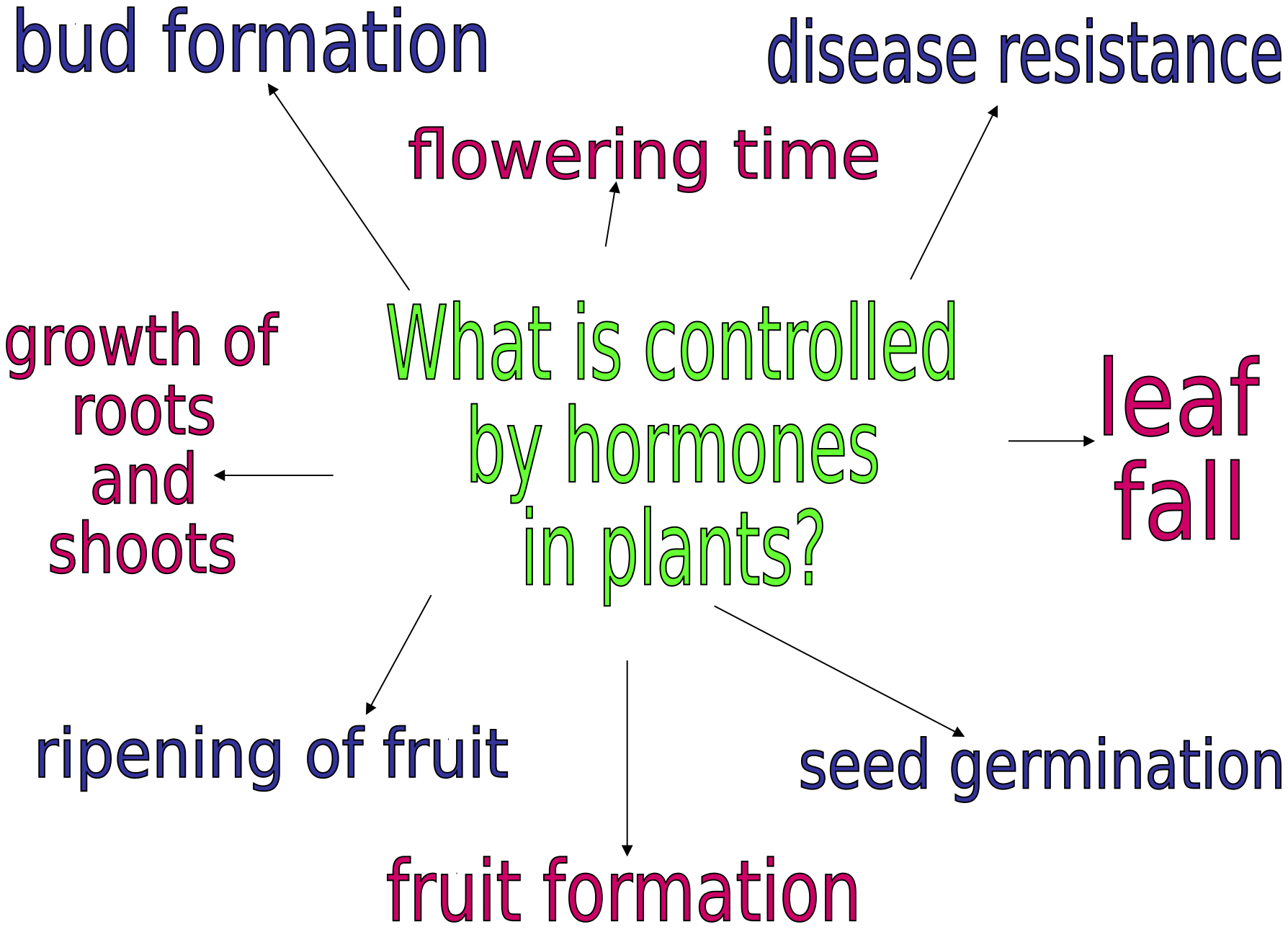
- Ethylene promotes
  fruit ripening!



Air Ethylene

Plant responses

- The ability to respond is one of the characteristics of life.
- Plants usually respond slowly (so that often we do not see their responses).
- Plants respond to light and gravity by growing towards or away from light or gravity.
- A **tropism** is the change in growth of a plant in response to an outside stimulus.


bud formation
disease resistance
flowering time
growth of roots and shoots
What is controlled by hormones in plants?
leaf fall
ripening of fruit
seed germination
fruit formation

Plant responses



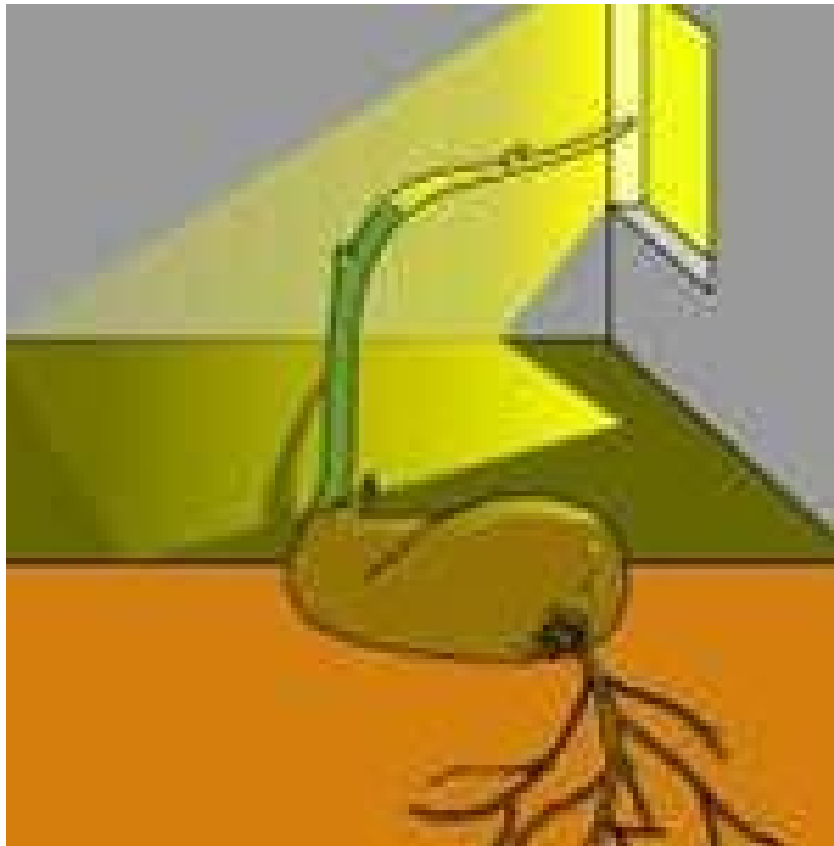
- Plants are rarely thought of as sensitive because their movements are not easily noticed when compared with animals.
- Animals respond to stimuli through nervous and chemical messages.

- Plants respond to stimuli through chemical messages, many of which are **plant hormones**.
- They play similar role to animal hormones; they are produced in one area of the plant, are transported around the body of the plant and have their affect on cells elsewhere.

Tropism

- Plants respond to a variety of stimuli by producing plant hormones which in turn affect the plant growth.
- These growth responses to environmental stimuli are known as **tropisms**.

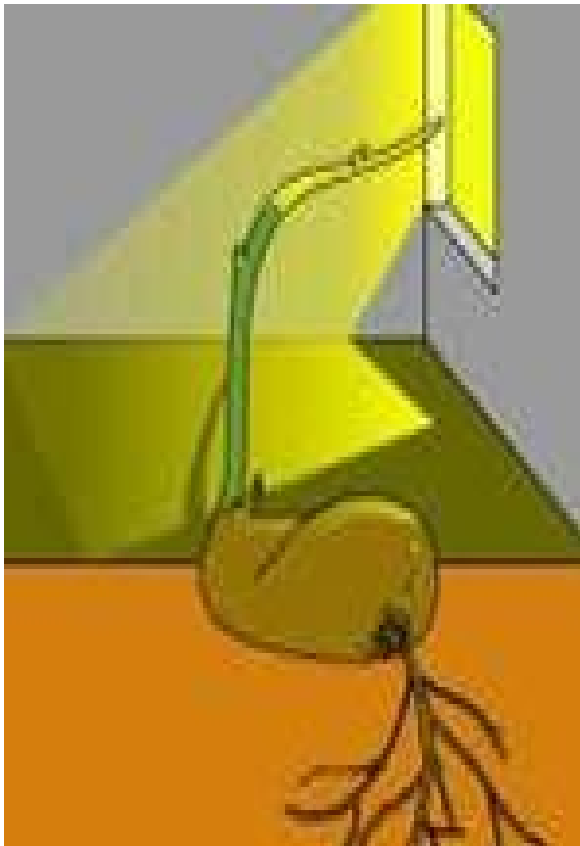
What is the difference between positive and negative tropism?



Tropism

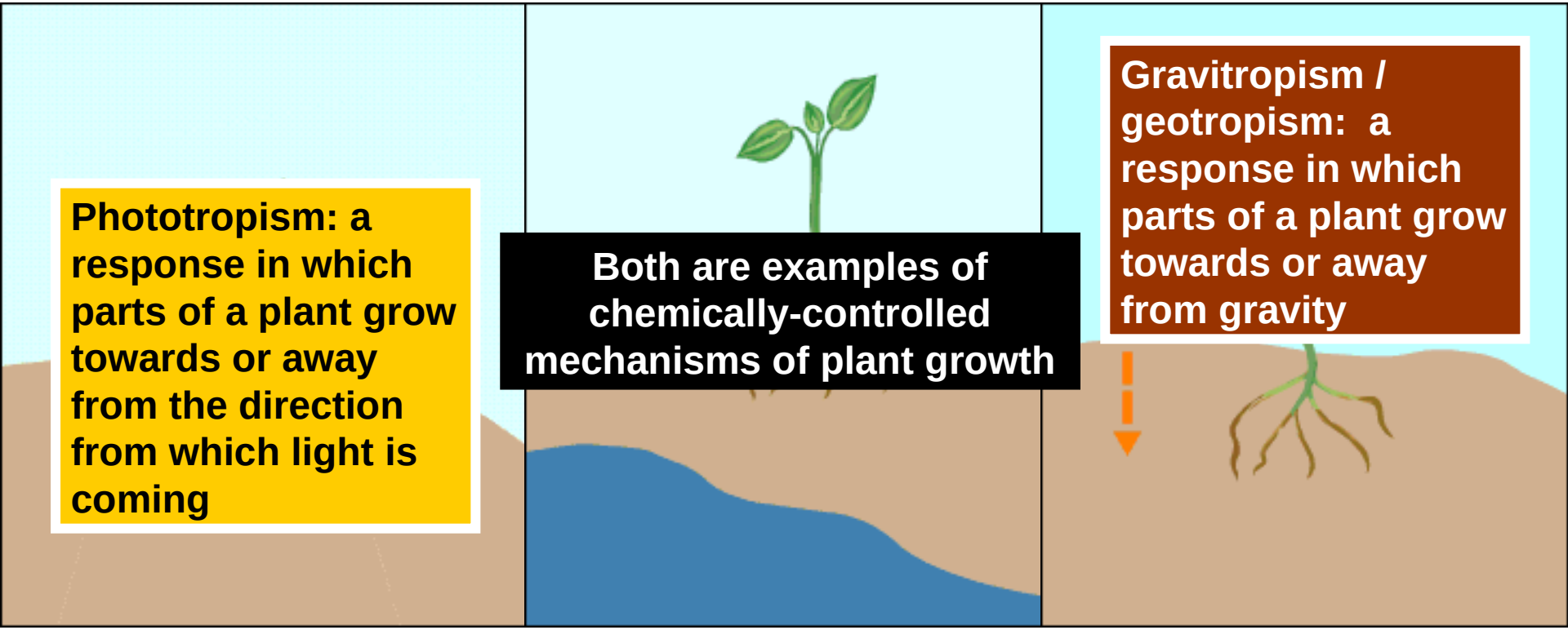
- ✓ Plants respond to a variety of stimuli by producing plant hormones which in turn affect the plant growth.
- ✓ These growth responses to environmental stimuli are known as **tropisms**.

- ➢ *A growth response that is towards the stimulus is called a **positive tropism**.*
- ➢ *A growth response that is away from the stimulus is called a **negative tropism.***



Phototropism

Geotropism



positve=towards
negative=away

Hydrotropism

Tropisms (+ and -)

Gravitropism: a response of a plant to gravity

Phototropism: a response of a plant to light

Thigmotropism: a response of a plant to touch

Hydrotropism: a response of a plant to water

Tropism

Responses of different parts of the plant

Response	Part of plant	Direction of growth	Advantage
Positive phototropism	Stem tip	Growth towards light	To get maximum light for photosynthesis
Negative phototropism	Root tip	Growth away from light	Less chance of drying out
Positive geotropism	Root tip	Towards gravity	More chance of finding moisture
Negative geotropism	Stem tip	Away from gravity	More chance of finding light

TROPISM

Plant growth in response to a stimulus

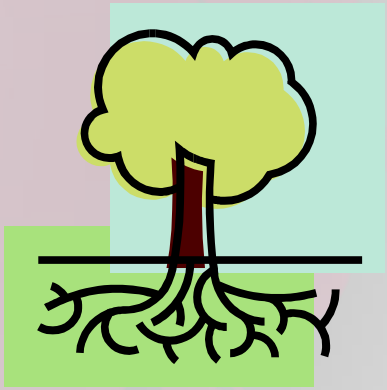
("tropo" – "turn")

.

There are many types of tropisms :

- *Phototropism*
- *Geotropism*
- *Thigmotropism*
- *Hydrotropism*
- *Chemotropism*
- *Thermotropism*

3 main types



*Can be positive or negative

GEOTROPISM

("Geo" – Earth)

***Geotropism** is the growth of a plant in response to gravity.*

Positive Geotropism

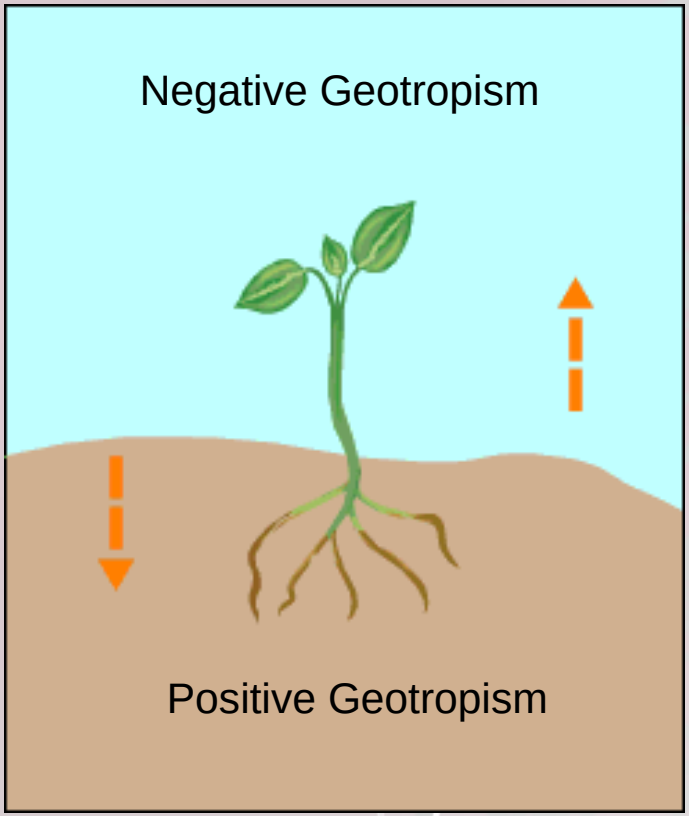
It is the growth of a plant towards the center of the earth- down with gravity.

Ex. roots growing down

Negative Geotropism

It is the growth of a plant away from the center of the earth- opposite from the pull of gravity

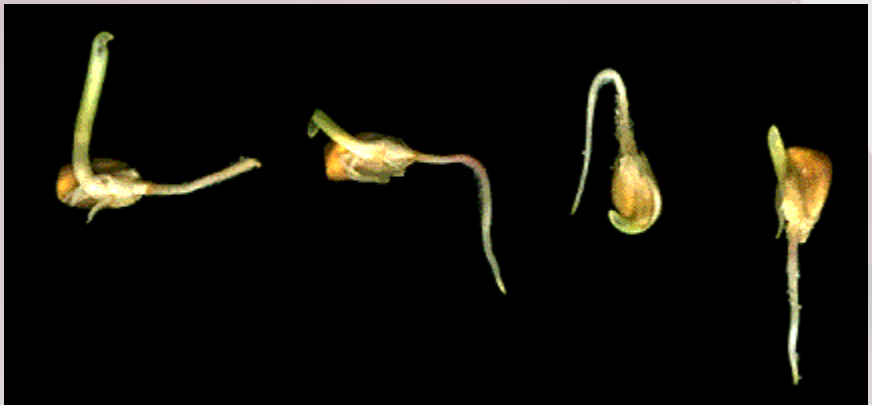
Ex. stems grow up



NEXT

IMPORTANCE OF GEOTROPISM

- *Pulls roots down to anchor a plant*
- *Roots can get needed water and minerals if they stay in the soil*



PHOTOTROPISM

("Photo" – light)

The growth response of a plant in response to light direction is called ***phototropism.***

Enables leaves to be in the best position possible to receive adequate light for photosynthesis



Ex. Stems growing toward the window to get to the light



THIGMOTROPISM *("Thigmo" – "touch")*

Thigmotropism *is the growth of a plant in response to touch/contact.*



Tendrils on a sweet pea





Vines growing on a wall or fence

THERMOTROPISM *("Therm" – "heat")*

Thermotropism is the tendency of plants or other organisms to bend toward or away from heat.

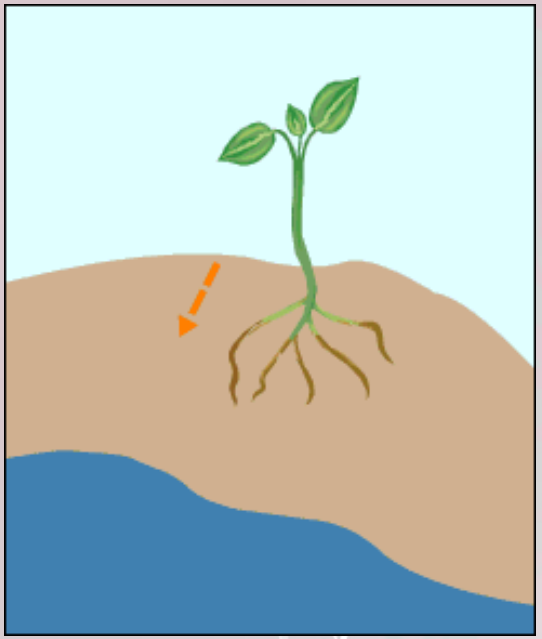
Ex. curling of *Rhododendron* leaves in response to cold temperatures.



HYDROTROPISM

("hydro" – "water")

Hydrotropism is the growth in response to water. Ex. roots growing toward moisture



Chemotropism

("Chemo" – chemical")

Chemotropism is movement caused by chemical stimuli. Ex. Growth of a pollen tube is always towards the ovules so that reproduction can occur