PHYSIOLOGICAL PROCESSES AFFECTING CROP PRODUCTION

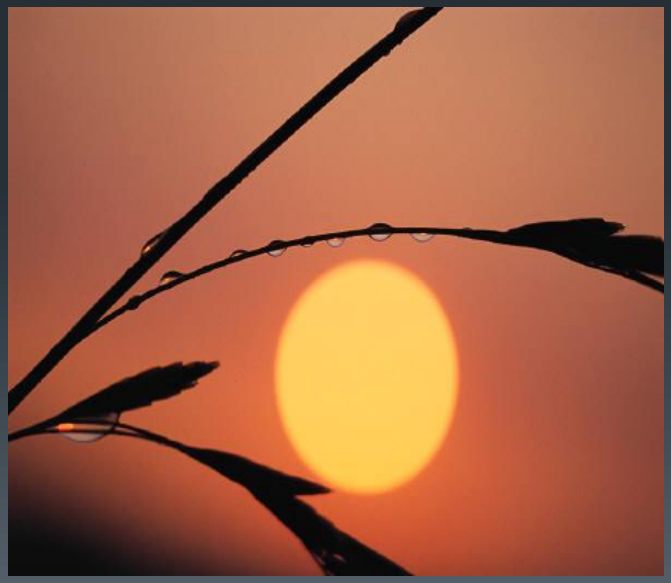
Growth and development of crops result from the interaction of various physiological processes, namely:

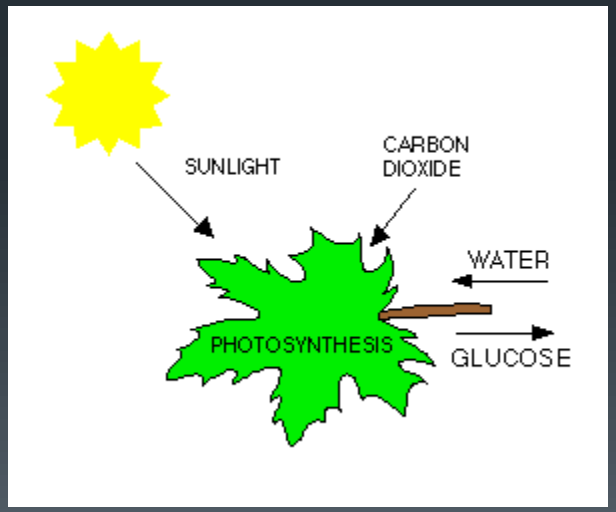
- Photosynthesis
- Respiration
- Transpiration
- Translocation

• These processes form the basis for crop yield.

PHOTOSYNTHESIS- a chemical reaction

- Autotrophic Process: Plants and plant-like organisms, algae, make their energy (glucose) from sunlight.
- Stored as carbohydrate in their bodies.



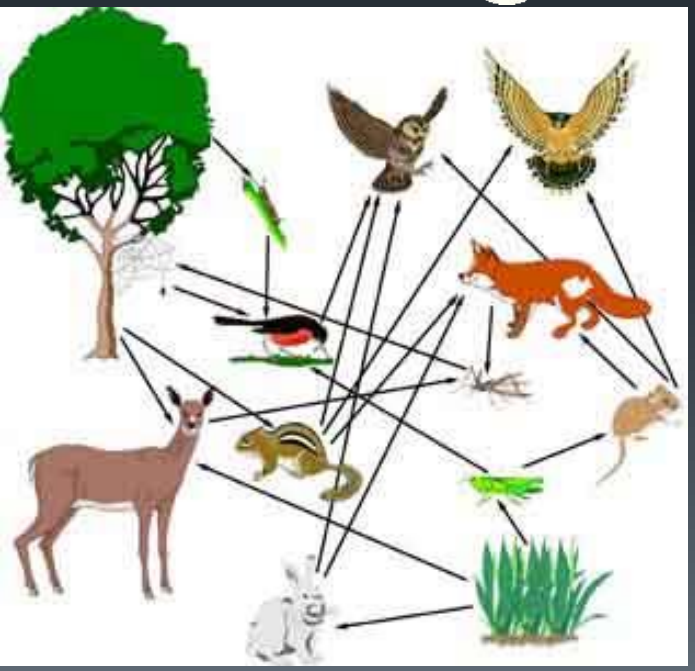


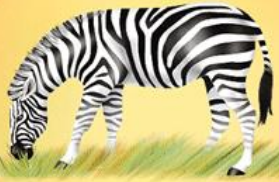
PHOTOSYNTHESIS is considered as the most important biological process. Why?

- Makes organic molecules (glucose) out of inorganic materials (carbon dioxide and water).
- It begins all food chains/webs. Thus all life is supported by this process.
- It also makes oxygen gas!!

Photosynthesis-starts to ecological food webs!

The sun is the source of energy for most living things.





The zebra obtains energy by eating grass.

Plants such as grass use energy from the sun to make their own food.

The lion obtains energy by feeding on the zebra.

What do plants need for photosynthesis?

- Water
- Carbon dioxide
- Light
- chlorophyll

Photo-synthesis

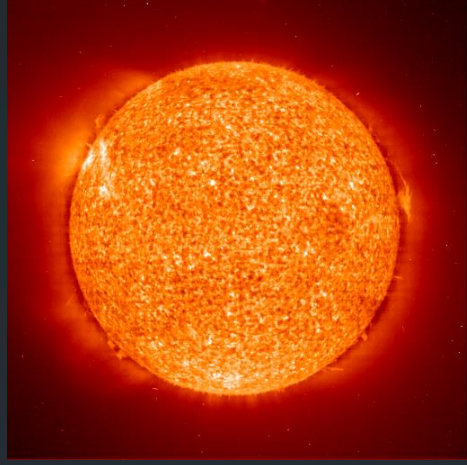
means "putting together with light."

- Plants use sunlight to turn water and carbon dioxide into glucose. Glucose is a kind of sugar.
- Plants use glucose as food for energy and as a building block for growing.
- Autotrophs make glucose and heterotrophs are consumers of it.

TWO TYPES OF PHOTOSYNTHESIS

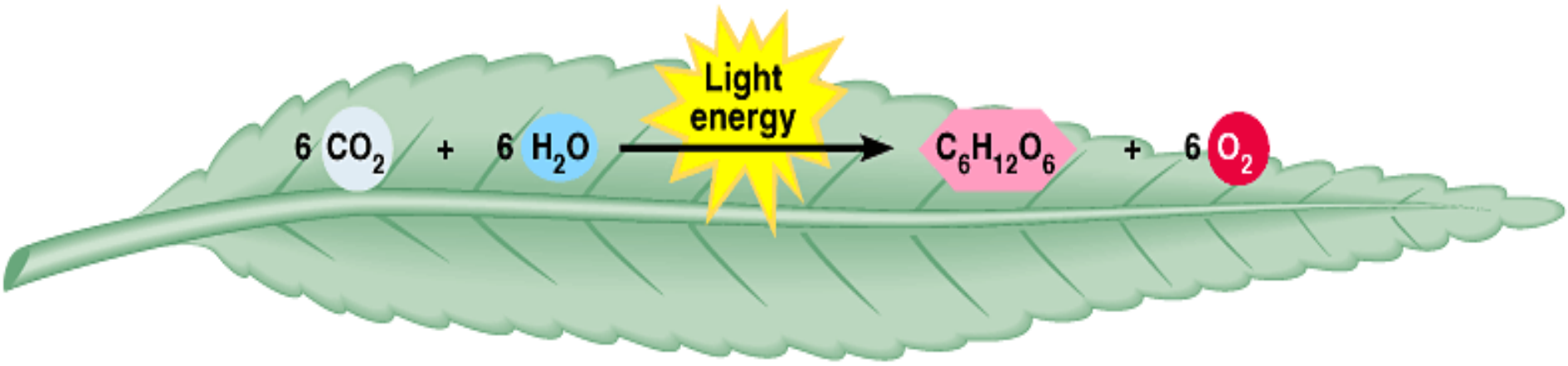
- **ANOXYGENIC PHOTOSYNTHESIS** is the phototrophic process of obigate anaerobes, where light energy is captured and converted to ATP, without the production of oxygen. Water is therefore not used as an electron donor.
- **OXYGENIC PHOTOSYNTHESIS** is the most common and is seen in plants, algae and cyanobacteria. It is a non-cyclic photosynthetic electron chain where water is the initial electron donor and, as a consequence, molecular oxygen is freed as a byproduct.

Photosynthesis



Carbon dioxide + water —(sunlight; absorbed by chlorophyll)→ **glucose + oxygen**

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

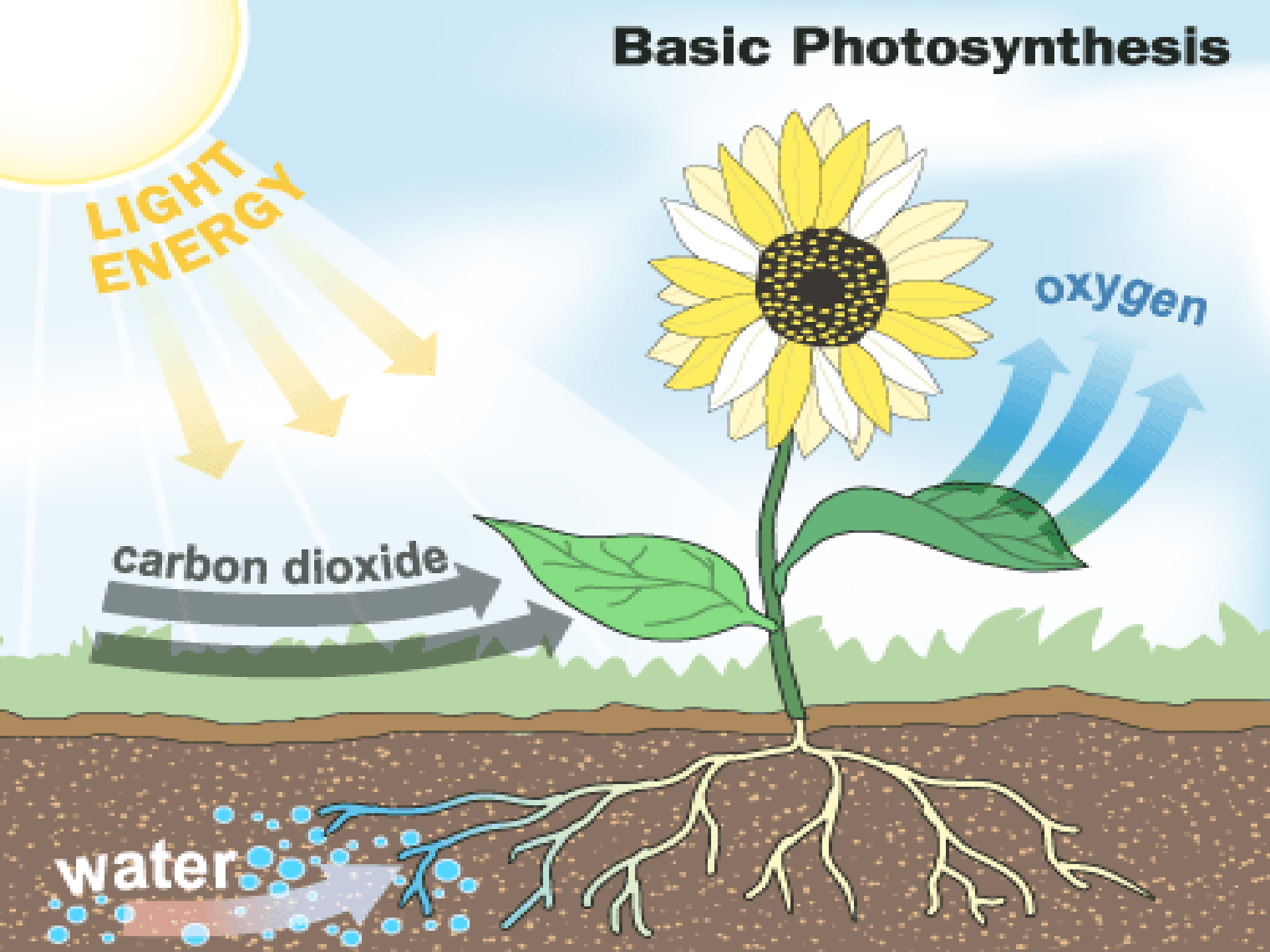


SIGNIFICANCE OF PHOTOSYNTHESIS

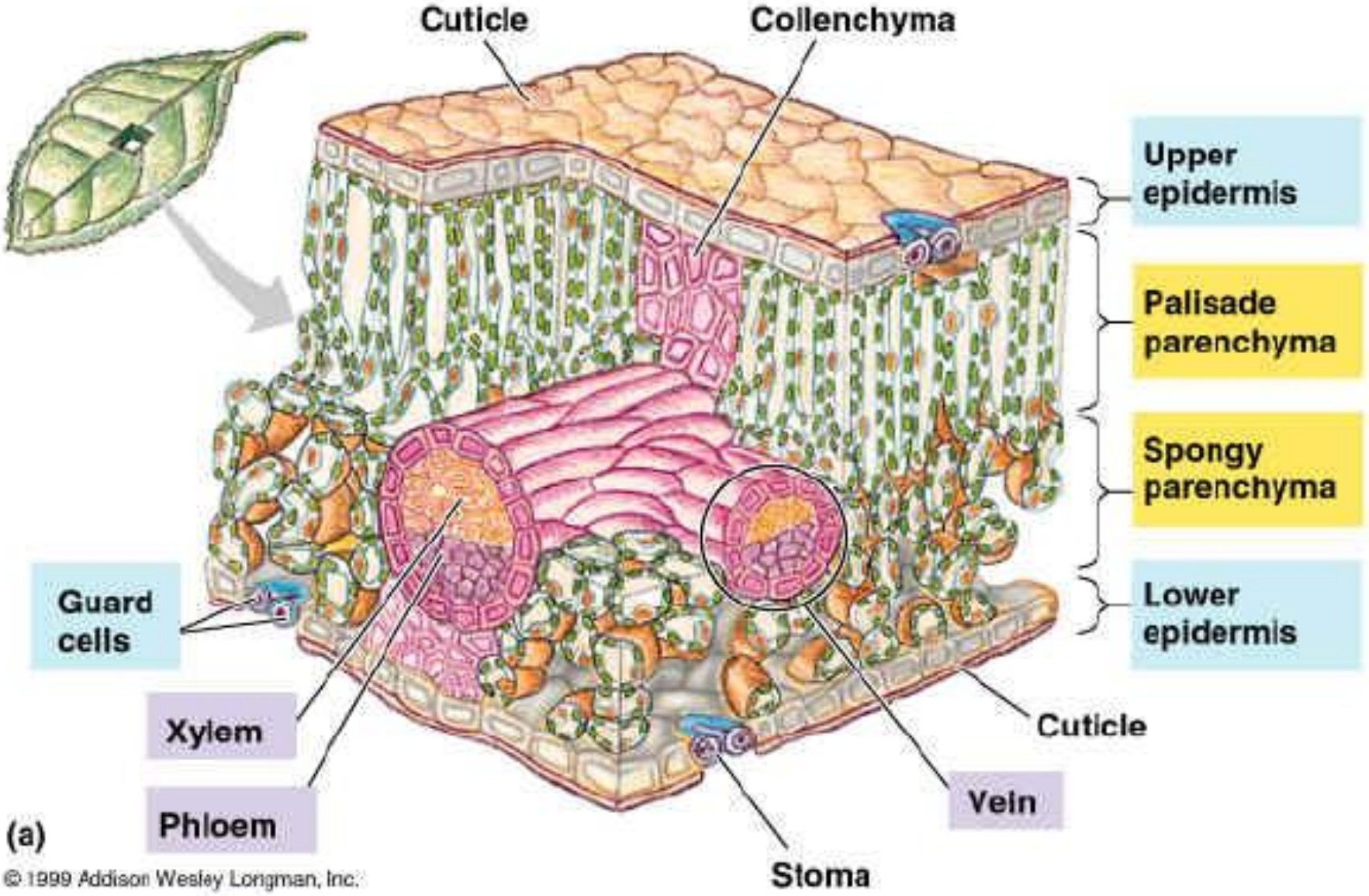
- Green plants possess the green pigment, chlorophyll which can capture, transform, translocate and store energy which is readily available for all forms of life on this planet.
- Photosynthesis is a process in which light energy is converted into chemical energy.
- Except green plants, no other organism can directly utilize solar energy to synthesize food; hence they are dependent on green plants for their survival.

SIGNIFICANCE OF PHOTOSYNTHESIS

- During photosynthesis, oxygen liberated into the atmosphere makes the environment livable for all aerobic organisms.
- Plants and plant products are the major food sources of almost all organisms on the earth.
- Fossil fuels like coal, gas, and oil represent the photosynthetic products of the plants belonging to early geological periods.


Basic Photosynthesis
LIGHT ENERGY
oxygen
carbon dioxide
water

Plant leaves have many types of cells!



THE PHOTOSYNTHETIC ORGAN

- **LEAF-** chief site of photosynthesis.

STRUCTURAL PARTS

- upper and lower epidermis - stomates
- mesophyll cells - chlorophyll
- vascular bundles - transport

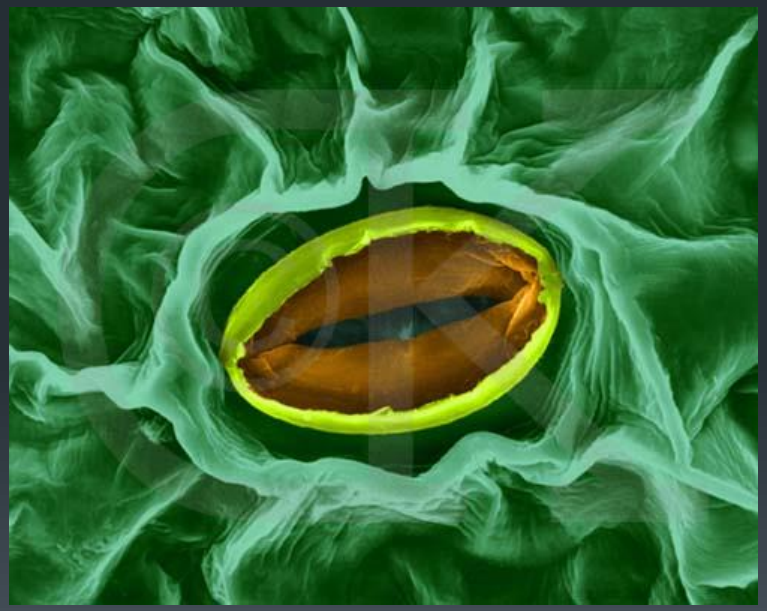
- The Mesophyll
  - upper side: - palisade parenchyma - regular shaped palisade cells
  - lower side: - spongy parenchyma - irregular shaped

STOMA

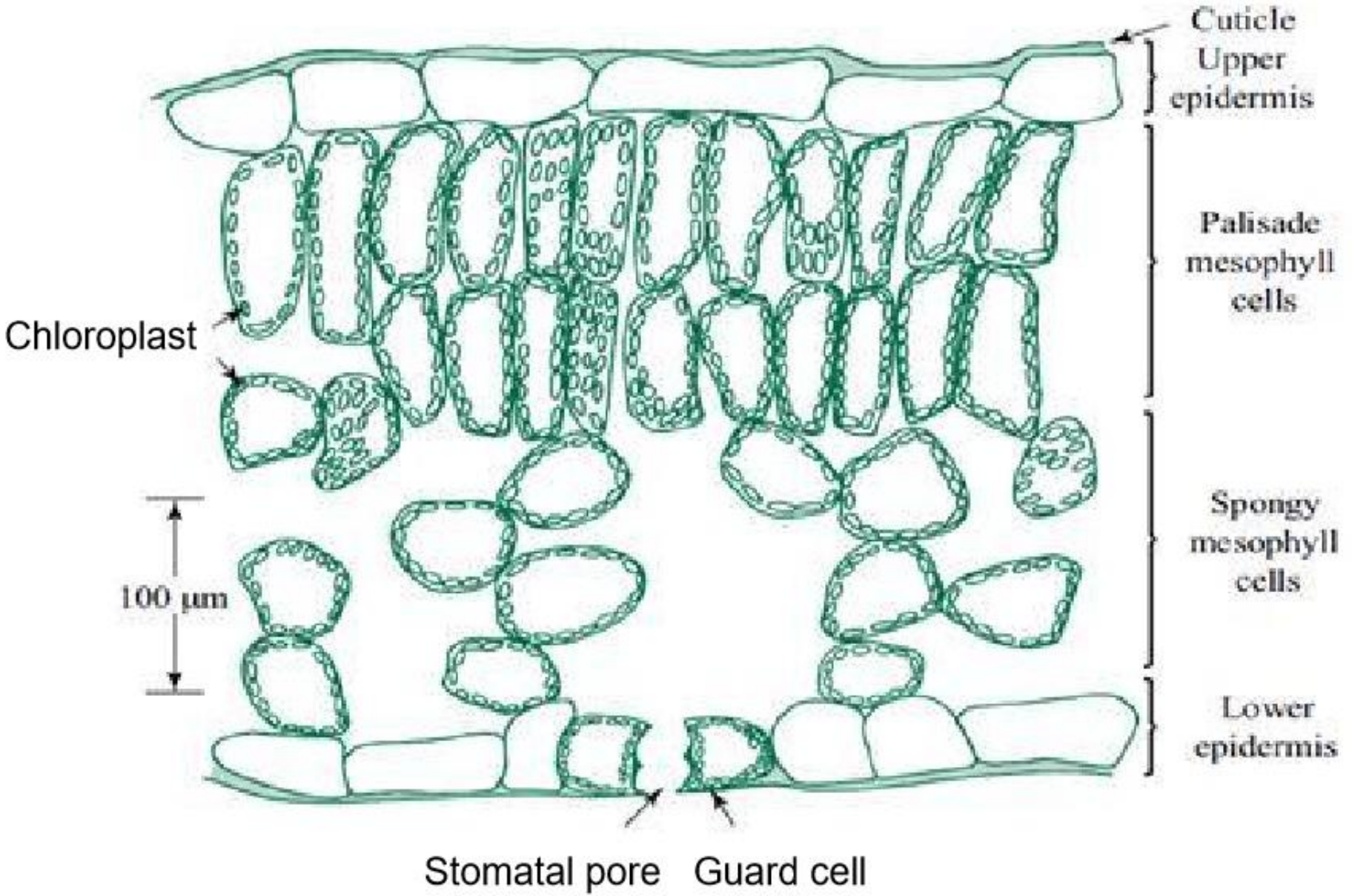
This opening how plants exchange gases!

Check it! Can you name the two important gases that go in and out of the leaves?

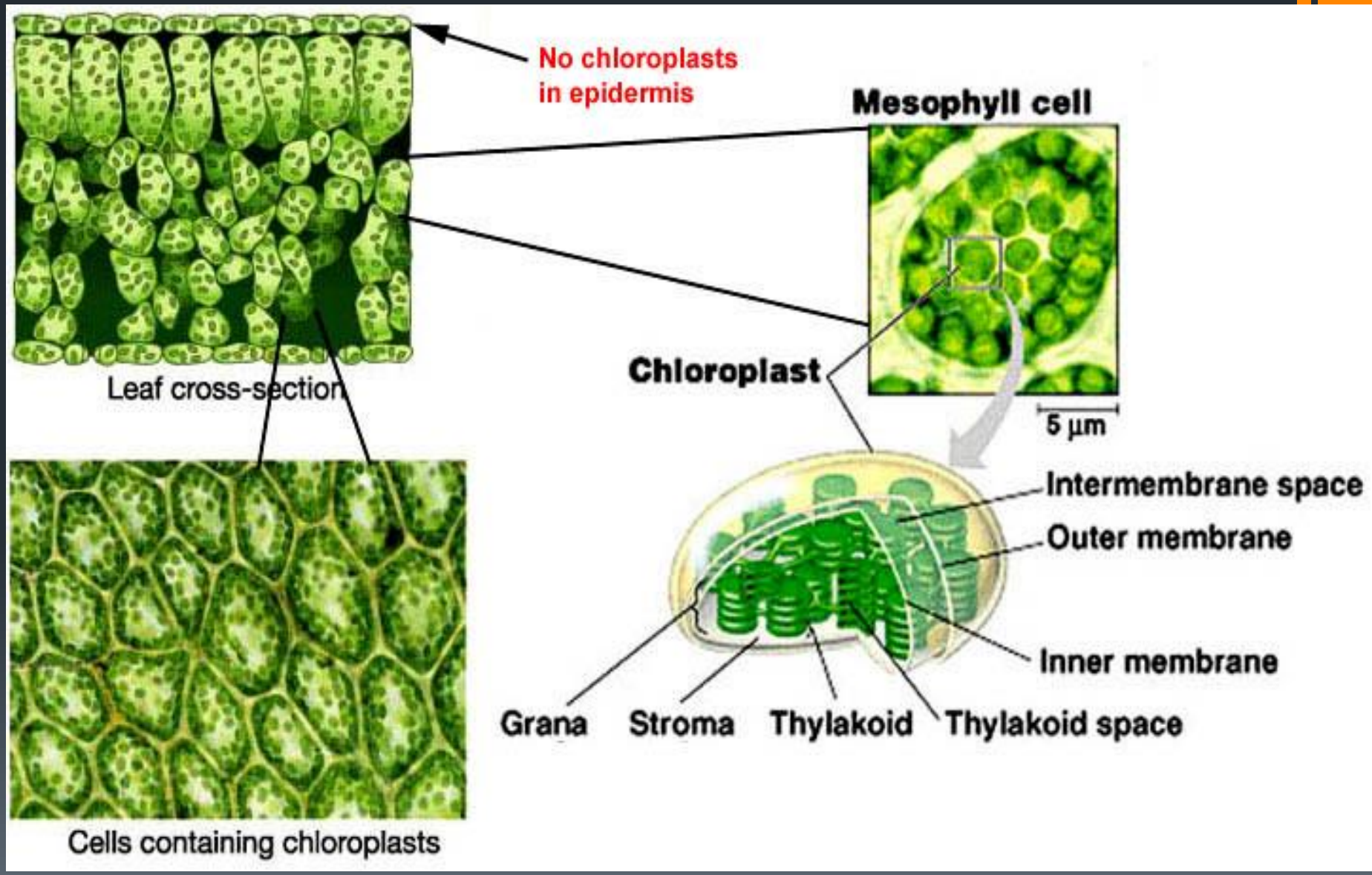
Why are the stomata located on the underside of leaves?



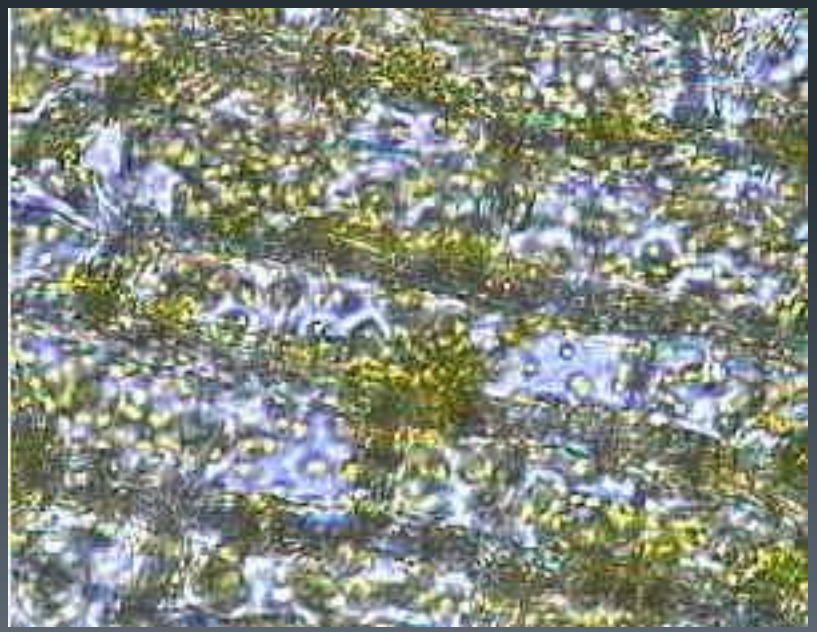
Schematic transverse section through a leaf (Heldt, 2005)

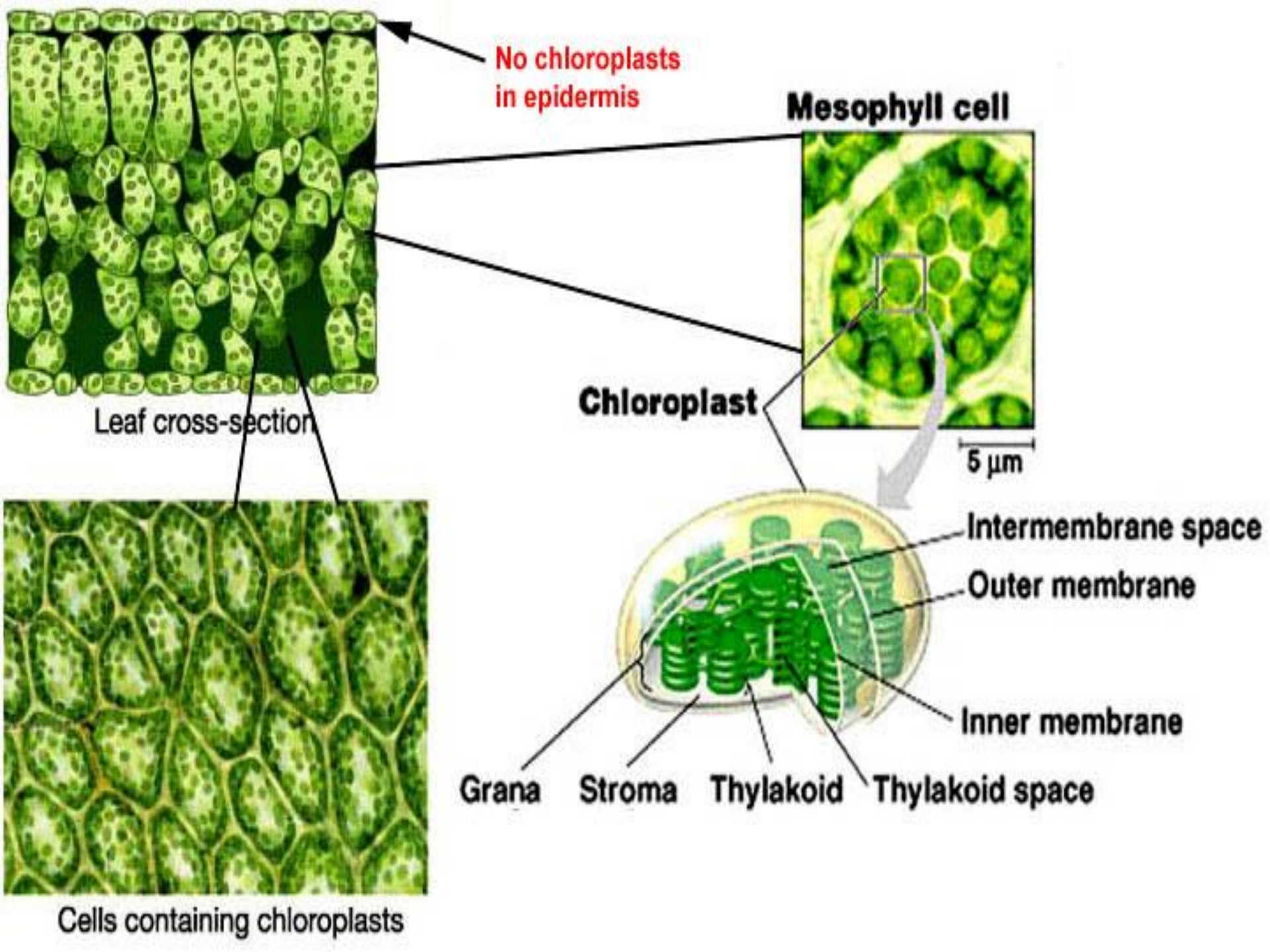


Plant Cells


No chloroplasts in epidermis
Mesophyll cell
Leaf cross-section
Chloroplast
5 µm
Intermembrane space
Outer membrane
Inner membrane
Grana
Stroma
Thylakoid
Thylakoid space
Cells containing chloroplasts

The photograph below is an elodea leaf (magnification X 400). Individual cells are clearly visible. The tiny green structures within the cells are chloroplasts
this is where
photosynthesis
happens.

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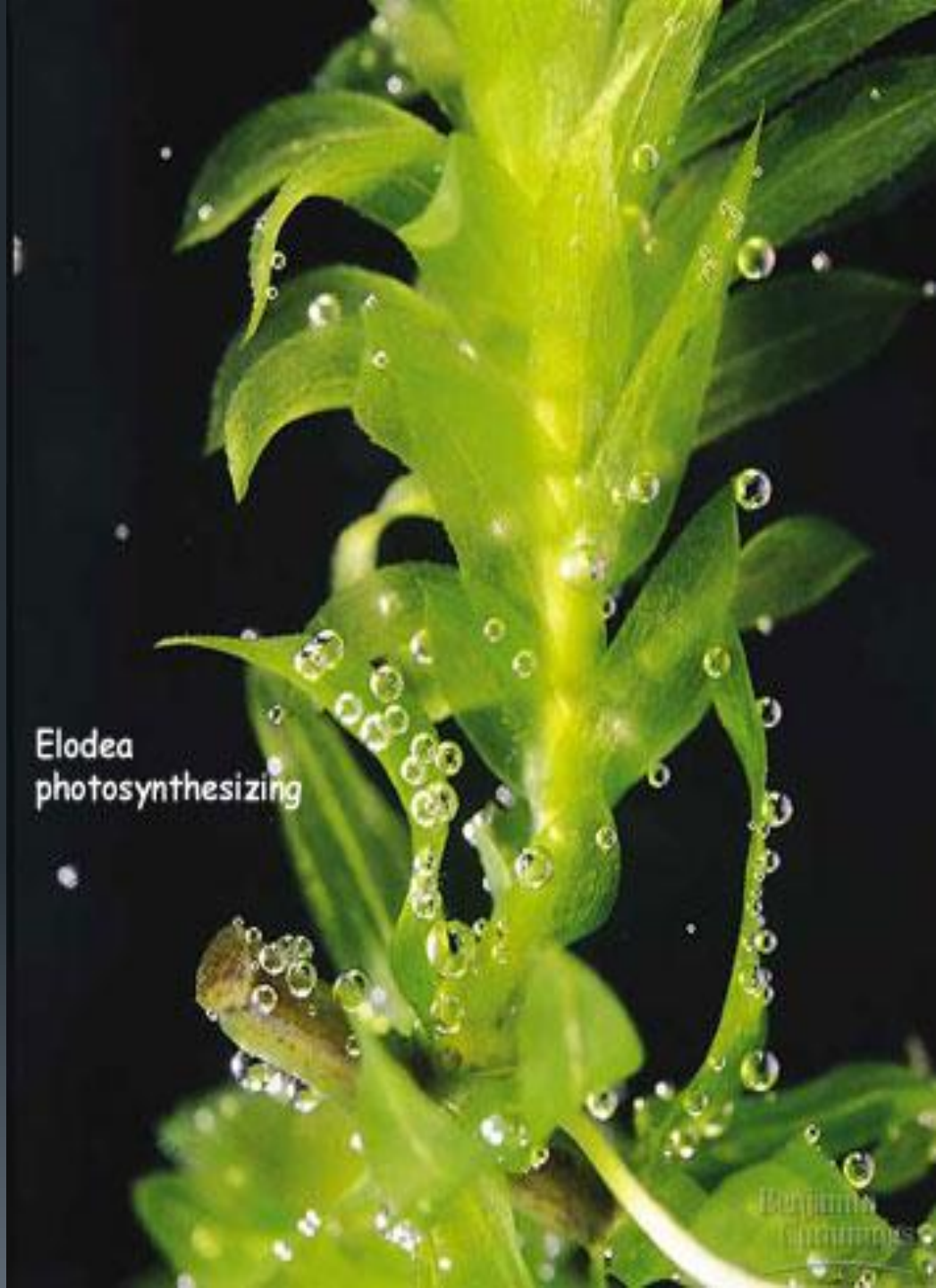
Chloroplast
5 µm
Intermembrane space
Outer membrane
Inner membrane
Grana
Stroma
Thylakoid
Thylakoid space
Cells containing chloroplasts

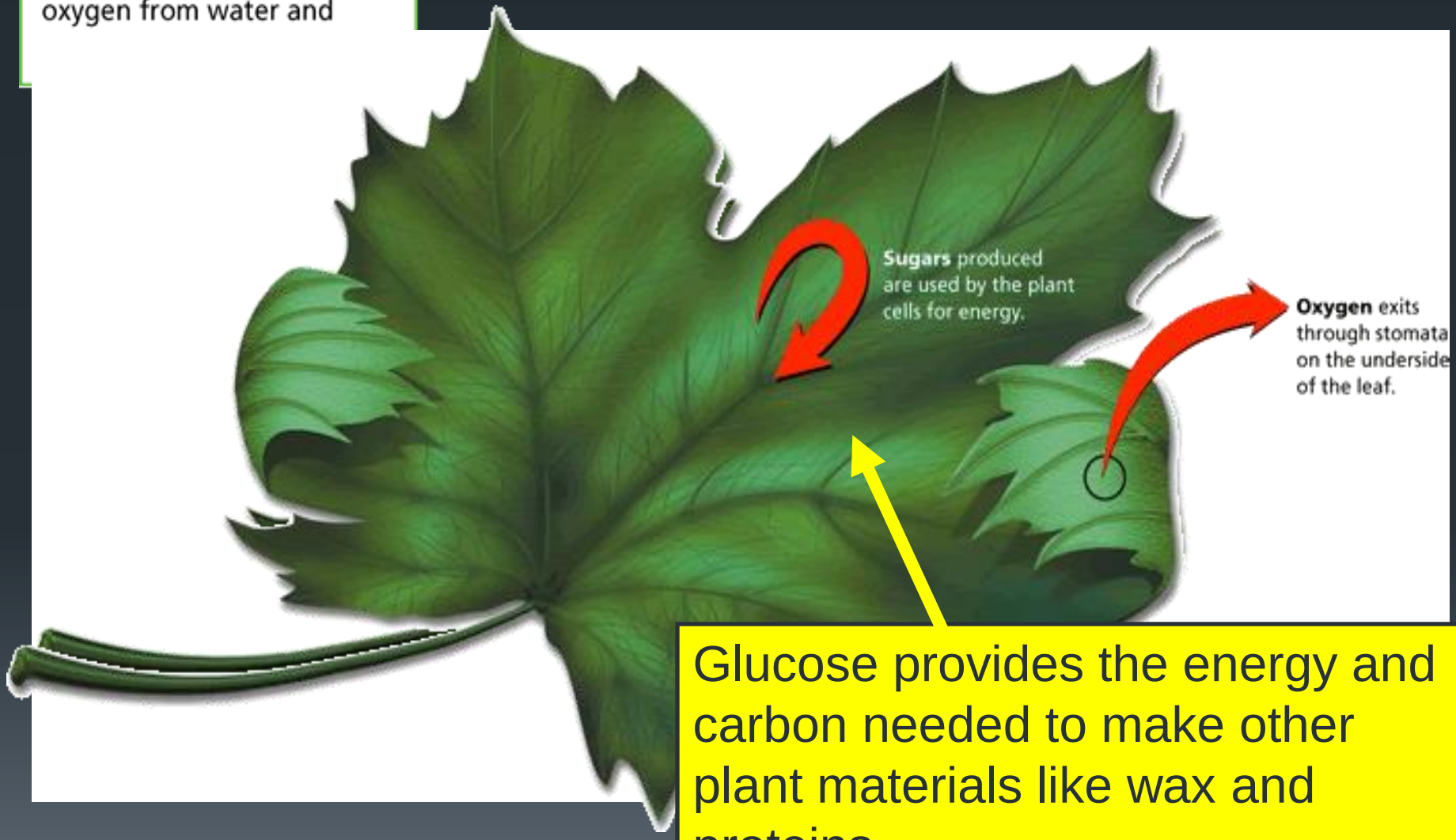
Chloroplasts make the sugars!

Chloroplasts make the oxygen too!



Photosynthesis

Stage 2
The captured light energy is used to produce sugars and oxygen from water and



Glucose provides the energy and carbon needed to make other plant materials like wax and proteins.

Leaves are green because they contain the pigment:

CHLOROPHYLL

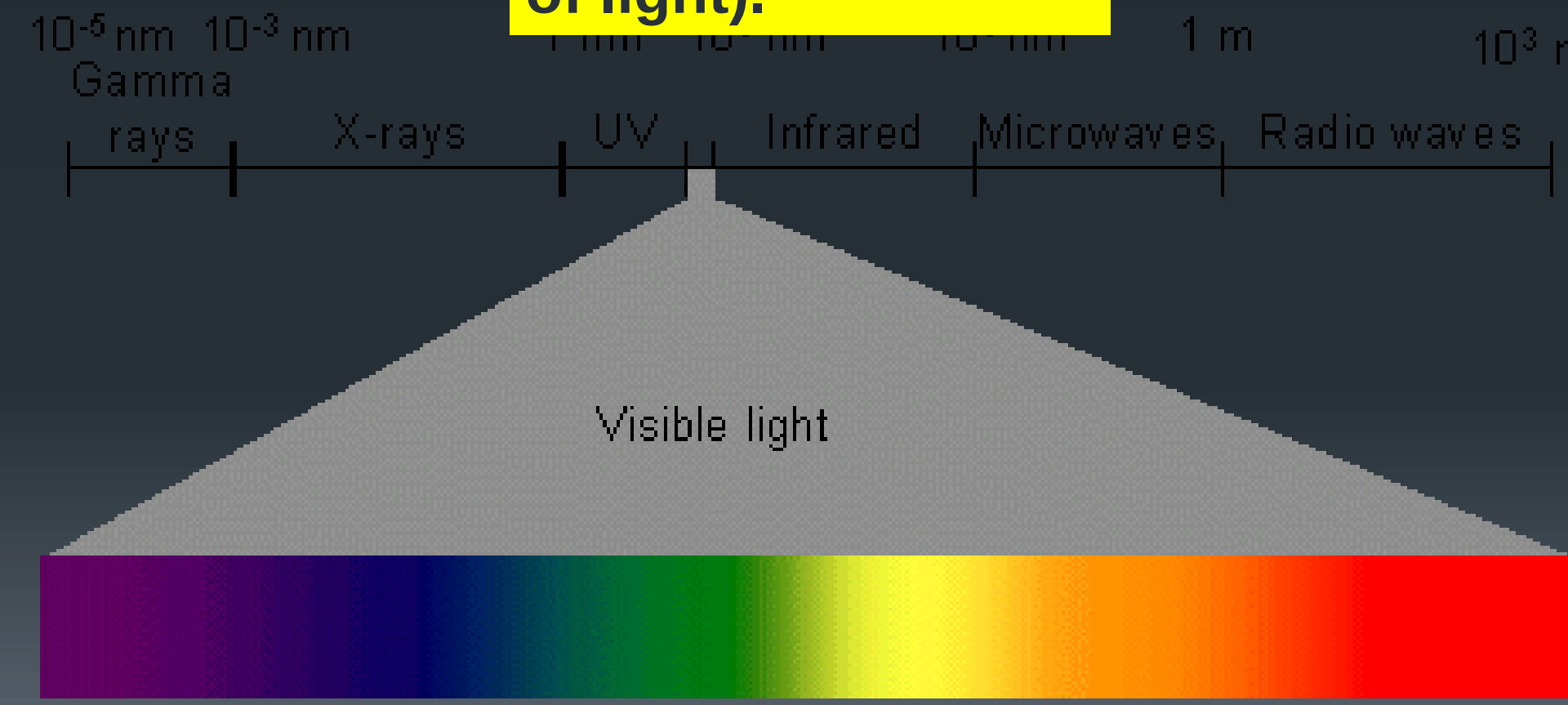
Leaves have a large surface area to absorb as much light as possible

PHOTOSYNTHETIC PIGMENTS

The photosynthetic pigments of higher plants are divided into two classes:

- CAROTENOIDS (carotene and xanthophyll) absorb light in the regions of the spectrum not absorbed by the chlorophylls and transfer that energy to chlorophyll to be used in photosynthesis.
- CHLOROPHYLL- the principal pigment involved in photosynthesis. It is a large molecule and absorbs light maximally in the violet blue and in the red region of the visible spectrum and reflects green light and thus leaves appear green in color. (ROYGBIV)

Visible light is only a small part of the electromagnetic spectrum (all forms of light).



Chlorophyll…

- Location at the partition between two adjacent thylakoids.
- Its basic unit is a porphyrin ring system, a structure composed of four pyrrole nuclei joined by carbon linkages.
- The center of porphyrin is occupied by a single magnesium atom.

PHOTOSYNTHETIC PIGMENTS

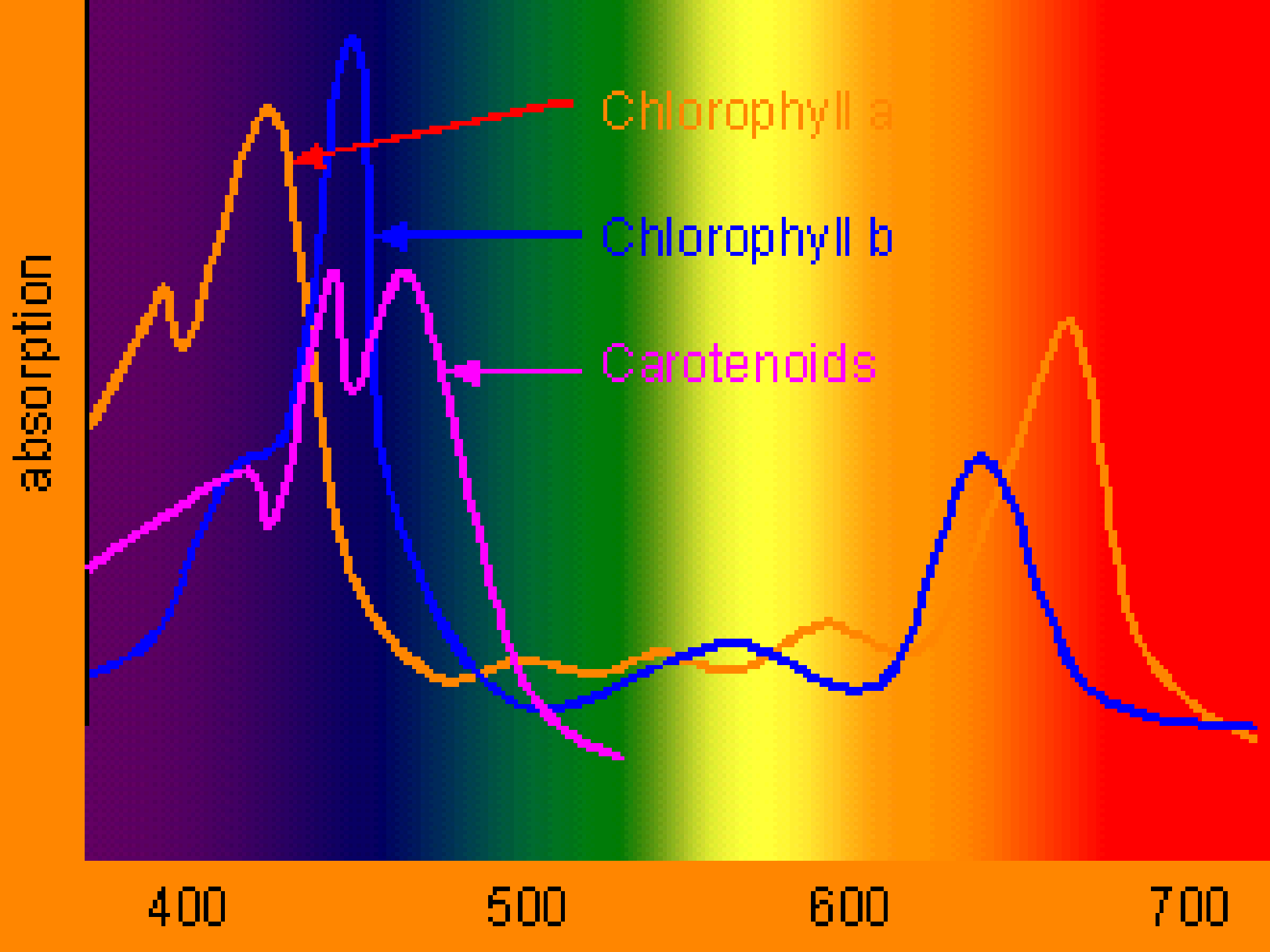
2 KINDS OF CHLOROPHYLL

- chlorophyll a (bluish green)- can be found in all autotrophic organisms except photosynthetic bacteria.
- chlorophyll b (yellowish green)

RATIO: 3a:1b •

OTHER PIGMENTS: carotene, xanthophyll

LIGHT ABSORPTION: most intense in red and blue and lowest in green


Chlorophyll a
Chlorophyll b
Carotenoids
absorption
400
500
600
700

- Absorbing Light Energy to make chemical energy: GLUCOSE!
  - Pigments: Absorb different colors of white light (ROY G BIV)
    - Main pigment: Chlorophyll a- **REACTION CENTERS!**
    - Accessory pigments: Chlorophyll b, xanthophyll, carotenoids- **HARVESTING CENTER**

  These pigments, that is the reaction center and the harvesting center are packed into functional clusters called **photosystems**

- About 250-400 Chl-a molecules constitute a single photosystem. Two different photosystems have different forms of chlorophyll a in their reaction centres.
- In photosystem I (PSI), chlorophyll– a with maximum absorption at 700 nm (P700) and in photosystem II (PSII), chlorophyll– a with peak absorption at 680 nm (P680), act as reaction centres. (P stands for pigment).
- The primary function of the two photosystems, which interact with each other is to trap the solar energy and convert it into the chemical energy also called **assimilatory power** (ATP and NADPH2).

	PHOTOSYSTEM I	PHOTOSYSTEM II
Maximum Light Absorption	700 nm wavelength (P700)	680 nm wavelength (P680)
Primary Electron Acceptor	iron protein (Fe-S-protein)	**PHEOPHYTIN** -is a modified chlorophyll-a molecule with 2 hydrogen atoms in place of magnesium ion.
Electron Carriers	plastocyanin, ferredoxin and cytochromes.	heophytin, plastoquinone, and cytochromes.

LIGHT ABSORPTION

- In general, leaves absorb about 83% of light, while reflecting 12% and transmitting 5%

- Of the 83% absorbed, only 4% is actually used by the plants during photosynthesis, the remainder is dissipated as heat

PHOTOCHEMICAL and BIOSYNTHETIC PHASE

- The entire process of photosynthesis takes place inside the chloroplast. Photosynthesis involves two successive steps --- light reactions and dark reactions.

- LIGHT REACTIONS- take place in the grana of the chloroplasts where chlorophyll can be found located on the membranes
- DARK REACTIONS- take place at the stroma of the chloroplasts where it is absent from chlorophyll.

LIGHT REACTION…

- The light reaction of light dependent reaction occurs in the chloroplast of the mesophyll cells of the leaves.
- The main purpose of the light reaction is to generate organic molecules such as ATP and NADPH which are needed for the subsequent dark reactions.

LIGHT REACTION…STEPS!

- Chlorophyll absorbs the red and blue segment of the white light and photosynthesis occurs most efficiently at these wavelengths.
- When the light falls on the plant, the chlorophyll pigment absorbs this light and electron in it gets excited.
- This process occurs as a photosystem. Remember photosystems?? The PSI and PSII.

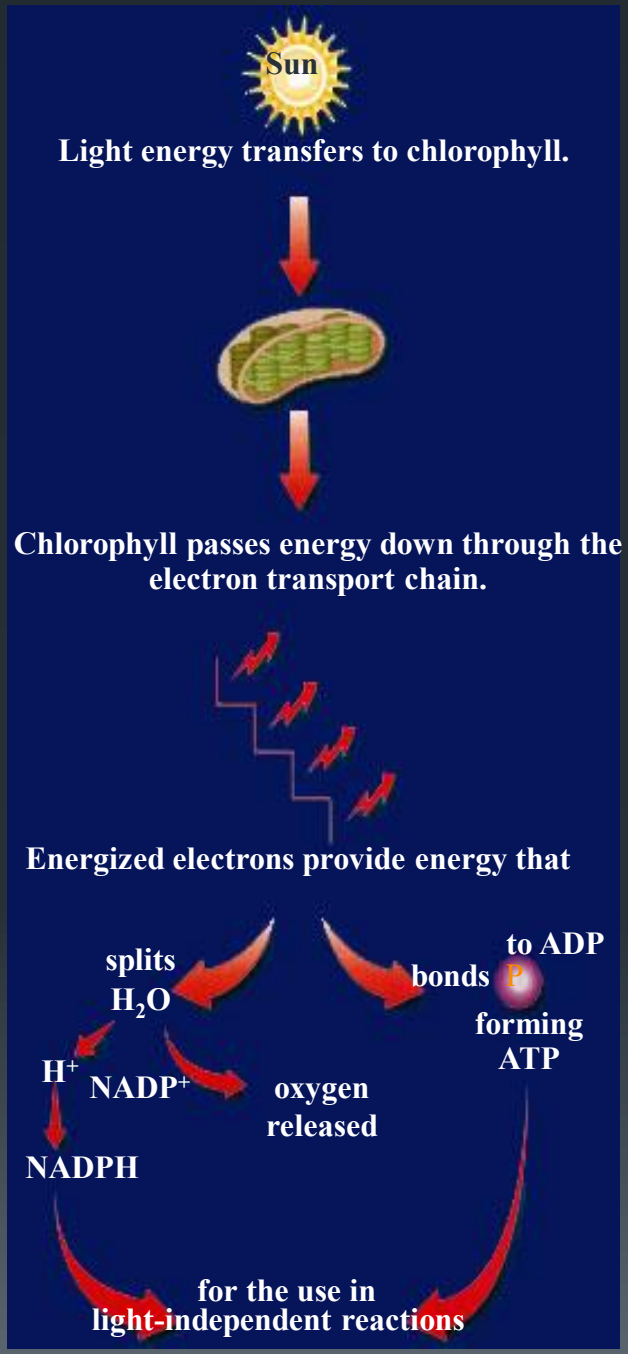
LIGHT REACTION…STEPS!

- The chlorophyll pigments which are excited give up their electrons and to compensate for the loss of electrons, water is split to release four hydrogen ions and four electrons and oxygen.
- The electrons finally reach the reaction center where they combine with NADP+ and reduce it to NADPH.
  - *NADP+ - Nicotinamide adenine dinucleotide phosphate.*
  - *NADPH- Dihydronicotinamide adenine dinucleotide phosphate.*

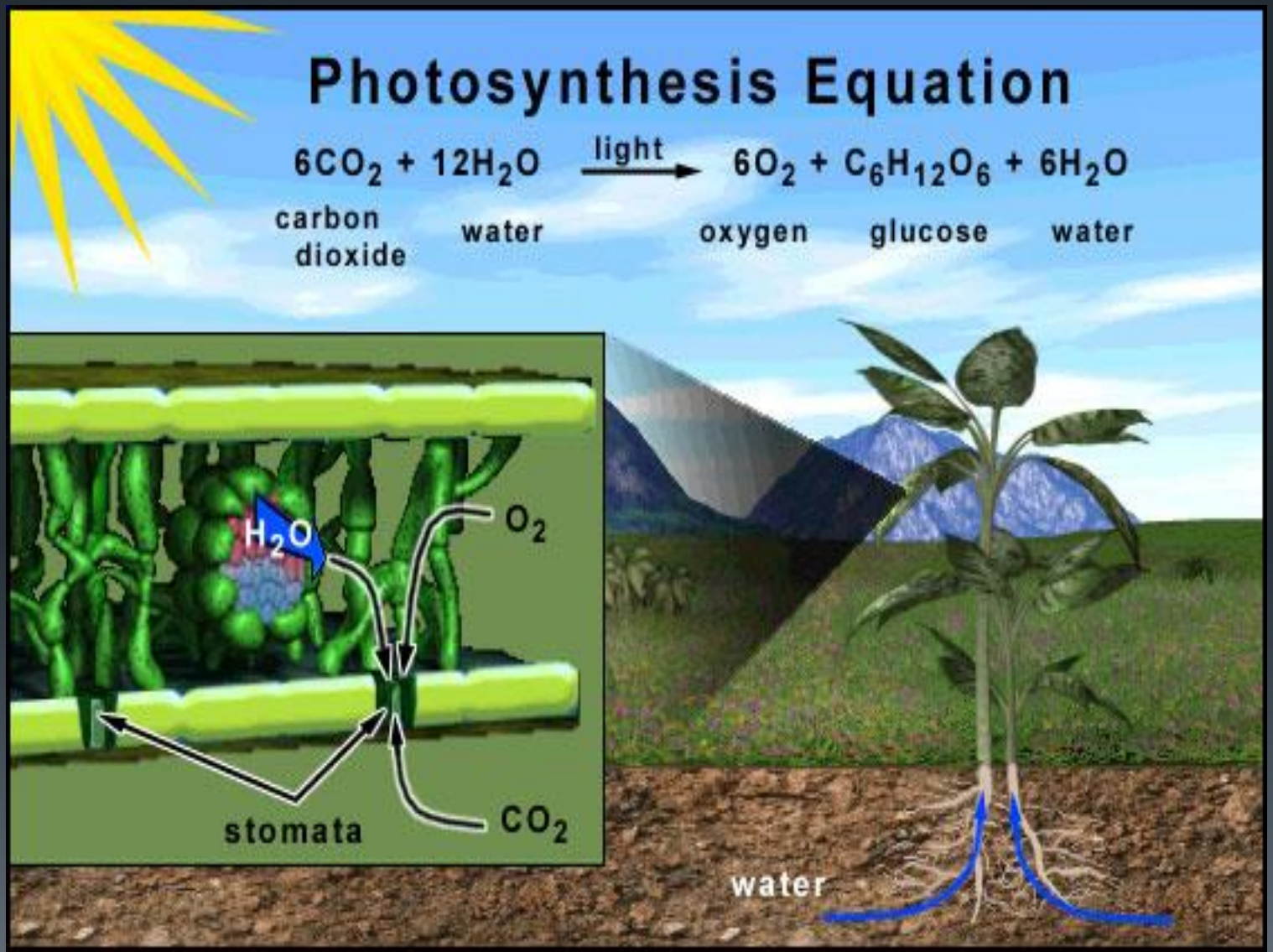
LIGHT REACTION…STEPS!

- While the electrons are taken care of, the built up of hydrogen ions inside the thylakoid lumen is of equal importance.
- The hydrogen ions building up inside the lumen creates a positive gradient and in the presence of the enzyme ATP synthetase, these hydrogen ions combine with ADP in the nearby region to form ATP.
- The oxygen that is a waste product is released by the plant into the atmosphere and some of it is used in photorespiration if the plants needs to.

- At each step along the transport chain, the electrons lose energy.



- In plants and simple animals, waste products are removed by **diffusion**. Plants, for example, excrete O_2, a product of photosynthesis.



LIGHT REACTION…

- The end product of light reaction, ATP and NADPH are used to fix CO_2.
- The synthesis of ATP by the light - induced **phosphorylation** (addition of a phosphate group to a molecule) of ADP is known as photophosphorylation Two types of photophosphorylation are **non- cyclic photophosphorylation** and the **Cyclic phtophosphorylation.**

NON-CYCLIC PHTOPHOSPHORYLATION.	CYCLIC PHTOPHOSPHORYLATION.
Both PSI and PSII are functional.	Only PSI is functional.
Water is the primary source of the electrons molecule and returns to the same and H+. It gets photolysed through the process called Photolysis; NADP is the final acceptor of the electrons and H+ ions.	Electron comes from the chlorophyll P700 molecule and returns to the same chlorophyll P700
Oxygen is evolved as a bye product.	Oxygen is not evolved because there is no photolysis of water.
This mainly takes place in all green plants and cyanobacteria except photosynthetic eubacteria.	This process is found mainly in photosynthetic eubacteria e.g. purple sulphur bacteria.

DARK REACTION…

- Occurs in the stroma
- Primary process by which inorganic carbon is converted to carbon.
- CO2 is reduced by the reducing power generated in the first step and carbohydrates are produced
- Carbon fixation reactions produce sugar in the leaves of the plant from where it is exported to other tissues of the plant as source of both organic molecule and energy for growth and metabolism.

DARK REACTION…

- The end product of light reaction, ATP and NADPH are used to fix CO2.
- Occur both in the presence or absence of light.
- The end product of light reaction, ATP and NADPH are used to fix CO2.
- The carbon dioxide fixation/ reduction into carbohydrates can occur via three pathways:

DARK REACTION… 3 Pathways

1. CALVIN BENSON CYCLE/ REDUCTIVE PENTOSE PATHWAY

- Fixation and reduction of one molecule of CO_2 requires three molecules of ATP and 2 NADPH.
- Occurs in the mesophyll cell chloroplast
- CO_2 acceptor is RUBP
- RUBP carboxylase enzyme is needed
- The first stable product is 3-PGA

DARK REACTION… 3 Pathways

2. C4 OR HATCH SLACK PATHWAY

- First product is 4- C oxaloacetic acid. STEPS are

a. carboxylation of PEP to OAA, PEP carboxylase is enzyme involved
b. reduction of OAA to malate or aspartate
c. decarboxylation of malate in the bundle sheath cells to form pyruvic acid
d. transfer of pyruvic acid to the mesophyll cell
e. fixation of carbon dioxide to form 3-PGA

- Presence of KRANZ ANATOMY.

DARK REACTION… 3 Pathways

3. **CAM OR CRASSULACEAN ACID METABOLISM PATHWAY** – operates in orchids, pineapple, other succulent plants wherein stomates are closed during the day and open during the night.

FACTORS AFFECTING PHOTOSYNTHESIS

Factors affecting photosynthesis can be divided into two general categories,

- Internal
- External (environmental) factors.

INTERNAL FACTORS

CHLOROPHYLL

The amount of chlorophyll present has a direct relationship with the rate of photosynthesis because this pigment is directly involved in trapping light energy responsible for the light reactions.

INTERNAL FACTORS

LEAF AGE AND ANATOMY

Newly expanding leaves show gradual increase in rate of photosynthesis and the maximum is reached when the leaves achieve full size. Chloroplast functions decline as the leaves age. Rate of photosynthesis is influenced by variation in

(i) number, structure and distribution of stomata,

(ii) size and distribution of intercellular spaces

(iii) relative proportion of palisade and spongy tissues and

(iv) (iv) thickness of cuticle.

INTERNAL FACTORS

DEMAND FOR PHOTOSYNTHATE : Rapidly growing plants show increased rate of photosynthesis in comparison to mature plants.

EXTERNAL FACTORS

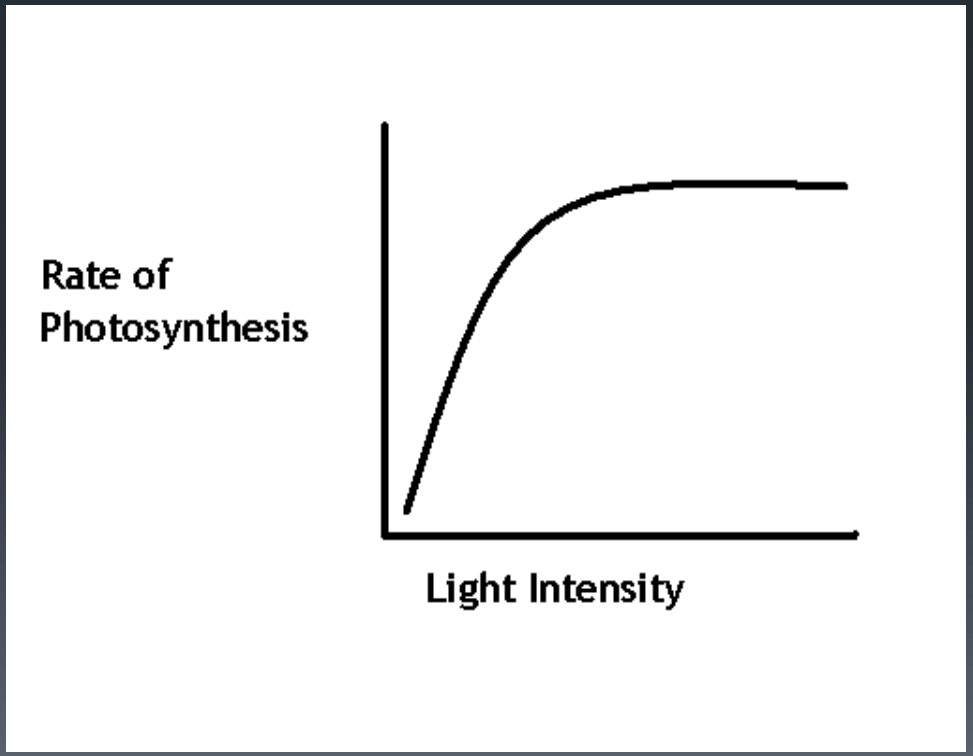
Remember… CONCEPT OF LIMITING FACTORS!

What are the external factors???

The major external factors which affect the rate of photosynthesis are temperature, light, carbon dioxide, water, and mineral elements.

EXTERNAL FACTORS

LIGHT: The rate of photosynthesis increases with increase of intensity of light within physiological limits or rate of photosynthesis is directly proportional to light intensity.

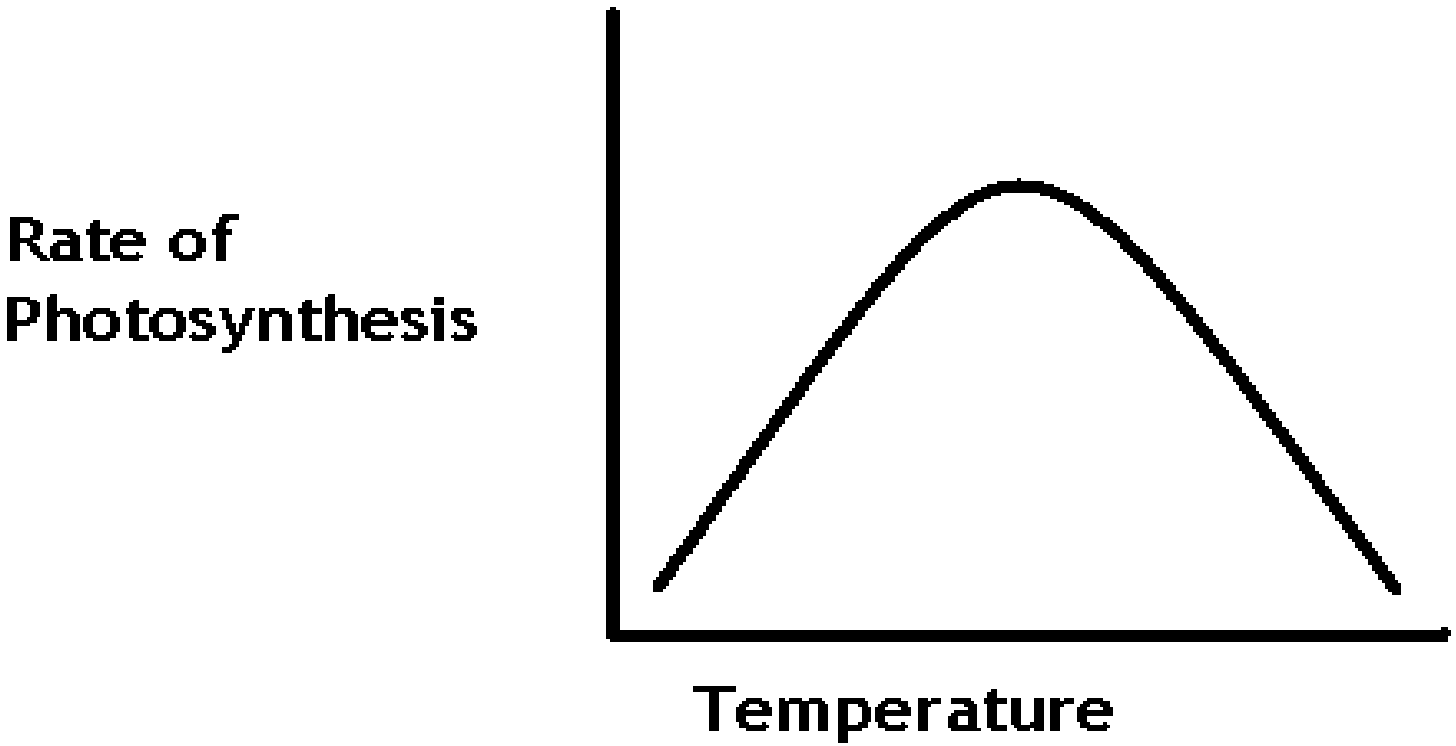


EXTERNAL FACTORS

TEMPERATURE:

- Very high and very low temperature affect the rate of photosynthesis adversely.
- Rate of photosynthesis will rise with temperature from 5°-37°C beyond which there is a rapid fall, as the enzymes involved in the process of the dark reaction are denatured at high temperature.
- Between 5°-35°C, with every 10°C rise in temperature rate of photosynthesis doubles.

EXTERNAL FACTORS

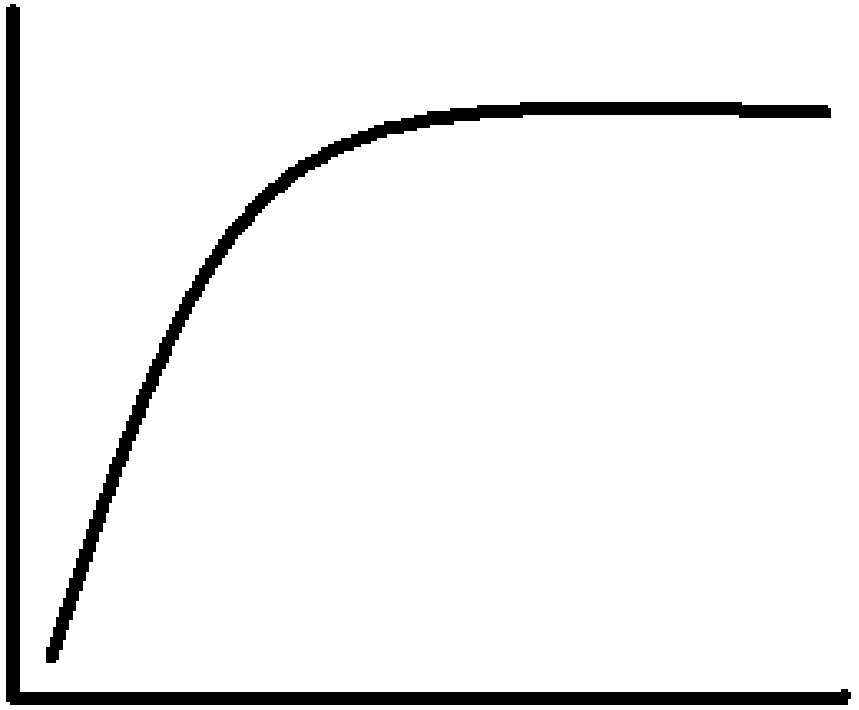


EXTERNAL FACTORS

CARBON DIOXIDE :

- Since carbon dioxide being one of the raw materials for photosynthesis, its concentration affects the rate of photosynthesis markedly.
- Because of its very low concentration (0.03%) in the atmosphere, it acts as limiting factor in natural photosynthesis.

Rate of Photosynthesis



Carbon Dioxide

EXTERNAL FACTORS

WATER

- Water has an indirect effect on the rate of photosynthesis.
- Loss of water in the soil is immediately felt by the leaves, which get wilted and their stomata close down thus hampering the absorption of CO_2 from the atmosphere.
- This causes decline in photosynthesis.

EXTERNAL FACTORS

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- Loss of water in the soil is immediately felt by the leaves, which get wilted and their stomata close down thus hampering the absorption of CO_2 from the atmosphere.
- This causes decline in photosynthesis.

EXTERNAL FACTORS

MINERAL ELEMENTS

- Some mineral elements like magnesium, copper, manganese and chloride ions, which are components of photosynthetic enzymes, and magnesium as a component of chlorophylls are important.
- Their deficiency would affect the rate of photosynthesis indirectly by affecting the synthesis of photosynthetic enzymes and chlorophyll.

END OF PRESENTATION!....