6. PHOTOSYNTHESIS

PHOTOSYNTHESIS

6.1 OVERVIEW OF PHOTOSYNTHESIS

6.2 ABSORPTION SPECTRUM OF PHOTOSYNTHETIC PIGMENTS

6.3 LIGHT DEPENDENT REACTION

6.4 LIGHT INDEPENDENT REACTION/ CALVIN CYCLE

6.5 ALTERNATIVE MECHANISM OF CARBON FIXATION (C4 AND CAM PATHWAYS)

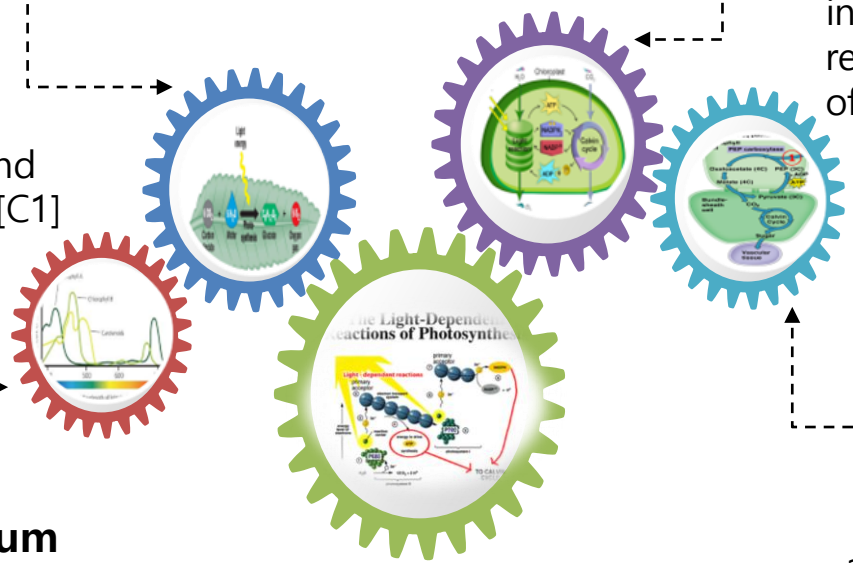
LEARNING OUTCOME

6.1 Overview of photosynthesis

a. Outline the complete process of photosynthesis: Light dependent reaction and light independent reaction [C1]

6.4 Light independent reaction

a. Explain Calvin cycle involving carbon fixation, reduction and regeneration of RuBP [C2]



6.2 Absorption spectrum of photosynthetic pigments

a. State the photosynthetic pigments involved in Photosynthesis [C1]

6.5 Alternative mechanism of carbon fixation

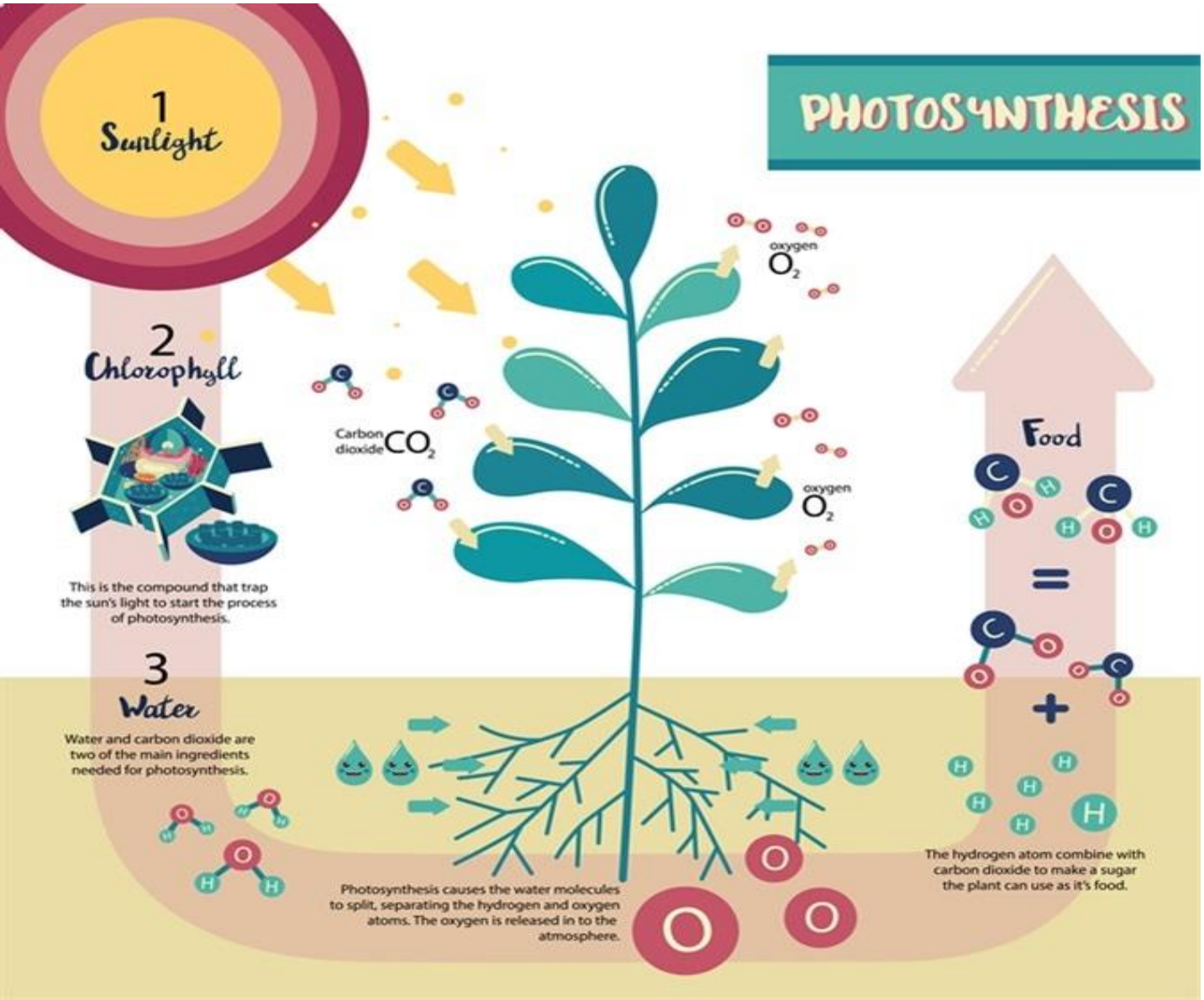
a. Explain photorespiration and state the alternative mechanism of carbon fixation (C4 and CAM pathway) [C2]

a. Compare carbon fixation in C4 and CAM plant [C3]

6.3 Light dependent reaction

a. Explain the cyclic and non cyclic Photophosphorylation [C2]

PHOTOSYNTHESIS

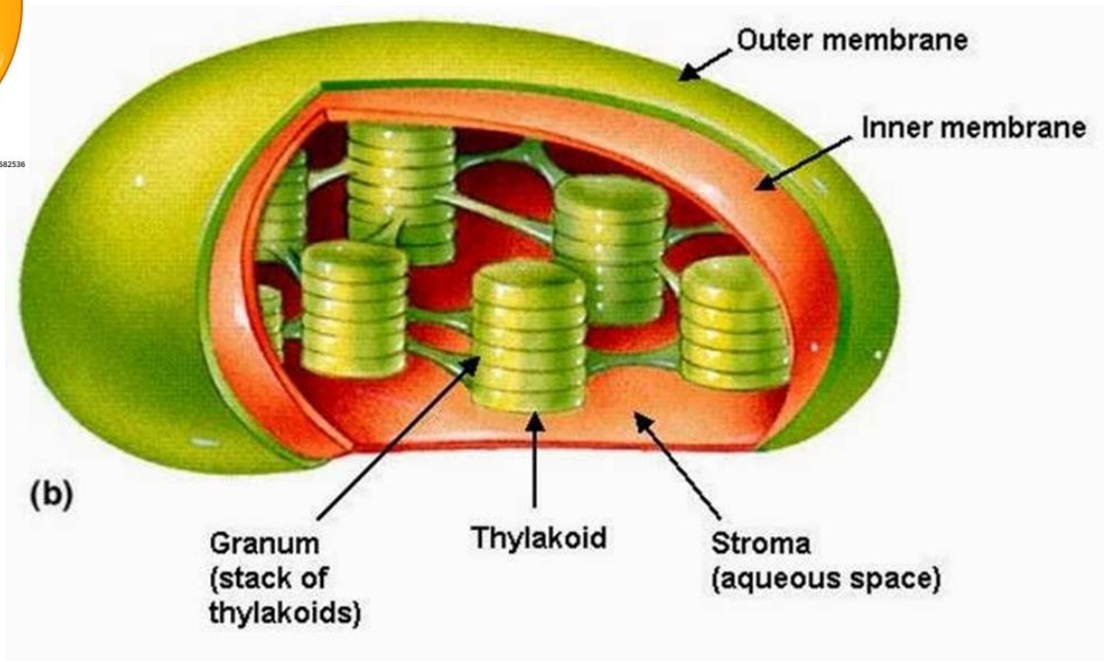


[The amazing of photosynthesis]

6.1 OVERVIEW OF PHOTOSYNTHESIS

Where photosynthesis takes place?

In the chloroplast



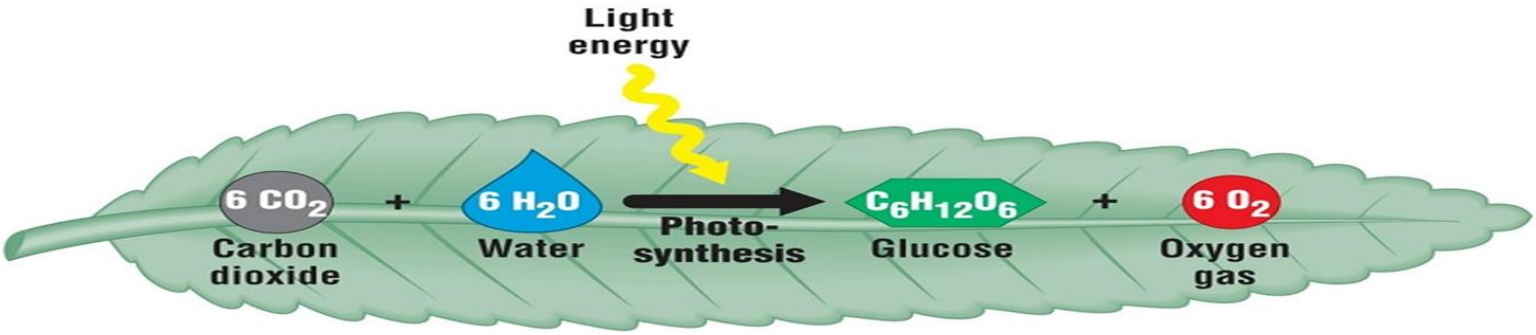
6.1 OVERVIEW OF PHOTOSYNTHESIS

Definition:

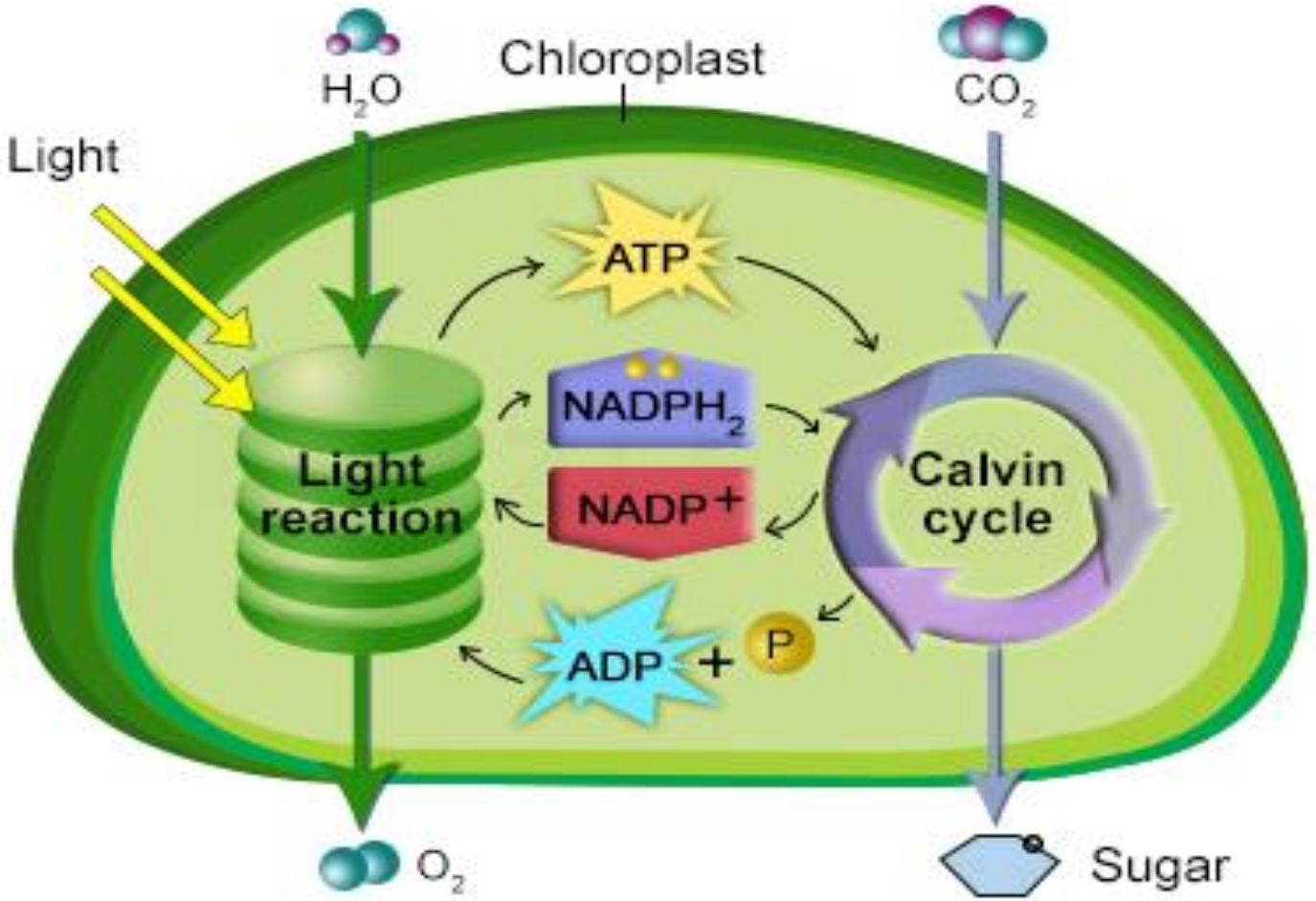
The conversion of light energy to chemical energy that is stored in sugar or other organic compound (occurs in plants, algae & certain prokaryotes).

(Campbell 10th edition)

$$6CO_2 + 12\,H_2O \xrightarrow[\text{CHLOROPHYLL}]{\text{LIGHT}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$



6.1 OVERVIEW OF PHOTOSYNTHESIS



6.2 Absorption spectrum of photosynthetic pigments

Why leaves are green?

The photosynthetic pigment (chlorophyll) of chloroplast absorb violet-blue and red light and reflect green light.

Absorption spectrum is a visual representation of how well a particular pigments absorbs different wavelength of visible light

6.2 Absorption spectrum of photosynthetic pigments

3 types of pigments in chloroplast:

01

CHLOROPHYLL A

- blue-green pigment
- main pigment

02

CHLOROPHYLL B

- yellow-green pigments
- accessory pigments

03

CAROTENOID

- yellow/orange pigments
- accessory pigments

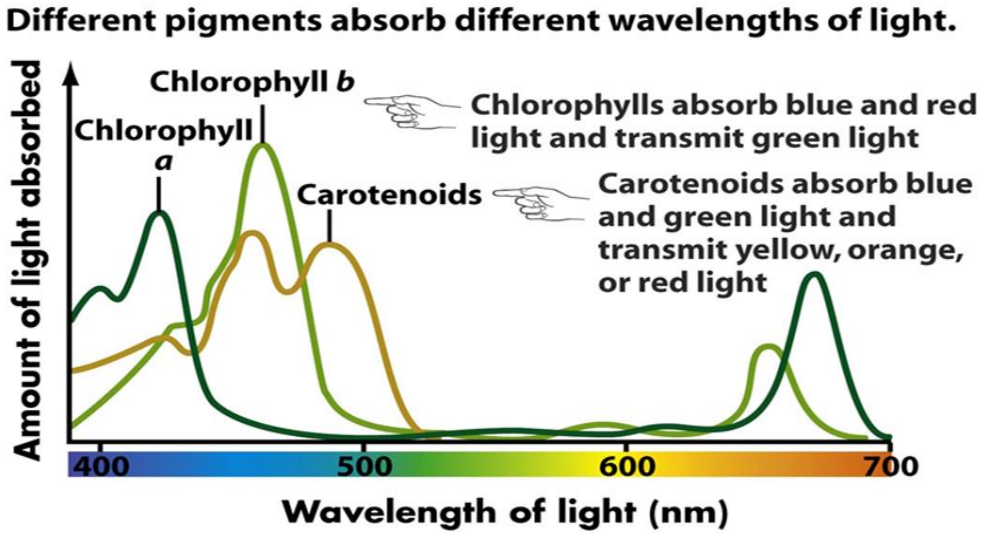
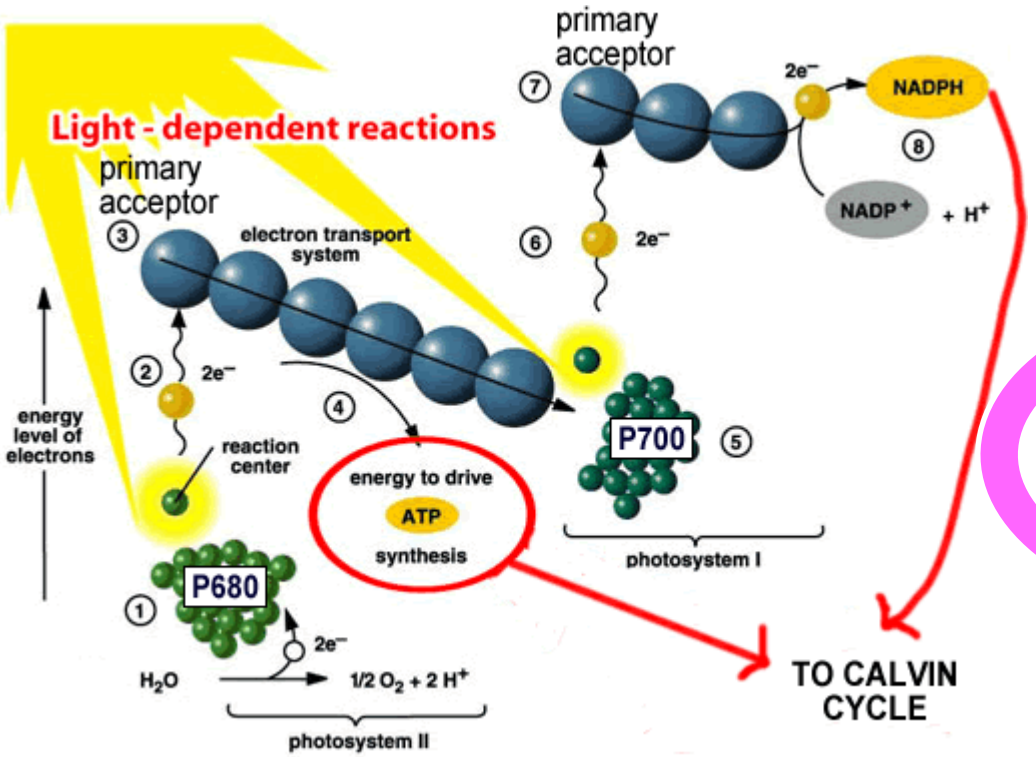


Figure 10-7a Biological Science, 2/e

6.3 Light dependent reaction



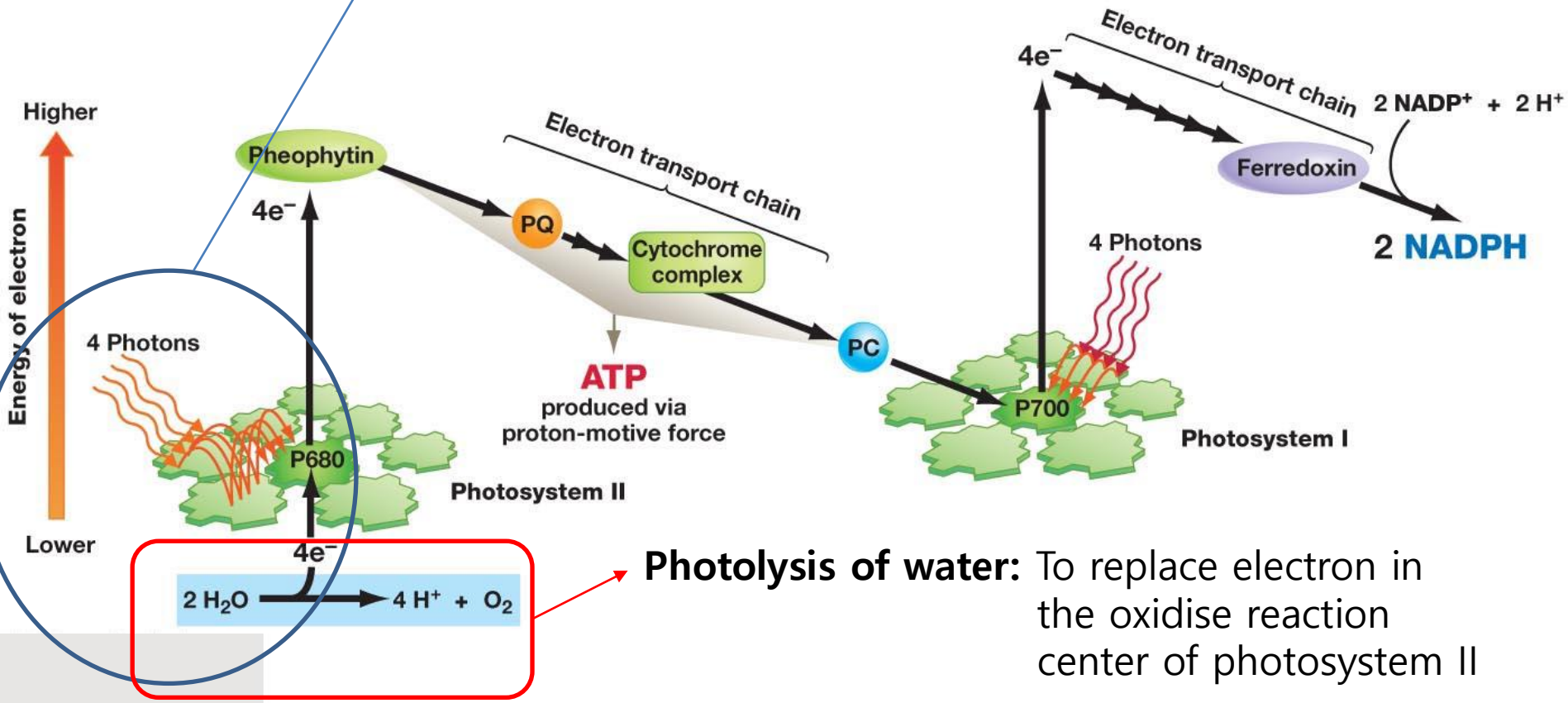
Occur in the presence of light

Occurs in the thylakoid membrane of grana

Converts light energy into chemical energy (**ATP and NADPH**)

6.3 Light dependent reaction

Photoexcitation: When a chlorophyll molecule absorbs a photon of light ; the molecule's electron boosts to an orbital of higher energy

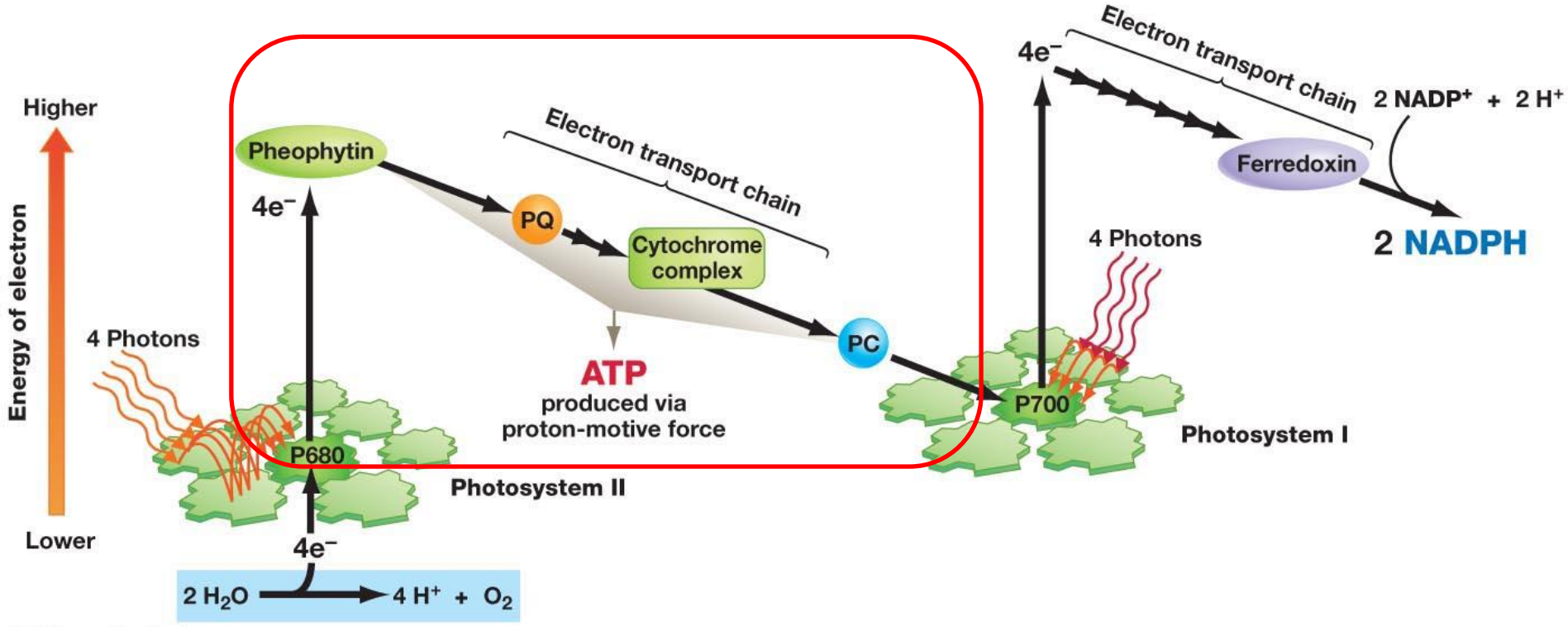


Photolysis of water: To replace electron in the oxidise reaction center of photosystem II

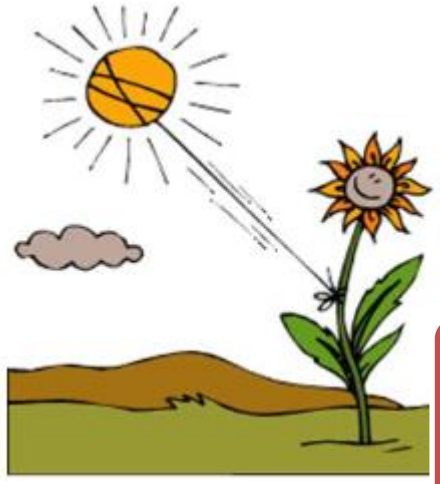
6.3 Light dependent reaction

Photophosphorylation:

- Process of generating ATP from ADP and phosphate by chemiosmosis
- Using a proton motive force generated across the thylakoid membrane
- Occurs during light dependent reaction

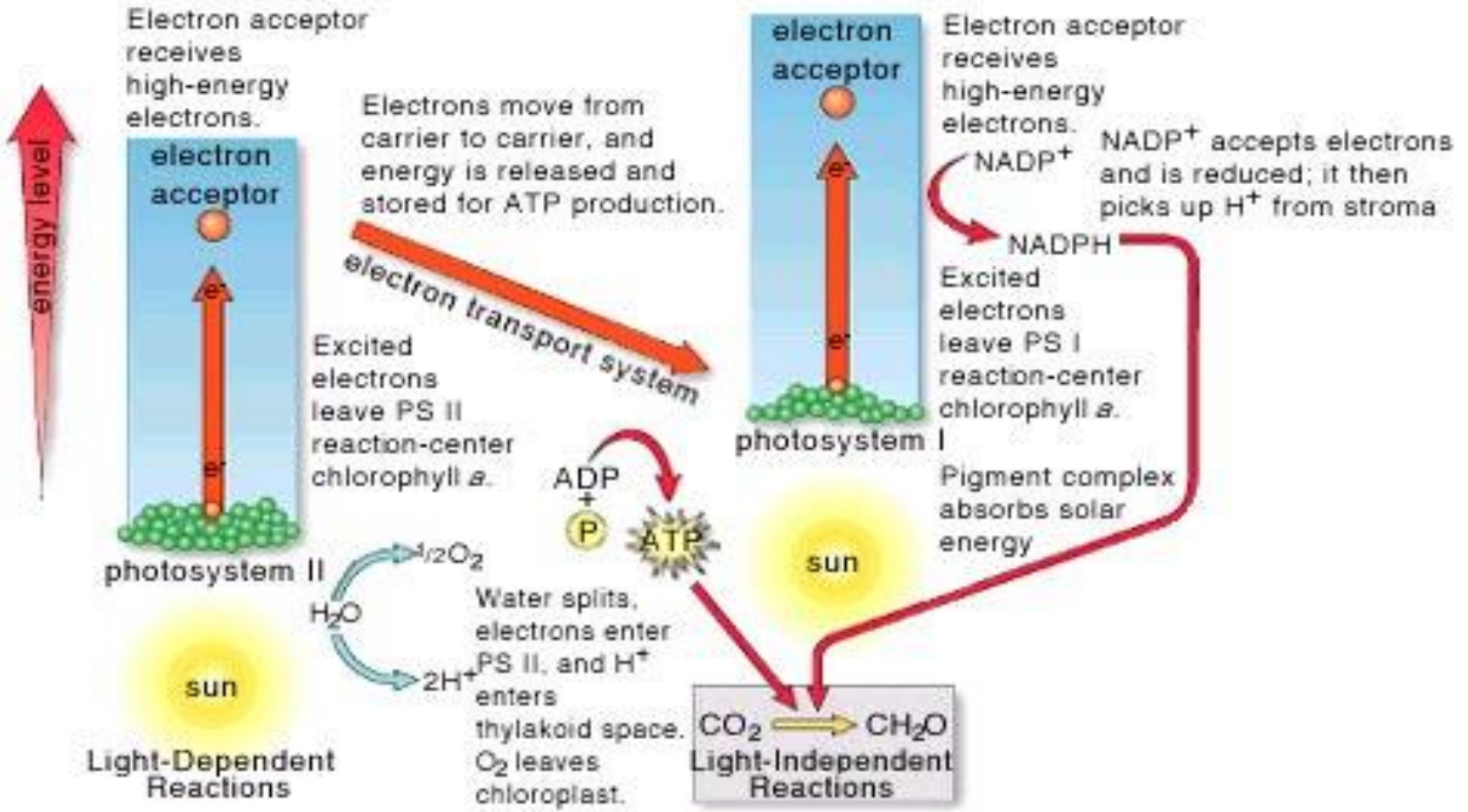


6.3 Light dependent reaction



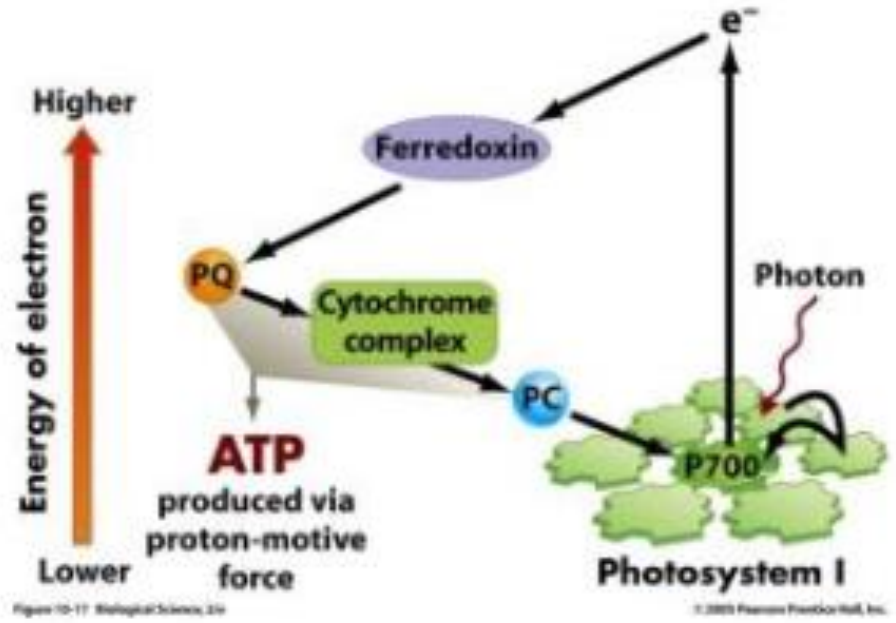
6.3 Light dependent reaction

Non cyclic photophosphorylation



6.3 Light dependent reaction

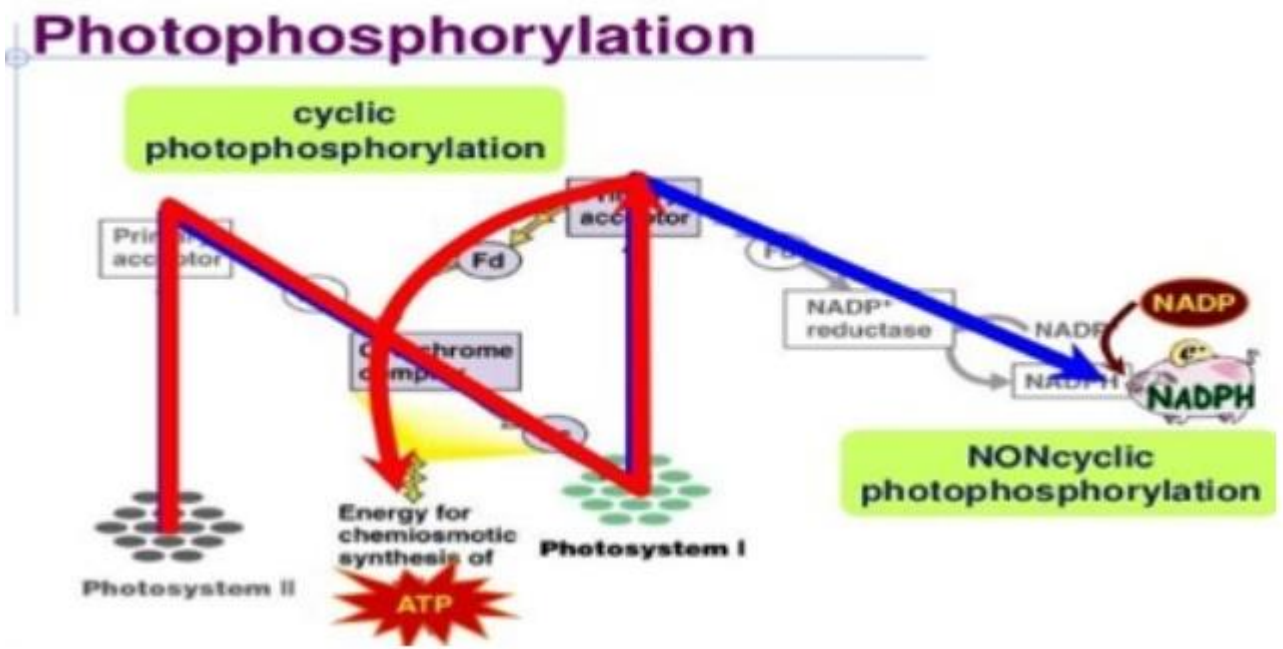
Cyclic photophosphorylation



- Photosystem I acts on its own →without photosystem II
- The electrons pass along the electron transport chain before back to reaction centre of photosystem I
- Produced only ATP (when pass through the ETC)

6.3 Light dependent reaction

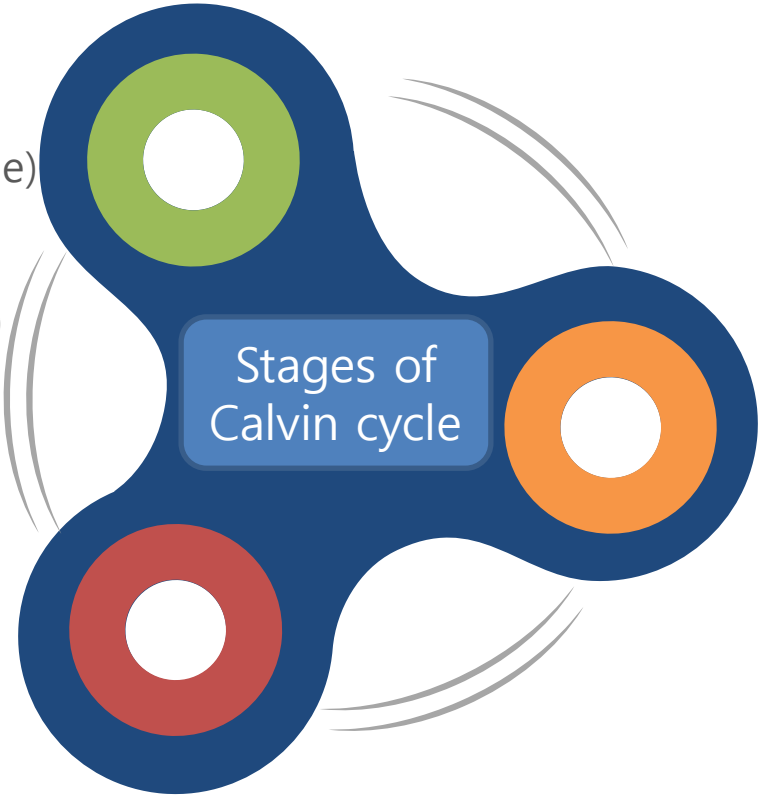
Cyclic Photophosphorylation	Non-Cyclic Photophosphorylation
Only PS I is involved	PS I and PS II are both involved
Water is not required	Photolysis of water is required
Oxygen is not evolved	Oxygen is evolved
NADPH is not synthesized	NADPH is synthesized
Used to produce additional ATP in order to meet cell energy demands	Products can be used for the light independent reactions



- Calvin cycle occur in stroma.
- Use the ATP and NADPH (products from light dependent reaction) to reduce CO_2 to sugar.

1. Carbon fixation

CO_2 (entering one at a time) attach to RuBP (5C sugar); the reaction catalyzed by RuBP carboxylase (rubisco)



2. Reduction

3-phosphoglycerate phosphorylised by ATP forming 1,3-bisphosphoglycerate; Then reduced by NADPH forming glyceraldehyde-3-phosphate

3. Regeneration of carbon acceptor

5 molecules of glyceraldehyde-3-phosphate (3C) are rearranged into 3 molecules of RUBP (5C).

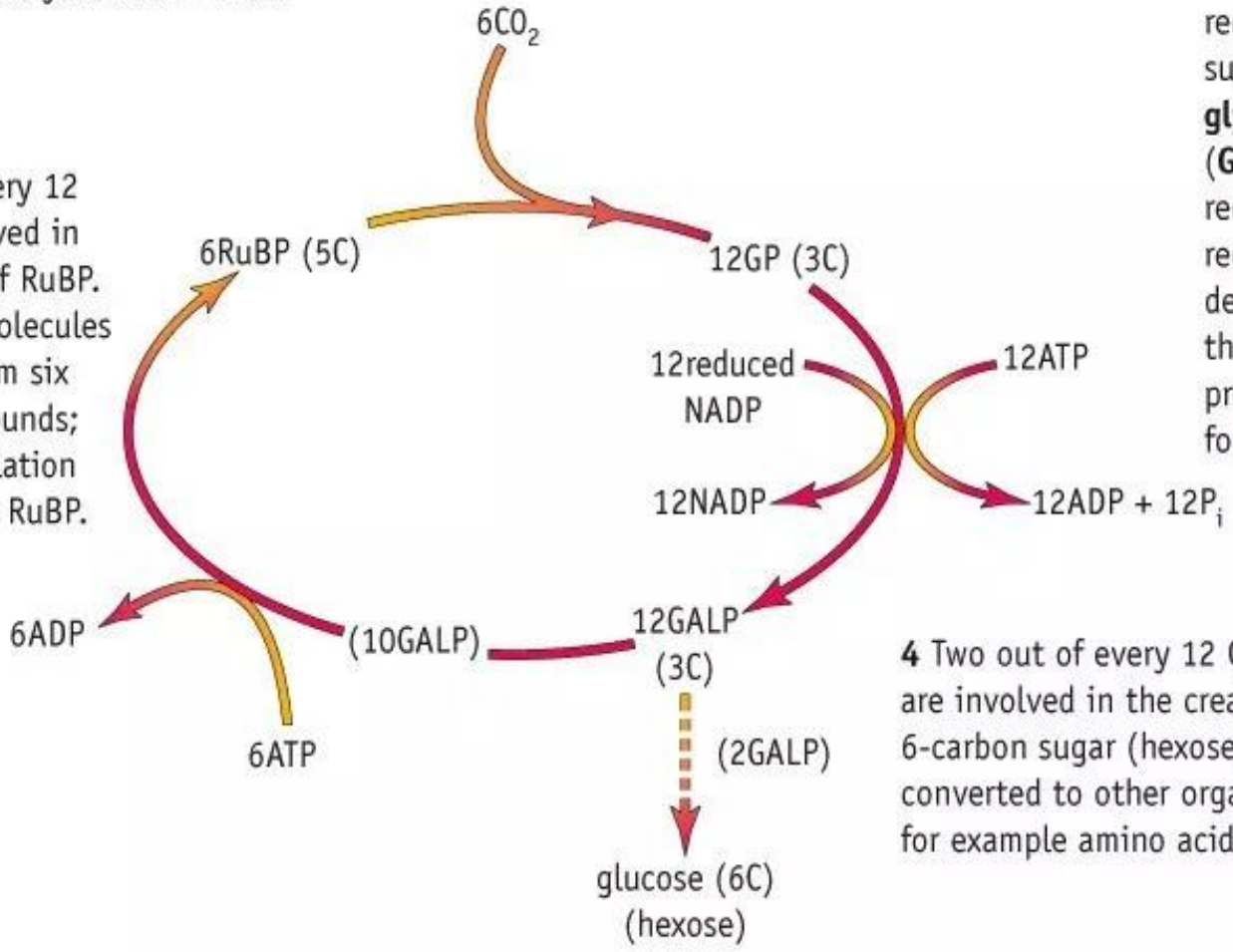
6.4 Light independent reaction / Calvin cycle

1 Carbon dioxide combines with a 5-carbon compound called **ribulose bisphosphate** (**RuBP**). This reaction is catalysed by the enzyme **ribulose bisphosphate carboxylase** (**RuBISCO**), the most abundant enzyme in the world.

2 The 6-carbon compound formed is unstable and immediately breaks down into two 3-carbon molecules, **glycerate 3-phosphate** (**GP**).

3 This 3-carbon compound is reduced to form a 3-carbon sugar phosphate called **glyceraldehyde 3-phosphate** (**GALP**). The hydrogen for the reduction comes from the reduced NADP from the light-dependent reactions. ATP from the light-dependent reactions provides the energy required for the reaction.

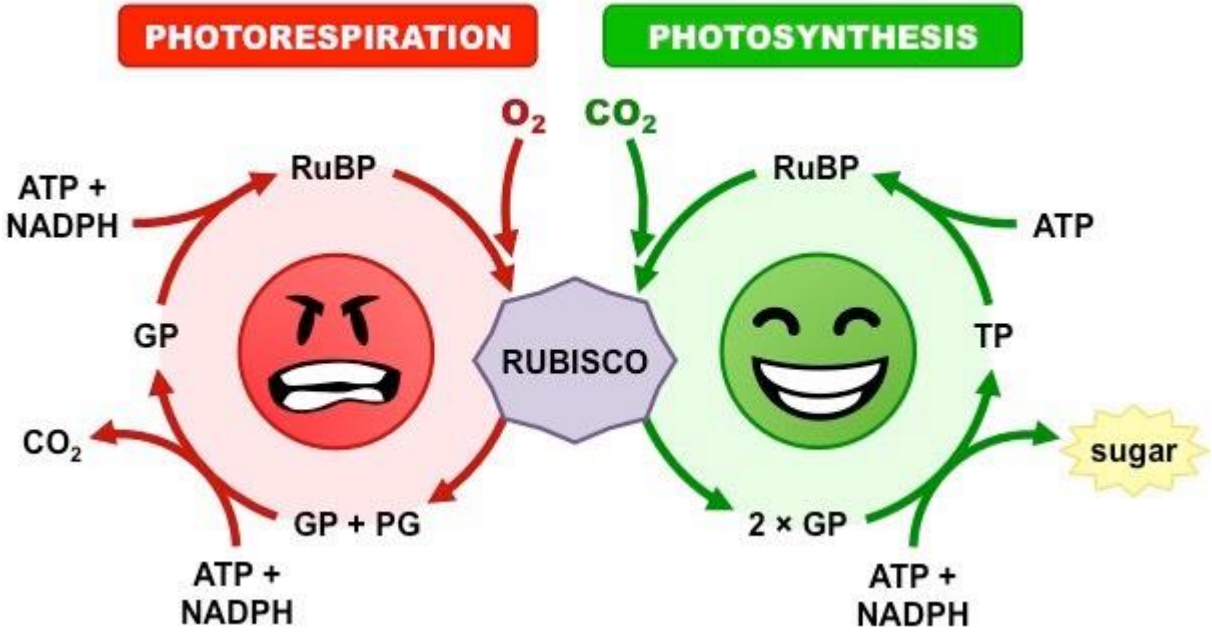
5 Ten out of every 12 GALPs are involved in the recreation of RuBP. The ten GALP molecules rearrange to form six 5-carbon compounds; then phosphorylation using ATP forms RuBP.



4 Two out of every 12 GALPs formed are involved in the creation of a 6-carbon sugar (hexose) which can be converted to other organic compounds, for example amino acids or lipids.

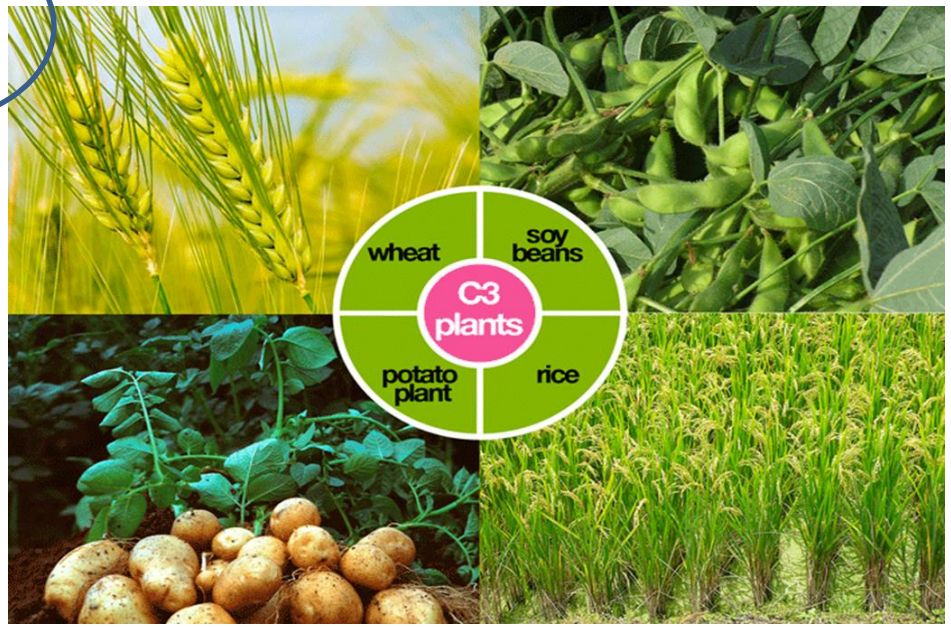
6.5 Alternative mechanism of carbon fixation

A metabolic pathway that consumes oxygen and ATP, releases carbon dioxide and decreases photosynthetic output.
Generally occur on hot, dry, bright days when stomata close and the O_2/ CO_2 ratio in the leaves increase favouring the binding of O_2 rather than CO_2 by rubisco."



6.5 Alternative mechanism of carbon fixation

Why photorespiration lowers photosynthetic output?



In **C3 plant**, photorespiration decreases photosynthetic output by fixing oxygen, instead of carbon dioxide to Calvin cycle.

6.5 Alternative mechanism of carbon fixation

In some plant species, alternate modes of carbon fixation have evolved that minimize the photorespiration and optimize the Calvin cycle even in hot, arid climates.

C4 plant

C4 plant so named because they preface the Calvin cycle with an alternate mode of carbon fixation that forms a four-carbon compound as its first product.

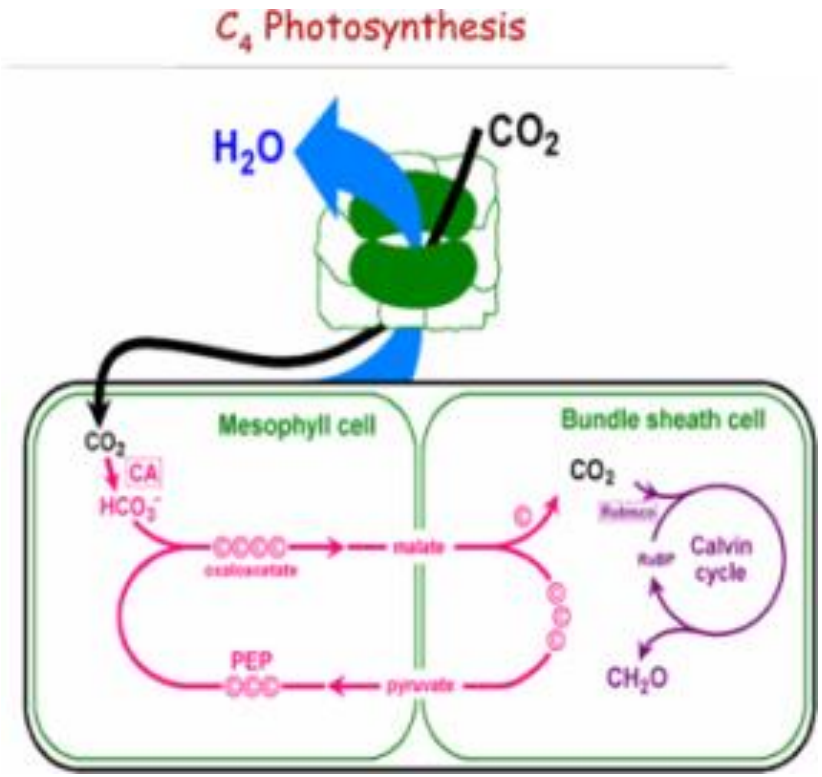
CAM plant

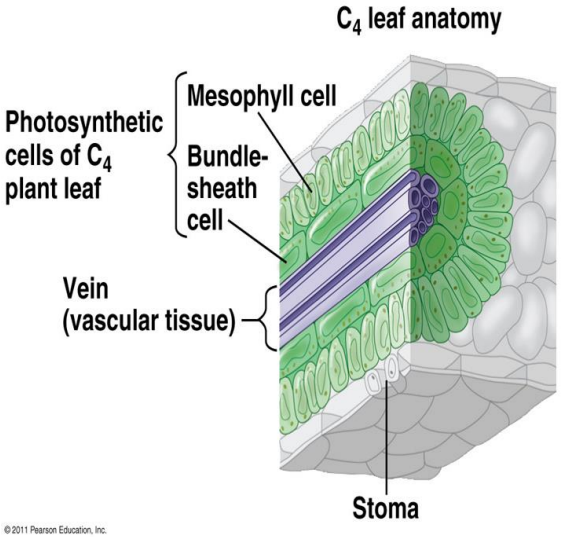
Some plants that are adapted to dry environments, use the crassulacean acid metabolism (CAM) pathway to minimize photorespiration.

6.5 Alternative mechanism of carbon fixation (C4 plant)

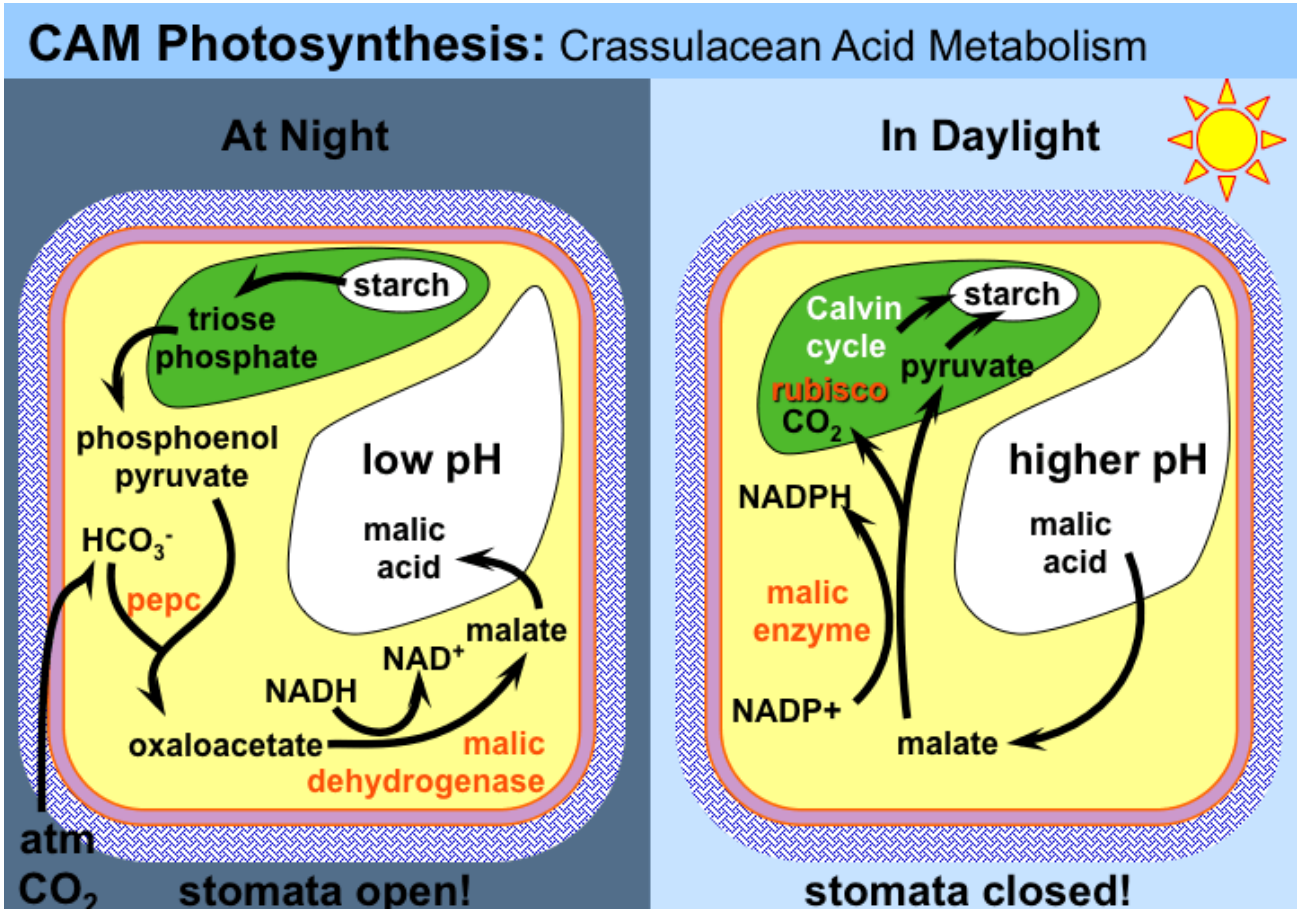
In **C4 plants**, there are two types of photosynthetic cells:

Bundle sheath cells: arrange tightly packed sheath around the veins of leaf.
Mesophyll cells: loosely arranged between bundle sheath and leaf surface





6.5 Alternative mechanism of carbon fixation (CAM plant)



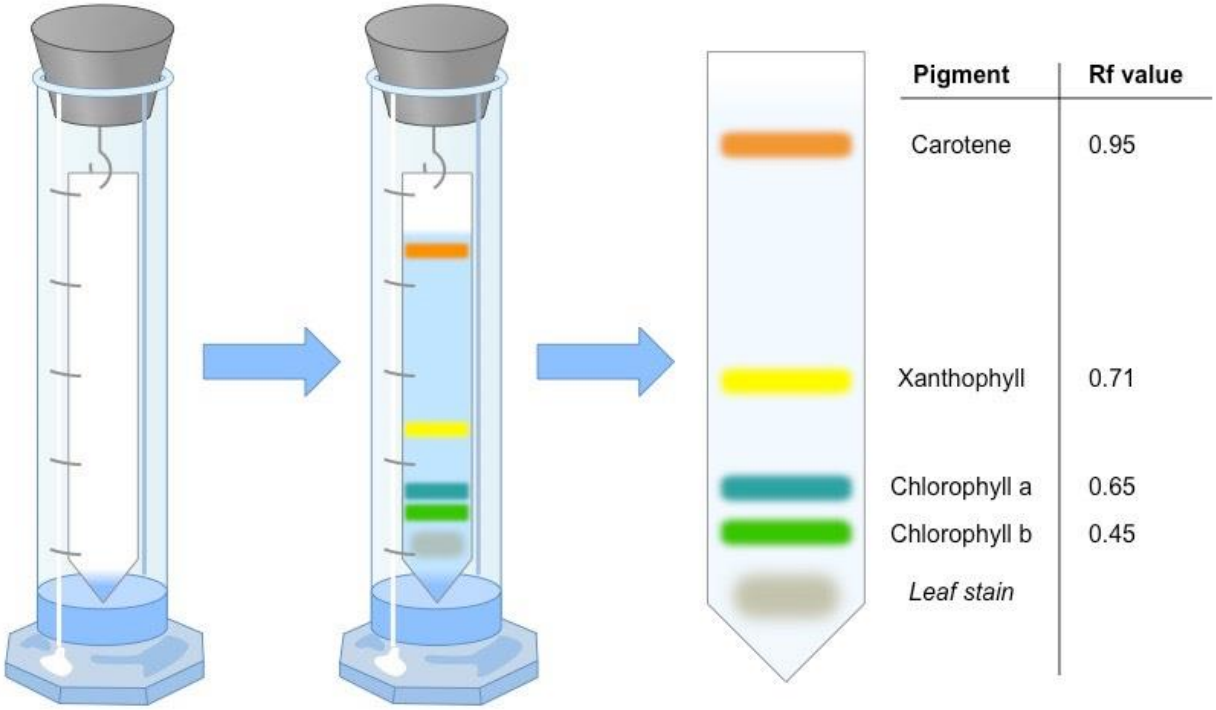
6.5 Alternative mechanism of carbon fixation

FEATURE/ CHARACTERISTIC	C3 Plants	C4 Plants	CAM Plants
Distribution in the plant kingdom (% of plant species)	~85% (Moore et al. 2003)	~3% (Simpson 2010), all angiospermous including most troublesome weeds; mostly monocots (C4 grasses and sedges about 79% of all C4 plants)	~8% (Simpson 2010), mostly succulent plants but not all succulents are CAM plants
Type of photosynthesis	C3 photosynthesis	C4 photosynthesis	CAM photosynthesis
CO2 fixation pathway	via C3 cycle only	via C3 and C4 cycles, spatially (C4 in the mesophyll cell then C3 in the bundle sheath cell)	via C3 and C4 cycles, both spatially (in different parts of same cell) and temporally (C4 at night, C3 at day time)
Leaf anatomy	Large air spaces bordered by loosely arranged spongy mesophyll cells; mesophyll cells but not bundle sheath cells (BSC) contain chloroplasts	Generally thinner leaves, closer arrangement of vascular bundles, smaller air spaces than C3; veins sorrounded by thick-walled BSC further sorrounded by thin-walled mesophyll cells (wreath-like arrangement of BSC is called Kranz anatomy); mesophyll cells and BSC contain chloroplasts, those of the BSC much larger	Thick and fleshy leaves, mesophyll cells having large, water-filled vacuoles
Stomatal movement	Stomata open at daytime, close at night	Stomata open at daytime, close at night	Inverted stomatal cycle (open at night, close in the day)
Typical Environmental / Geographical adaptation (where	Temperate most common)	Tropical or semi-tropical, high light intensity, high temperature, drought conditions	Desert or arid (xeric) habitats

Comparison between C3, C4 and CAM plant

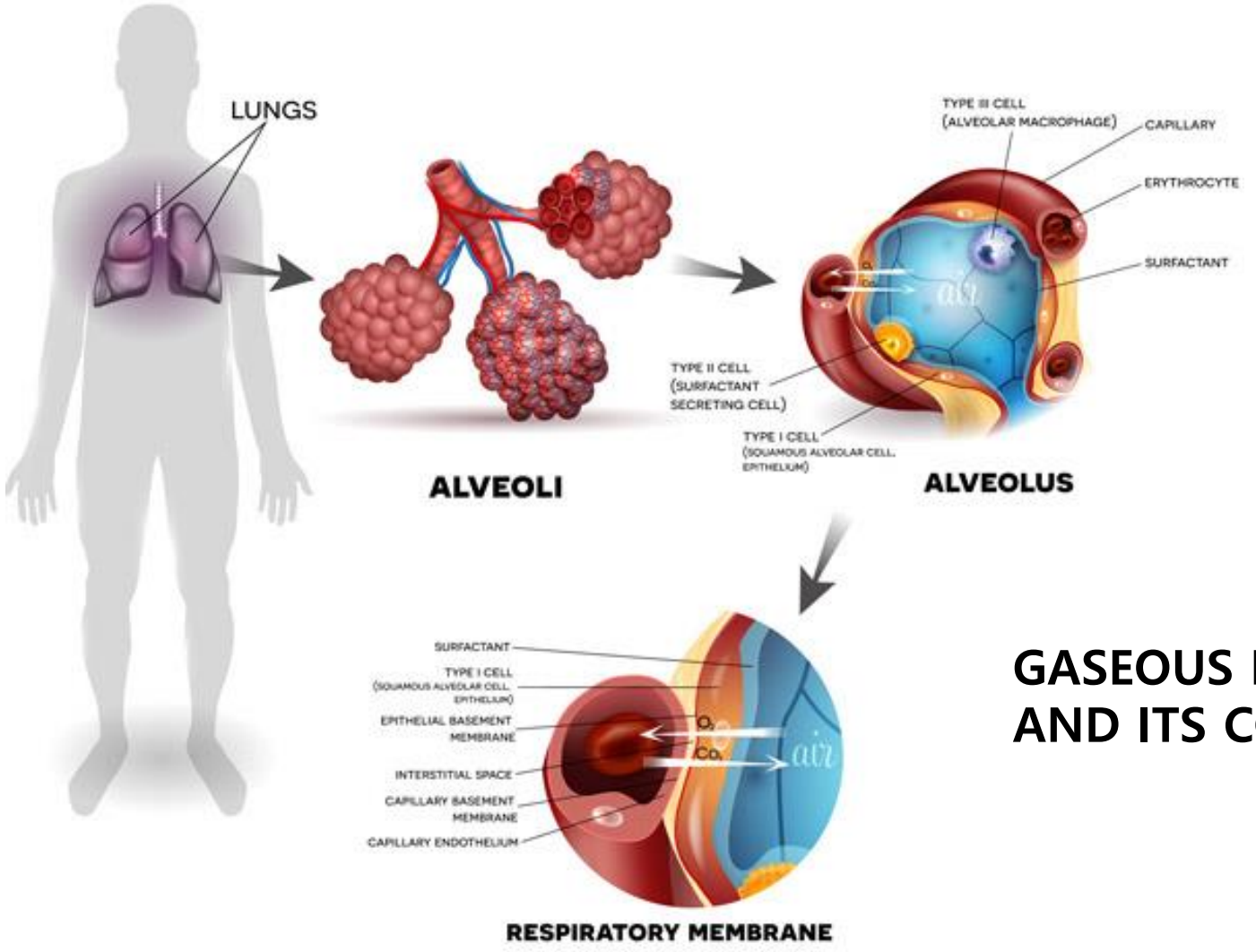
CHROMATOGRAPHY TECHNIQUE

- Separation of Plant Pigments Using Chromatography set up
- Paper chromatography is a useful technique in the separation and identification of different plant pigments.



Chromatography technique

NEXT CHAPTER



GASEOUS EXCHANGE AND ITS CONTROL