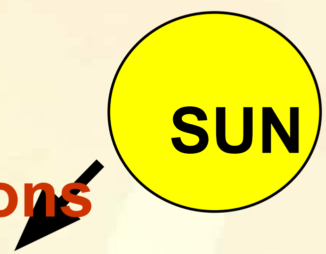
# PHOTOSYNTHESIS

# Photosynthesis

- Anabolic (small molecules combined)
- Endergonic (stores energy)
- Carbon dioxide ($CO_2$) requiring process that uses light energy (photons) and water ($H_2O$) to produce organic macromolecules (glucose).




photons

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

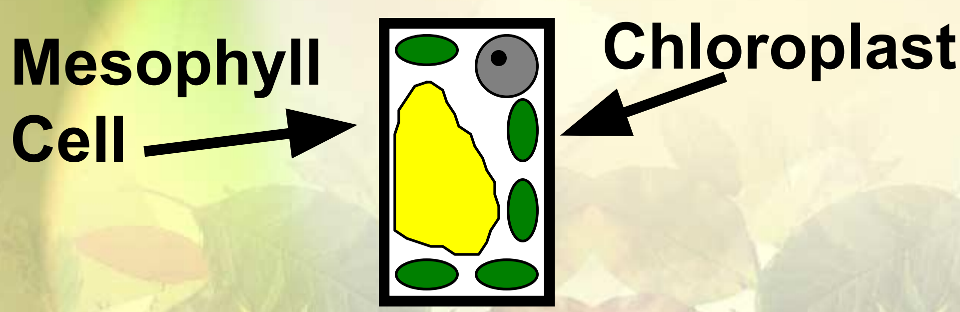
glucose

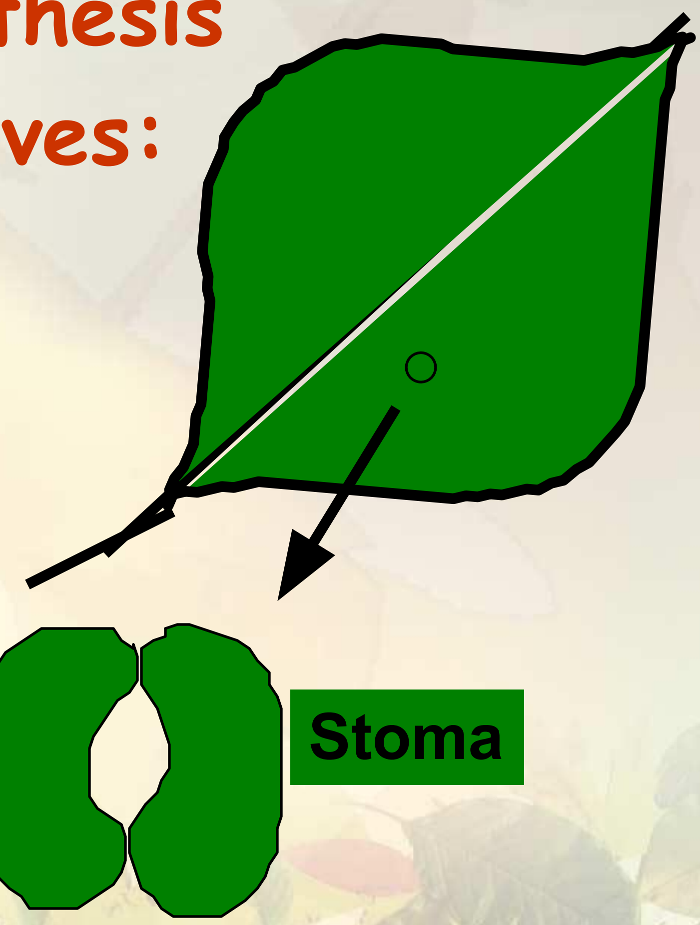
# Question:

## Where does photosynthesis take place?

# Plants

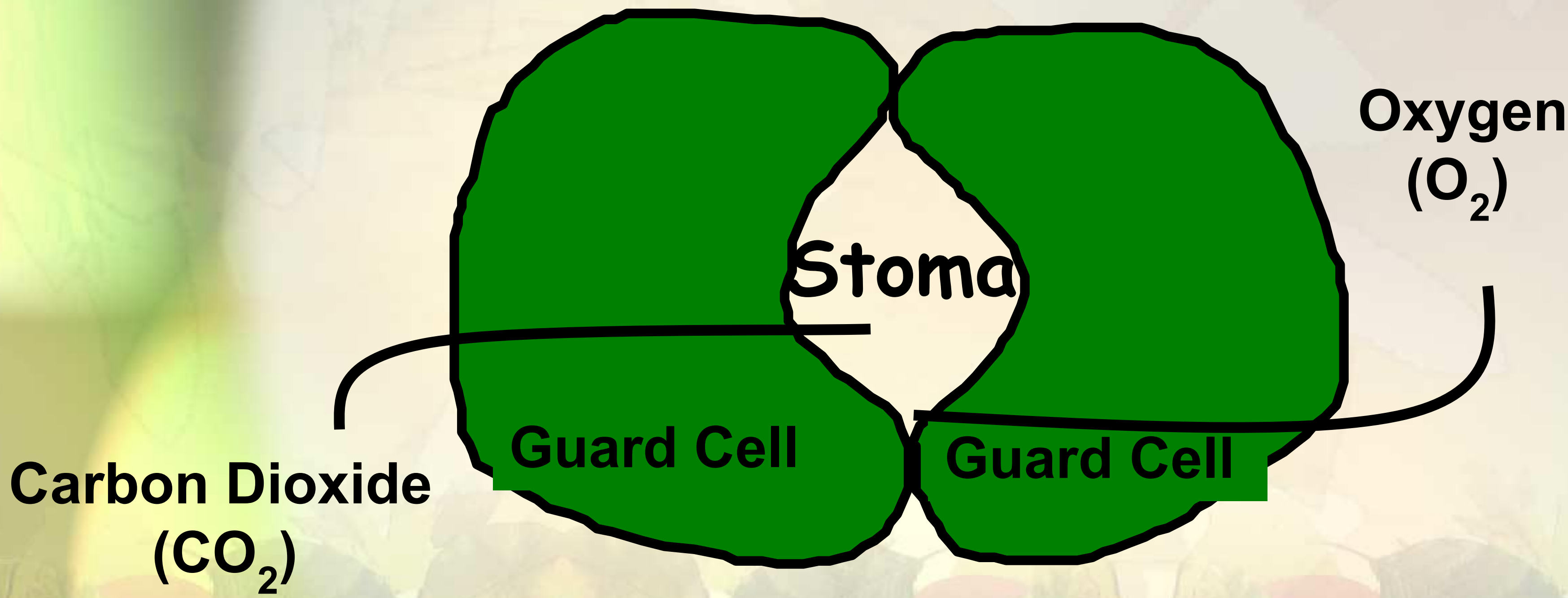
- Autotrophs – produce their own food (glucose)
- Process called photosynthesis
- Mainly occurs in the leaves:
  a. stoma - pores
  b. mesophyll cells



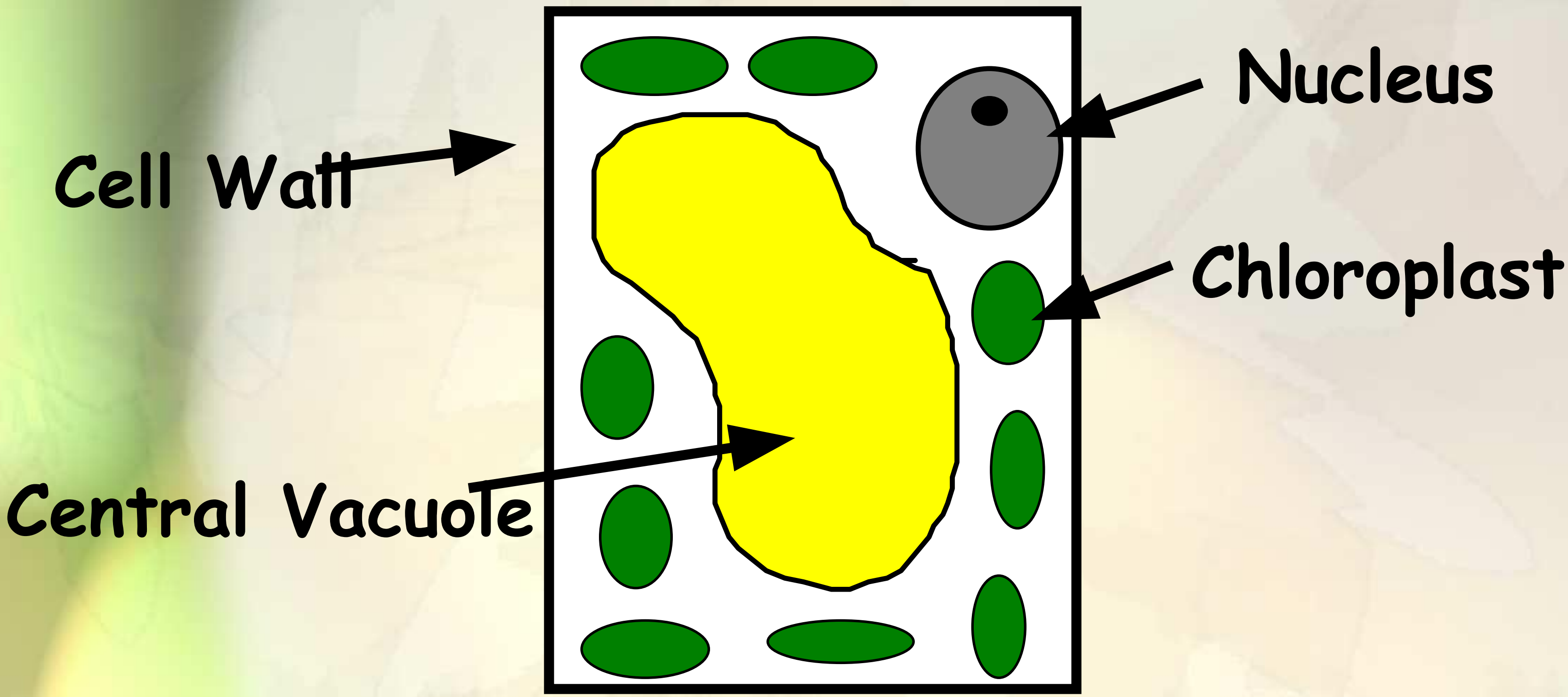
# Stomata (stoma)

**Pores** in a plant's cuticle through which **water vapor** and **gases** ($CO_2$ & $O_2$) are exchanged between the plant and the atmosphere.




Found on the underside of leaves

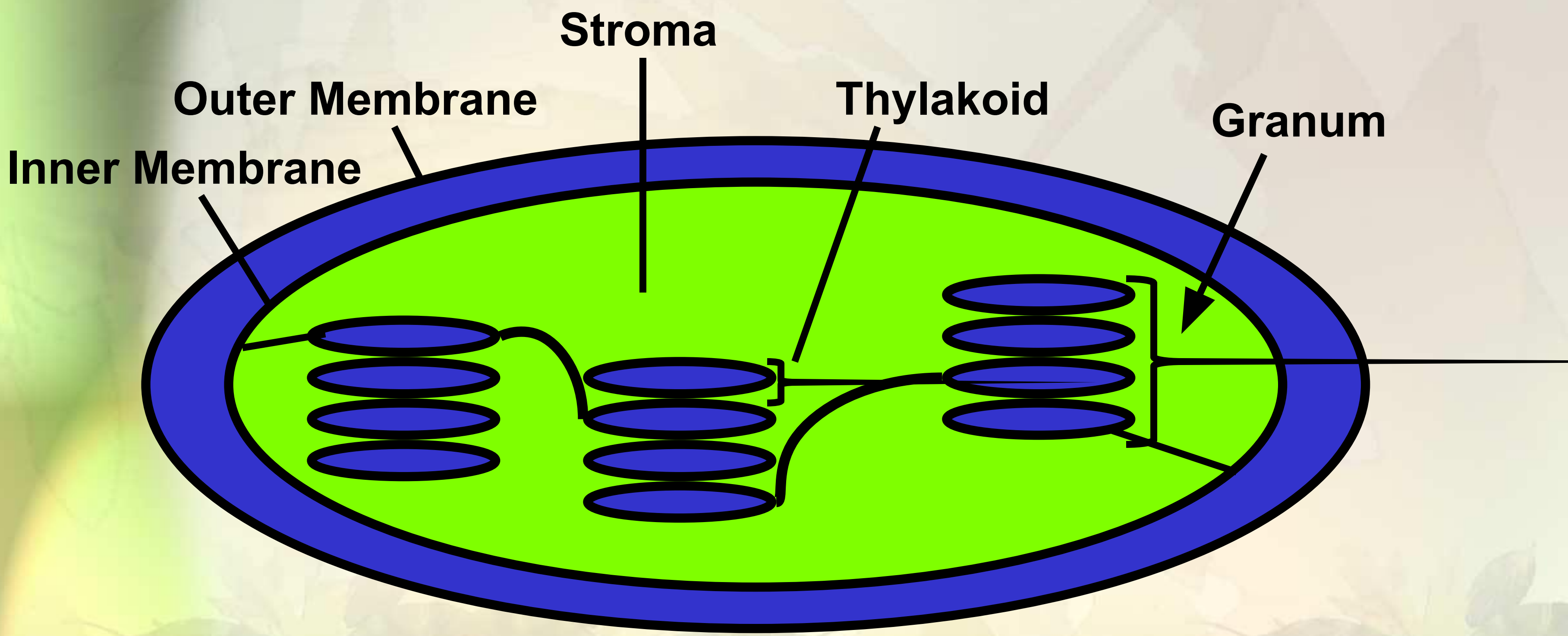
# Mesophyll Cell of Leaf




**Photosynthesis occurs in these cells!**

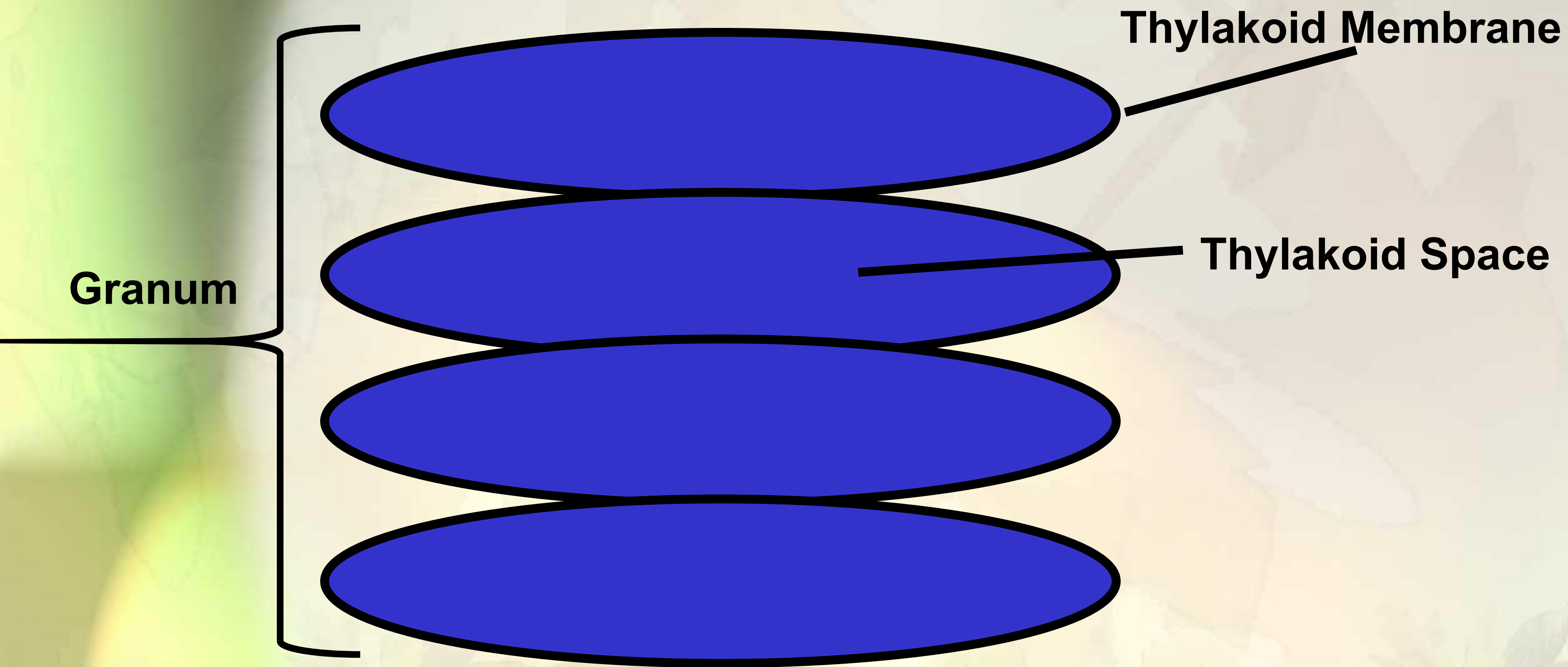
# Chloroplast

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




**Thylakoid stacks are connected together**

# Thylakoid




**Grana make up the inner membrane**

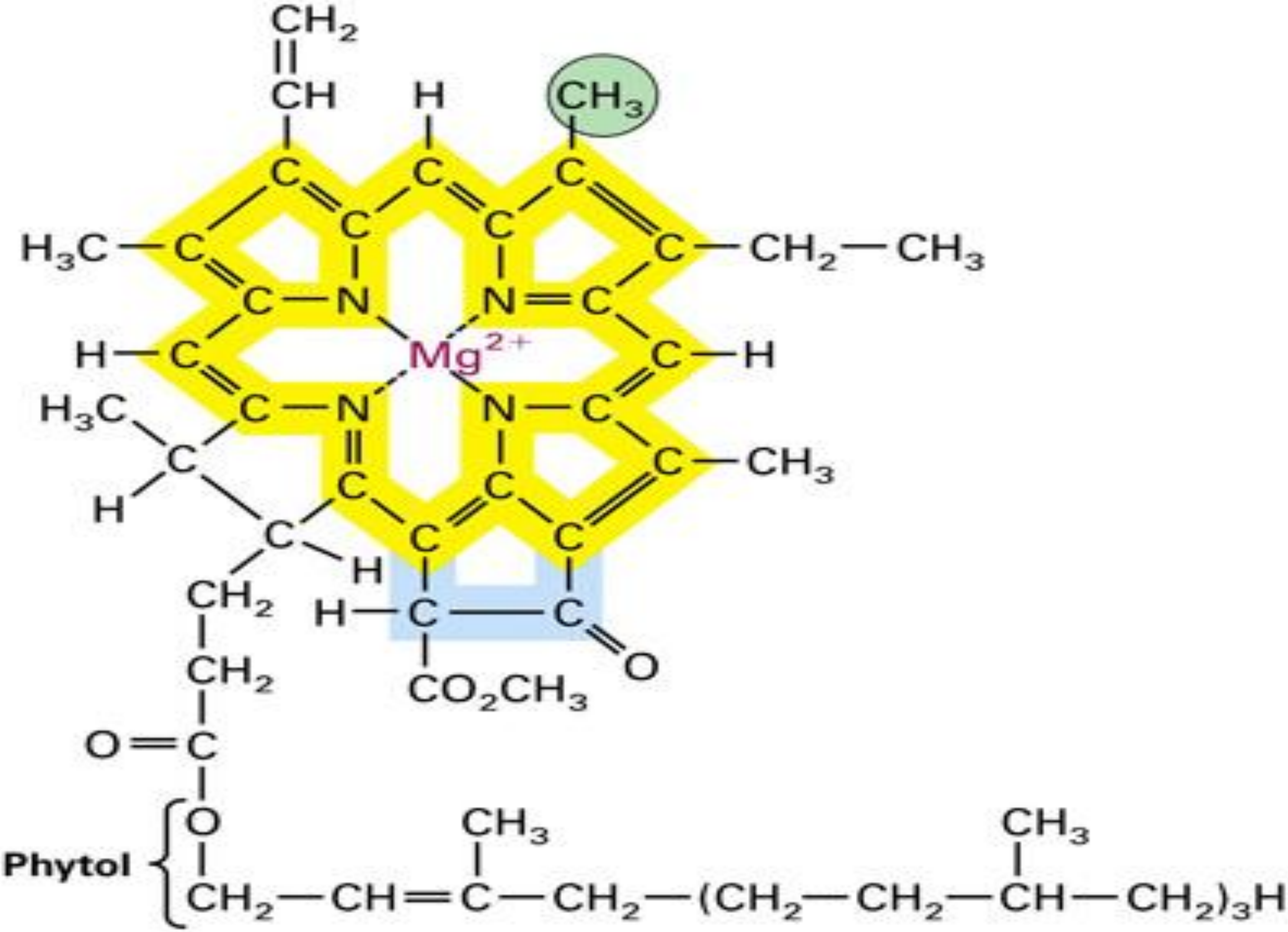
# Question:

# Why are plants green?

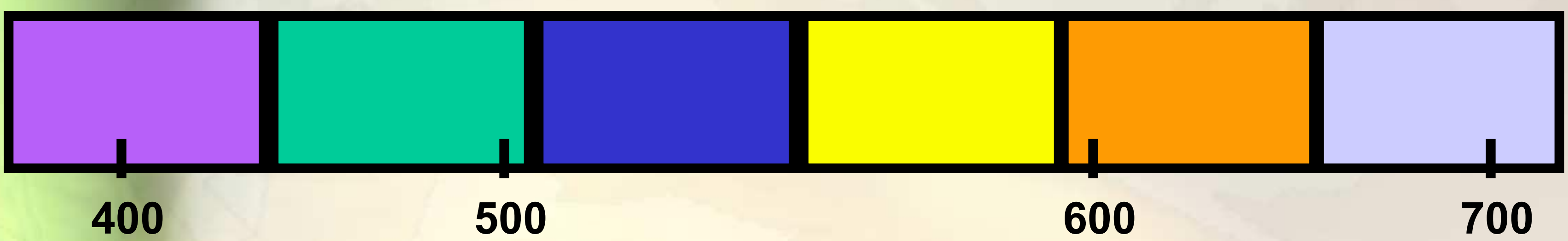
# Chlorophyll Molecules

- 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.

# Chlorophyll *a*



# Wavelength of Light (nm)




**Short wave**
(more energy)

**Long wave**
(less energy)

# Absorption of Light by Chlorophyll

Chlorophyll absorbs blue-violet & red light best

# 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, orange, or yellow

# Redox Reaction

The transfer of one or more electrons from one reactant to another

Two types:

1. Oxidation is the loss of $e^-$
2. Reduction is the gain of $e^-$

# Oxidation Reaction

The loss of electrons from a substance or the gain of oxygen.

Oxidation

$6CO_2$ + $6H_2O$ → $C_6H_{12}O_6$ + $6O_2$

Carbon dioxide

Water

glucose

Oxygen

# Reduction Reaction

The gain of electrons to a substance or the loss of oxygen.

$$6CO_2 + 6H_2O \xrightarrow{\text{Reduction}} C_6H_{12}O_6 + 6O_2$$

glucose

# Question:

# Why do cells use for energy?

# Energy for Life on Earth

- Sunlight is the ULTIMATE energy for all life on Earth
- Plants store energy in the chemical bonds of sugars
- Chemical energy is released as ATP during cellular respiration

# Structure of ATP

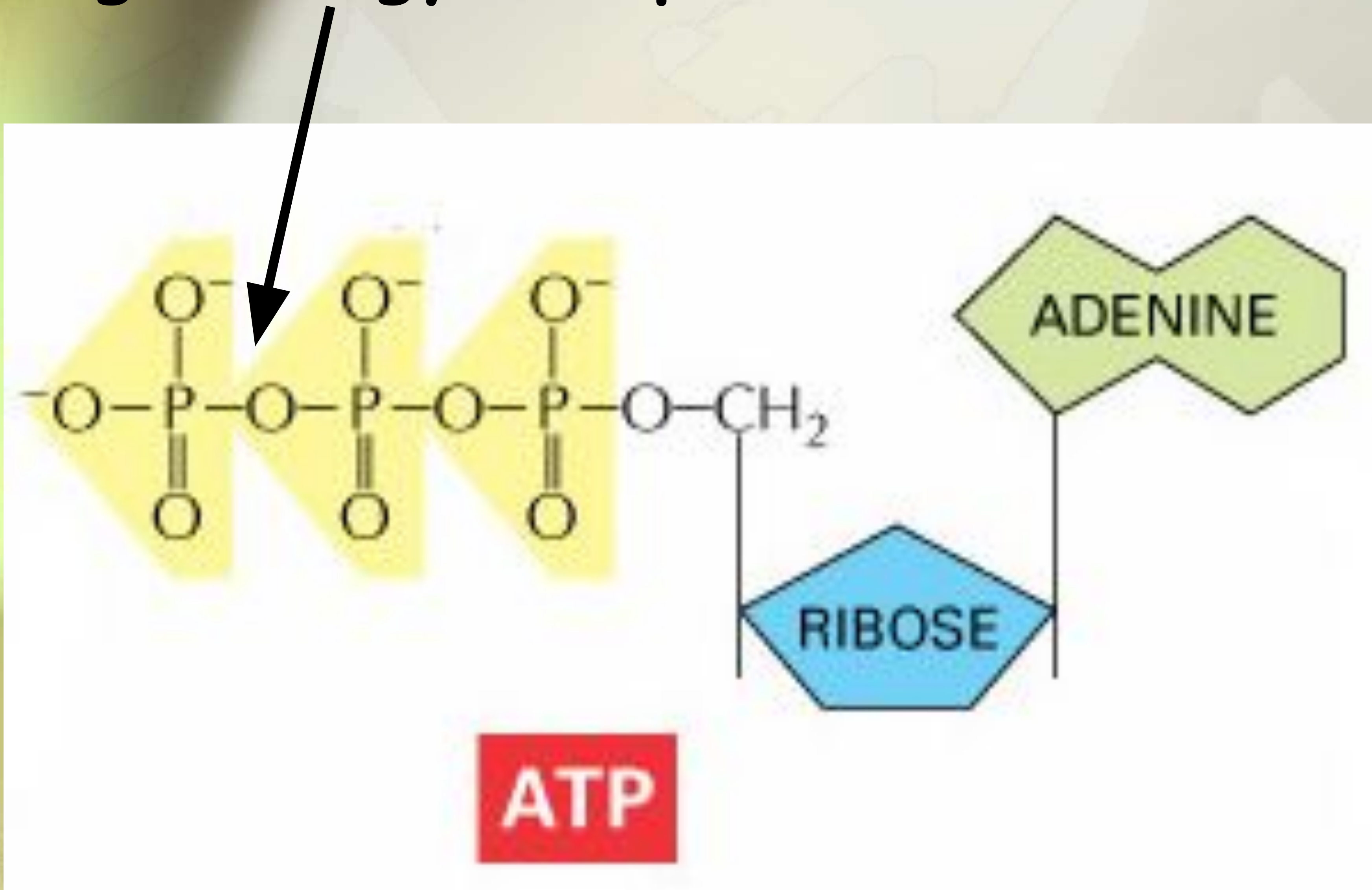
- ATP stands for adenosine triphosphate
- It is composed of the nitrogen base ADENINE, the pentose (5C) sugar RIBOSE, and three PHOSPHATE groups
- The LAST phosphate group is bonded with a HIGH ENERGY chemical bond
- This bond can be BROKEN to release ENERGY for CELLS to use

# Removing a Phosphate from ATP

Breaking the LAST PHOSPHATE bond from ATP, will ---

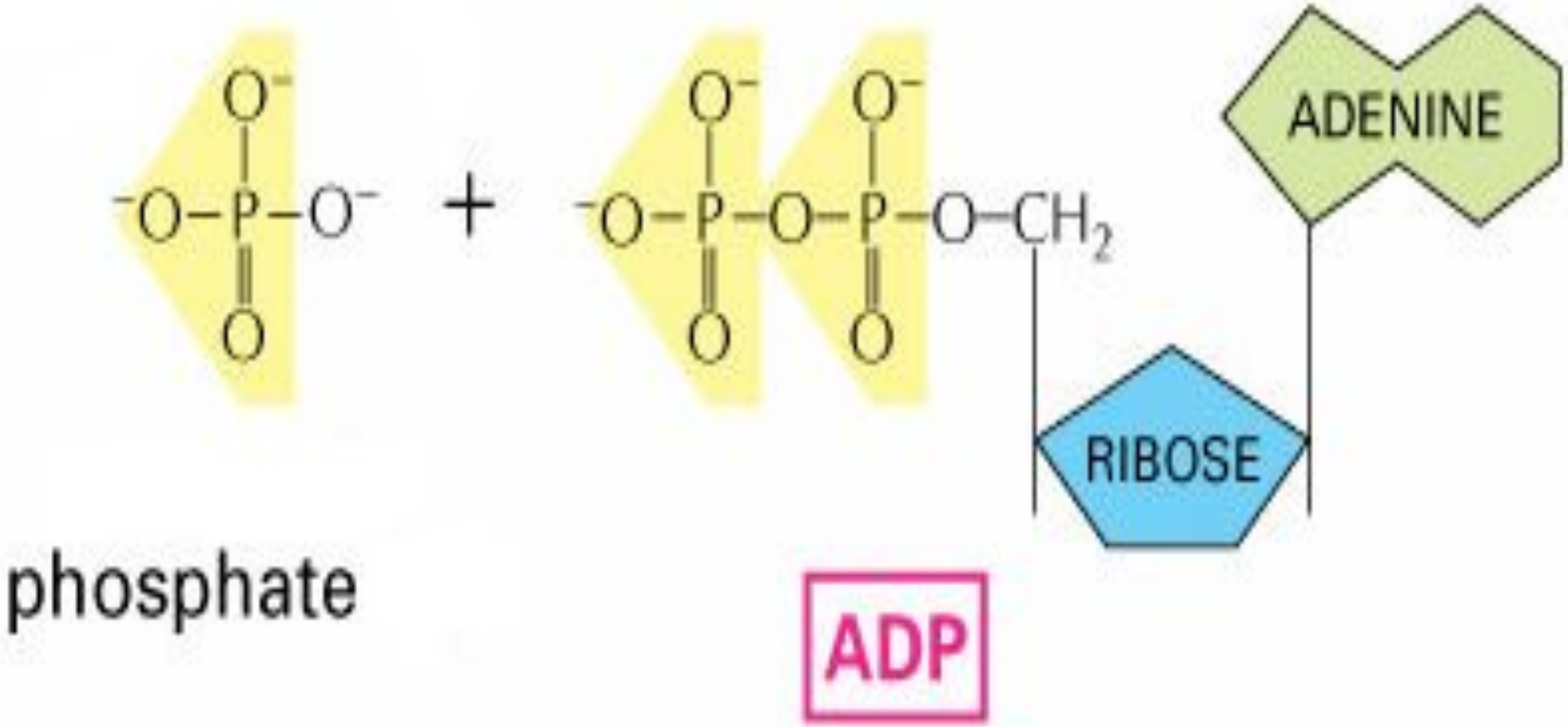
- Release ENERGY for cells to use
- Form ADP
- Produce a FREE PHOSPHATE GROUP

# High Energy Phosphate Bond

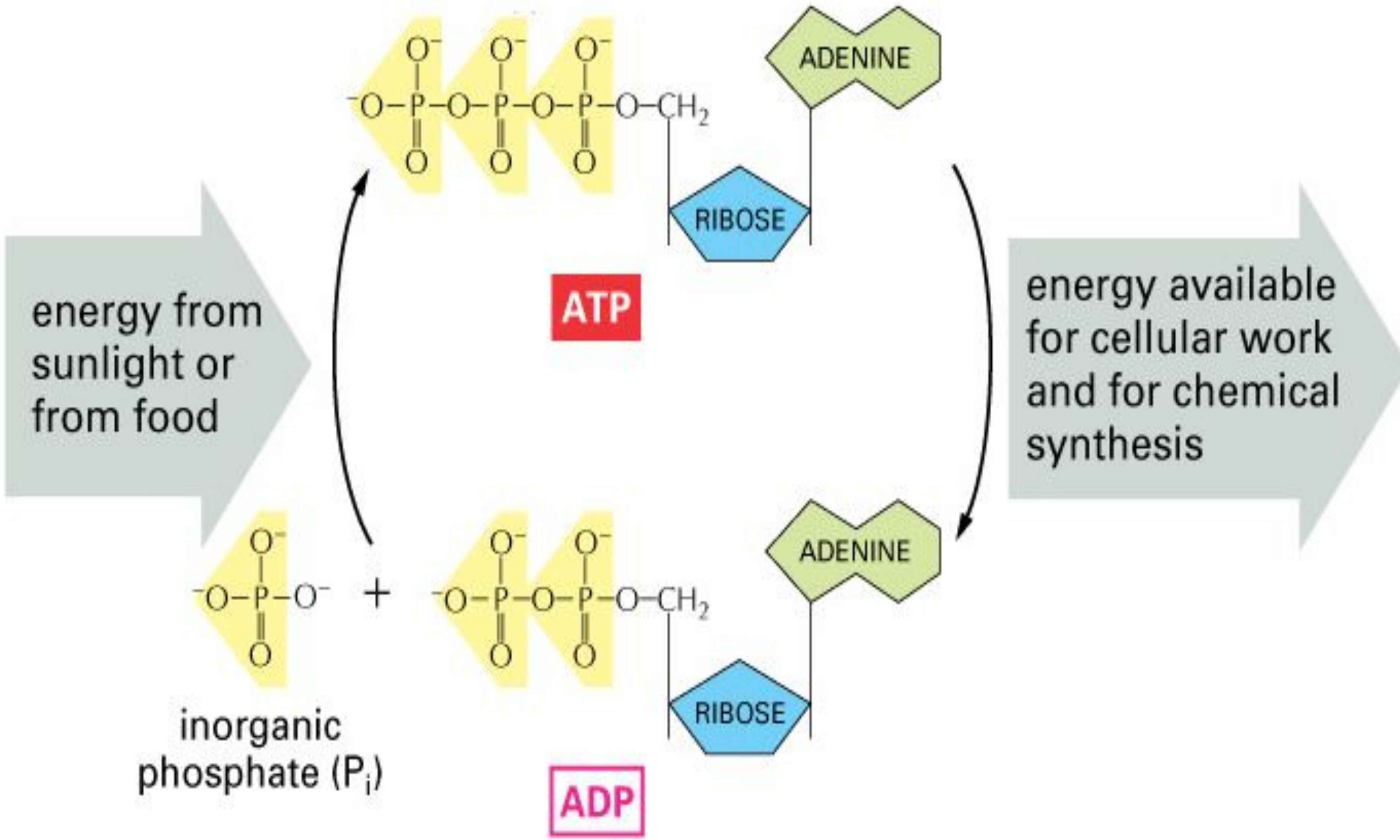


FREE PHOSPHATE can be re-attached to ADP reforming ATP

Process called **Phosphorylation**



# Phosphorylation



# Parts of Photosynthesis

# Two Parts of Photosynthesis

Two reactions make up photosynthesis:

1. Light Reaction or Light Dependent Reaction –

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

# Two Parts of Photosynthesis

2. Calvin Cycle or Light Independent Reaction

- Also called Carbon Fixation or $C_3$ Fixation
- Uses energy (ATP and NADPH) from light reaction to make sugar (glucose).

# 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

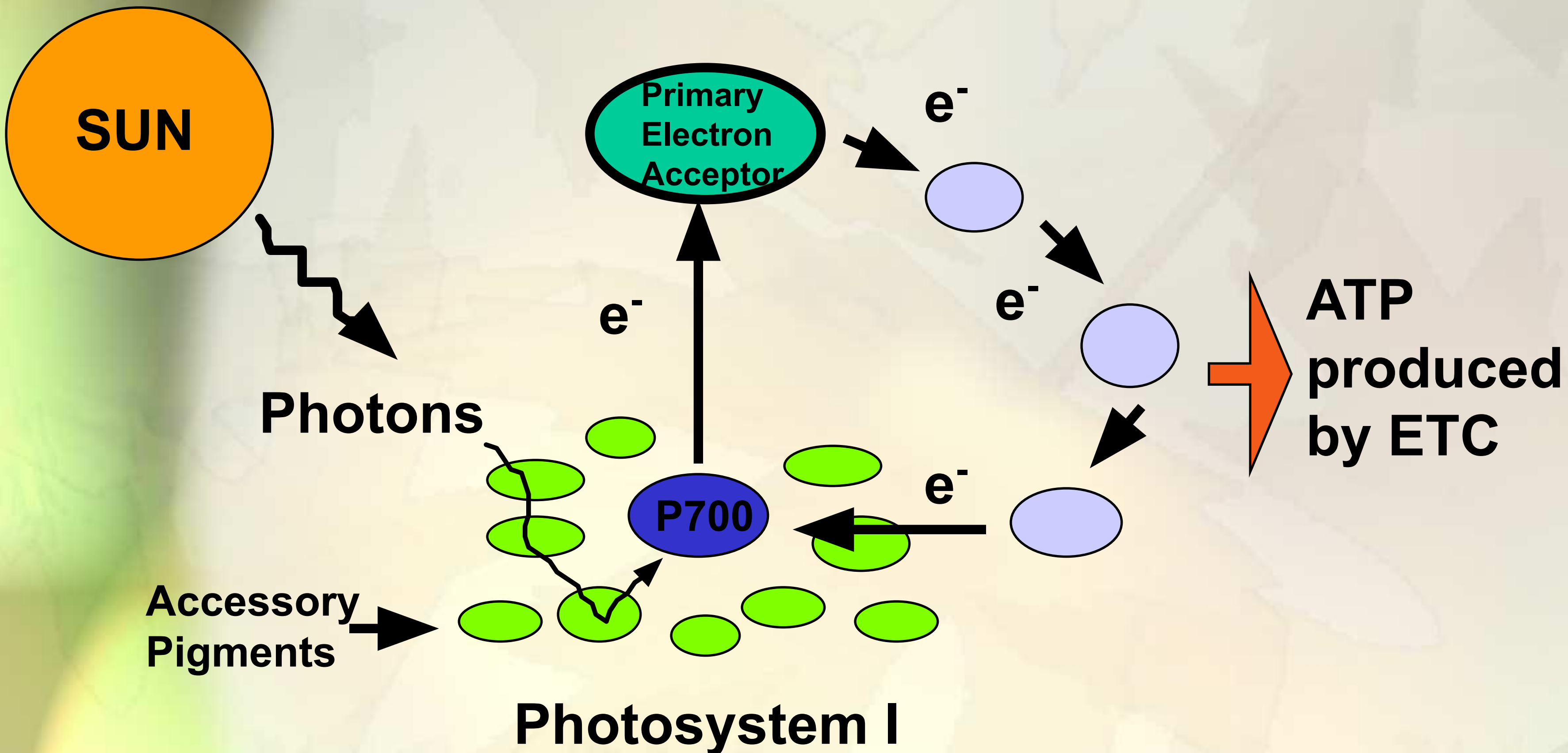
B. Noncyclic Electron Flow

# 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

ADP + P → ATP

# Cyclic Electron Flow

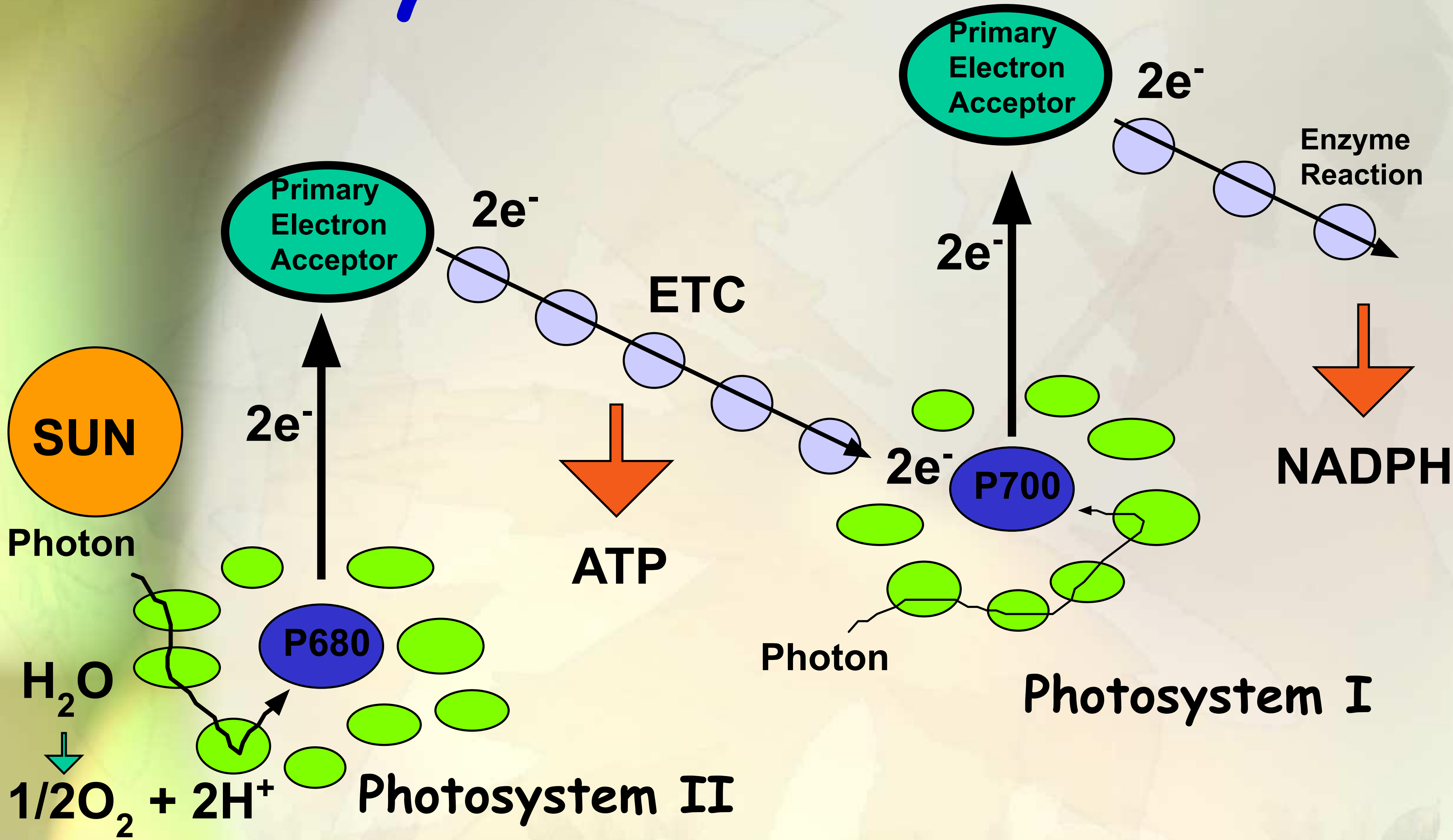



Pigments absorb light energy & excite e- of Chlorophyll a to produce ATP

# Noncyclic Electron Flow

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

# Noncyclic Electron Flow




$H_2O$ is split in PSII & ATP is made, while the energy carrier NADPH is made in PSI

# Noncyclic Electron Flow

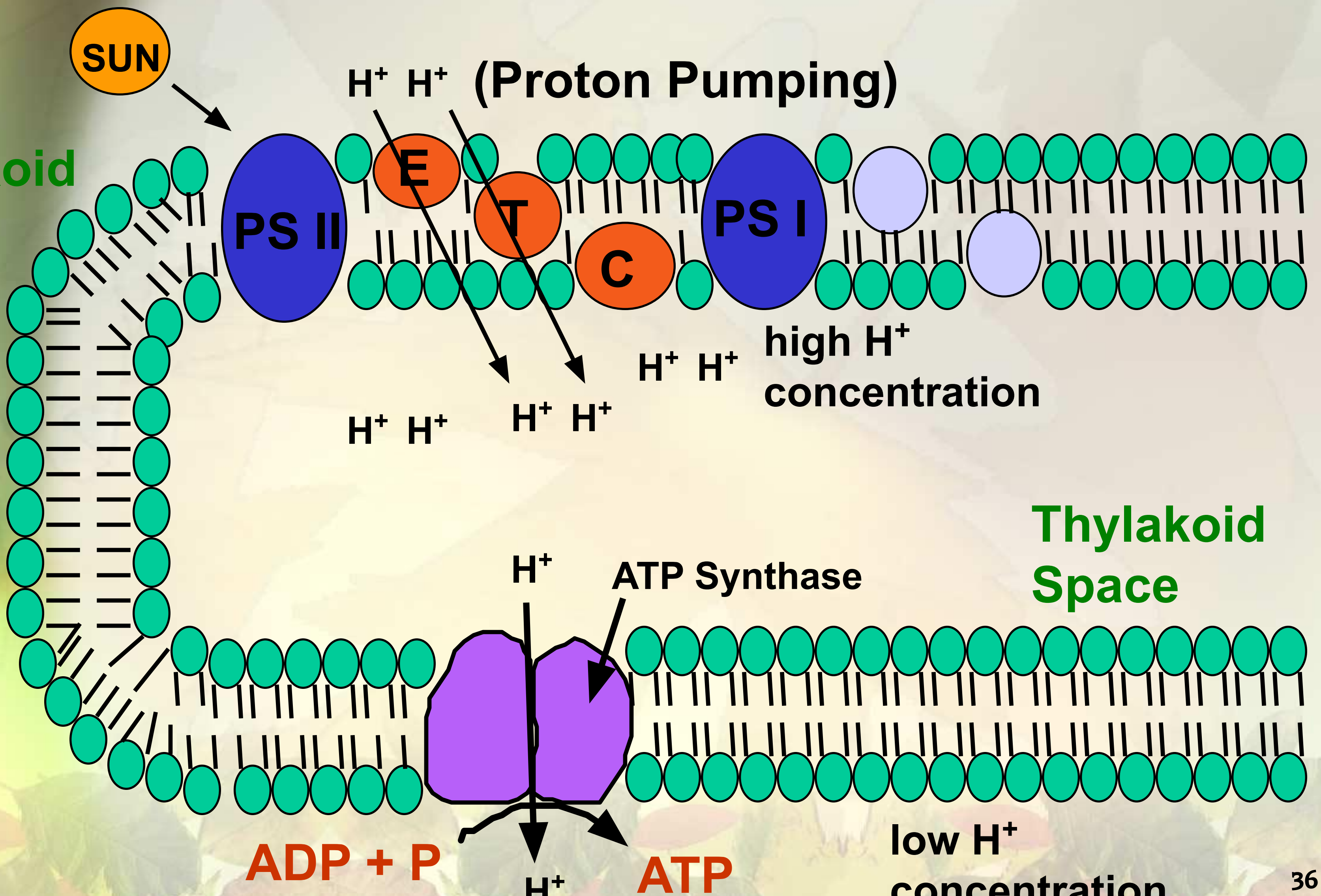
- ADP + P → ATP
- $NADP^+$ + H → NADPH
- Oxygen comes from the splitting of $H_2O$, not $CO_2$

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

# Chemiosmosis

- Powers ATP synthesis
- Takes place across the thylakoid membrane
- Uses ETC and ATP synthase (enzyme)
- $H^+$ move down their concentration gradient through channels of ATP synthase forming ATP from ADP

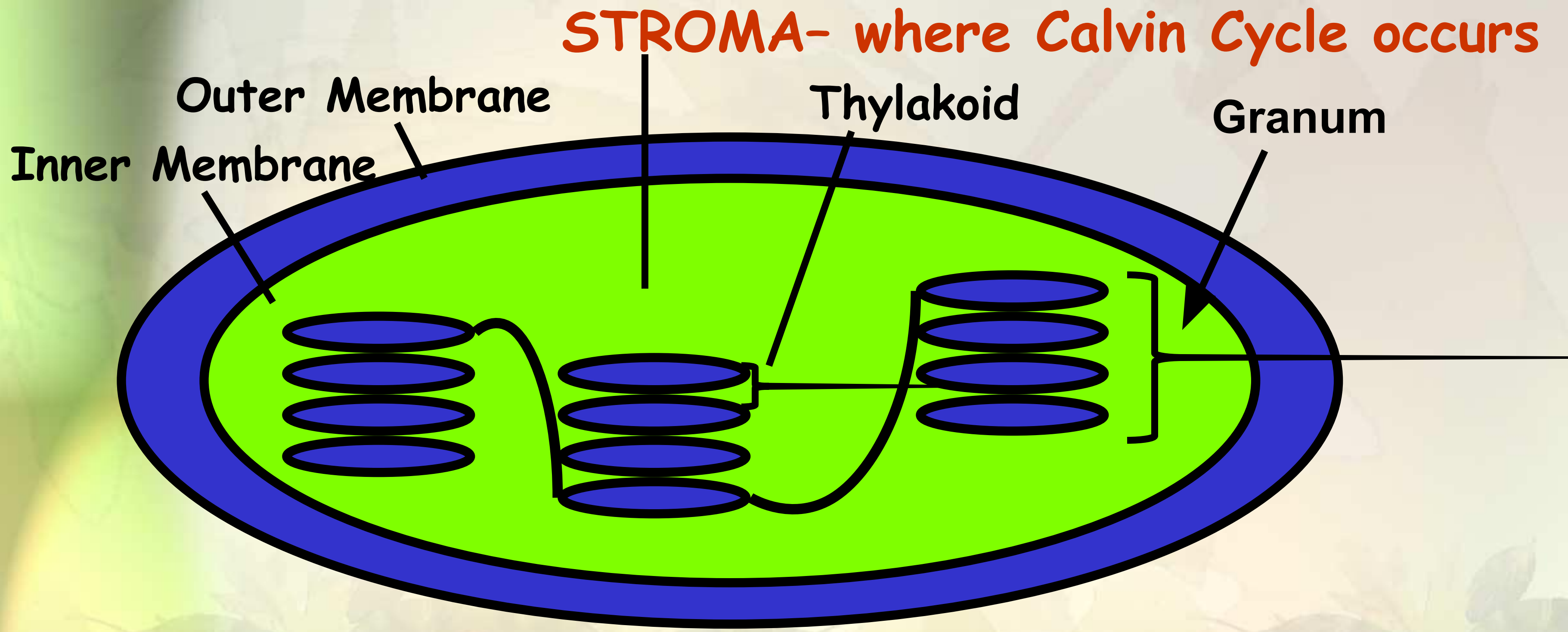
# Chemiosmosis



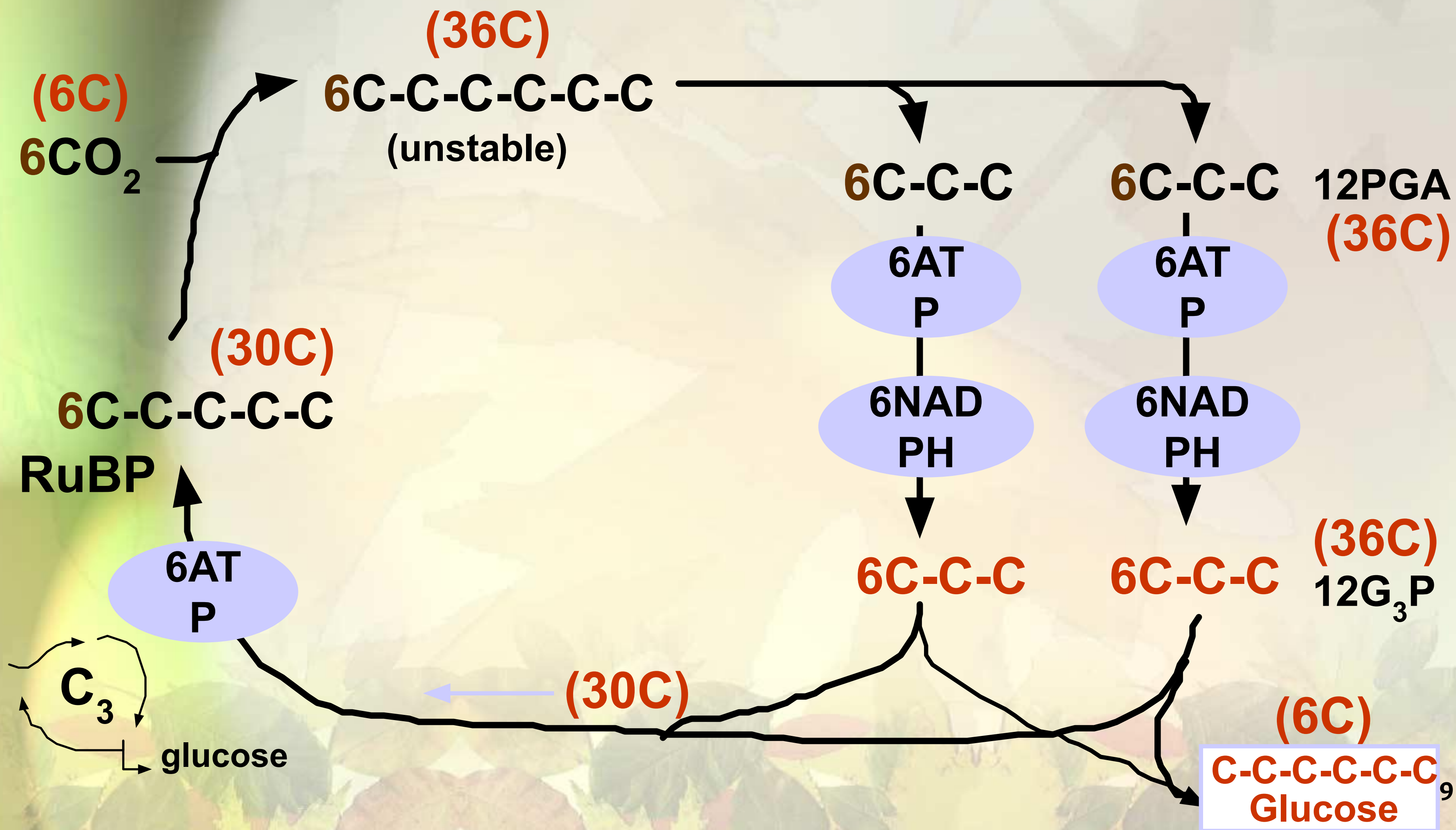
# Calvin Cycle

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

# Chloroplast

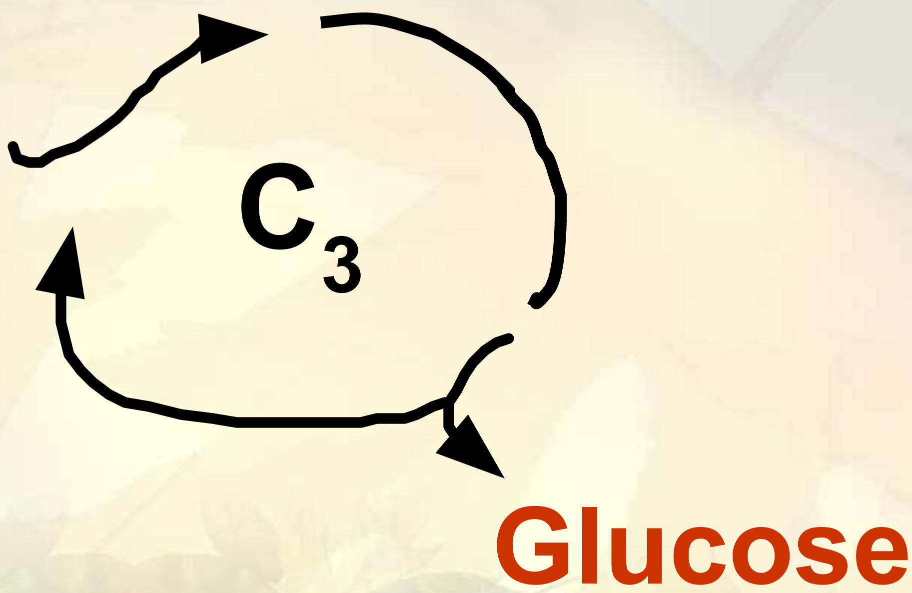


# Calvin Cycle ($C_3$ fixation)



# Calvin Cycle

Remember: $C_3$ = Calvin Cycle



# 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

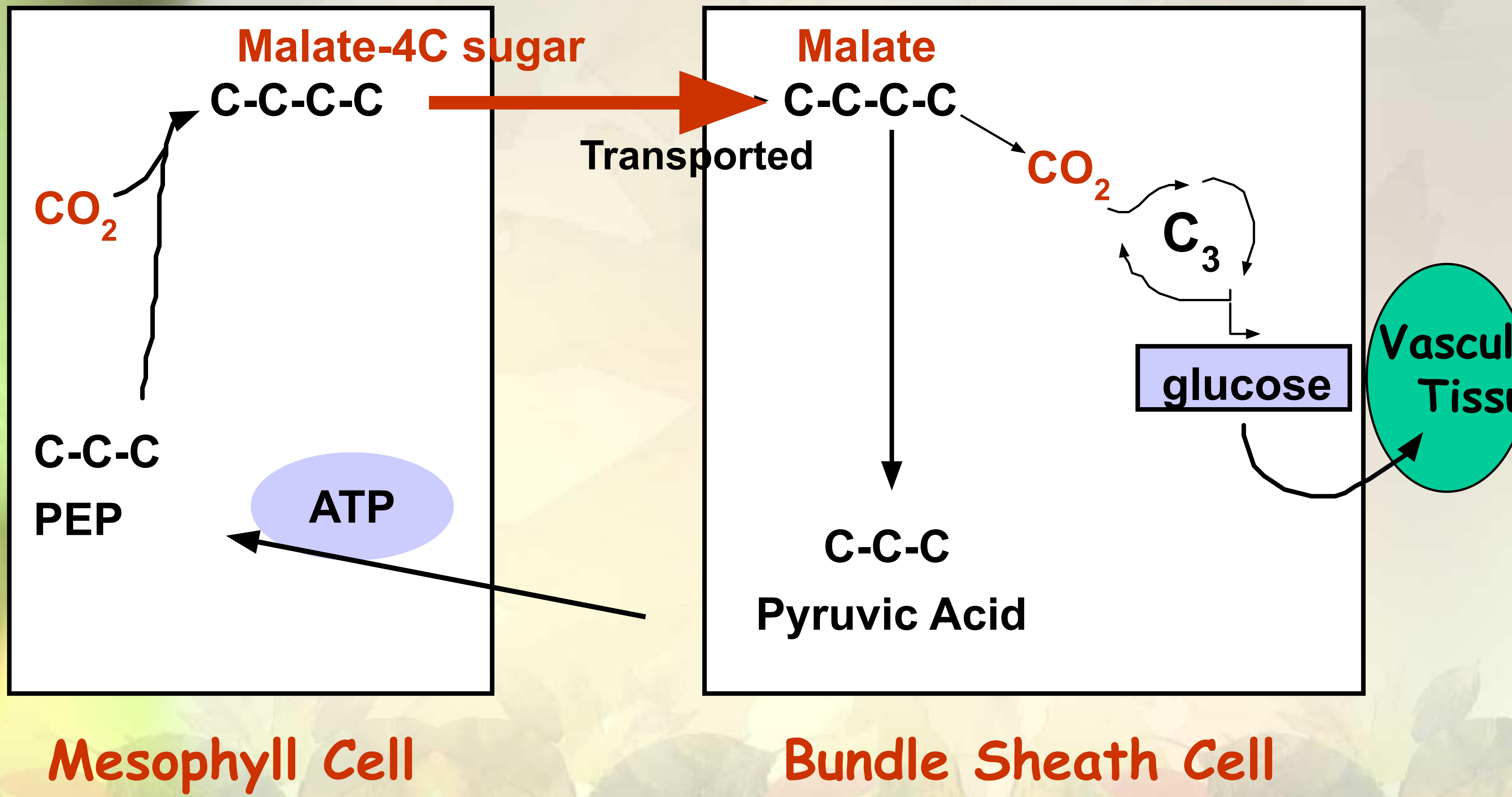
Because of photorespiration, plants have special adaptations to limit the effect of photorespiration:

1. $C_4$ plants
2. CAM plants

# $C_4$ Plants

- Hot, moist environments
- 15% of plants (grasses, corn, sugarcane)
- Photosynthesis occurs in 2 places
- Light reaction - mesophyll cells
- Calvin cycle - bundle sheath cells

# $C_4$ Plants

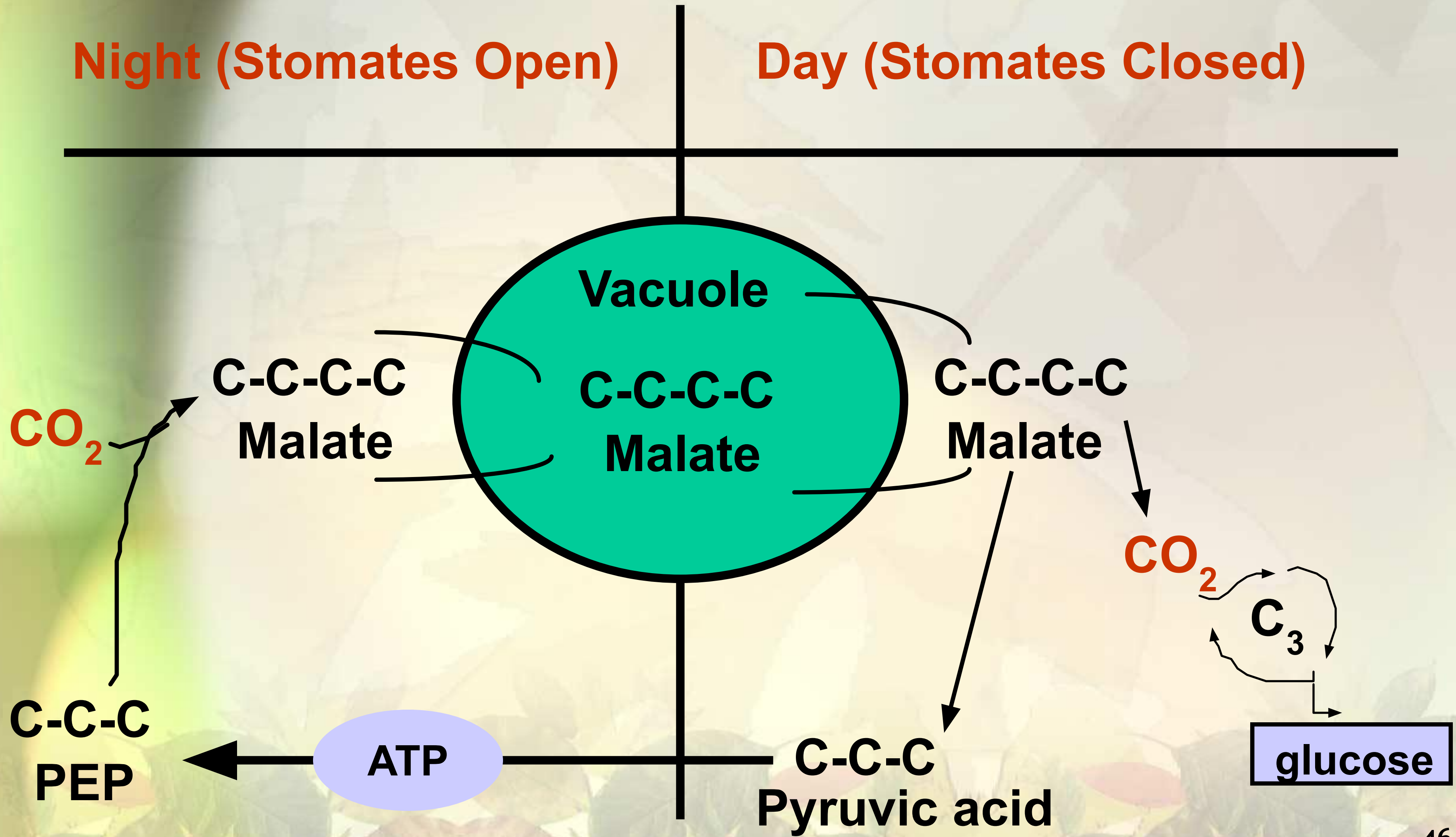


Malate-4C sugar
C-C-C-C
$CO_2$
C-C-C
PEP
ATP
Transported
Malate
C-C-C-C
$CO_2$
$C_3$
glucose
Vascul
Tissu
C-C-C
Pyruvic Acid
Mesophyll Cell
Bundle Sheath Cell

# CAM Plants

- Hot, dry environments
- 5% of plants (cactus and ice plants)
- Stomates closed during day
- Stomates open during the night
- Light reaction - 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
CO2
C-C-C
PEP
ATP
C-C-C
Pyruvic acid
CO2
C3
glucose

# Question:

## Why do CAM plants close their stomata during the day?

Cam plants close their stomata in the hottest part of the day to conserve water