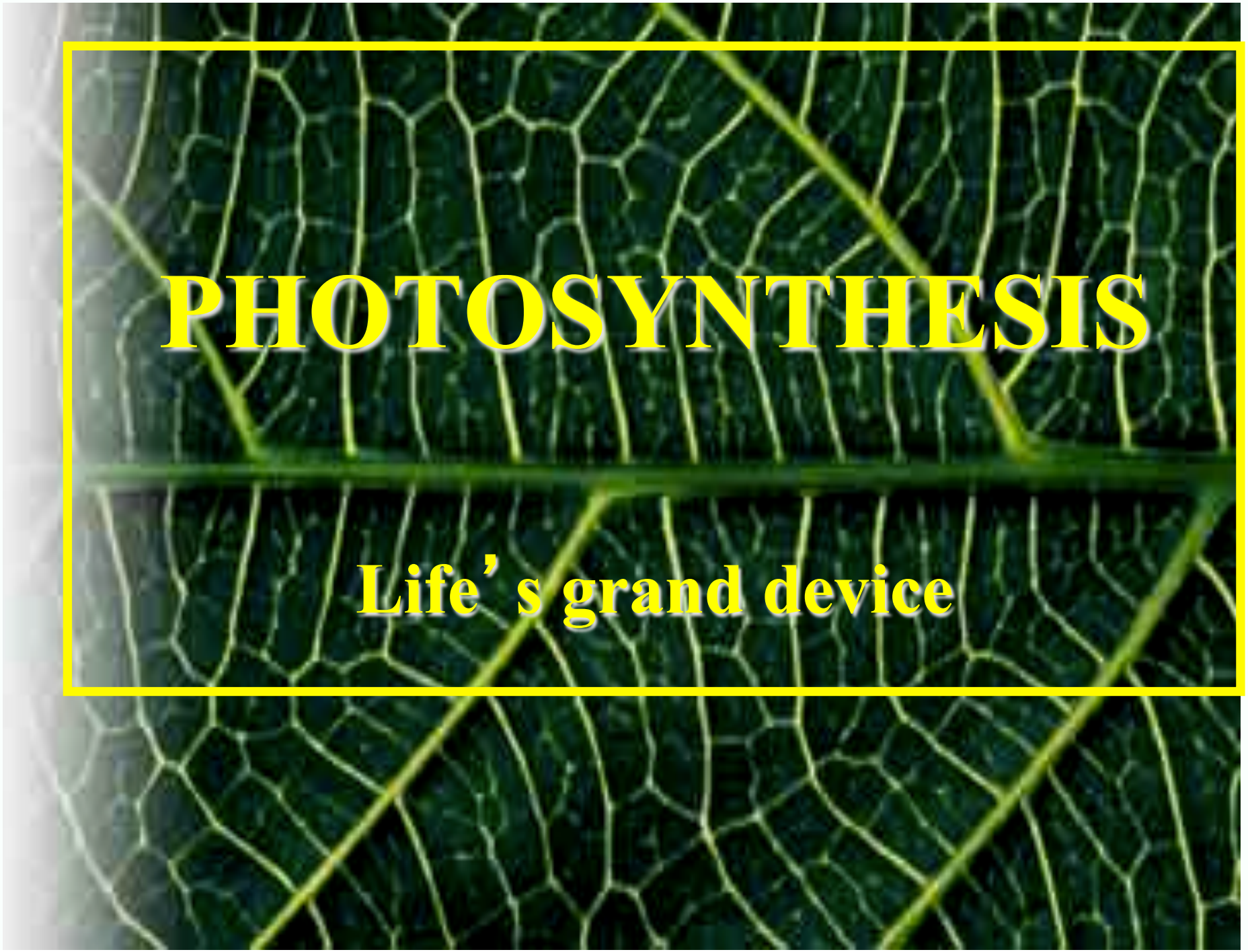

PHOTOSYNTHESIS
Life's grand device

- **Photosynthesis**
  - I. Intro
  - II. Properties of light and pigments
  - III. Chloroplast structure and function
  - IV. Light reactions
  - V. “Dark” or Carbon reactions
  - VI. Summary and conclusions

- **Respiration**
  - I. Energy and food chains
  - II. Carbon Cycle

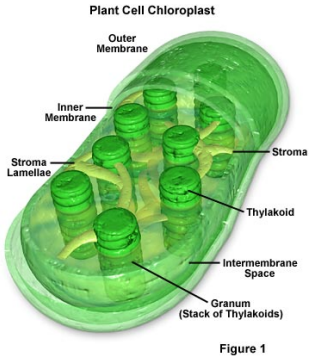


Figure 1

I. Introduction to photosynthesis

- From the Greek

  PHOTO = produced by light

  SYNTHESIS = a whole made of parts put together.

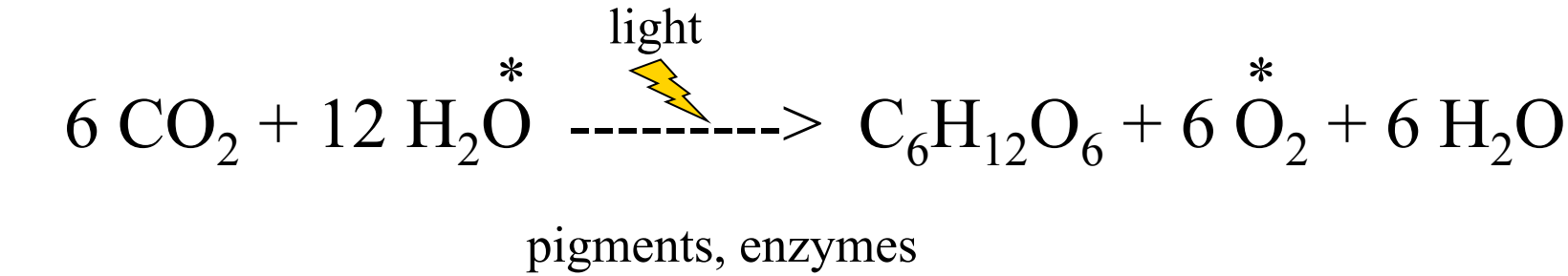
Definition: **PHOTOSYNTHESIS** is the process whereby plants, algae, some bacteria, use the energy of the **sun** to synthesize organic compounds (**sugars**) from inorganic compounds (**CO_2 and water**).

WHY IS PHOTOSYNTHESIS SO IMPORTANT?

PHOTOSYNTHESIS is one of the most important biological process on earth!

- Provides the oxygen we breathe
- Consumes much of the CO_2
- Food
- Energy
- Fibers and materials

GENERAL FORMULA FOR PHOTOSYNTHESIS



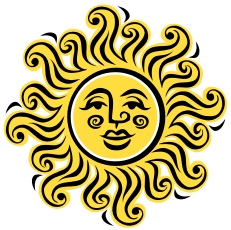
- Oxygen on earth allowed for the evolution of aerobic respiration and higher life-forms.

- Respiration: extracting energy from compounds (sugars)

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

II. PROPERTIES OF LIGHT

Virtually all life depends on it!



- Light moves in waves, in energy units called PHOTONS
- Energy of a PHOTON inversely proportional to its wavelength
- Visible light (between UV and IR) occurs in a spectrum of colors

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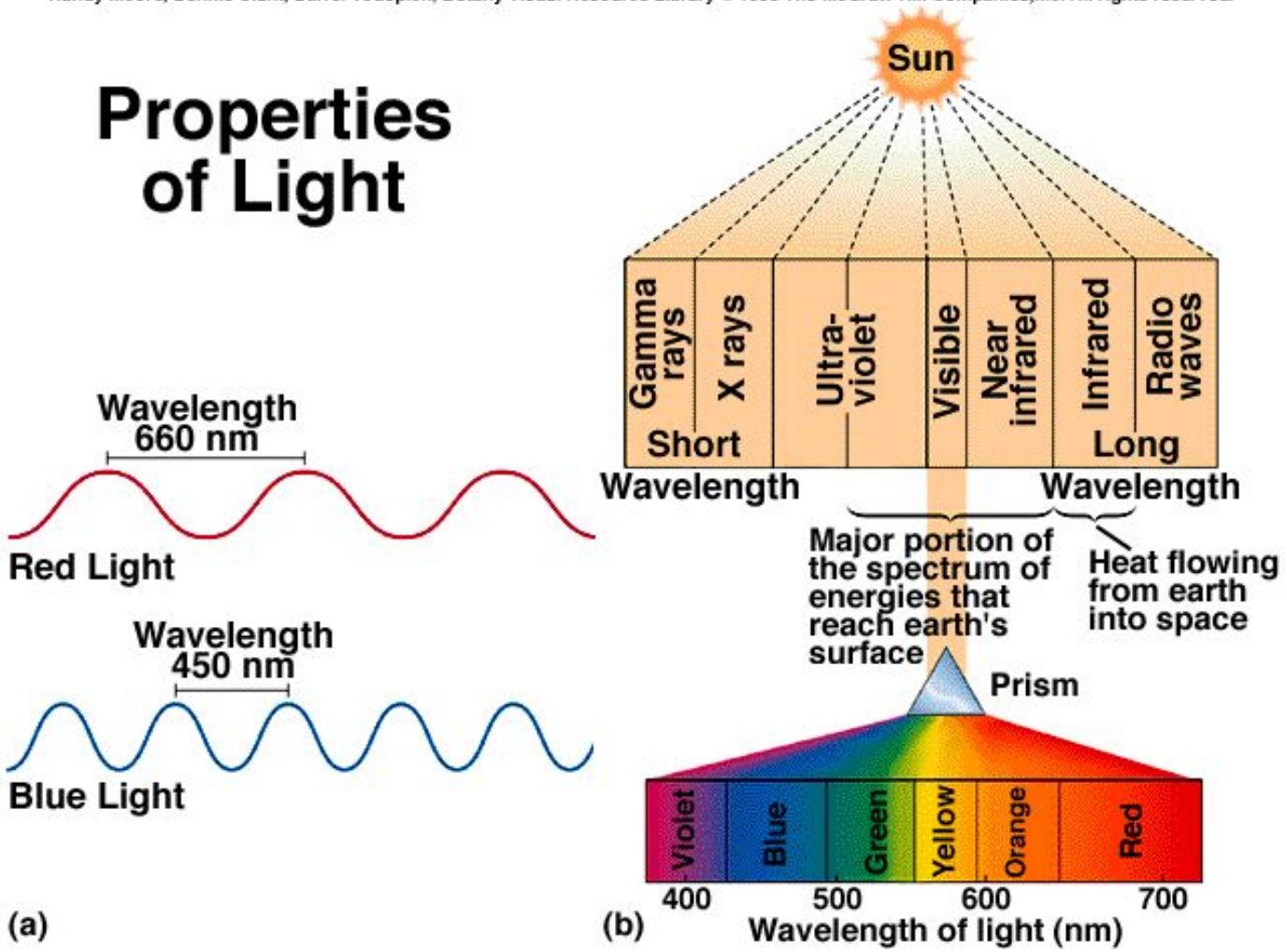
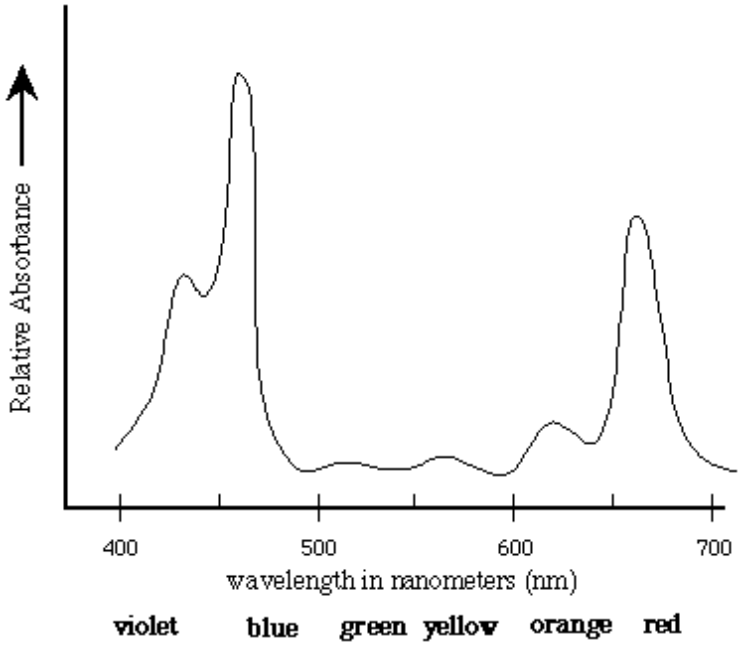


Visible light contains just the right amount of energy for biological reactions

Light is absorbed by **pigments**

- The primary pigment for photosynthesis is *chlorophyll a*
- It absorbs blue and red light, not green (green light is reflected back!)

Absorption spectrum of *chlorophyll a*



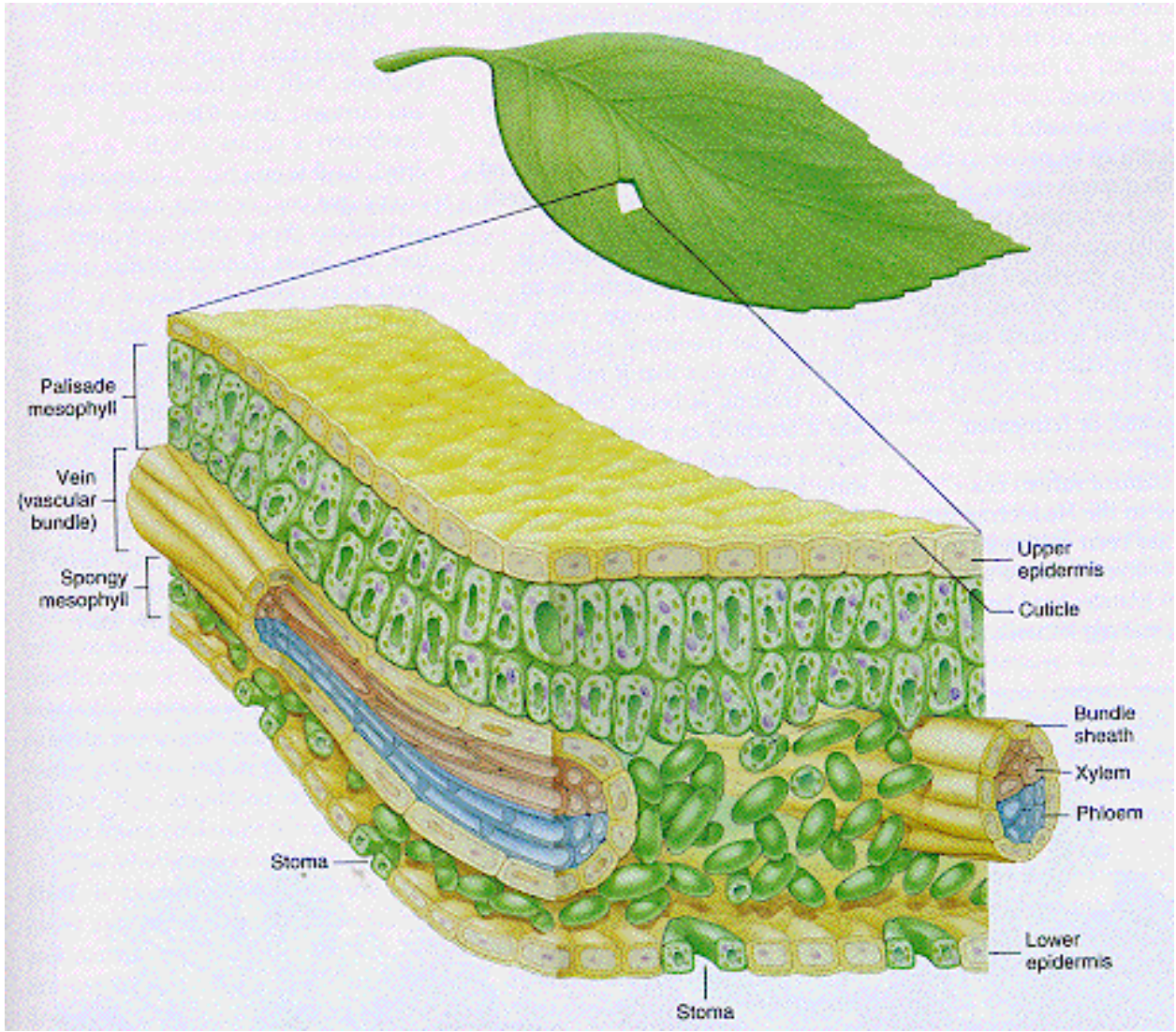
Accessory pigments like *chlorophyll b* and carotenoids (beta-carotene, lycopene):

- absorb light at different wavelengths, (extending the absorption range)
- help transfer some energy to *chlorophyll a*
- protect cell from harmful byproducts

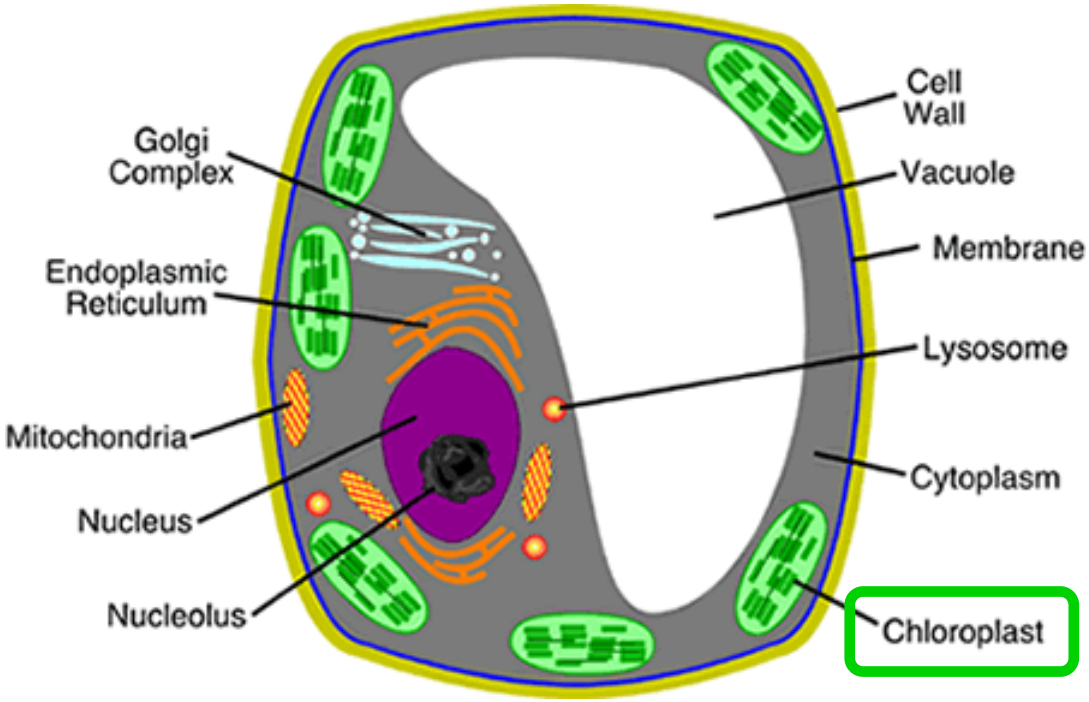
Chlorophyll a is the primary photosynthetic pigment that drives photosynthesis.

Accessory pigments absorb at different wavelengths, extending the range of light useful for photosynthesis.

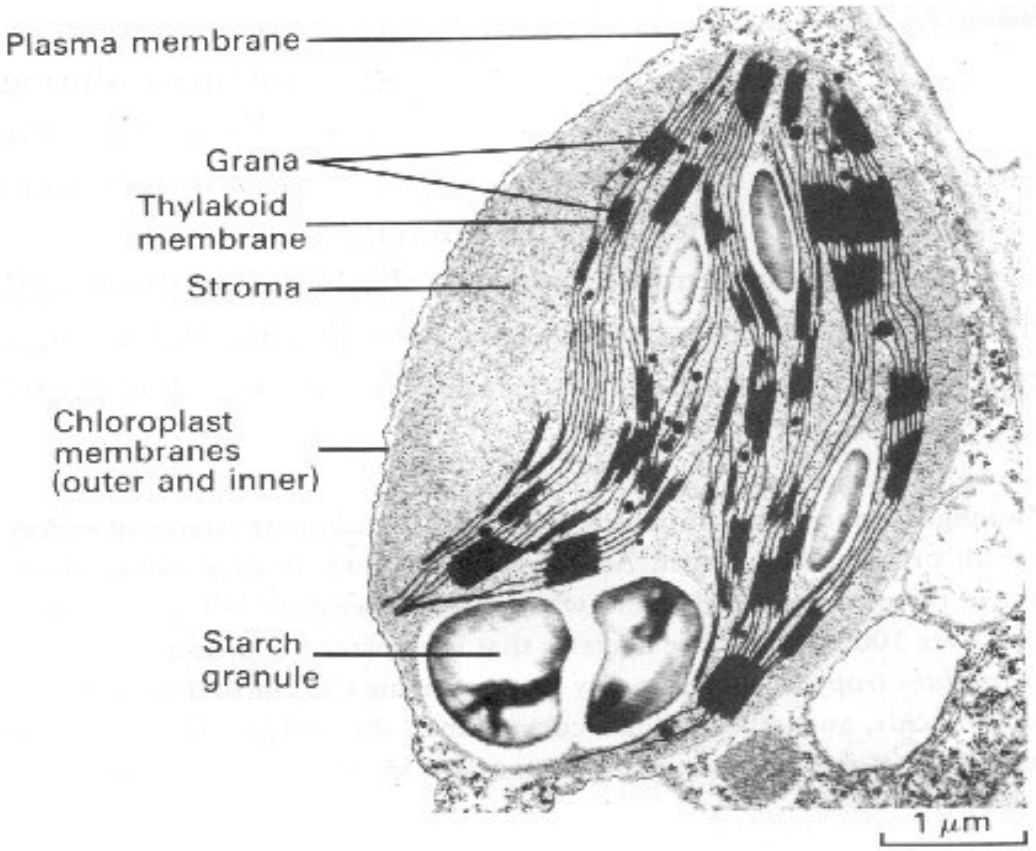
Where does photosynthesis occur?



The plant cell

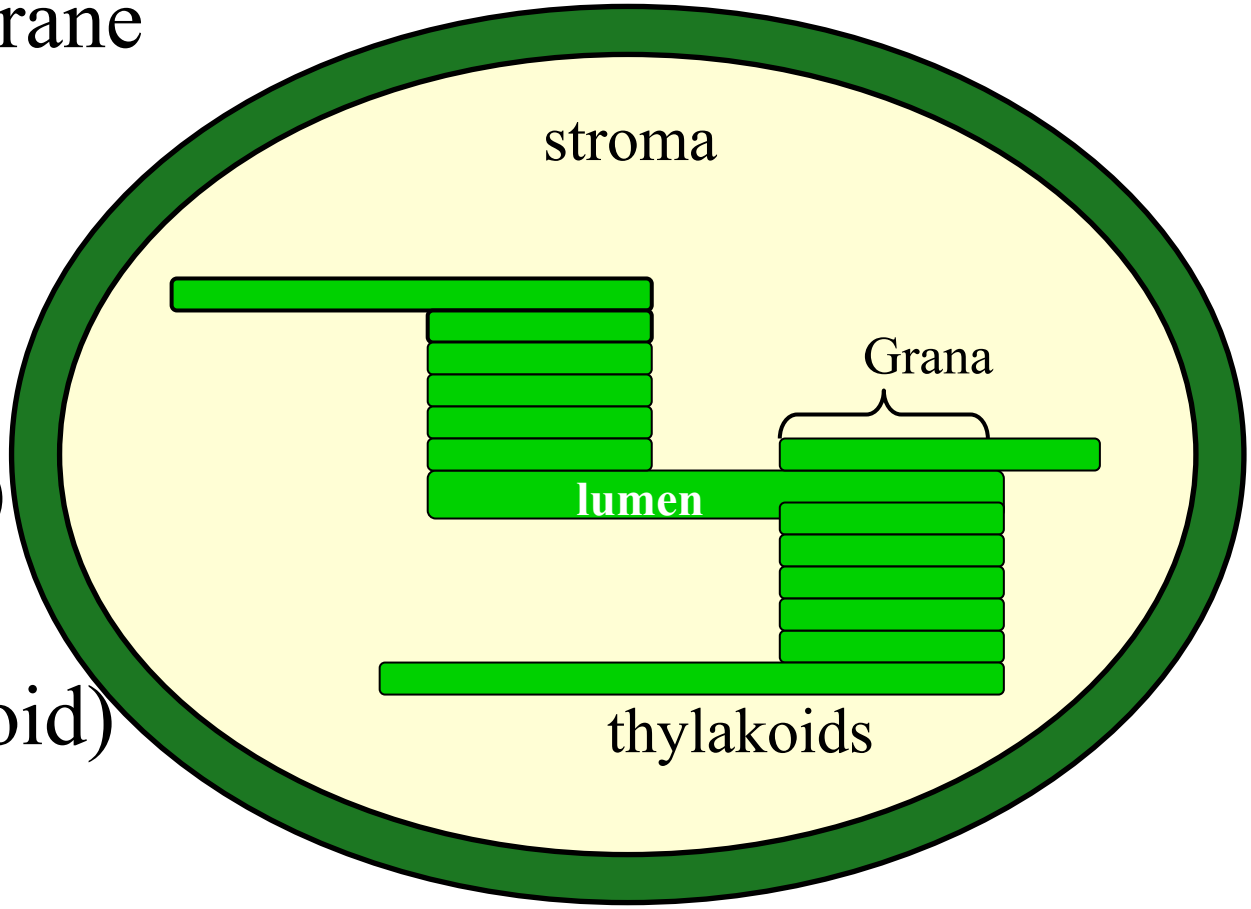


III. Chloroplast structure and function: solar chemical factory

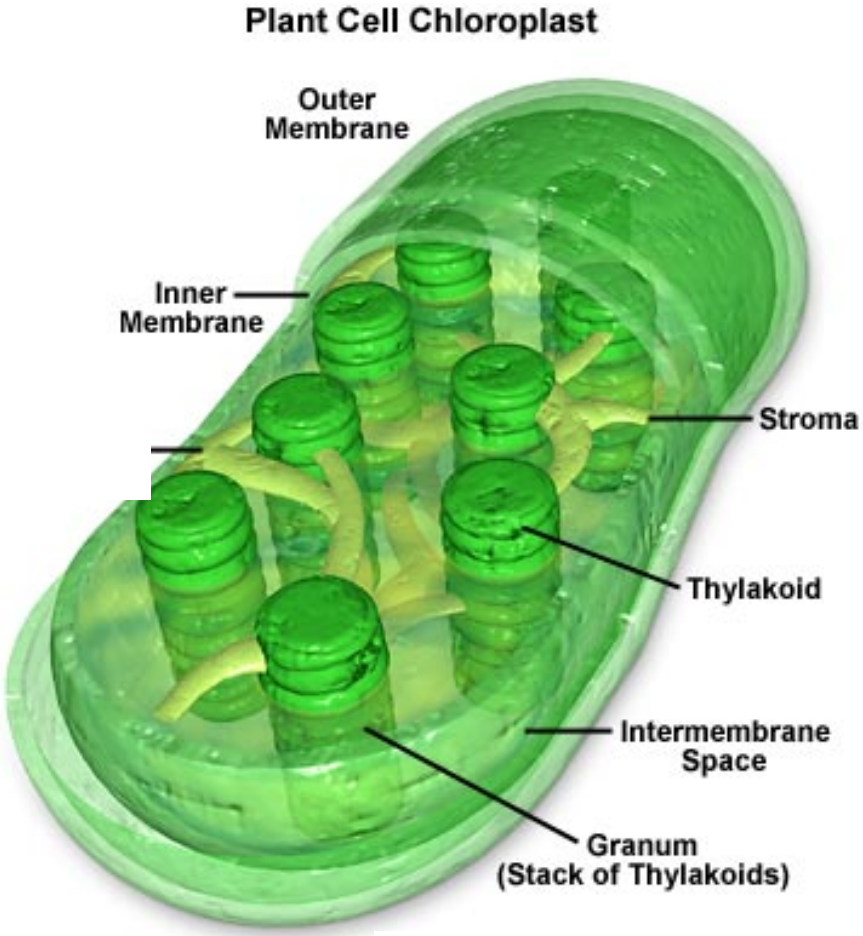


Chloroplast structure

- Football shaped
- Double membrane
- Stroma
- Thylakoid membrane
- Grana (stacks)
- Lumen (inside thylakoid)



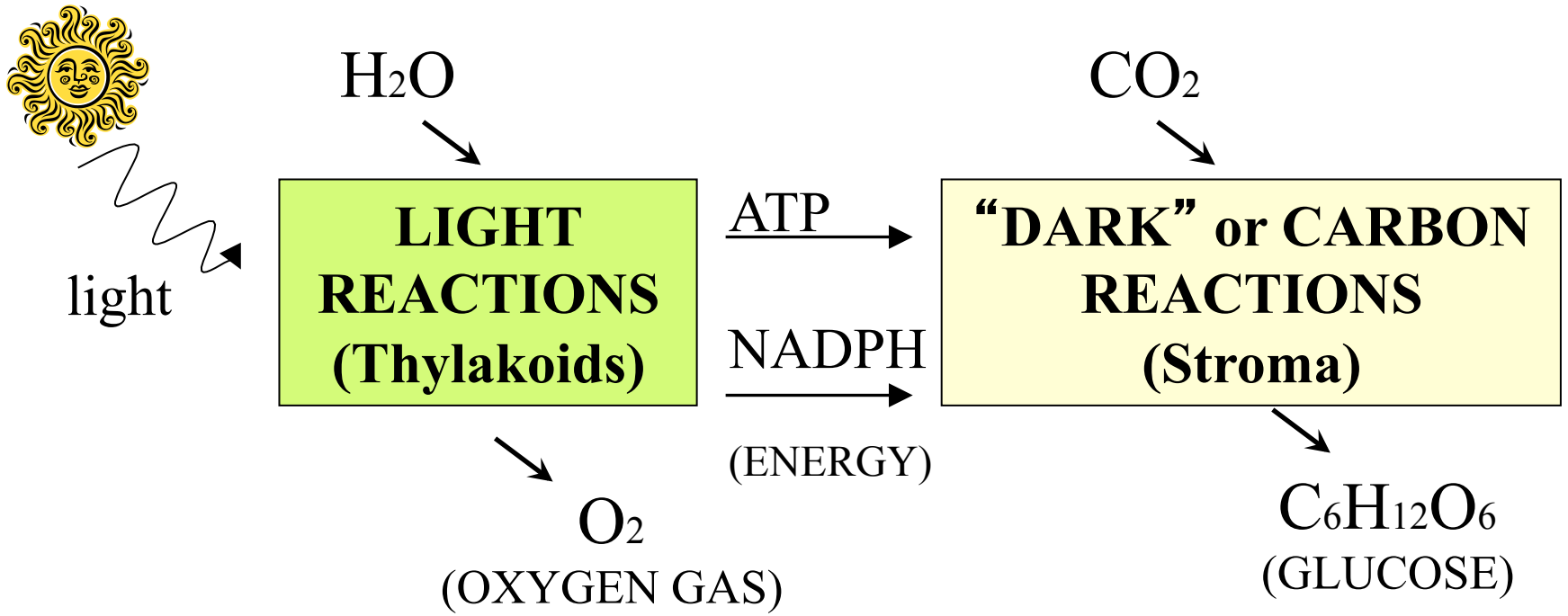
Inside a Chloroplast



- Remember: Structure correlates to function!

Overview of photosynthesis:

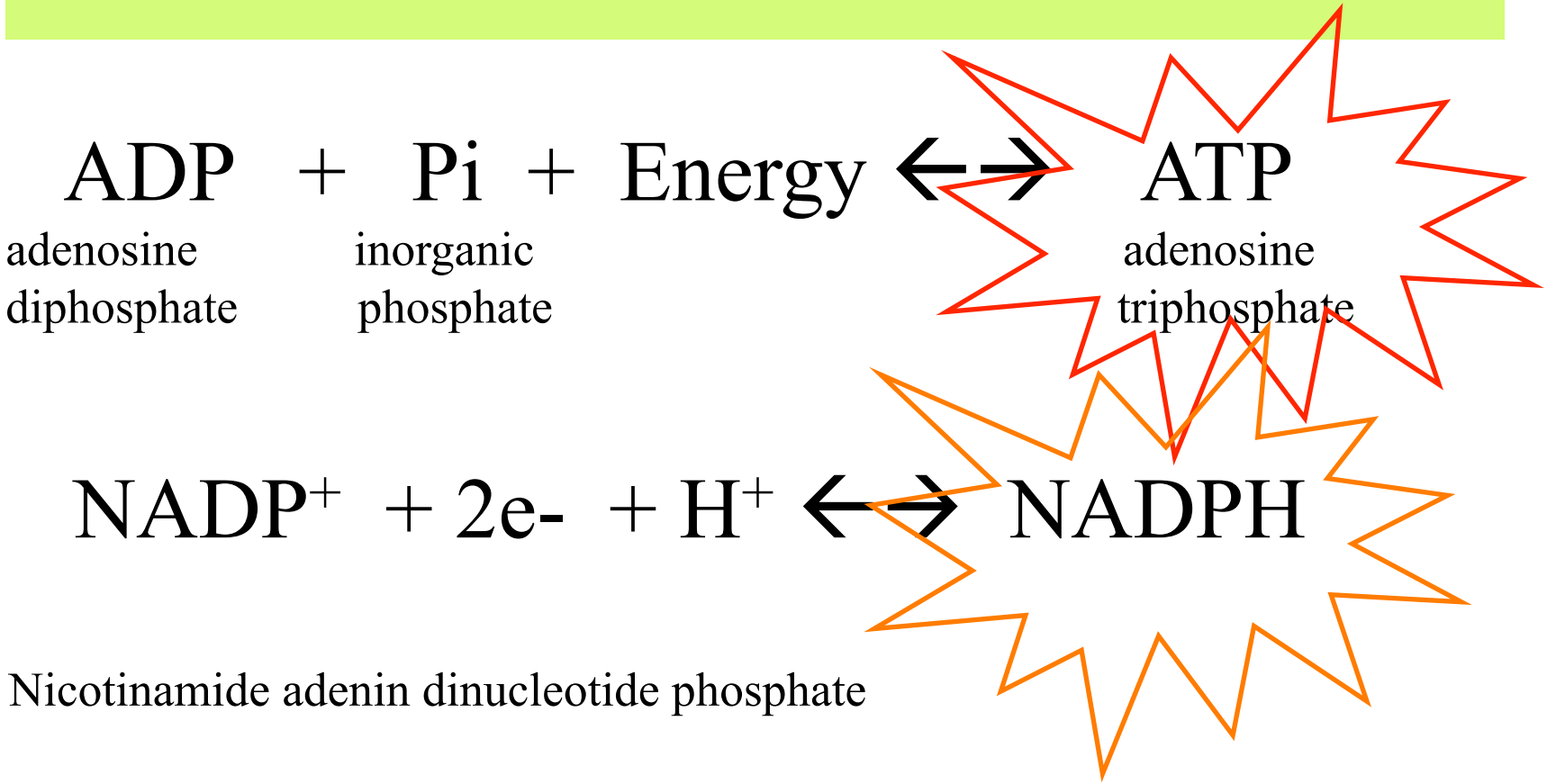
Note: The Light and "Dark" or Carbon reactions happen at different sites in the chloroplast



IV. The Light Reactions

1. Light dependent
2. Occur in the **thylakoid membrane** of chloroplast
3. **Water** is split into **oxygen gas** (O_2) and **H^+**
4. Use **light energy** (photons) to generate two **chemical energy** compounds: ATP & NADPH

Chemical energy compounds made in the light reactions



Nicotinamide adenin dinucleotide phosphate

Summary of the Light reactions

$$2\ H_2O\ +\ 2\ NADP^+\ +\ 3\ ADP\ +\ 3\ P_i$$

$$O_2\ +\ 2\ NADPH\ +\ 3\ ATP\ +\ 4\ e^-\ +\ 2\ H^+$$

(gas)

Light reactions: Chemical energy compounds are made from light energy, water is split into O_2 and protons

V. The "Dark" or Carbon Reactions

1. Light independent (can occur in light or dark; some enzymes require activation by light)
2. Occur in the **stroma** of chloroplasts
3. Use the **chemical energy** produced in Light Reactions (ATP; NADPH) to reduce CO_2 to carbohydrate (sugar).
4. CO_2 is converted to sugar by entering the Calvin Cycle

The Calvin Cycle

- CO_2 enters the **Calvin Cycle**
- First product is a 3-carbon molecule: 3-PGA (phosphoglyceric acid). That's why it's also called C-3 cycle.
- Enzyme RUBISCO (ribulose bisphosphate carboxylase/oxygenase) is the main enzyme that catalyzes the first reactions of the Calvin Cycle.
- RUBISCO: Is the most abundant protein on earth!

Summary of Carbon Reactions

$$6\ CO_2 + 18\ ATP + 12\ NADPH + 12\ H_2O$$

$$C_6H_{12}O_6 + 18\ ADP + 18\ P_i + 12\ NADP^+$$

glucose

$$+ 6\ H_2O + 6\ O_2$$

Carbon reactions: Use CO_2 and chemical energy (ATP & NADPH) to produce sugars by means of the Calvin Cycle

VI. Summary of Photosynthesis:

1. Light energy absorbed by *chlorophyll a* drives the reactions of photosynthesis.

2. Converts light energy into chemical energy to make organic compounds.

3. CO_2 and H_2O used to produce $C_6H_{12}O_6$ (glucose) and O_2 (gas).

4. Light Reactions occur in thylakoids of the chloroplasts; ATP and NADPH are formed; water is split to O_2 (gas) and protons.

5. Carbon Reactions occur in stroma – Calvin Cycle fixes CO_2 to produce $C_6H_{12}O_6$ (glucose).

6. Low efficiency, about 1- 4% in C-3 plants.

7. Nevertheless, PHOTOSYNTHESIS is still the most important biological process on earth!

Importance of photosynthesis and the impact that it has in all our lives.

Without photosynthesis, virtually all plants and animals would become extinct.

Respiration, Energy & Carbon Cycle

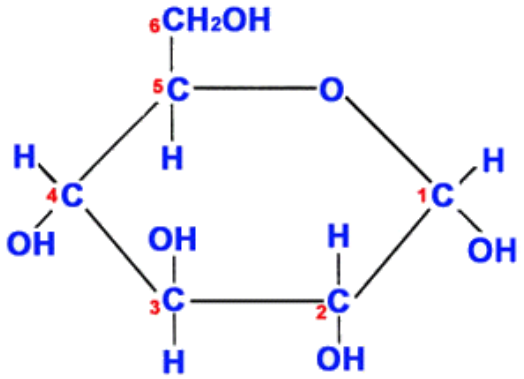
- **Energy**
- **Virtually all organisms require energy of food for**:
- Making chemicals
  (proteins, carbs, etc.)
- Movement
- Cell division
- Heat, electricity and light production

- The way living organisms obtain energy is through Cell respiration

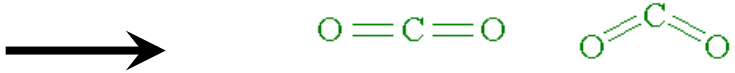
RESPIRATION

- Process of making energy of food available in the cell…
- Involves breaking down
  - Complicated molecules → into simple molecules

($C_6H_{12}O_6$, sugars) (CO_2, water)



glucose

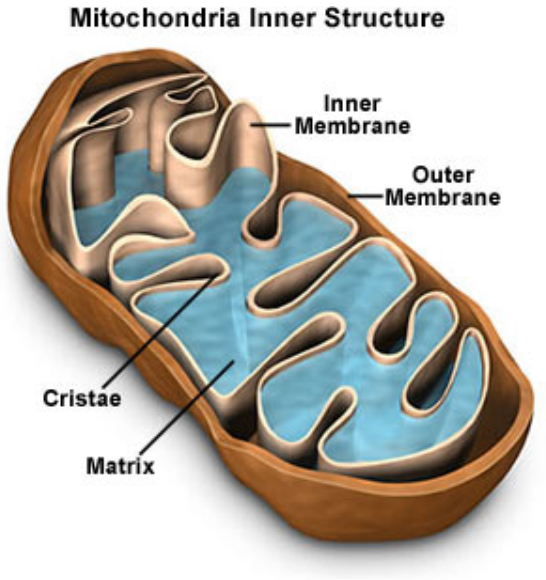


RESPIRATION

The energy held by complicated molecules is held temporarily as ATP (energy currency)

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6CO_2 + 6\ H_2O + 36\ ATP$

(glucose) (energy)



Respiration occurs mainly in Mitochondria and Cytoplasm

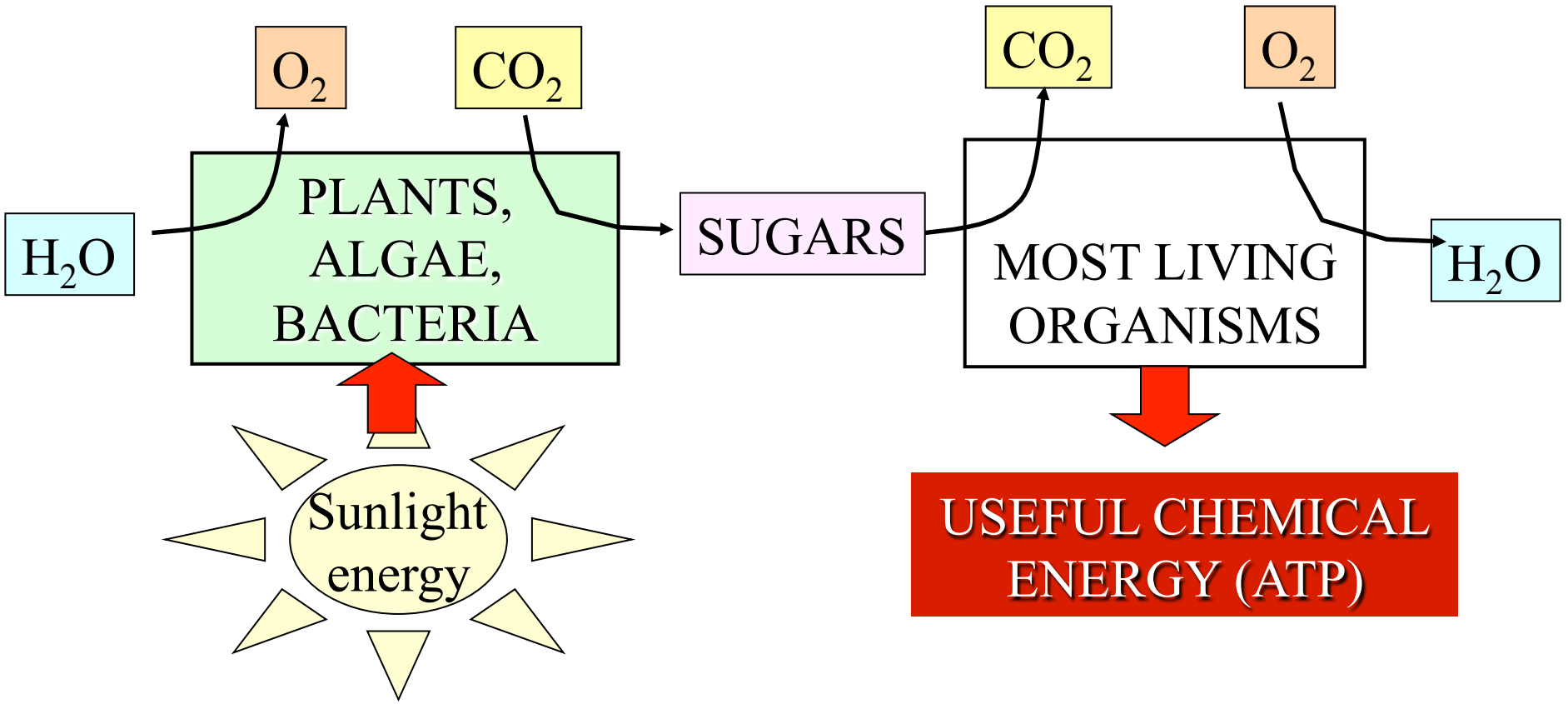
	Photosynthesis	Respiration
• **Reaction:**	$CO_2+H_2O+sun \rightarrow C_6H_{12}O_6+O_2+H2O$	$C_6H_{12}O_6+O_2 \rightarrow CO_2+H_2O+36ATP$
• **Reactants:**	Carbon dioxide, water, sun	Glucose, oxygen
• **Products:**	Glucose	Energy
• **By-products:**	Oxygen	Carbon dioxide, water
• **Cellular location:**	Chloroplasts	Cytoplasm, mitochondria
• **Energetics:**	Requires energy	Releases energy
• **Chemical paths:**	Light reactions & Calvin cycle	Glycolysis, Krebs cycle & Electron Transport Syst.
• **Summary:**	Sugar synthesized using energy from the sun	Energy released from sugar breakdown

PHOTOSYNTHESIS

$CO_2 + H_2O \rightarrow O_2 + SUGARS$

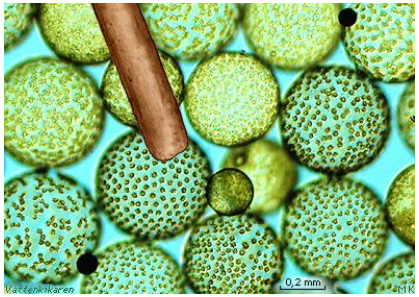
RESPIRATION

$SUGARS + O_2 \rightarrow H_2O + CO_2$



Food Chains

- Food chains demonstrate linear nature of energy
- **Producers** are the base of the food chain, they include photosynthetic organisms like:
  - Plants
  - Algae
  - Certain bacteria



Food chains

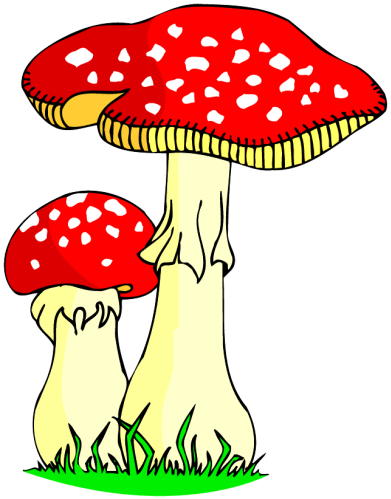
- **Primary consumers** – all plant eaters (herbivores).

- **Secondary consumers** –

  Eat primary consumers, (carnivores)

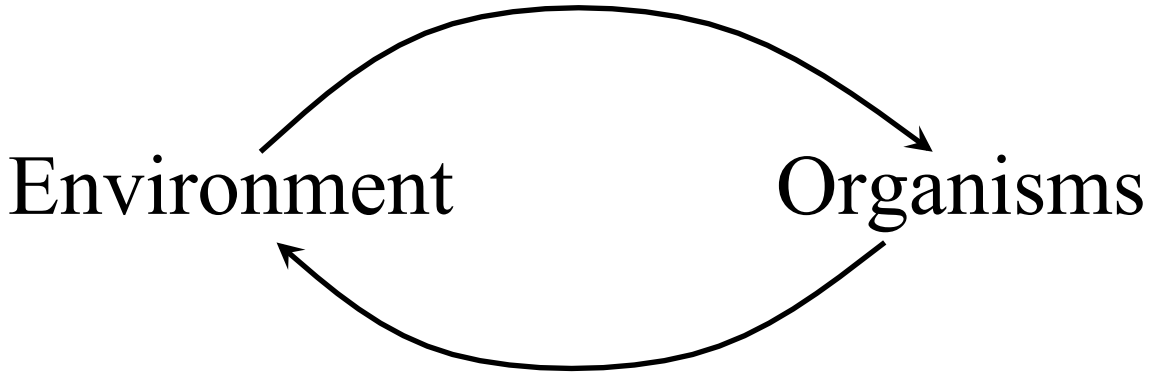
Food chains

- **Decomposers** – obtain energy by breaking down remaining organic material of the other members of the food chain.
- Fungi and bacteria.



Matter

- All important elements move in cycles;



Cycles called **biogeochemical** cycles:

Water cycle

Carbon cycle

Nitrogen cycle

The Carbon Cycle

- Carbon from the atmosphere (CO_2) enters the biosphere by way of plants!
  - CO_2 used in photosynthesis
  - Carbon moves into food chain
- Carbon is released to the physical environment by respiration
  - Release CO_2 during respiration
  - Amount CO_2 fixed in photosynthesis = the amount released by respiration