Biology 102

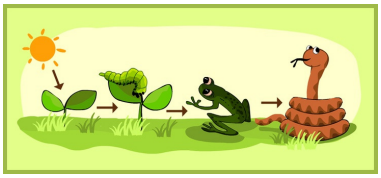
Lecture 7: Photosynthesis And Cellular Respiration

Energy

- Required to drive all chemical reactions that sustain life
- Cannot be created or destroyed, so living things must obtain it from the environment

Trapping Sunlight

- Ultimately, all living things on Earth derive energy from the sun
- Some directly by photosynthesis
  - Plants, some protists and bacteria
- Others indirectly through the food chain



Photosynthesis

- Process by which the sun's energy is trapped as chemical energy in molecular bonds of sugar
- Overall chemical reaction:

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Energy from sunlight}} C_6H_{12}O_6 + 6\ O_2$$

- Extremely simplified
  - Compilation of dozens of reaction steps
  - Utilizes dozens of enzymes

Photosynthesis in Plants

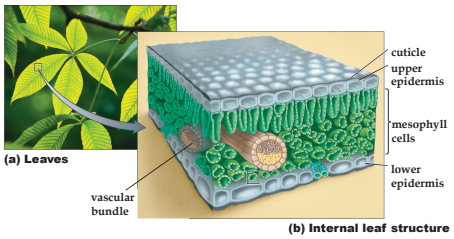
$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Energy from sunlight}} C_6H_{12}O_6 + 6\ O_2$$

- Takes place mostly in the leaves
- Large, flat, maximum surface area
- Specialized structures that allow all required components to come together
  - H_2O
  - CO_2
  - Sunlight

Photosynthesis in Plants

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Energy from sunlight}} C_6H_{12}O_6 + 6\ O_2$$

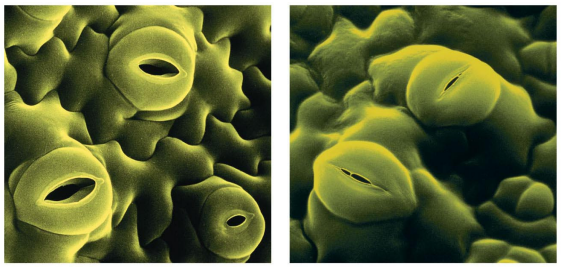
- Source of H_2O: taken in through roots, transported to leaves by vascular bundles
- Problem: large surface area means potential water loss
- Solution: cuticle
  - Waxy protective coating reduces water loss



Photosynthesis in Plants

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Energy from sunlight}} C_6H_{12}O_6 + 6\ O_2$$

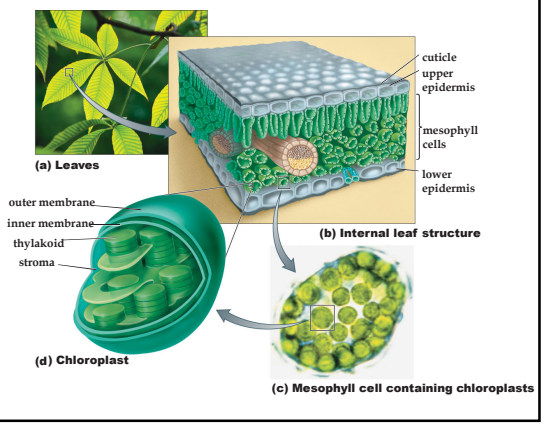
- Source of CO_2: air
- Problem: cuticle keeps gases out
- Solution: stomata
  - Adjustable pores allow gases in (and out)
  - Where the plant "breathes"



Photosynthesis in Plants

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Energy from sunlight}} C_6H_{12}O_6 + 6\ O_2$$

- Sunlight captured by *chloroplasts*
- Primarily in mesophyll layer of leaf
- One cell may contain 40-50 chloroplasts

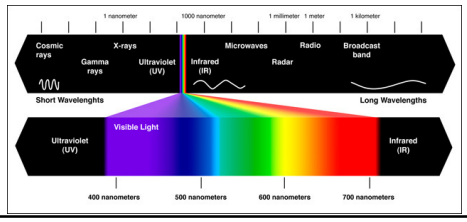


Light

- Composed of tiny packets of energy called *photons*
- Energy of photons correspond to wavelength
  - Long wavelength = low energy
  - Short wavelength = high energy

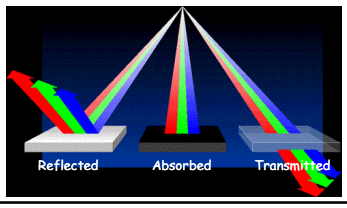
Light

- Infinite number of wavelengths contained in sunlight
  - Correspond to different colors
  - Some wavelengths are visible to humans; most are not



Light

- 3 possible outcomes when photons strike an object
  - Absorbed (captured)
  - Reflected (bounce back)
  - Transmitted (pass through)

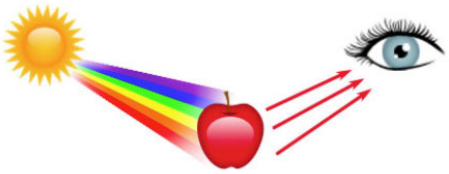


Light

- Absorbed wavelengths generate heat, drive biological processes

Light

- Reflected or transmitted wavelengths reach the eye of observers
- Perceived as color



Thought Question

- Why is white so "bright?"

Thought Question

- Why are our pupils black?

Photosynthesis

- Sunlight is captured by pigments in chloroplasts
- Primarily chlorophyll
  - Others (example: catotenoids)
- What colors does chlorophyll absorb? Reflect?

Photosynthesis

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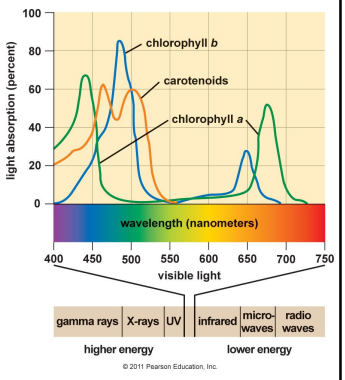
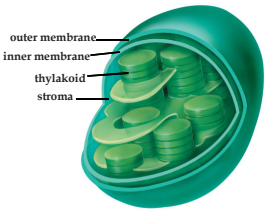


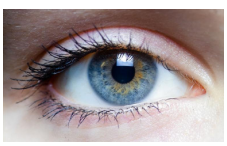
Photosynthesis

- Photosynthesis can be split into 2 sets of reactions
- Take place in different parts of the chloroplast
  - Light reactions (thylakoids)
    - Light-dependent
  - Calvin cycle (stroma)
    - Light-independent



Just Because It's Interesting

- Beta-carotene
  - Plant pigment that gives orange vegetables their color
- Converted to vitamin A in animals
- Forms light-absorbing pigments in eye
- Same compounds capture light in plants and animals



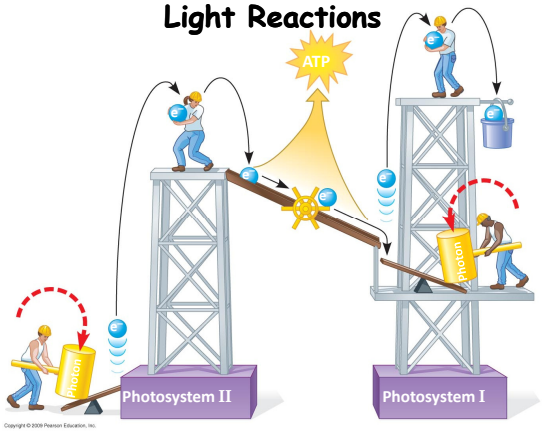
Light Reactions of Photosynthesis

- Light can strike an object and eject electrons from its surface
  - Photoelectric effect
  - Can be useful, damaging

Light Reactions of Photosynthesis

- Light strikes chlorophyll and ejects an electron
- High energy electrons release energy to make…
  - ATP
  - NADPH
  - Both of these go on to fuel the Calvin cycle (more on that in a minute)

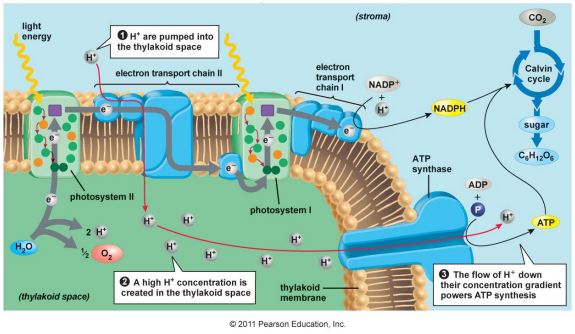
Light Reactions



Light Reactions

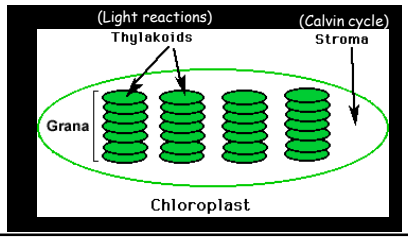
- Water split apart in the process
  - Hydrogen fuels more ATP generation
  - Oxygen goes to mitochondria to fuel cellular respiration (more on that in a minute)
  - Some oxygen is also released

Light Reactions



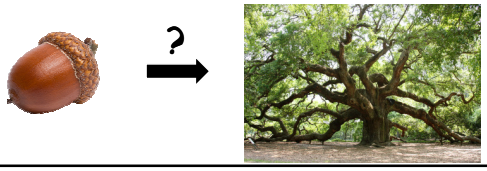
Calvin Cycle

- ATP and NADPH go on to fuel the Calvin cycle
  - Light-independent reactions of photosynthesis
  - Still in the chloroplast, just a different part



Question

- How does an acorn become an oak?
- Needs energy
  - Stored in seed initially
  - Later from photosynthesis
- Needs carbon to form biomolecules
  - Where does the carbon come from?



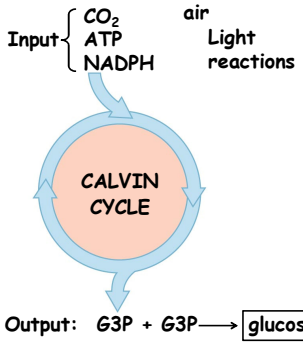
Answer

- Carbon in biomolecules of plants (and ultimately all living things) comes from CO_2 in the air
- Carbon is "fixed" into larger organic molecules (sugars) through the Calvin cycle
- Comes up through the food chain to higher organisms

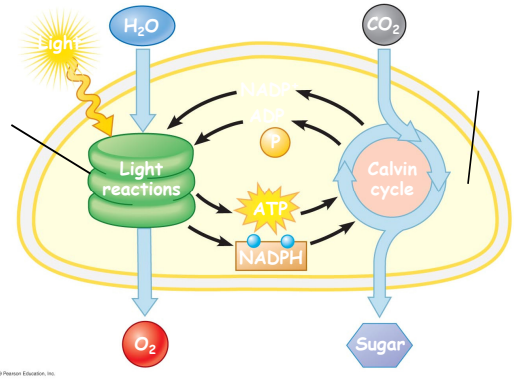
Energy

CO_2

Calvin Cycle



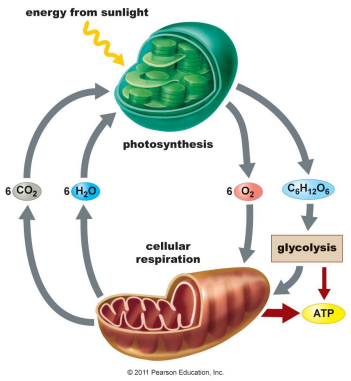
Photosynthesis



Photosynthesis

- Products of photosynthesis: sugars, oxygen
- What happens to these products?
  - Some sugar turned into tissues, stored for later use
  - Oxygen and most sugars used to fuel cellular respiration in mitochondria

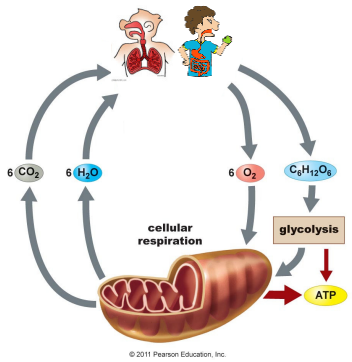
Cellular Respiration



Cellular Respiration

- Animals do this too
- We just bypass photosynthesis by eating, breathing

Cellular Respiration



Cellular Respiration

- Process by which organisms liberate energy stored in glucose

$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + 38\ ATP + heat$

- Extremely simplified
- Dozens of steps involving dozens of enzymes

Cellular Respiration

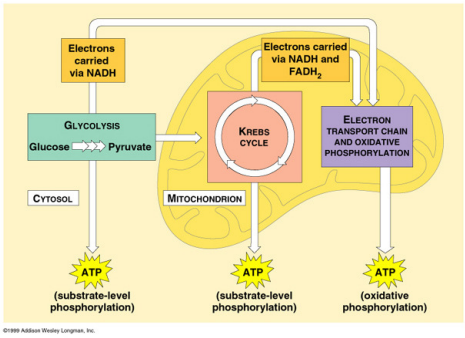
$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O + 38\ ATP + heat$

- Process is EXTREMELY important
- Organisms absolutely depend on ATP generated this way
- Blocking the process causes death in a few minutes
  - Oxygen depravation
  - Metabolic poisons (eg cyanide, CO, Rotenone)

Cellular Respiration

- Three steps
  - Glycolysis – generates 2 ATP
  - Kreb's Cycle – generates 2 ATP
  - Electron Transport Chain – generates 34 ATP
  - 38 ATP total (in theory)

Cellular Respiration



Fermentation

- What happens when oxygen is unavailable?
- Cells must generate ATP without oxygen
  - *Fermentation*
    - Less efficient – 2 ATP per glucose
  - Waste products
    - Lactic acid (animals, bacteria)

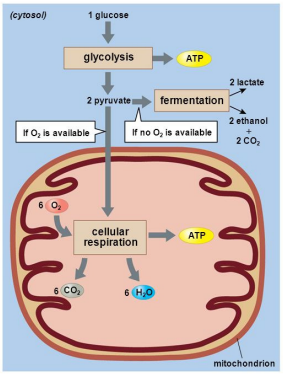
$C_6H_{12}O_6 \longrightarrow 2$ Lactic acid + 2 ATP + heat

Fermentation

- Waste products in yeast: ethanol and CO_2

$C_6H_{12}O_6 \longrightarrow 2\ CO_2 + 2$ Ethanol $+ 2$ ATP + heat

Cellular Respiration



Summary

- Photosynthesis
  - Where: in chloroplast
  - Uses: light, water, CO_2
  - Produces: sugar, O_2, ATP, NADPH
- Cellular respiration
  - Where: in mitochondria
  - Uses: products of photosynthesis
  - Produces: ATP, CO_2
  - Alternate pathway: fermentation

Summary

- Plants, animals are interdependent in the energy cycle