PowerLecture:
Chapter 7
Where It Starts - Photosynthesis
Section 7.0: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 7.0 : ASU Center for the Study of Early Events in Photosynthesis

- Section 7.0 : When Did Photosynthesis Emerge on Earth? David Des Marais, *Science,* Sept. 8, 2000.

How Would You Vote?

The following is the question for this chapter. See national results below.

- Should public funds be used to find potentially life supporting planets too far away for us to visit?

Impacts, Issues: Sunlight and Survival

- Plants are *autotrophs*, or self-nourishing organisms

- The first autotrophs filled Earth's atmosphere with oxygen, creating an ozone (O_3) layer

- The ozone layer became a shield against deadly UV rays from the sun, allowing life to move out of the ocean

Section 7.1: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 7.1: Chemistry of Autumn Colors

- Section 7.1: Molecule of the Month—Chlorophyll

- Section 7.1: Foliage Afire: Why Leaves Change Colors. Esther McGuire. *New York State Conservationist,* Oct. 1998.

- Section 7.1: Photochemistry of Chlorophyll. *Bulletin of the South Carolina Academy of Science,* 2002.

Electromagnetic Spectrum

Shortest wavelength

Gamma rays
X-rays
UV radiation
Visible light
Infrared radiation
Microwaves
Radio waves

Longest wavelength

Photons

- Packets of light energy

- Each type of photon has fixed amount of energy

- Photons having most energy travel as shortest wavelength (blue-violet light)

Visible Light

- Wavelengths humans perceive as different colors
- Violet (380 nm) to red (750 nm)
- Longer wavelengths, lower energy

Visible Light

Pigments

- Color you see is the wavelengths not absorbed
- Light-catching part of molecule often has alternating single and double bonds
- These bonds contain electrons that are capable of being moved to higher energy levels by absorbing light

Variety of Pigments

Chlorophylls *a* and *b*

Carotenoids

Anthocyanins

Phycobilins

Chlorophylls

Main pigments in most photoautotrophs

Accessory Pigments

Pigments in Photosynthesis

- Bacteria
  - Pigments in plasma membranes
- Plants
  - Pigments and proteins organized into photosystems that are embedded in thylakoid membrane system

Section 7.2: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 7.2: Milestones in Photosynthesis Research
- Section 7.2: Photosynthetic Pigments in Bacteria and Plants
- Section 7.2: Sunlight at Southall Green. Norman & Elaine Beale. *Perspectives in Biology and Medicine,* Summer 2001.
- Section 7.2: Photosynthesis and Respiration in a Jar. Joseph Buttner. *Science Activities,* Summer 2000.

T.E. Englemann's Experiment

Background

- Certain bacterial cells will move toward places where oxygen concentration is high
- Photosynthesis produces oxygen

T.E. Englemann's Experiment

Linked Processes

Photosynthesis

- Energy-storing pathway
- Releases oxygen
- Requires carbon dioxide

Aerobic Respiration

- Energy-releasing pathway
- Requires oxygen
- Releases carbon dioxide

Section 7.3: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 7.3: MIT Biology Hypertextbook—Physics of Photosynthesis

Chloroplast Structure
Photosynthesis Equation

Where Atoms End Up
Two Stages of Photosynthesis
Arrangement of Photosystems
Section 7.4: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 7.4: Photosynthetic Antennas and Reaction Centers

- Section 7.4: The Amazing All-Natural Light Machine (light-harvesting molecule LH2). Mark Caldwell. *scover*, Dec. 1995.

Light-Dependent Reactions

- Pigments absorb light energy, give up e^-, which enter electron transfer chains
- Water molecules split, ATP and NADH form, and oxygen is released
- Pigments that gave up electrons get replacements

Light-Dependent Reactions

Section 7.5
Photosystem Function: Harvester Pigments

- Most pigments in photosystem are harvester pigments

- When excited by light energy, these pigments transfer energy to adjacent pigment molecules

- Each transfer involves energy loss

Pigments in a Photosystem
Photosystem Function: Reaction Center

- Energy is reduced to level that can be captured by molecule of chlorophyll *a*

- This molecule (P700 or P680) is the reaction center of a photosystem

- Reaction center accepts energy and donates electron to acceptor molecule

Electron Transfer Chain

- Adjacent to photosystem

- Acceptor molecule donates electrons from reaction center

- As electrons pass along chain, energy they release is used to produce ATP

Cyclic Electron Flow

- Electrons
  - are donated by P700 in photosystem I to acceptor molecule
  - flow through electron transfer chain and back to P700
- Electron flow drives ATP formation
- No NADPH is formed

Cyclic Electron Flow
Noncyclic Electron Flow

- Two-step pathway for light absorption and electron excitation
- Uses two photosystems: type I and type II
- Produces ATP and NADPH
- Involves photolysis - splitting of water

Machinery of
Noncyclic Electron Flow
Energy Changes

Chemiosmotic Model
of ATP Formation

- Electrical and H^+ concentration gradients are created between thylakoid compartment and stroma

- H^+ flows down gradients into stroma through ATP synthesis

- Flow of ions drives formation of ATP

Chemiosmotic Model for ATP Formation
Section 7.6: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 7.6: 1961 Nobel Prize—Melvin Calvin

- Section 7.6: Biographical Memoirs—Melvin Calvin

- Section 7.6: Robust Plants' Secret? Rubisco Activase! Marcia Wood. *Agricultural Research,* Nov. 2002.

- Section 7.6: Revealing the Secrets of Old Sol's Sugar Factories. Wim Vermaas. *World and I,* Mar. 1998.

Light-Independent Reactions

- Synthesis part of photosynthesis
- Can proceed in the dark
- Take place in the stroma
- Calvin-Benson cycle

Calvin-Benson Cycle

- Overall reactants
  - Carbon dioxide
  - ATP
  - NADPH
- Overall products
  - Glucose
  - ADP
  - $NADP^+$

Calvin- Benson Cycle

Section 7.7: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 7.7: Botany Online: Photosynthesis—C3, C4, and CAM

- Section 7.7: International Society of Crassulacean Acid Metabolism Research

- Section 7.7: CAM Photosynthesis: Not Just for Desert Plants. Elia Ben-Ari. *BioScience,* Dec. 1998.

- Section 7.7: Evolution of CAM and C4 Carbon-Concentrating Mechanisms. Jon Keeley et al. *International Journal of Plant Sciences,* May 2003.

The C3 Pathway

- In Calvin-Benson cycle, the first stable intermediate is a three-carbon PGA

- Because the first intermediate has three carbons, the pathway is called the C3 pathway

Photorespiration in C3 Plants

- On hot, dry days stomata close
- Inside leaf
  - Oxygen levels rise
  - Carbon dioxide levels drop
- Rubisco attaches RuBP to oxygen instead of carbon dioxide
- Only one PGAL forms instead of two

C4 Plants

- Carbon dioxide is fixed twice
  - In mesophyll cells, carbon dioxide is fixed to form four-carbon oxaloacetate
  - Oxaloacetate is transferred to bundle-sheath cells
  - Carbon dioxide is released and fixed again in Calvin-Benson cycle

CAM Plants

- Carbon is fixed twice (in same cells)
- Night
  - Carbon dioxide is fixed to form organic acids
- Day
  - Carbon dioxide is released and fixed in Calvin-Benson cycle

Summary of Photosynthesis

Section 7.8: Weblinks and InfoTrac

See the latest Weblinks and InfoTrac articles for this chapter online or click highlighted articles below (articles subject to change)

- Section 7.8: NASA's Earth Observatory—Phytoplankton

- Section 7.8: The Plankton Net

- Section 7.8: A Model of Phytoplankton Blooms. Amit Huppert et al. *The American Naturalist,* Feb. 2002.

- Section 7.8: Rust in the Wind (absence of phytoplankton in the ocean). Mary Beth Aberlin. *The Sciences,* March–April 1996.

Carbon and Energy Sources

- Photoautotrophs
  - Carbon source is carbon dioxide
  - Energy source is sunlight
- Heterotrophs
  - Get carbon and energy by eating autotrophs or one another

Photoautotrophs

- Capture sunlight energy and use it to carry out photosynthesis
  - Plants
  - Some bacteria

- Many protistans

Satellite Images Show Photosynthesis