Slide 1

Chapter 10

Photosynthesis

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

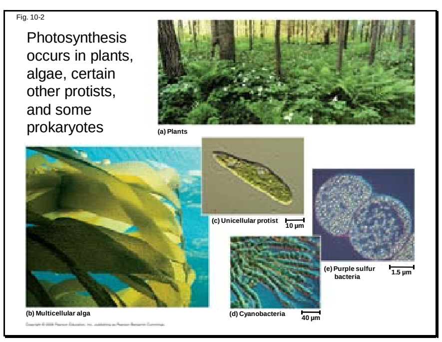
Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

Slide 2

Overview: The Process That Feeds the Biosphere

- **Photosynthesis** is the process that converts solar energy into chemical energy
- Directly or indirectly, photosynthesis nourishes almost the entire living world

Slide 3



Slide 4

- **Autotrophs** sustain themselves without eating anything derived from other organisms
- Autotrophs are the *producers* of the biosphere, producing organic molecules from CO_2 and other inorganic molecules
- Almost all plants are *photo*autotrophs, using the energy of sunlight to make organic molecules from H_2O and CO_2

Slide 5

- **Heterotrophs** obtain their organic material from other organisms
- Heterotrophs are the *consumers* of the biosphere
- Almost all heterotrophs, including humans, depend on photoautotrophs for food and O_2

Slide 6

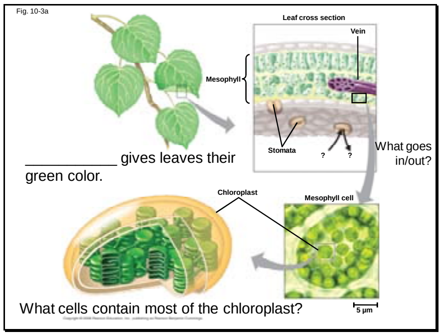
Concept 10.1: Photosynthesis converts light energy to the chemical energy of food

- __________ are the major site of photosynthesis.
- __________ are structurally similar to and likely evolved from photosynthetic bacteria
- Photosynthesis can be summarized as the following equation:

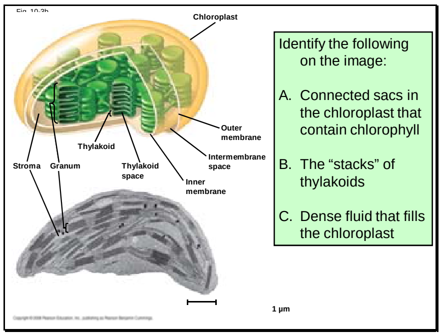
$6\ CO_2 + 12\ H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$

How does this equation differ from cellular respiration?

Slide 7



Slide 8



Slide 9

The Splitting of Water

- Chloroplasts split H_2O into hydrogen and oxygen, incorporating the electrons of hydrogen into sugar molecules
- Photosynthesis is a redox process in which ______ is oxidized and _____ is reduced

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

Slide 10

The Two Stages of Photosynthesis: *A Preview*

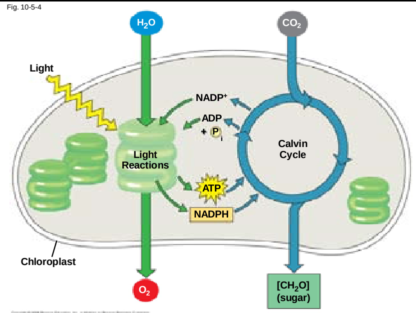
- Photosynthesis consists of the **light reactions** (the *photo* part) and **Calvin cycle** (the *synthesis* part)
- The light reactions (in the thylakoids):
  - Split H_2O
  - Release O_2
  - Reduce **NADP⁺** to NADPH
  - Generate ATP from ADP by **photophosphorylation**

Slide 11

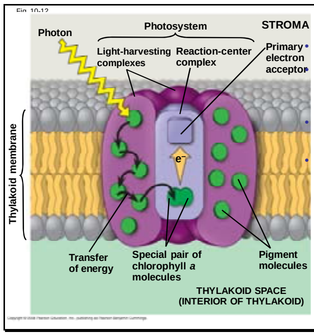
- The Calvin cycle (in the stroma) forms sugar from CO_2, using ATP and NADPH
- The Calvin cycle begins with **carbon fixation**, incorporating CO_2 into organic molecules

Slide 12

Fig. 10-5-4



Slide 13



- A **photosystem**
- 1) reaction-center complex (a type of protein complex)
- 2) light-harvesting complexes
- The **light-harvesting complexes** (pigment molecules bound to proteins) funnel the energy of photons to the reaction center

Slide 14

- A **primary electron acceptor** in the reaction center accepts an excited electron from chlorophyll *a*
- Solar-powered transfer of an electron from a chlorophyll *a* molecule to the primary electron acceptor is the first step of the light reactions

Slide 15

- There are two types of photosystems in the thylakoid membrane
- **Photosystem II (PS II)** functions first (the numbers reflect order of discovery) and is best at absorbing a wavelength of 680 nm
- The reaction-center chlorophyll *a* of PS II is called P680
- **Photosystem I (PS I)** is best at absorbing a wavelength of 700 nm
- The reaction-center chlorophyll *a* of PS I is called P700

Slide 16

A Comparison of Chemiosmosis in Chloroplasts and Mitochondria

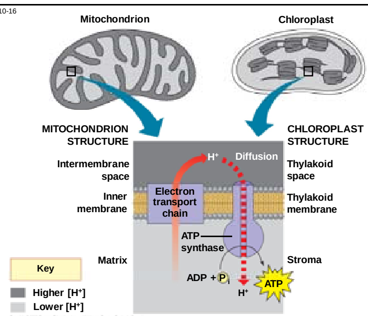
- Chloroplasts and mitochondria generate ATP by chemiosmosis, but use different sources of energy
- Mitochondria transfer chemical energy from food to ATP; chloroplasts transform light energy into the chemical energy of ATP
- Spatial organization of chemiosmosis differs between chloroplasts and mitochondria but also shows similarities

Slide 17

- In mitochondria, protons are pumped to the intermembrane space and drive ATP synthesis as they diffuse back into the mitochondrial matrix
- In chloroplasts, protons are pumped into the thylakoid space and drive ATP synthesis as they diffuse back into the stroma

Slide 18

Fig. 10-16

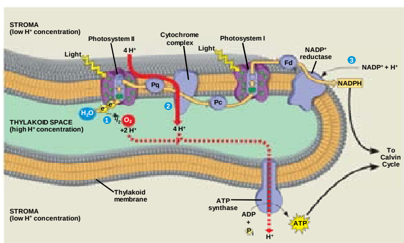


Slide 19

- ATP and NADPH are produced on the side facing the stroma, where the Calvin cycle takes place
- In summary, light reactions generate ATP and increase the potential energy of electrons by moving them from H_2O to NADPH

Slide 20

Fig. 10-17



Slide 21

Concept 10.3: The Calvin cycle uses ATP and NADPH to convert CO_2 to sugar

- The Calvin cycle, like the citric acid cycle, regenerates its starting material after molecules enter and leave the cycle
- The cycle builds sugar from smaller molecules by using ATP and the reducing power of electrons carried by NADPH

Slide 22

- Carbon enters the cycle as CO_2 and leaves as a sugar named **glyceraldehyde-3-phospate (G3P)**
- For net synthesis of 1 G3P, the cycle must take place three times, fixing 3 molecules of CO_2
- The Calvin cycle has three phases:
  - **Carbon fixation** (catalyzed by **rubisco**)
  - **Reduction**
  - **Regeneration of the CO_2 acceptor (RuBP)**

Slide 23

Concept 10.4: Alternative mechanisms of carbon fixation have evolved in hot, arid climates

- Dehydration is a problem for plants, sometimes requiring trade-offs with other metabolic processes, especially photosynthesis
- On hot, dry days, plants close stomata, which conserves H_2O but also limits photosynthesis
- The closing of stomata reduces access to CO_2 and causes O_2 to build up
- These conditions favor a seemingly wasteful process called photorespiration

Slide 24

Photorespiration: An Evolutionary Relic?

- In most plants (**C_3 plants**), initial fixation of CO_2, via rubisco, forms a three-carbon compound
- In **photorespiration**, rubisco adds O_2 instead of CO_2 in the Calvin cycle
- Photorespiration consumes O_2 and organic fuel and releases CO_2 without producing ATP or sugar

Slide 25

- Photorespiration may be an evolutionary relic because rubisco first evolved at a time when the atmosphere had far less O_2 and more CO_2
- Photorespiration limits damaging products of light reactions that build up in the absence of the Calvin cycle
- In many plants, photorespiration is a problem because on a hot, dry day it can drain as much as 50% of the carbon fixed by the Calvin cycle

Slide 26

C_4 Plants

- **C_4 plants** minimize the cost of photorespiration by incorporating CO_2 into four-carbon compounds in **mesophyll cells**
- This step requires the enzyme **PEP carboxylase**
- PEP carboxylase has a higher affinity for CO_2 than rubisco does; it can fix CO_2 even when CO_2 concentrations are low
- These four-carbon compounds are exported to **bundle-sheath cells**, where they release CO_2 that is then used in the Calvin cycle

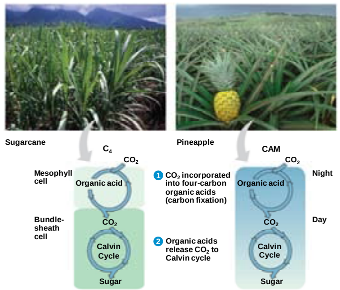
Slide 27

CAM Plants

- Some plants, including succulents, use **crassulacean acid metabolism (CAM)** to fix carbon
- **CAM plants** open their stomata at night, incorporating CO_2 into organic acids
- Stomata close during the day, and CO_2 is released from organic acids and used in the Calvin cycle

Slide 28

Fig. 10-20



(a) Spatial separation of steps (b) Temporal separation of steps

Slide 29

The Importance of Photosynthesis: *A Review*

- The energy entering chloroplasts as sunlight gets stored as chemical energy in organic compounds
- Sugar made in the chloroplasts supplies chemical energy and carbon skeletons to synthesize the organic molecules of cells
- Plants store excess sugar as starch in structures such as roots, tubers, seeds, and fruits
- In addition to food production, photosynthesis produces the O_2 in our atmosphere