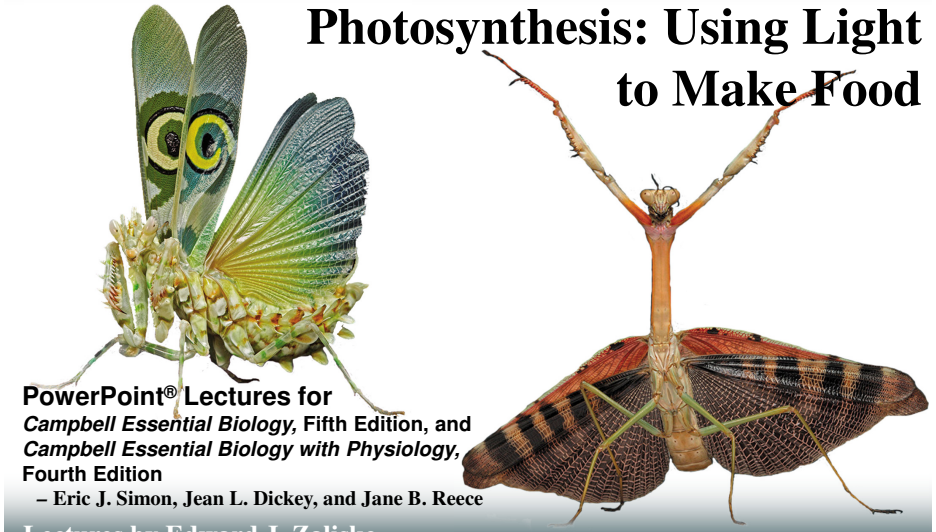
Chapter 7

1

Photosynthesis: Using Light to Make Food



PowerPoint® Lectures for
Campbell Essential Biology, Fifth Edition, and
Campbell Essential Biology with Physiology, Fourth Edition
– Eric J. Simon, Jean L. Dickey, and Jane B. Reece

Lectures by Edward J. Zalisko

ALWAYS LEARNING

PEARSON

Biology and Society: Biofuels

2

- Wood has historically been the main fuel used to produce
  - heat and
  - light.

Figure 7.0

3

Biology and Society: Biofuels

4

- Industrialized societies replaced wood with fossil fuels including
  - coal,
  - gas, and
  - oil.
- To limit the damaging effects of fossil fuels, researchers are investigating the use of biomass (living material) as efficient and renewable energy sources.

Biology and Society: Biofuels

- There are several types of biofuels.
  - Bioethanol is [illegible] produced by the fermentation [illegible] starches in crops such as [illegible], and sugar cane.
  - Bioethanol may [illegible]
    - directly [illegible] specially designed vehicles
    - as a gasoline additive.

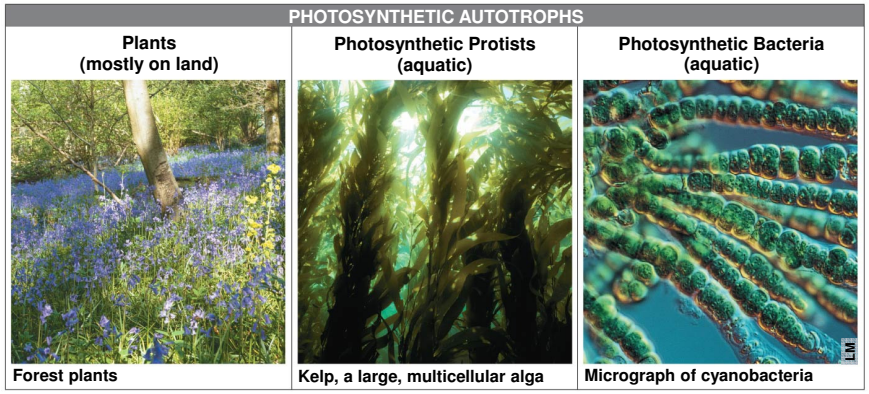
THE BASICS OF PHOTOSYNTHESIS

- **Photosynthesis**
  - is used by plants, algae (protists), and some bacteria,
  - transforms light energy into chemical energy, and
  - uses carbon dioxide and water as starting materials.

THE BASICS OF PHOTOSYNTHESIS

- The chemical energy produced via photosynthesis is stored in the bonds of sugar molecules.
- Organisms that use photosynthesis are
  - photosynthetic autotrophs and
  - the producers for most ecosystems.

Figure 7.1



Chloroplasts: Sites of Photosynthesis

- **Chloroplasts** are
  - the site of photosynthesis and
  - found mostly in the interior cells of leaves.
- Inside chloroplasts are interconnected, membranous sacs called **thylakoids,** which are suspended in a thick fluid called **stroma**.
- Thylakoids are concentrated in stacks called **grana**.

Chloroplasts: Sites of Photosynthesis

- The green color of chloroplasts is from **chlorophyll**, a light-absorbing pigment that plays a central role in converting solar energy to chemical energy.
  - The green light we see is the light that is not absorbed by these pigments
- **Stomata** are tiny pores in leaves where
  - carbon dioxide enters and
  - oxygen exits.
  - **Stoma** is the singular form. Do not confuse with Stroma!!!
    - Stoma is the greek root for mouth. Stomach has the same root.

Figure 7.2-1

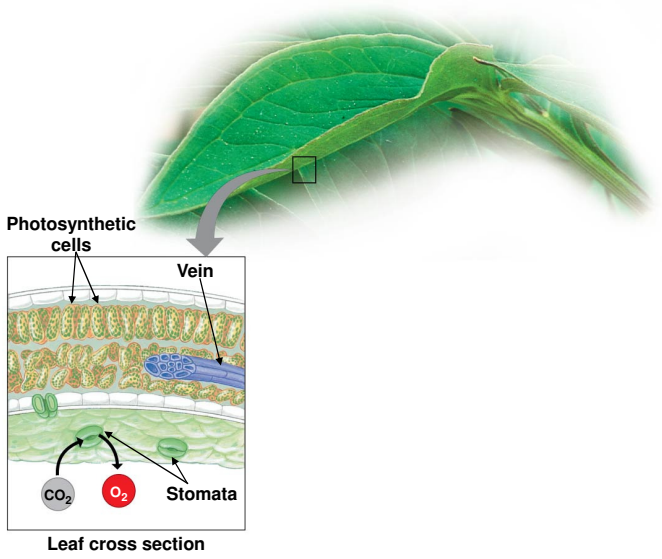


Figure 7.2-2

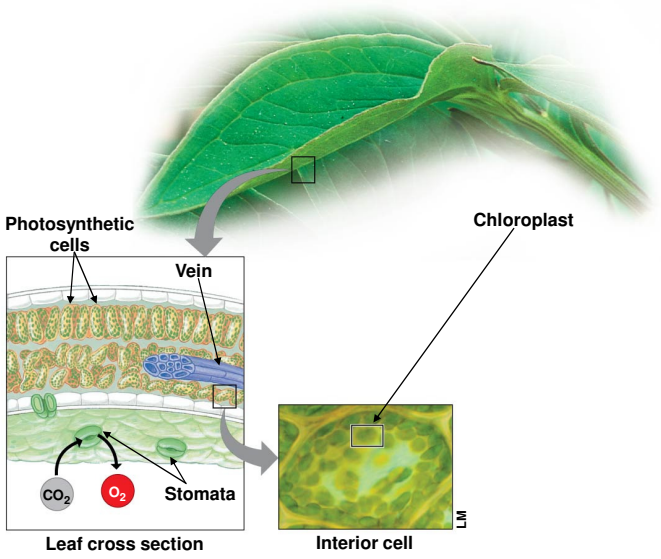


Figure 7.2-3

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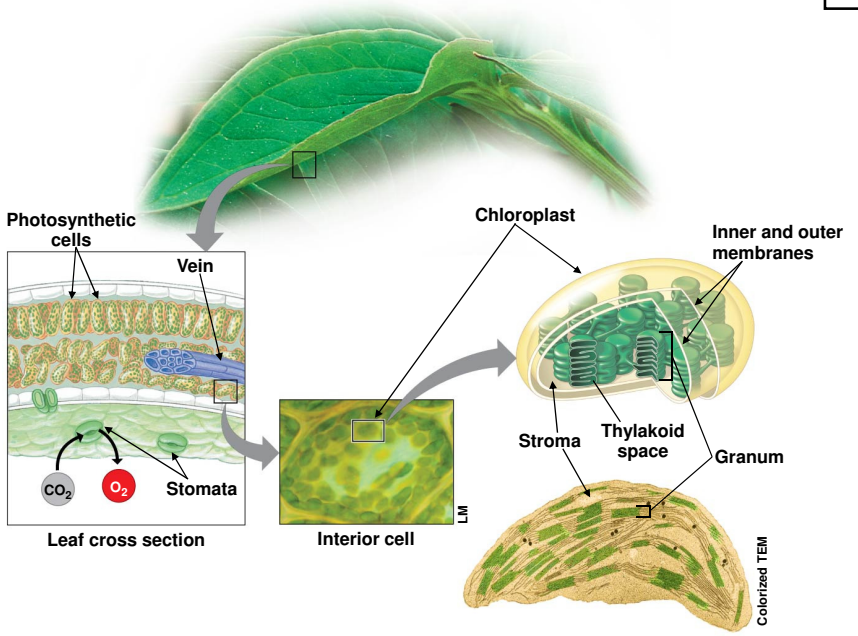

The Simplified Equation for Photosynthesis

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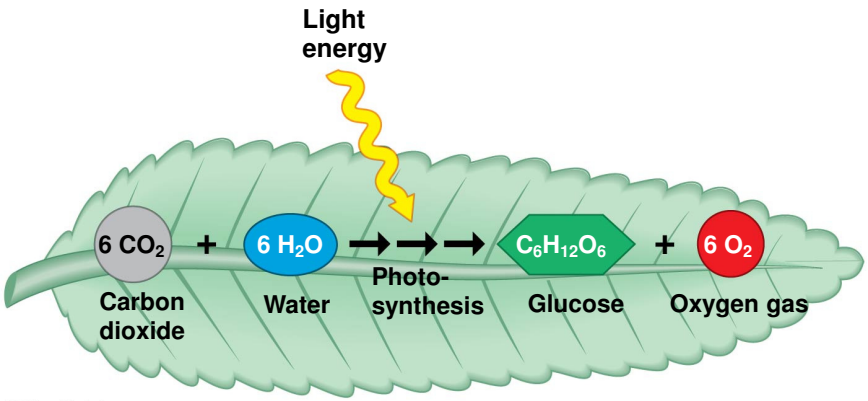
- In the overall equation for photosynthesis, notice that the reactants of photosynthesis are the waste products of cellular respiration.

The Simplified Equation for Photosynthesis

16



The Simplified Equation for Cellular Respiration

17

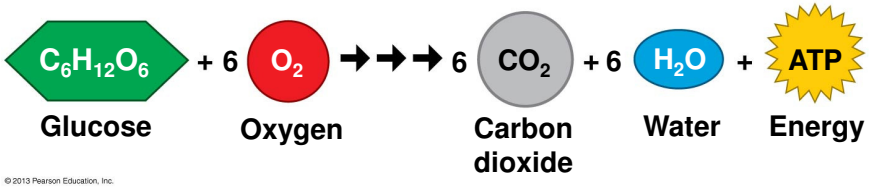
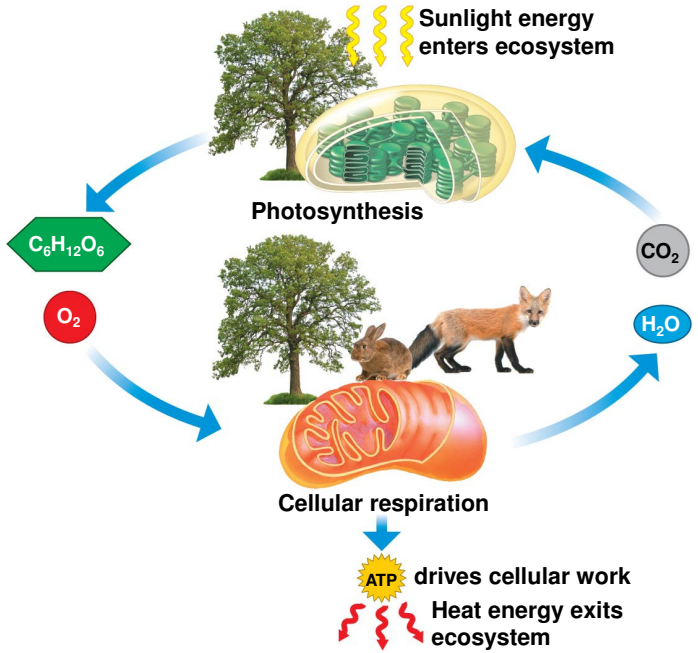


Figure 6.2



The Simplified Equation for Photosynthesis

- In photosynthesis,
  - sunlight provides the energy,
  - electrons are boosted “uphill” and added to carbon dioxide, and
  - sugar is produced.

The Simplified Equation for Photosynthesis

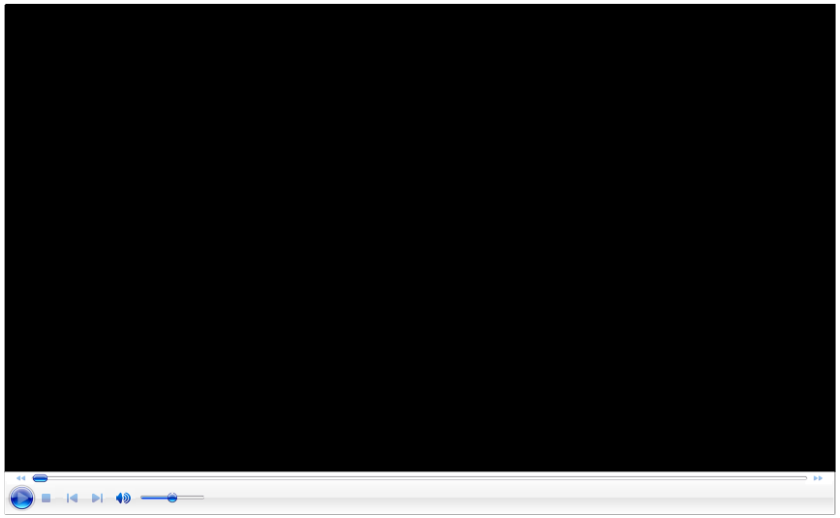
- During photosynthesis, water is split into
  - hydrogen and
  - oxygen.
- Hydrogen is transferred along with electrons and added to carbon dioxide to produce sugar.
- Oxygen escapes through stomata into the atmosphere.

A Photosynthesis Road Map

- Photosynthesis occurs in two multistep stages:
  1. the **light reactions** convert solar energy to chemical energy and
     - This occurs in the thylakoid membrane
  2. the **Calvin cycle** uses the products of the light reactions to make sugar from carbon dioxide.
     - This occurs in the stroma

A Photosynthesis Road Map

- The initial incorporation of carbon from the atmosphere into organic compounds is called **carbon fixation**.
  - This lowers the amount of carbon in the air.
  - Deforestation reduces the ability of the biosphere to absorb carbon by reducing the amount of photosynthetic plant life.



BioFlix Animation: Photosynthesis

Figure 7.3-1

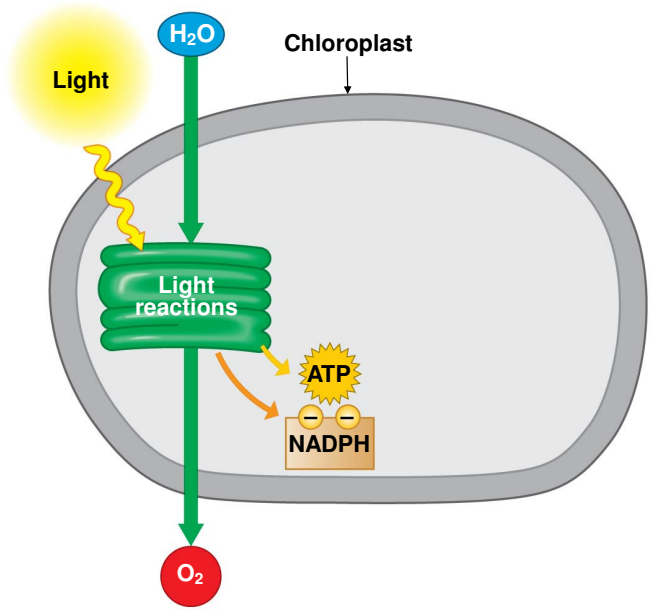
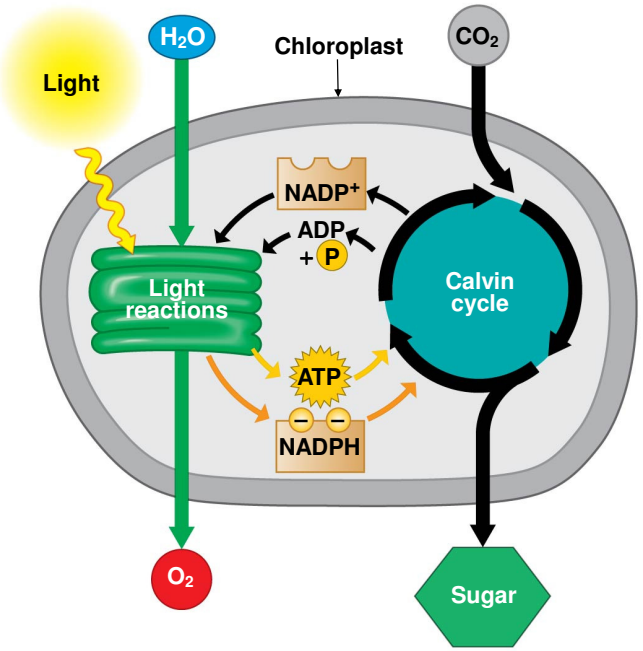


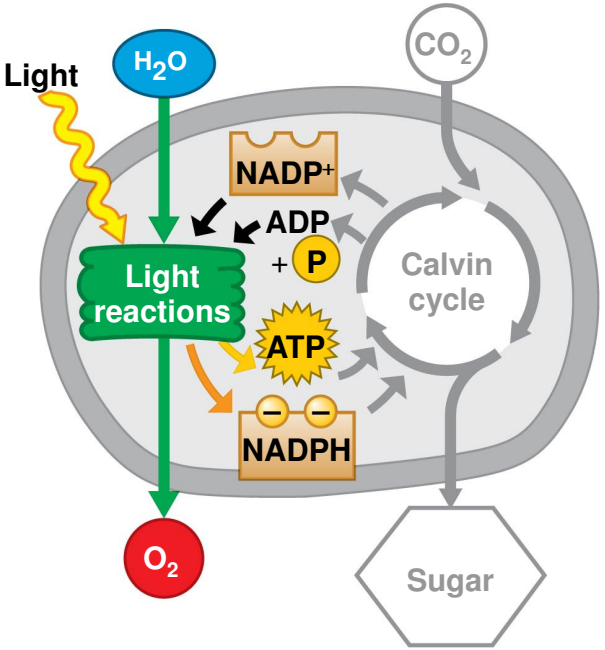
Figure 7.3-2



THE LIGHT REACTIONS: CONVERTING SOLAR ENERGY TO CHEMICAL ENERGY

- Chloroplasts
  - are chemical factories powered by the sun and
  - convert sunlight into chemical energy.

Figure 7-UN02



The Nature of Sunlight

- Sunlight is a type of energy called radiation, or electromagnetic energy.
- The distance between the crests of two adjacent waves is called a **wavelength**.
- The full range of radiation is called the **electromagnetic spectrum**.

Figure 7.4

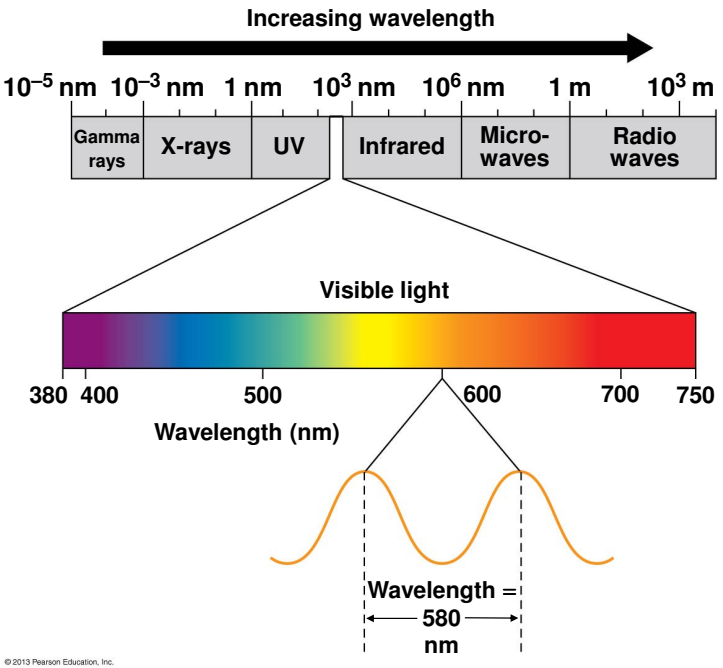


Figure 7.5

30

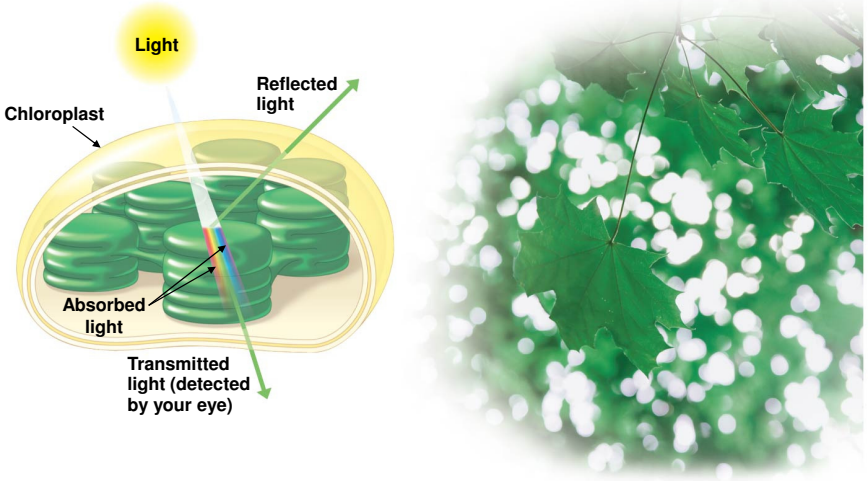


Figure 7.5a

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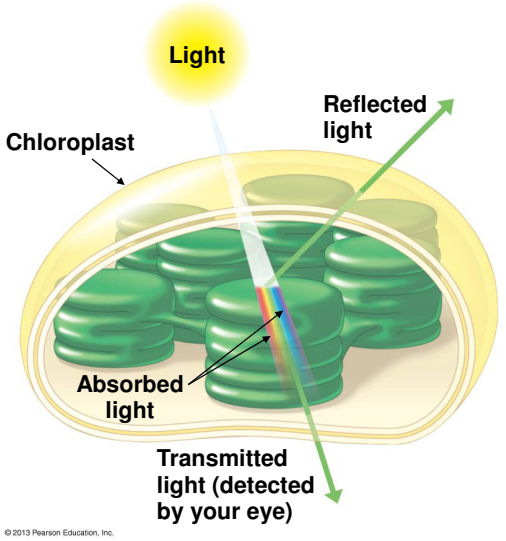

Figure 7.5b

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The Process of Science: What Colors of Light Drive Photosynthesis?

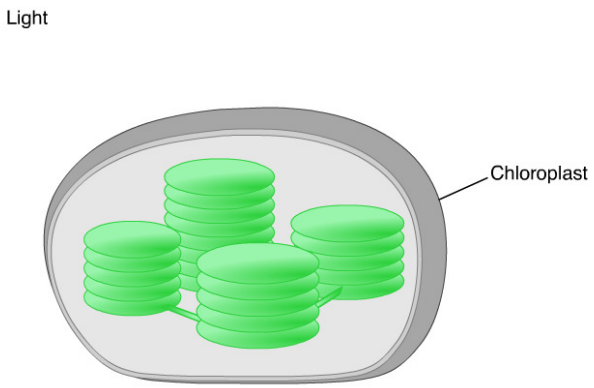
- **Observation**: In 1883, German biologist Theodor Engelmann saw that certain bacteria tend to cluster in areas with higher oxygen concentrations.
- **Question**: Could this information determine which wavelengths of light work best for photosynthesis?
- **Hypothesis**: Oxygen-seeking bacteria will congregate near regions of algae performing the most photosynthesis.

The Process of Science: What Colors of Light Drive Photosynthesis?

- **Experiment**: Engelmann
  - laid a string of freshwater algal cells in a drop of water on a microscope slide,
  - added oxygen-sensitive bacteria to the drop, and
  - used a prism to create a spectrum of light shining on the slide.

The Process of Science: What Colors of Light Drive Photosynthesis?

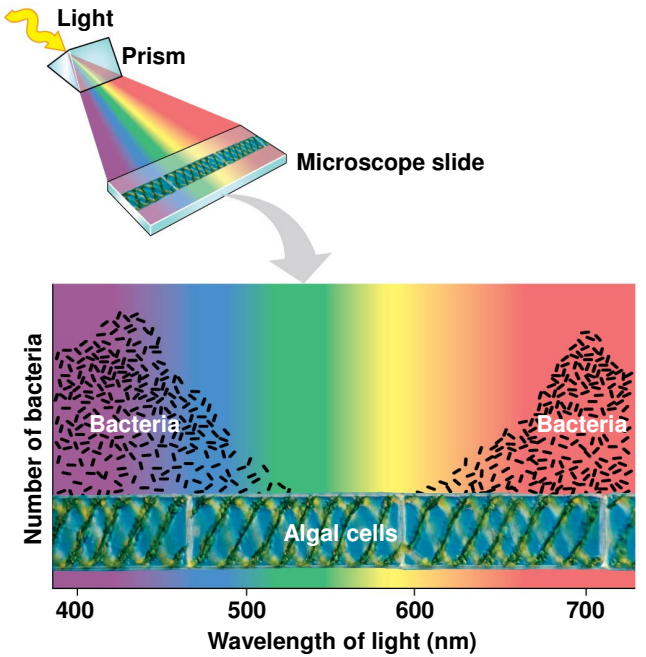
- **Results:** Bacteria
  - mostly congregated around algae exposed to red-orange and blue-violet light and
  - rarely moved to areas of green light.
- **Conclusion**: Chloroplasts absorb light mainly in the blue-violet and red-orange part of the spectrum.



Animation: Light and Pigments

Right click slide / select "Play"

Figure 7.6



Chloroplast Pigments

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- Chloroplasts contain several pigments:
  1. **Chlorophyll *a***
     - absorbs mainly blue-violet and red light and
     - participates directly in the light reactions.
  2. **Chlorophyll *b***
     - absorbs mainly blue and orange light and
     - participates indirectly in the light reactions.

Chloroplast Pigments

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- Carotenoids
  - absorb mainly blue-green light,
  - participate indirectly in the light reactions, and
  - absorb and dissipate excessive light energy that might damage chlorophyll.
- The spectacular colors of fall foliage are due partly to the yellow-orange light reflected from carotenoids.

Figure 7.7

40

How Photosystems Harvest Light Energy

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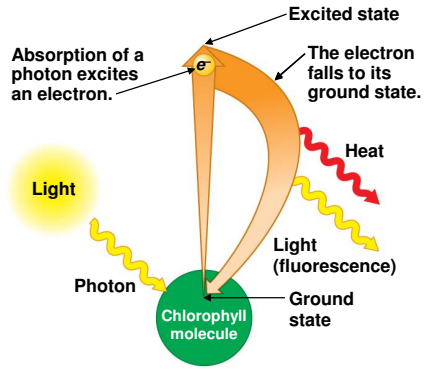
- Light behaves as **photons**, a fixed quantity of light energy.
- Chlorophyll molecules absorb photons.
  - Electrons in the pigment gain energy.
  - As the electrons fall back to their ground state, energy is released as heat or light.

Figure 7.8



(a) Absorption of a photon

(b) Fluorescence of a glow stick

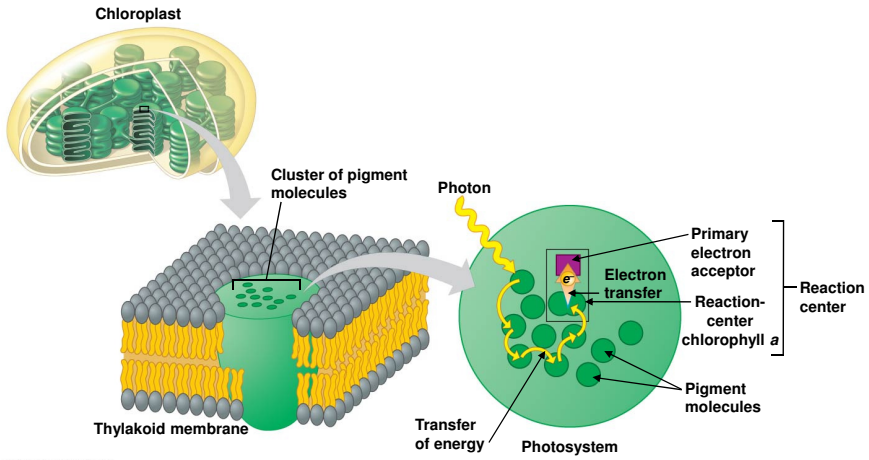
How Photosystems Harvest Light Energy

- In the thylakoid membrane, chlorophyll molecules are organized with other molecules into photosystems.
- A **photosystem** is a cluster of a few hundred pigment molecules that function as a light-gathering antenna.

How Photosystems Harvest Light Energy

- The **reaction center** of the photosystem consists of chlorophyll *a* molecules that sit next to another molecule called a **primary electron acceptor**, which traps the light-excited electron from chlorophyll *a.*
- Another team of molecules built into the thylakoid membrane then uses that trapped energy to make
  - ATP and
  - NADPH.

Figure 7.9



How the Light Reactions Generate ATP and NADPH

- Two types of photosystems cooperate in the light reactions:
  1. the water-splitting photosystem and
  2. the NADPH-producing photosystem.

Figure 7.10-1

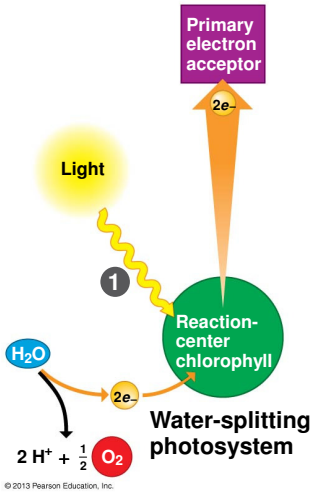


Figure 7.10-2

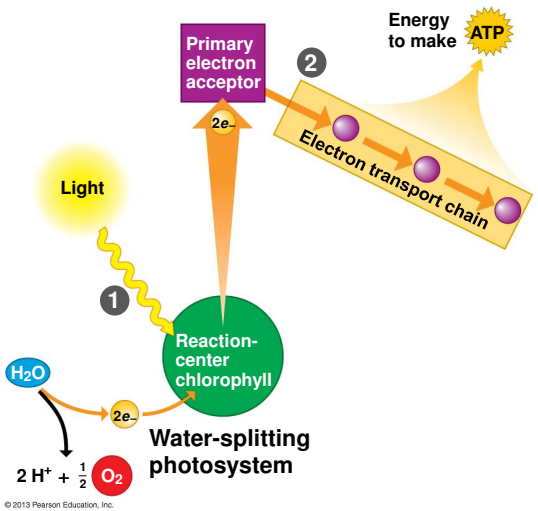
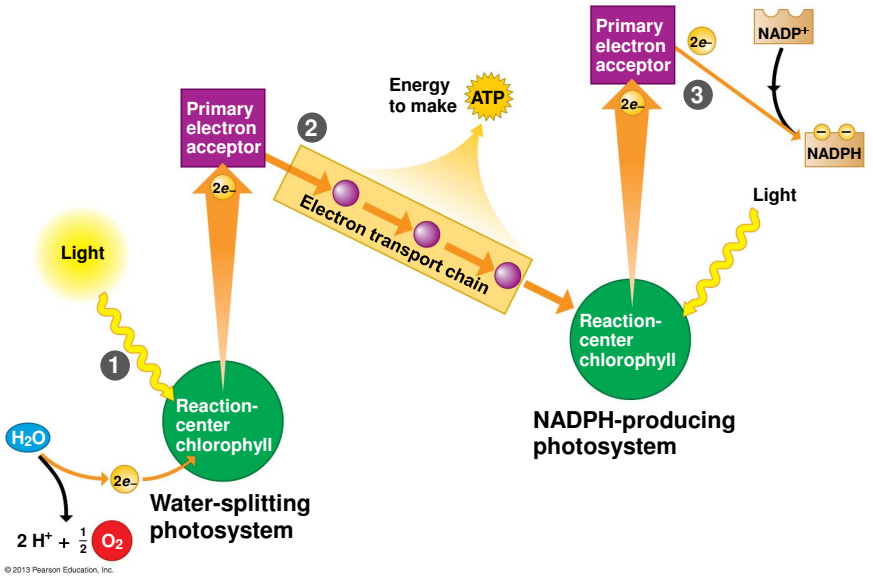


Figure 7.10-3



How the Light Reactions Generate ATP and NADPH

50

- The light reactions are located in the thylakoid membrane.
- An electron transport chain
  - connects the two photosystems and
  - releases energy that the chloroplast uses to make ATP.

Figure 7.11

51

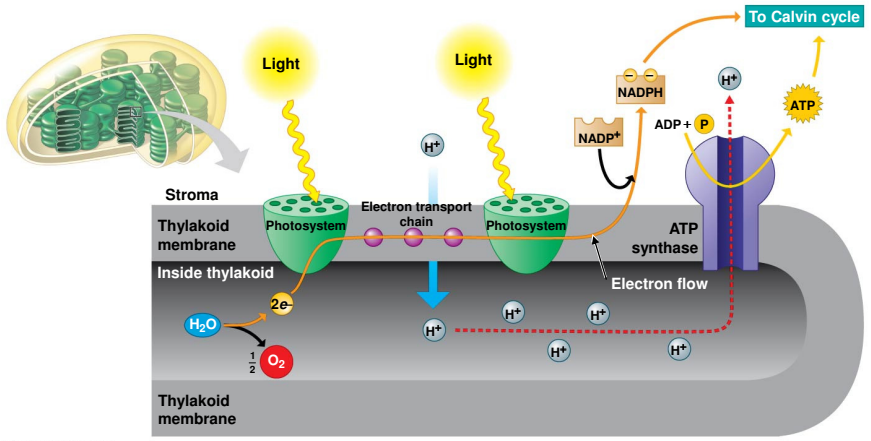
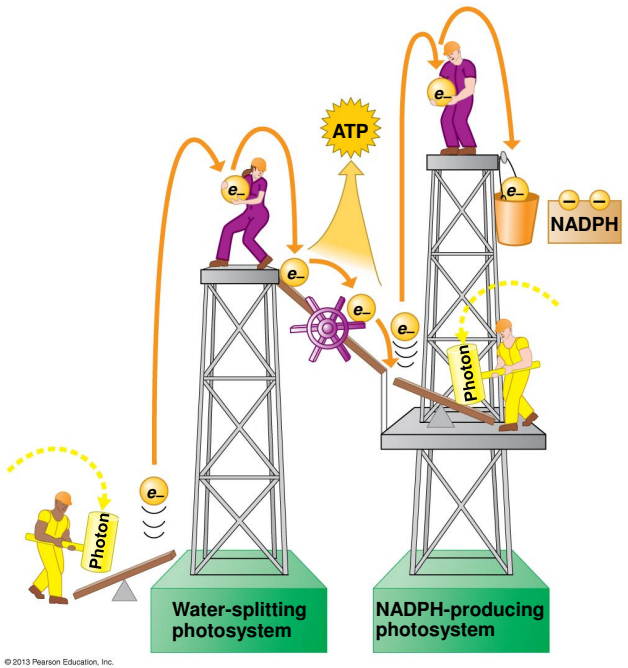


Figure 7.12

52



THE CALVIN CYCLE: MAKING SUGAR FROM CARBON DIOXIDE

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- The Calvin cycle
  - functions like a sugar factory within a chloroplast and
  - regenerates the starting material with each turn.

Blast Animation: Photosynthesis: Light-Independent Reactions

Select “Play”

Figure 7-UN03

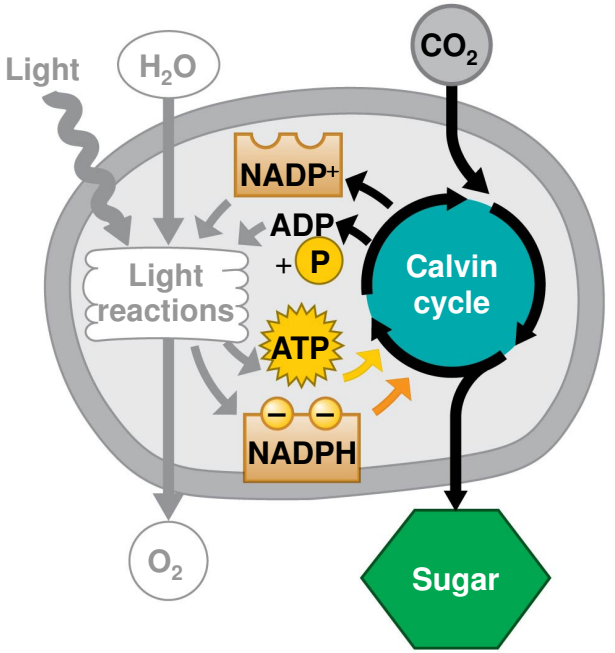


Figure 7.13-1

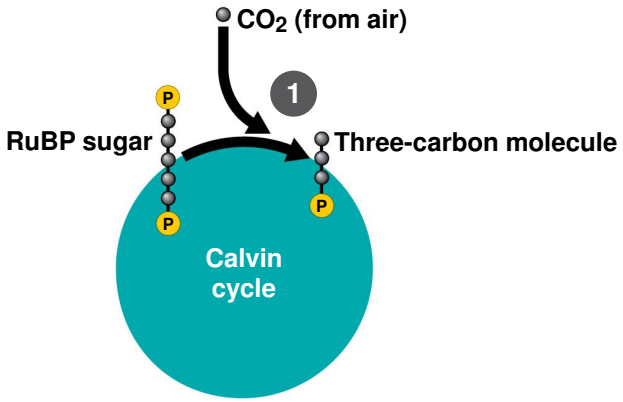
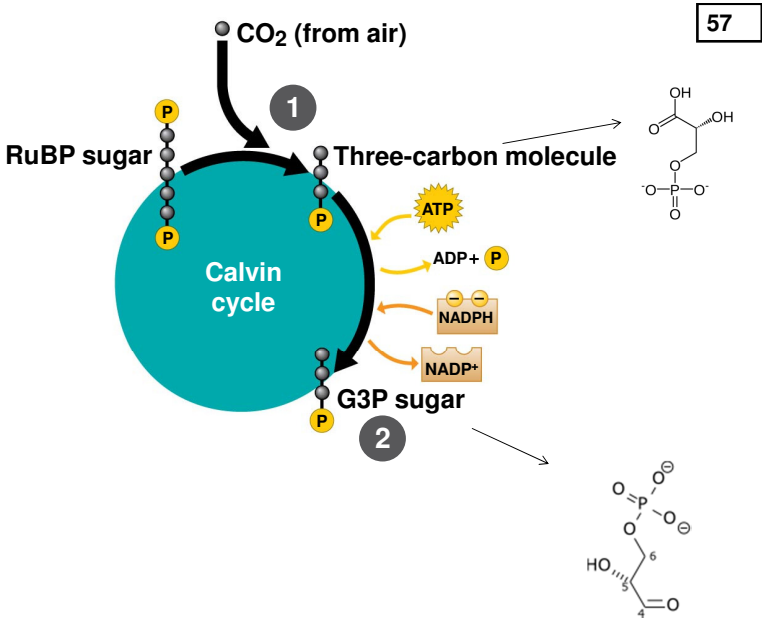


Figure 7.13-2



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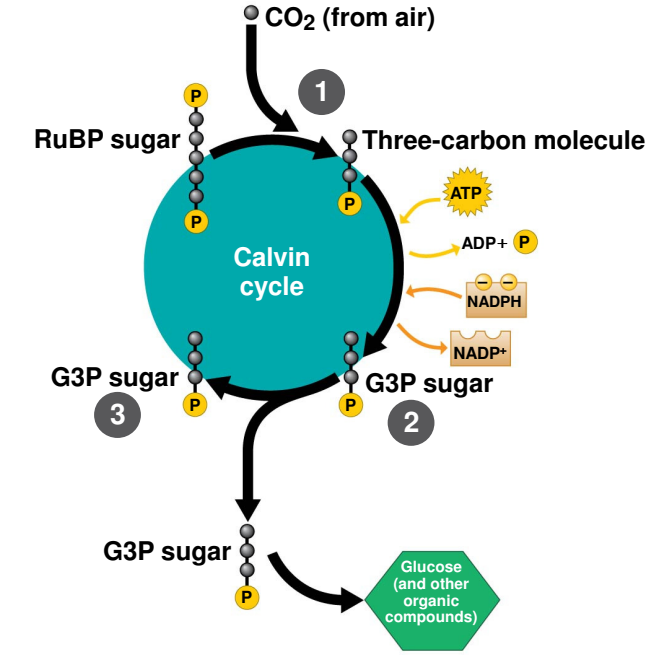

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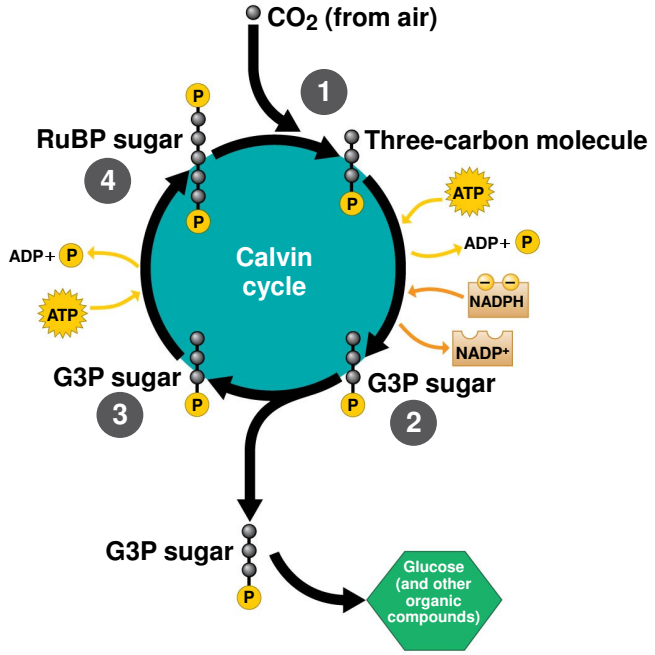

Evolution Connection: Solar-Driven Evolution

- **C_3 plants**
  - use CO_2 directly from the air and
  - are very common and widely distributed.

Evolution Connection: Solar-Driven Evolution

- **C_4 plants**
  - close their stomata to save water during hot and dry weather and
  - can still carry out photosynthesis.
- **CAM plants**
  - are adapted to very dry climates and
  - open their stomata only at night to conserve water.

Figure 7.14

62

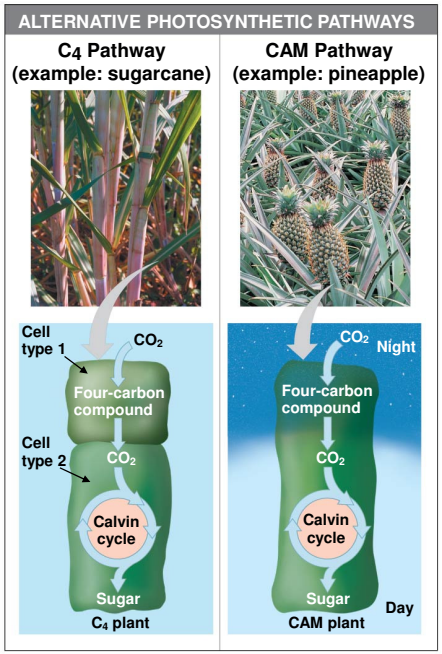

Figure 7.14a

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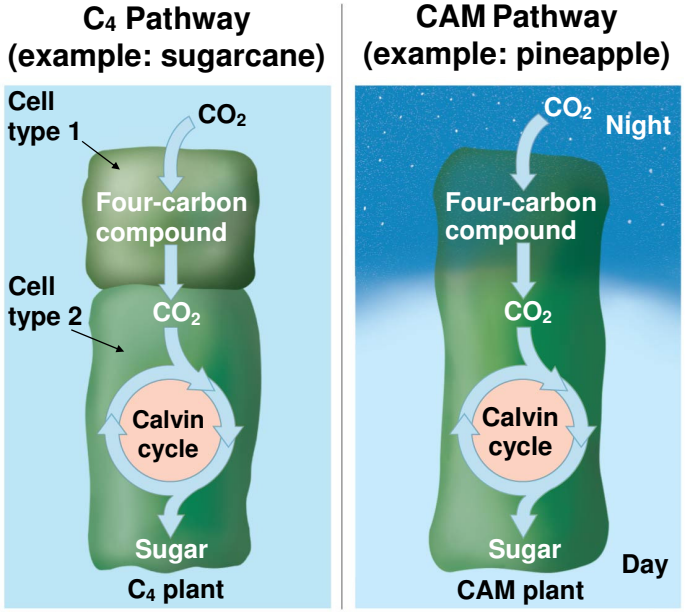

Figure 7.14b

64

C4 Pathway (example: sugarcane)

Figure 7.14c

65

CAM Pathway (example: pineapple)

Figure 7-UN04

66

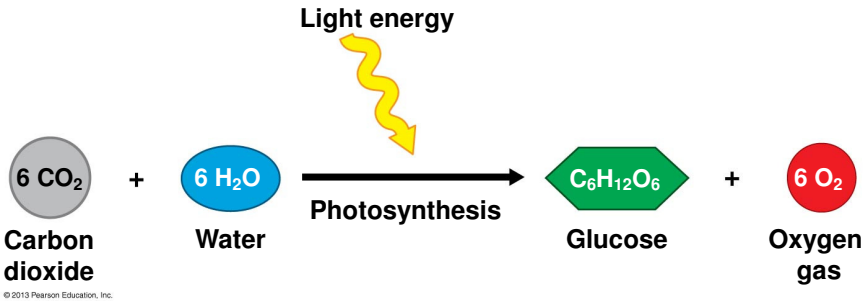

Figure 7-UN05

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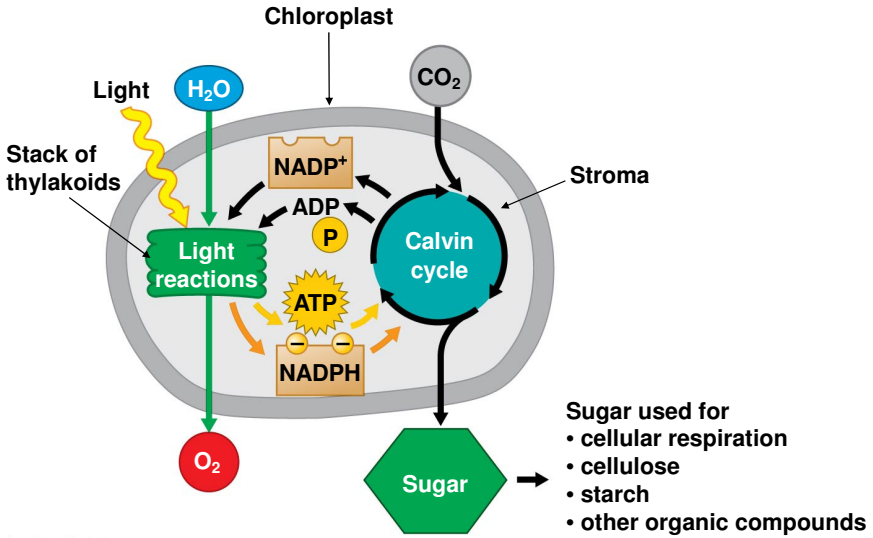

Figure 7-UN06

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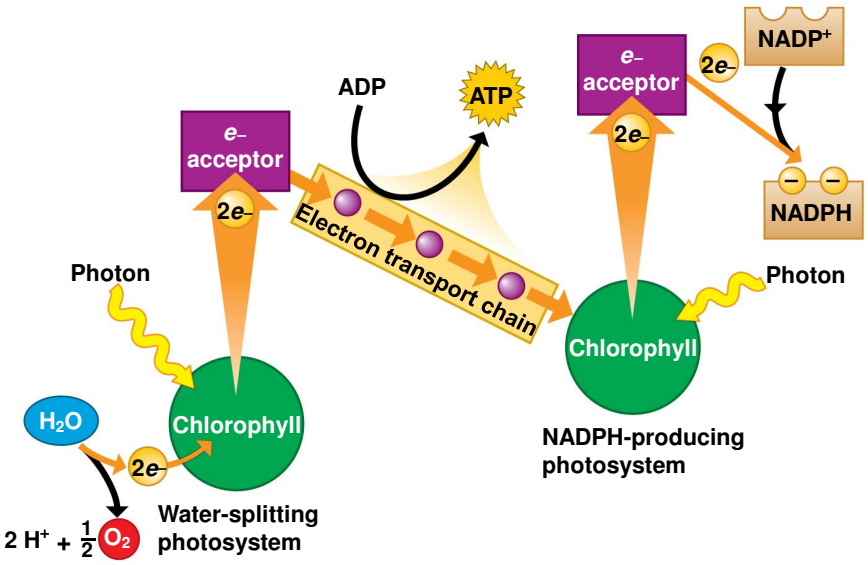

Figure 7-UN07

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