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CELS191 LECTURE MATERIAL

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Research & Interests:

Cyanobacterial Diversity, Genetics & Ecophysiology, Cyanobacteria & Renewable Energy

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CELS191 2025

Cell Structure & Diversity

Lecture 7

Photosynthesis

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Lecture 7 Objectives

After you have revised this lecture you should be able to:

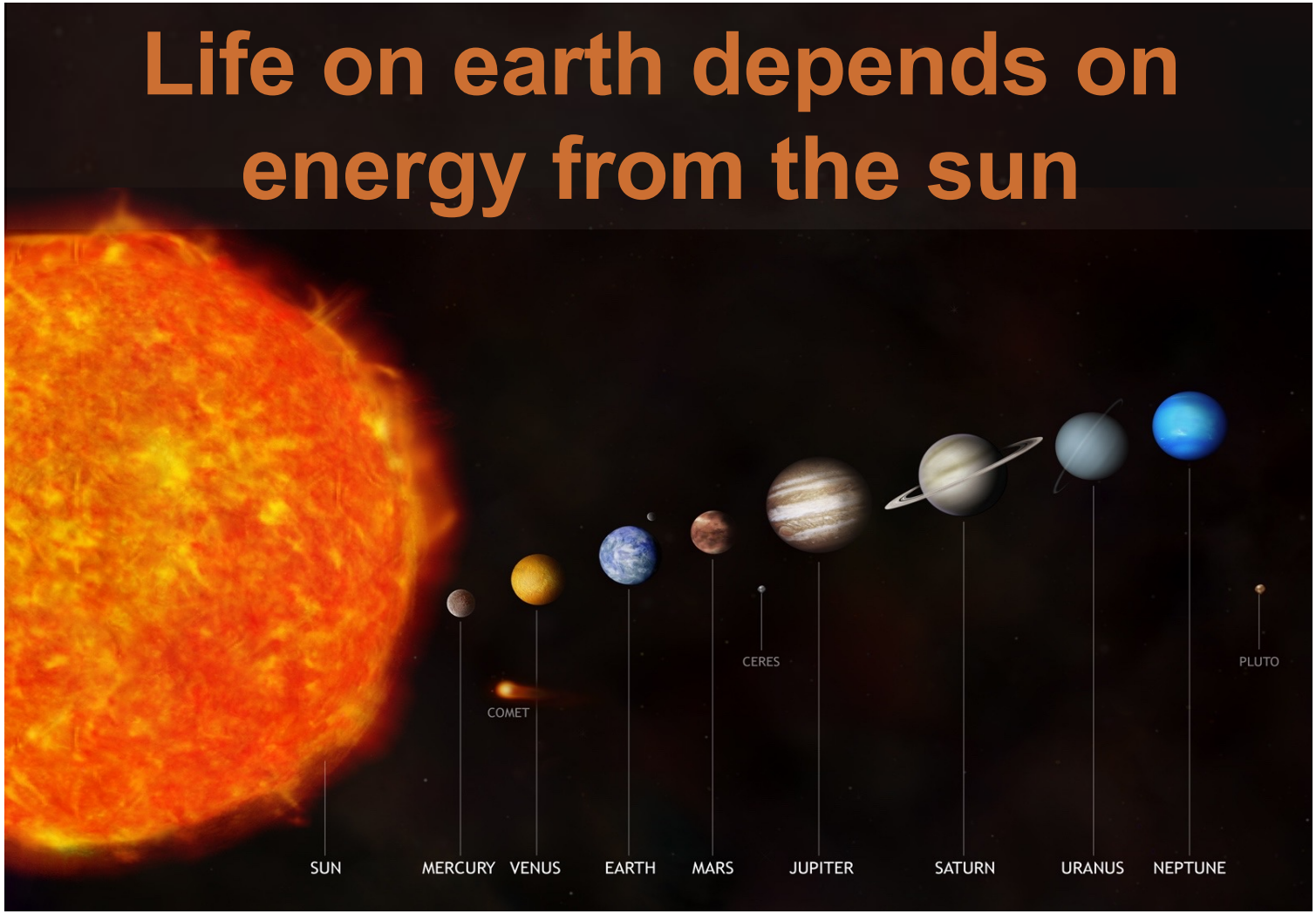
- Describe the structure and function of the chloroplast.
- Outline how cells capture light energy and transduce it to cellular energy in the two stages of photosynthesis.
- Outline the main inputs and outputs of photosynthesis.
- Outline the process of energy supply in both plant and animal cells.
- Outline the origin of chloroplasts and mitochondria *(endosymbiosis)*.

Context Slide

- What is the primary energy carrying molecule in our cells?
- What is the **main** process that makes this molecule?
- What is the starting molecule for this process?
- Where does this molecule come from?

Context Slide

Image: NASAs Chandra Observatory

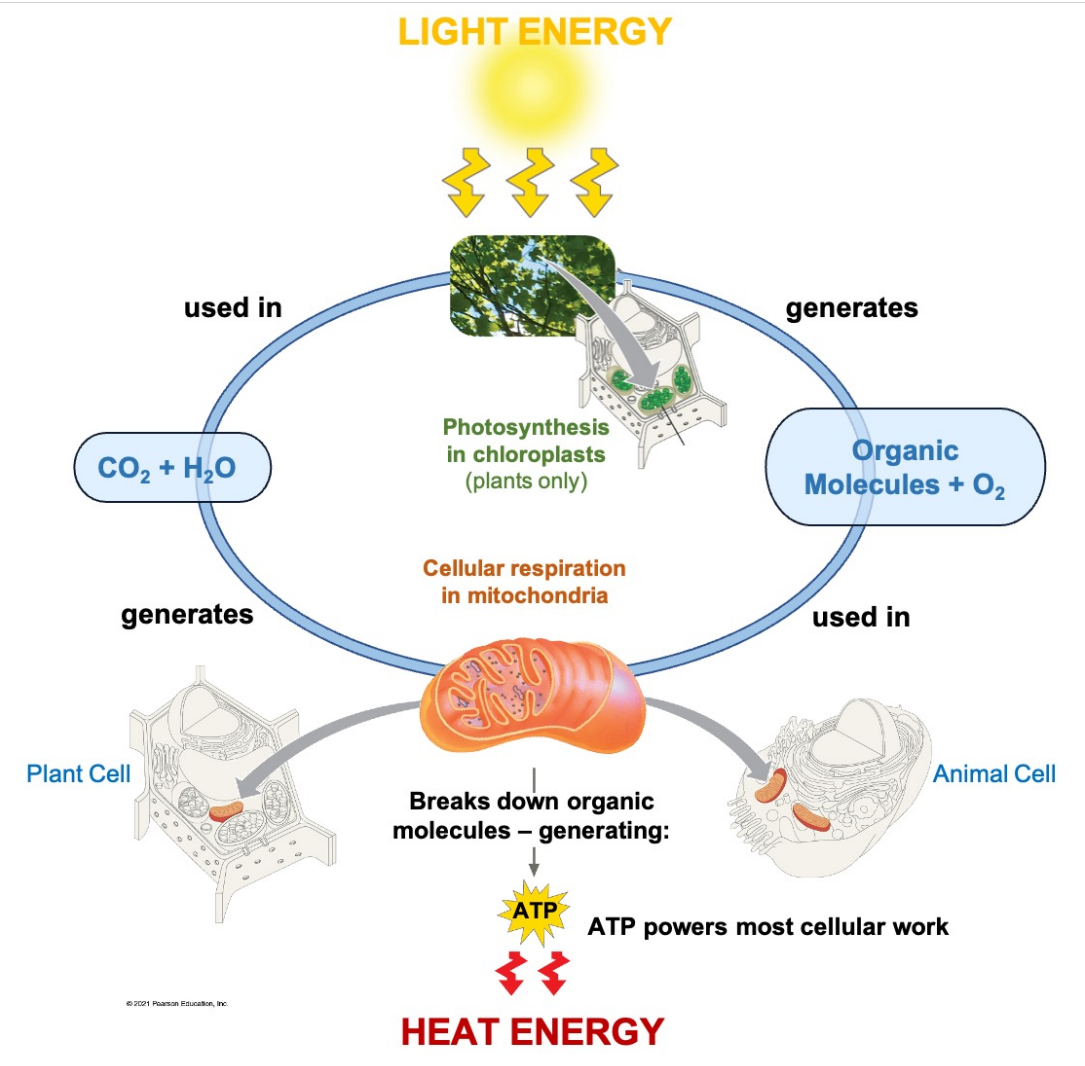


Adapted Textbook Figure 10.1

Energy Flow:
Cellular Respiration & Photosynthesis

Photosynthesis
Plants only

Cellular Respiration
Plants and animals

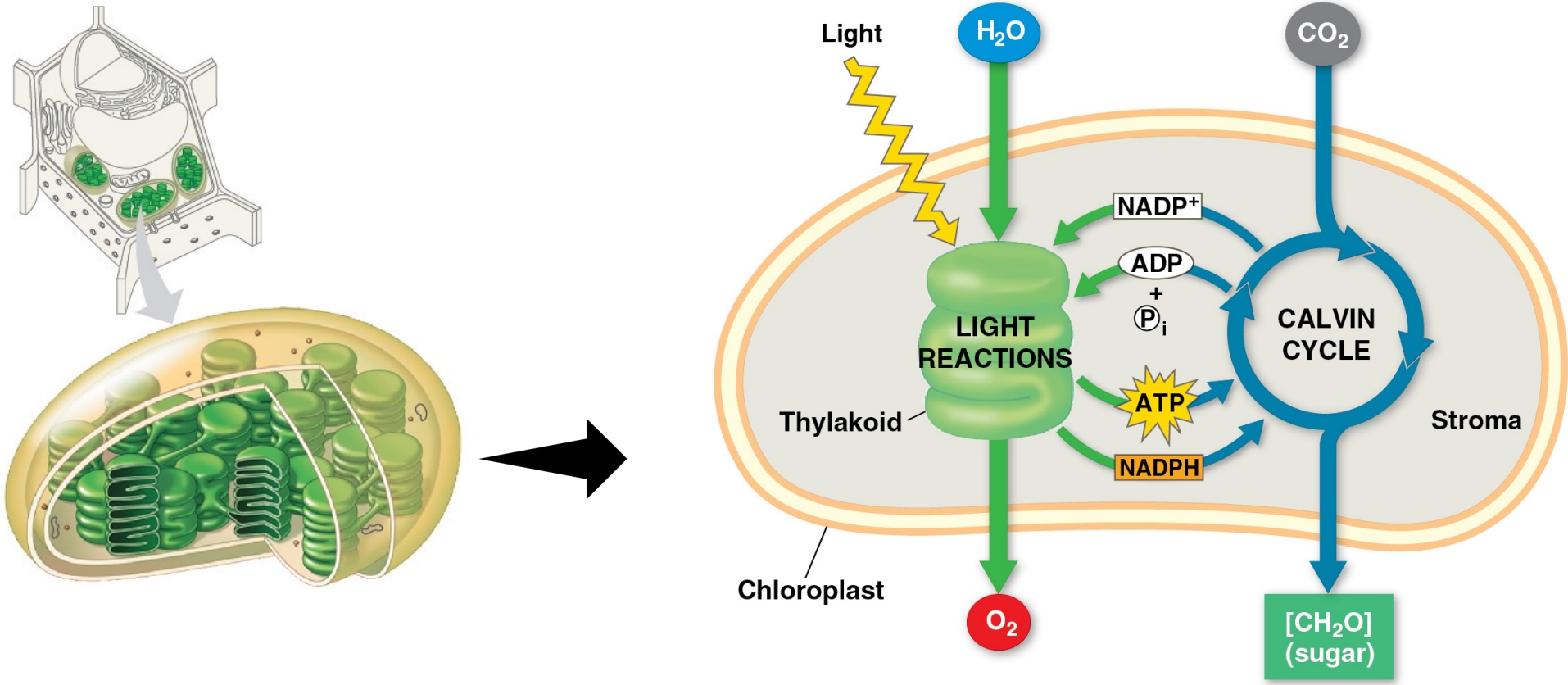


Photosynthesis Powers the Planet

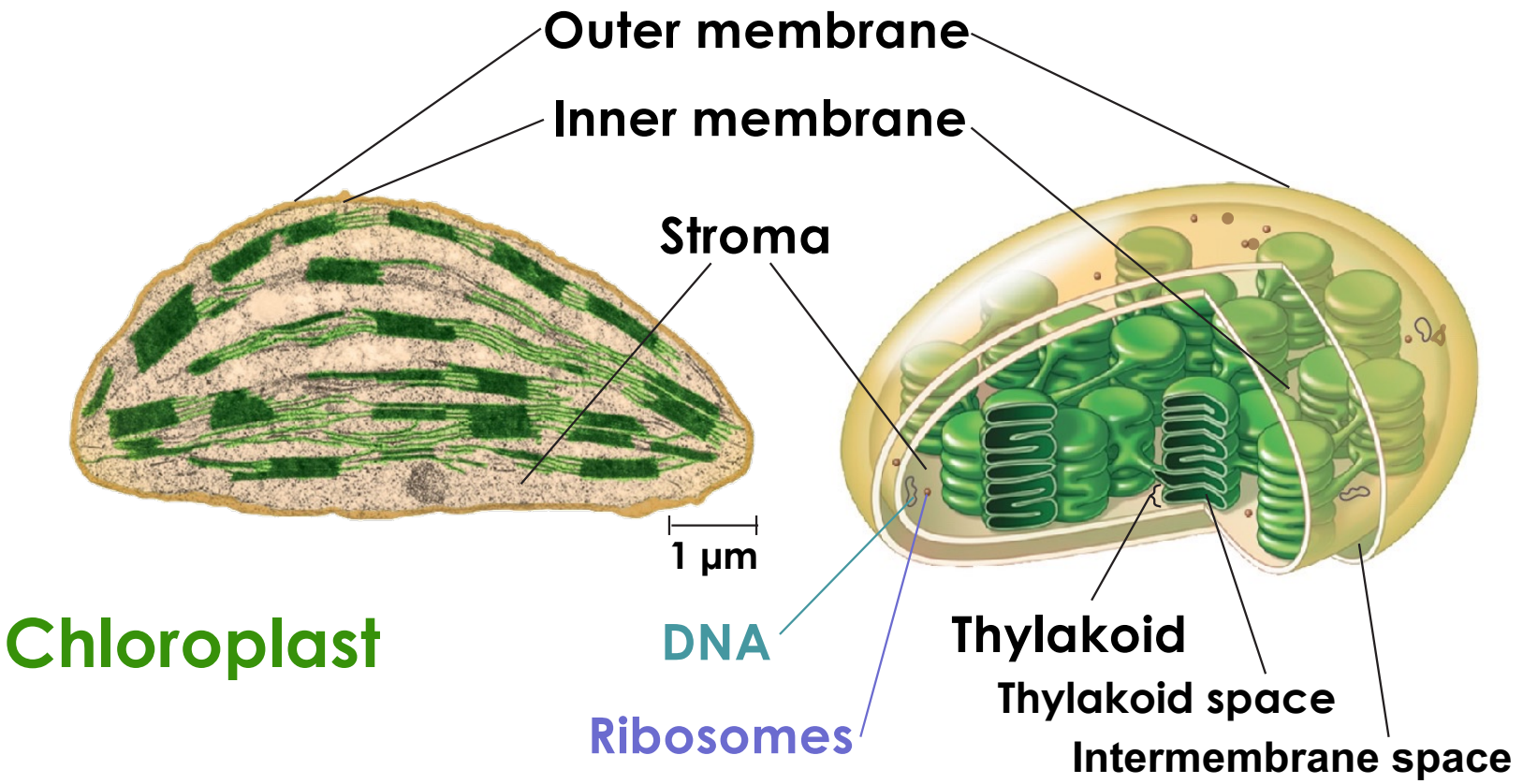
Photosynthesis "synthesis using light" is responsible for almost all the planet's energy resources.

$$6CO_2 + 6H_2O \xrightarrow{\text{plant, light}} C_6H_{12}O_6 + 6O_2$$

Chloroplasts: The Site of Photosynthesis



Chloroplasts: Structure



Chloroplasts: Structure & Function

Three Membranes

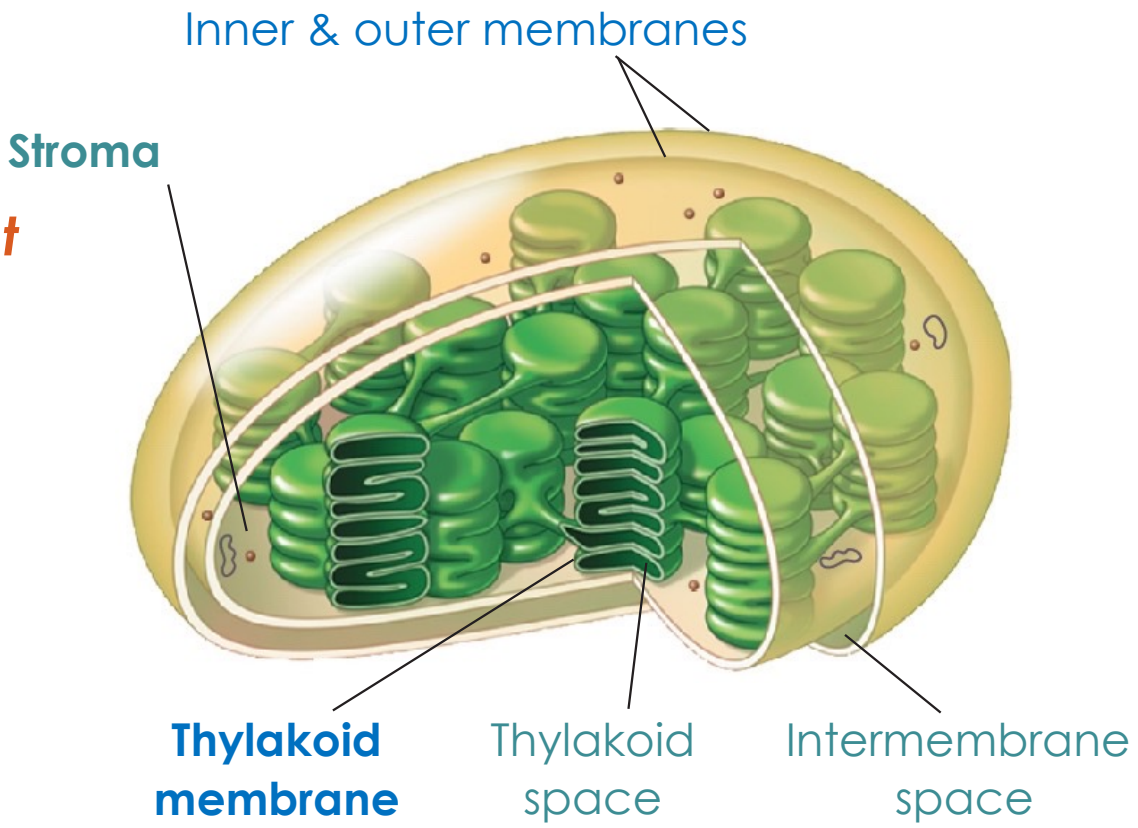
- Outer
- Inner
- Thylakoid ***functionally important***

Three Compartments

- Intermembrane space
- Stroma ***functionally important***
- Thylakoid space ***functionally important***

Light reactions take place on the **thylakoid membrane.**

Carbon fixation occurs in the **stroma**.



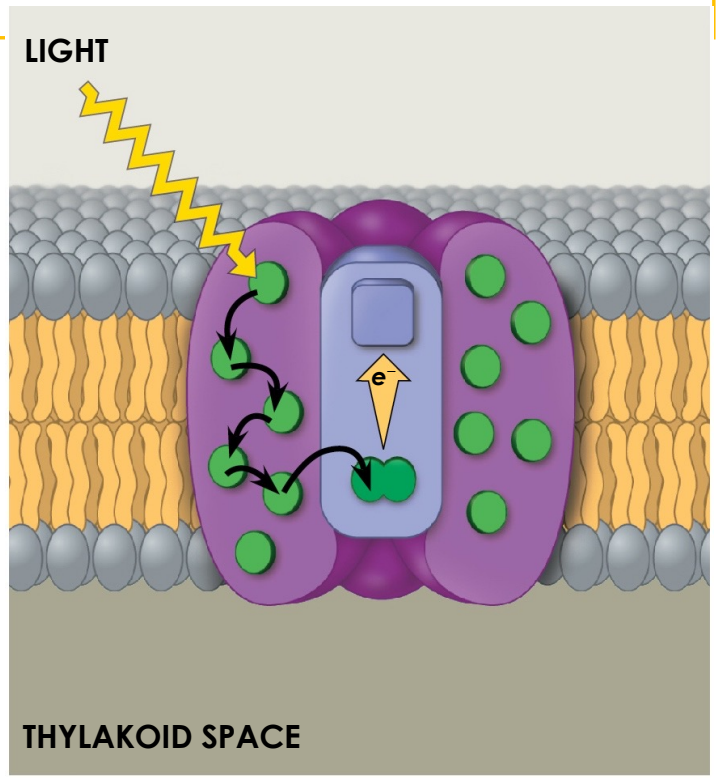
The Light Reactions:

Photosystems Capture Light Energy and covert it to Chemical Energy

1. In the **thylakoid membrane** there are protein complexes called **Photosystems** these contain chlorophyll

2. Chlorophyll absorbs light energy

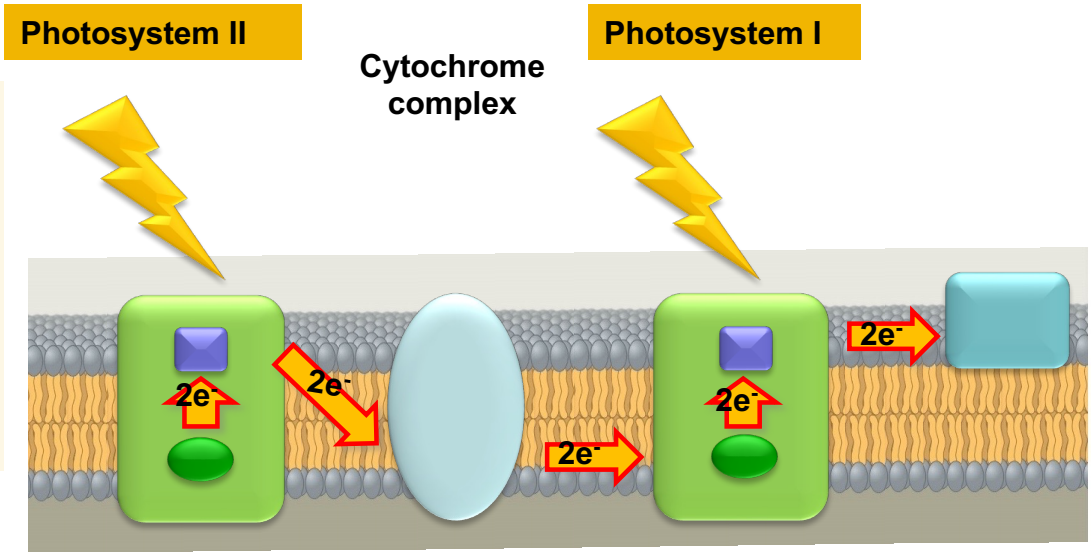
3. The light energy is passed to electrons and high energy electrons leave the Photosystem



Light Reactions:

High Energy Electrons move through the **Photosynthetic Electron Transport Chain**

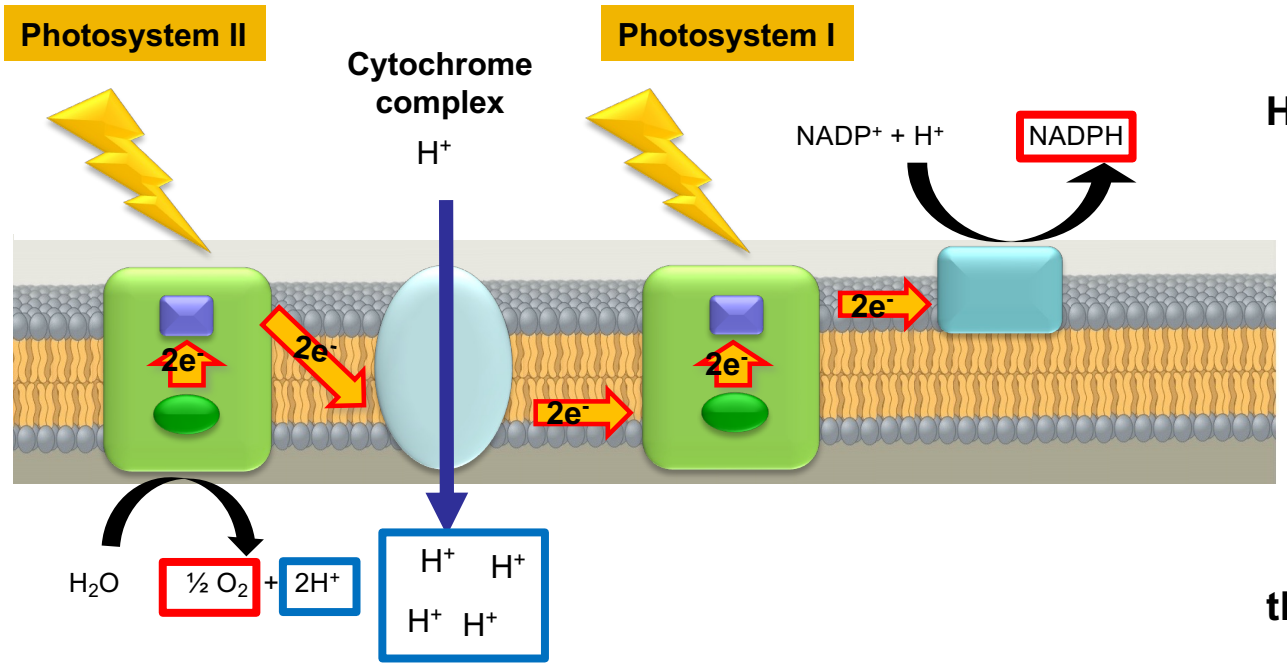
In the **thylakoid membrane** the high energy electrons pass through protein complexes. This is the Photosynthetic electron transport chain



Light Reactions:

The Photosynthetic electron transport produces:

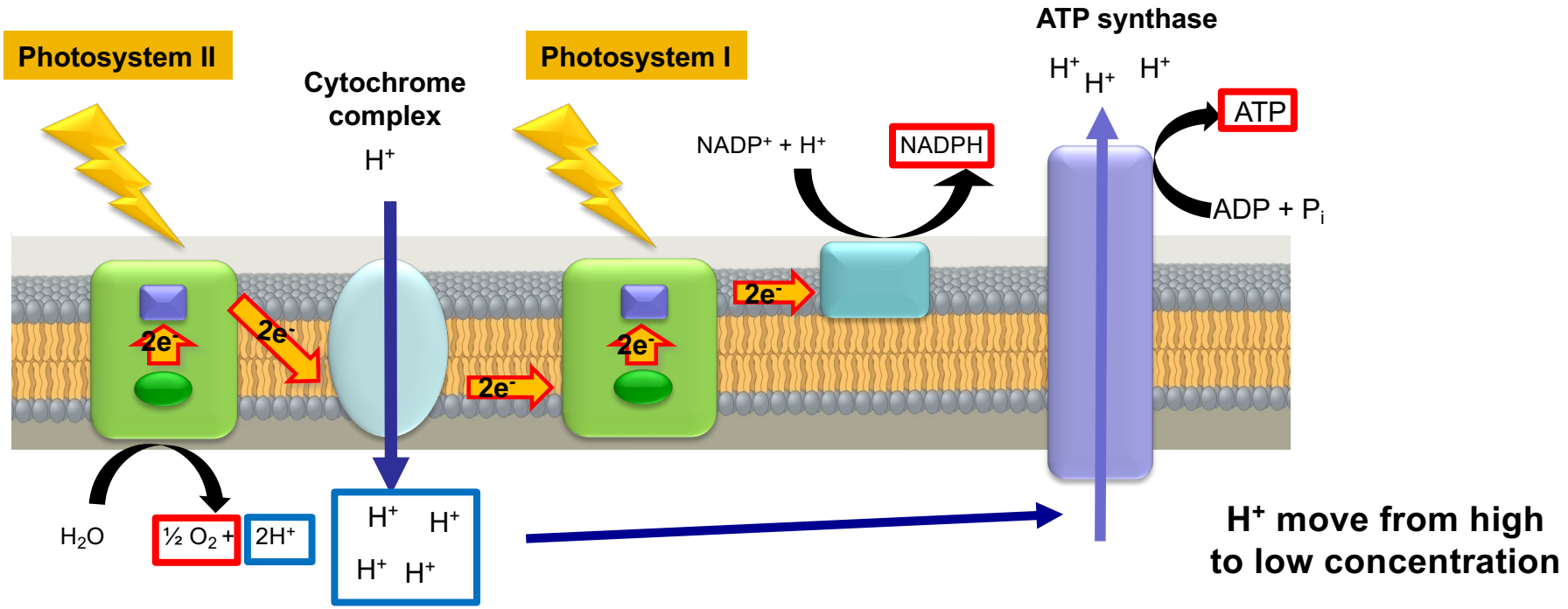
NADPH, Oxygen and a H^+ gradient



H^+ concentration lower in the stroma

H^+ accumulate in the thylakoid space

Light Reactions:
The H^+ gradient is used to produce **ATP**



Light Reactions

In the light reactions, light energy is converted into chemical energy

The outputs are: **ATP** and **NADPH** (high energy molecules) and $\mathbf{O_2}$

Light Reactions:
Photosynthetic Electron Transport Chain

Overall reaction for photosynthesis:

$$6CO_2 + \mathbf{6H_2O} \xrightarrow{\text{plant, light}} C_6H_{12}O_6 + \mathbf{6O_2}$$

In the light reactions, **water** is split to give **oxygen**

also **ATP** and **NADPH** produced

The Calvin Cycle or Carbon Fixation

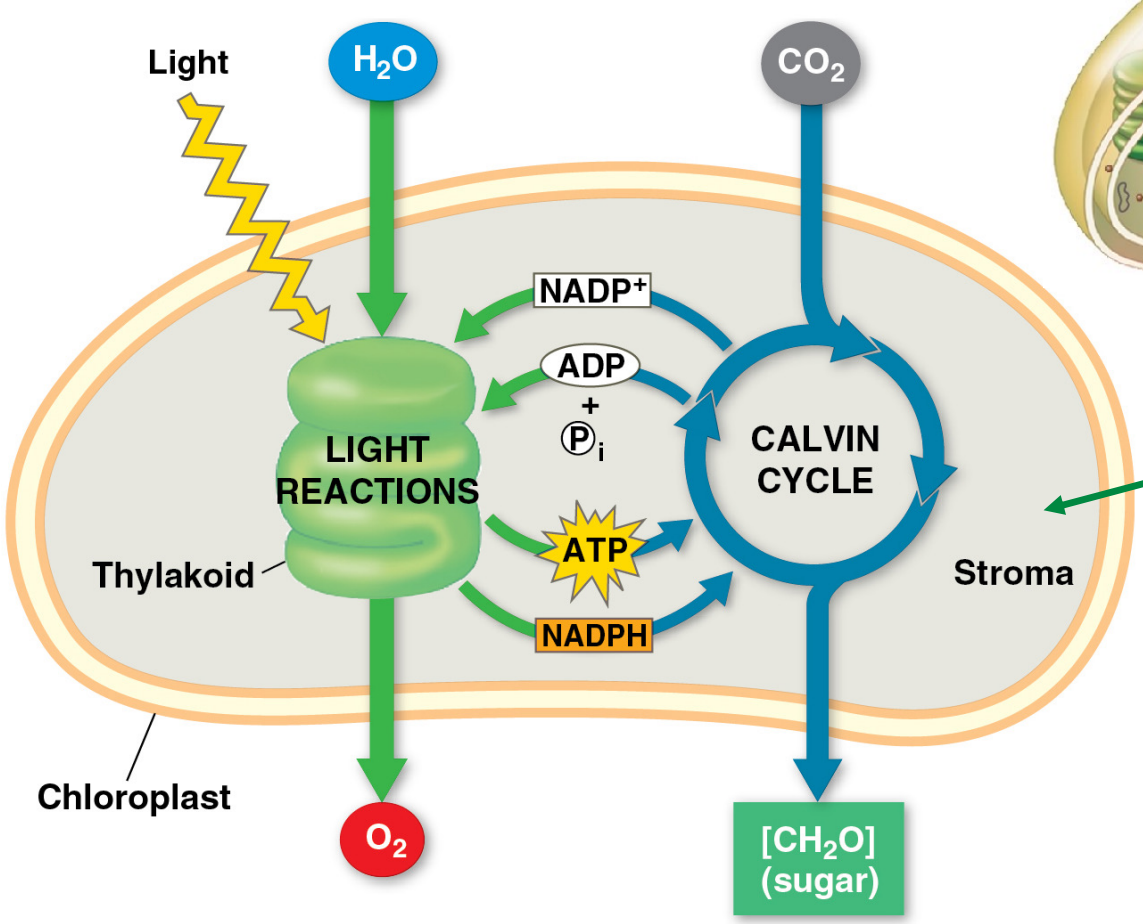
Overall reaction for photosynthesis:

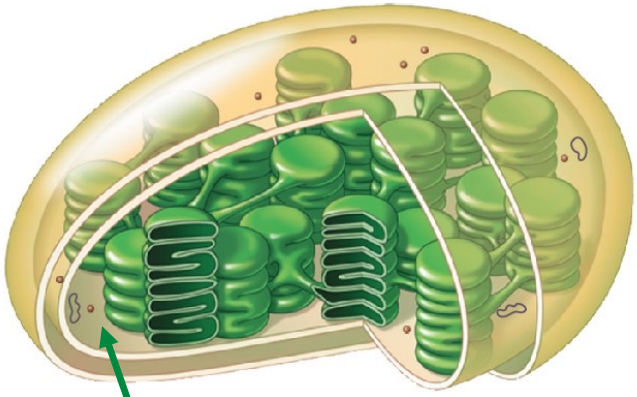
$$6CO_2 + 6H_2O \xrightarrow{\text{plant, light}} C_6H_{12}O_6 + 6O_2$$

ATP and **NADPH** produced in the light reactions are used to fix CO_2 and produce carbohydrate

Core Slide

Modified Textbook Figures 11.5 & 7.18a





Carbon fixation (Calvin cycle) occurs in the chloroplast stroma

Calvin cycle

Has three steps to go from carbon dioxide to *glucose*

Only the carbon and phosphorus atoms are shown in the molecules

carbon atom

CO_2

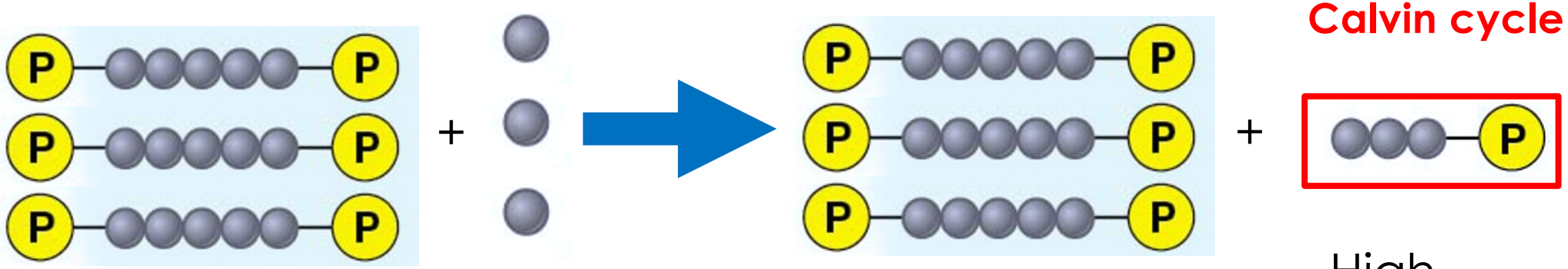
5-carbon molecule

Carbon atoms

Calvin cycle

Has three steps to go from carbon dioxide to *glucose*

Overall reaction



output of Calvin cycle

3 x 5-carbon molecule + 3 x CO_2 → 3 x 5-carbon molecules + High energy 3-carbon molecule

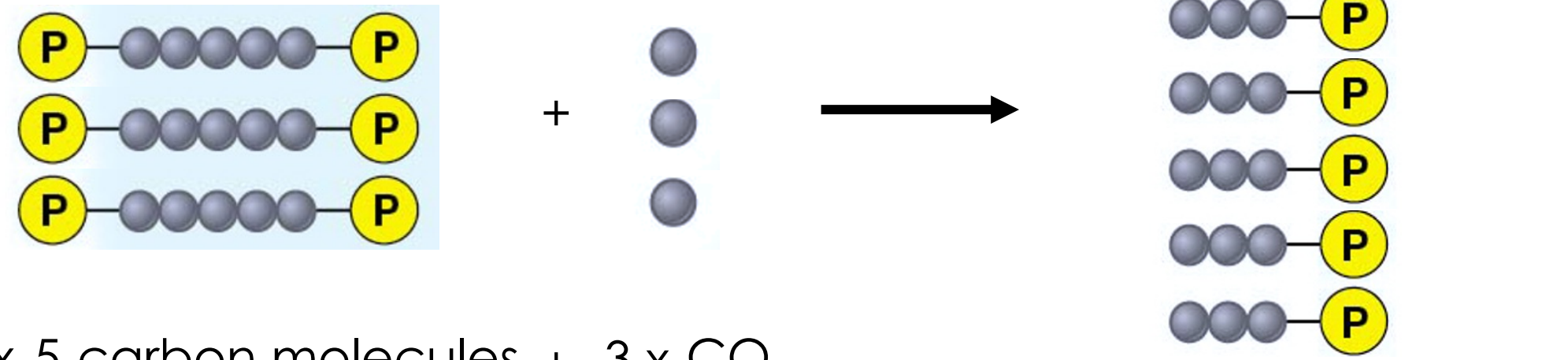
Stay in Calvin cycle

Carbon atoms

Calvin cycle

Has three steps to go from carbon dioxide to glucose

Step 1: Fixation



3 x 5-carbon molecules + 3 x CO_2

Ribulose-1,5-bisphosphate

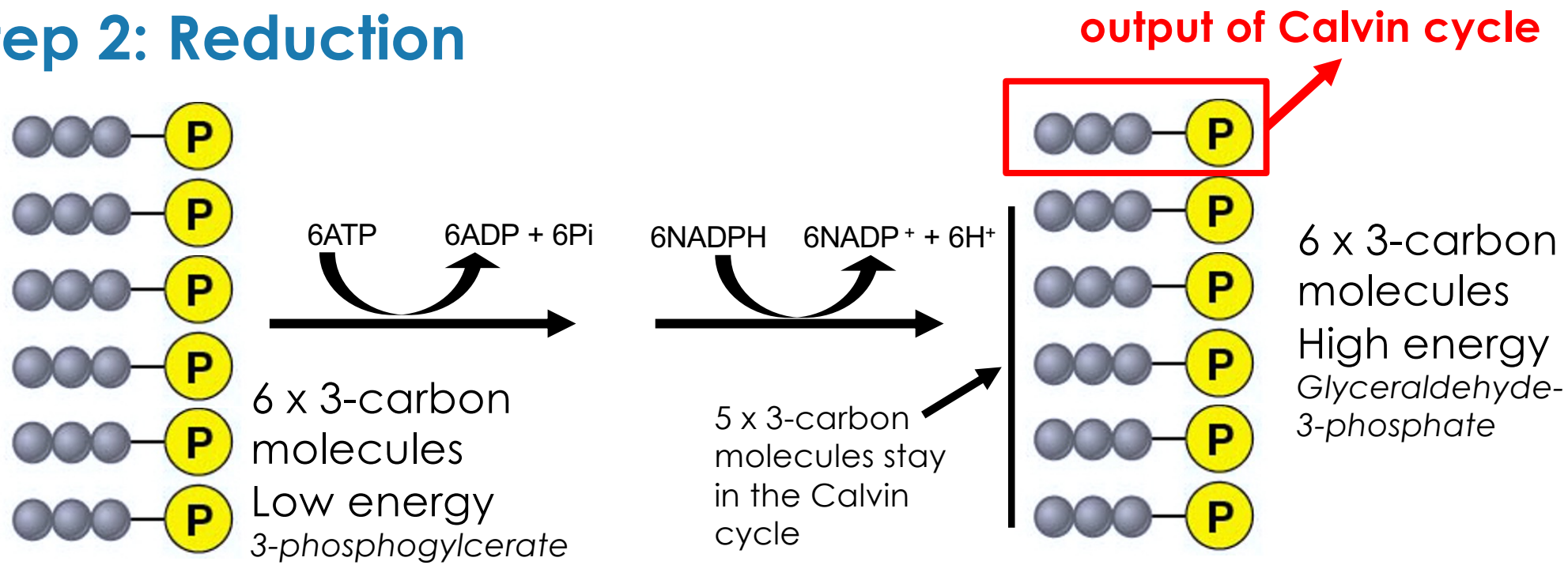
6 x 3-carbon molecules

3-phosphoglycerate

Calvin cycle

Has three steps to go from carbon dioxide to glucose

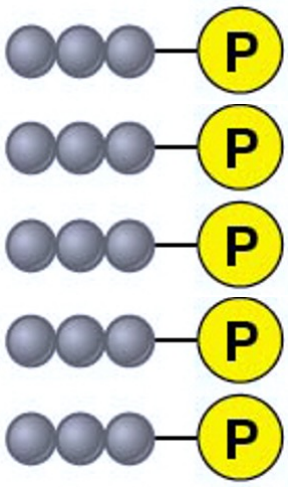
Step 2: Reduction



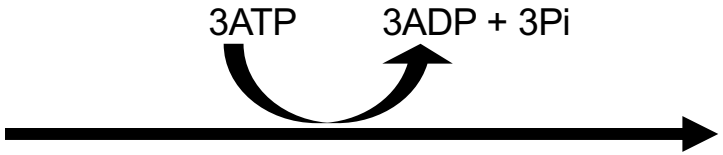
Calvin cycle

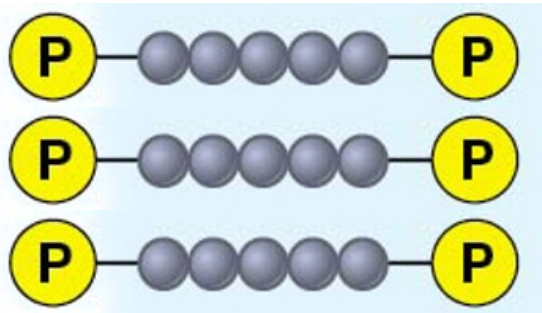
Has three steps to go from carbon dioxide to glucose

Step 3: Regeneration



5 x 3-carbon molecules
High energy
Glyceraldehyde-3-phosphate





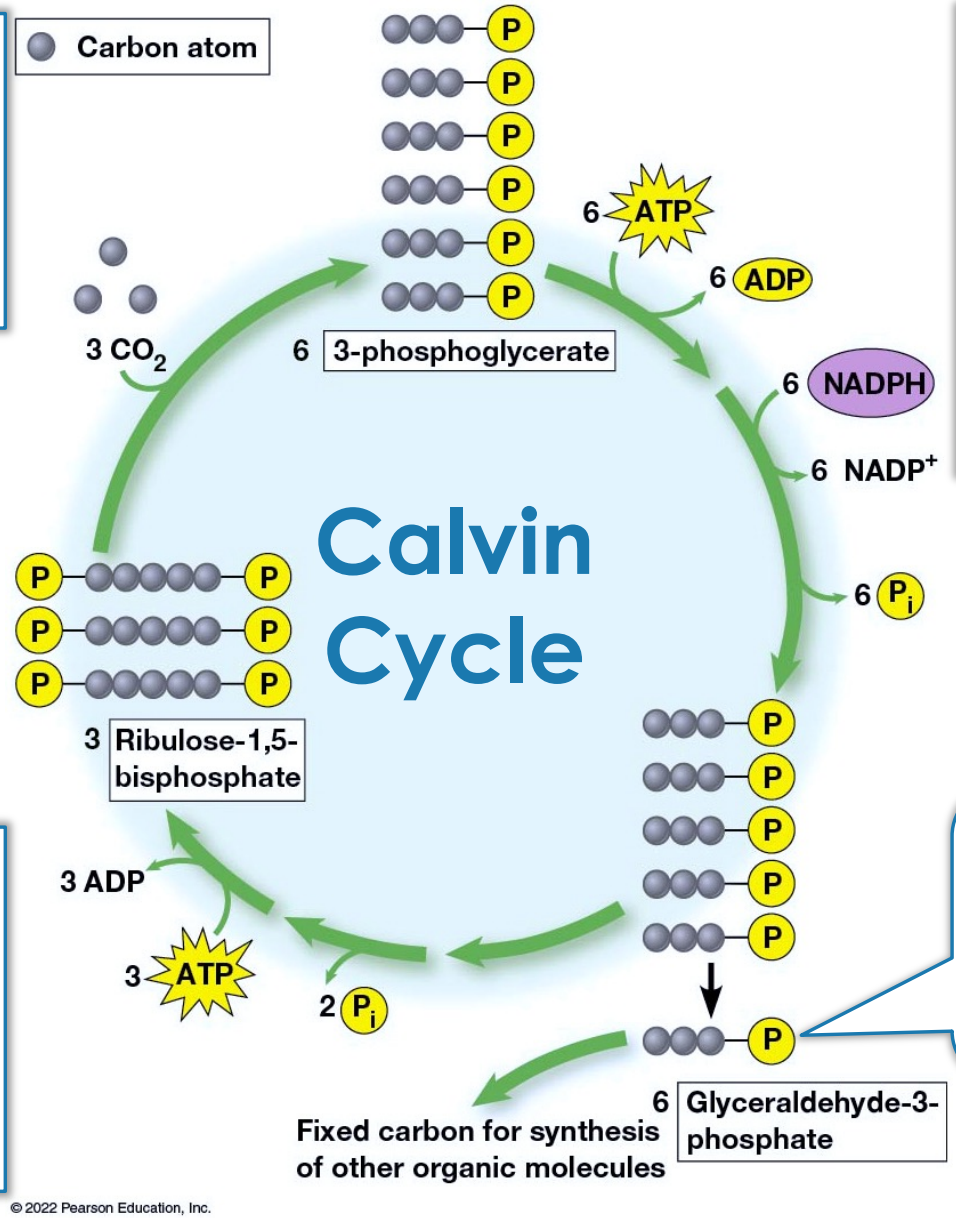
3 x 5-carbon molecules
Ribulose-1,5-bisphosphate

1. Fixation:
3 x 5-carbon molecules
+ 3 x CO_2
→ 6 x 3-carbon molecules

2. Reduction:
6 x 3-carbon molecules converted into a different type of 3-carbon molecule

Core Slide

Figure 11.12: Becker's World of the Cell 10ed



3. Regeneration:
converting the remaining 5 x 3-carbon molecules, to 3 x 5-carbon molecules.

1 x 3-carbon molecule leaves the cycle

This molecule combines with another 3-carbon molecule to make glucose

Overall reaction for photosynthesis

$$6CO_2 + 6H_2O \xrightarrow{\text{plant, light}} C_6H_{12}O_6 + 6O_2$$

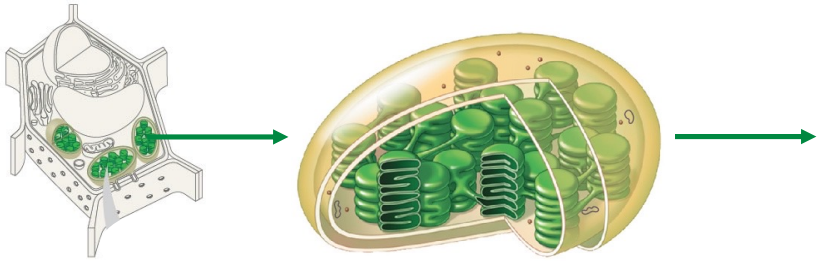
The output of the Calvin cycle is a high energy **3-carbon molecule.** Two of these **3-carbon molecules** are converted to give **glucose**.

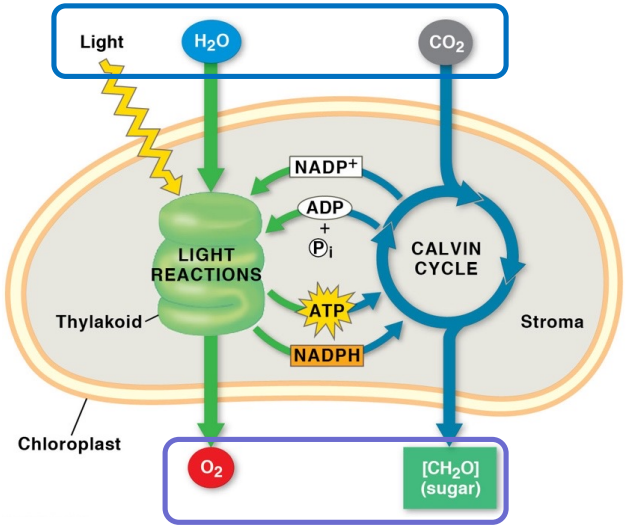
ATP *and* ***NADPH*** *produced in the light reactions are used to fix* CO_2 *and produce carbohydrate*

Plant cells break down glucose from photosynthesis in the mitochondria using cellular respiration.

Photosynthesis: Inputs & Outputs

Inputs: Light, Water, CO_2





Outputs: Glucose, Oxygen

$$6CO_2 + 6H_2O \xrightarrow{\text{plant, light}} C_6H_{12}O_6 + 6O_2$$

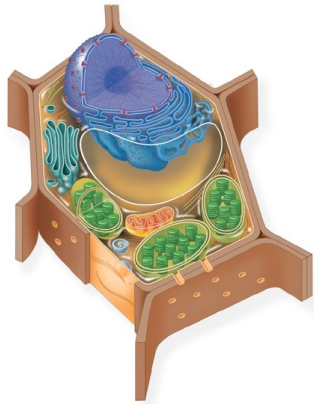
The **ATP** and **NADPH** produced in the light reactions are only used in the **Calvin Cycle**

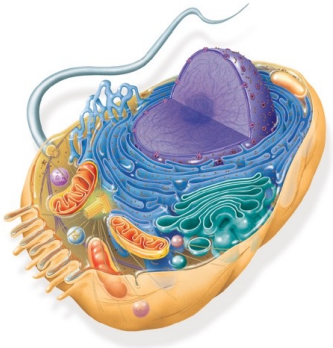
Modified Textbook Figure 7.8

Energy Supply in Plants & Animals: Glucose

- Both plants and animals breakdown glucose in cellular respiration to generate ATP
- Animals must have an external source of glucose
- Plants generate glucose during photosynthesis and then break this down during respiration
- Almost all glucose on Earth has directly or indirectly come from photosynthesis

Plant Cell



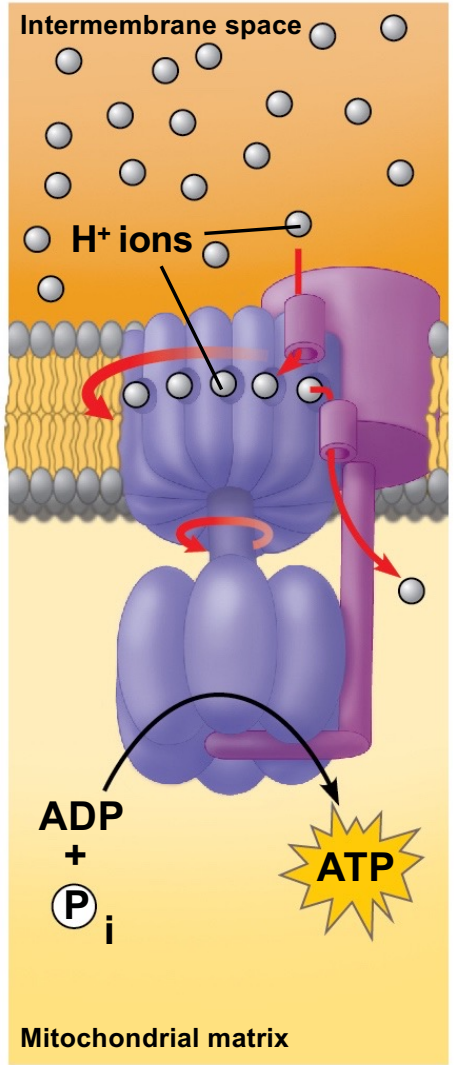


Animal Cell

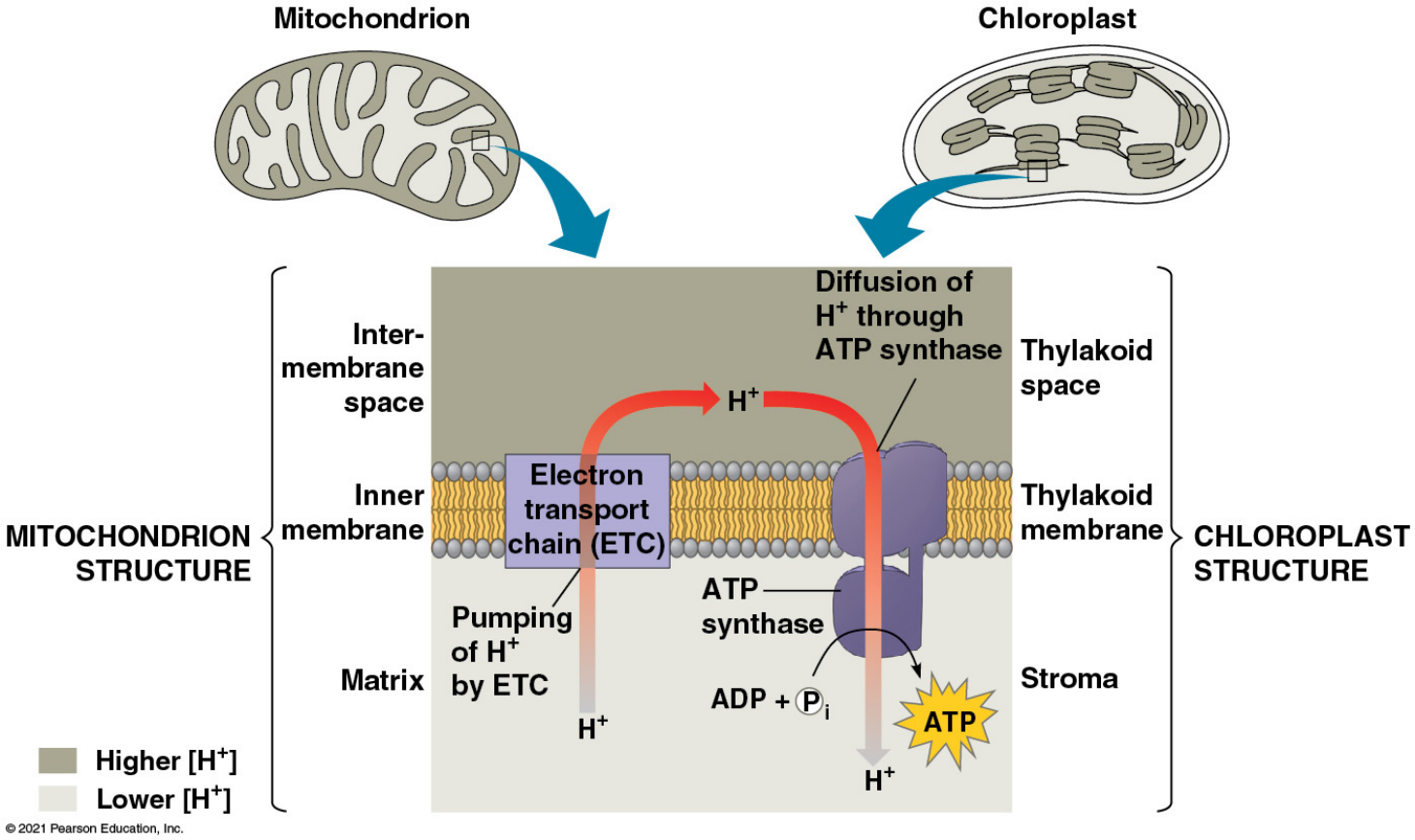
Modified Textbook Figure 10.13

Energy Supply in Plants & Animals: ATP

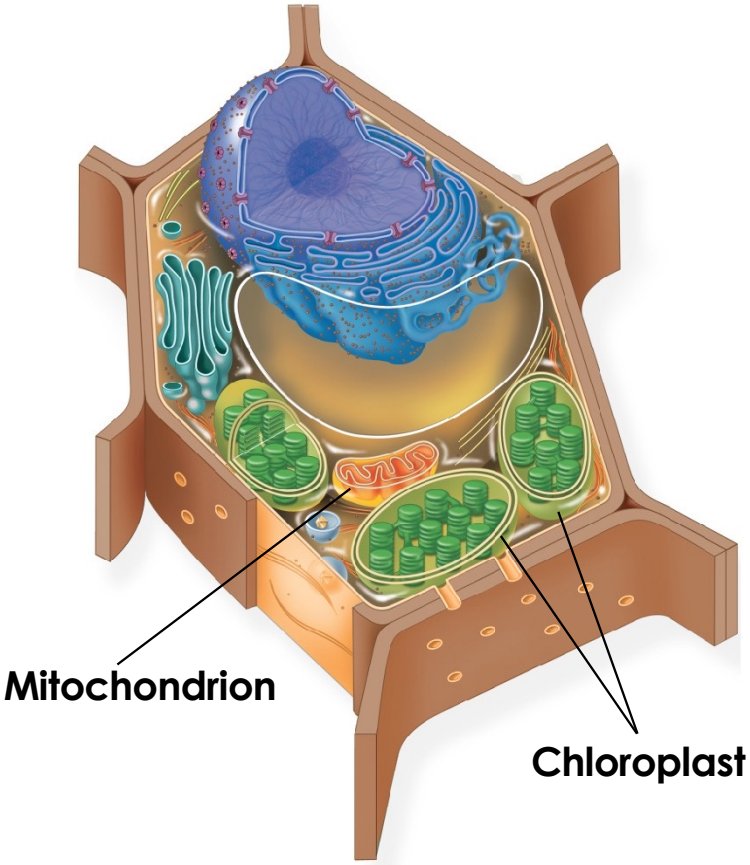
- ATP is generated in both respiration and photosynthesis
- ATP synthase is responsible for ATP generation in both processes
- This requires a proton gradient across a membrane in both the chloroplast and mitochondrion



Energy Supply in Plants & Animals: ATP Synthase



The Origin of Chloroplasts & Mitochondria

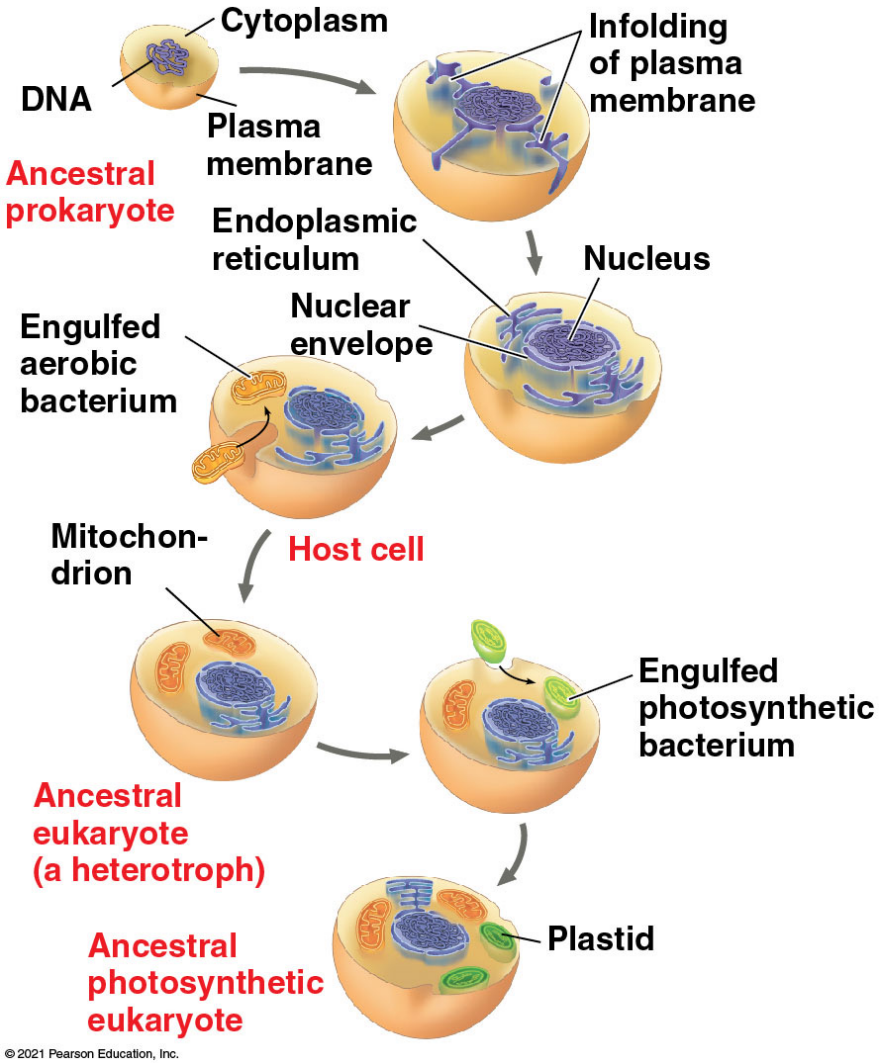


- Mitochondria and chloroplasts both contain DNA, ribosomes and are able to make some proteins

- Both have an outer and inner membrane *(chloroplasts have a third membrane system too)*

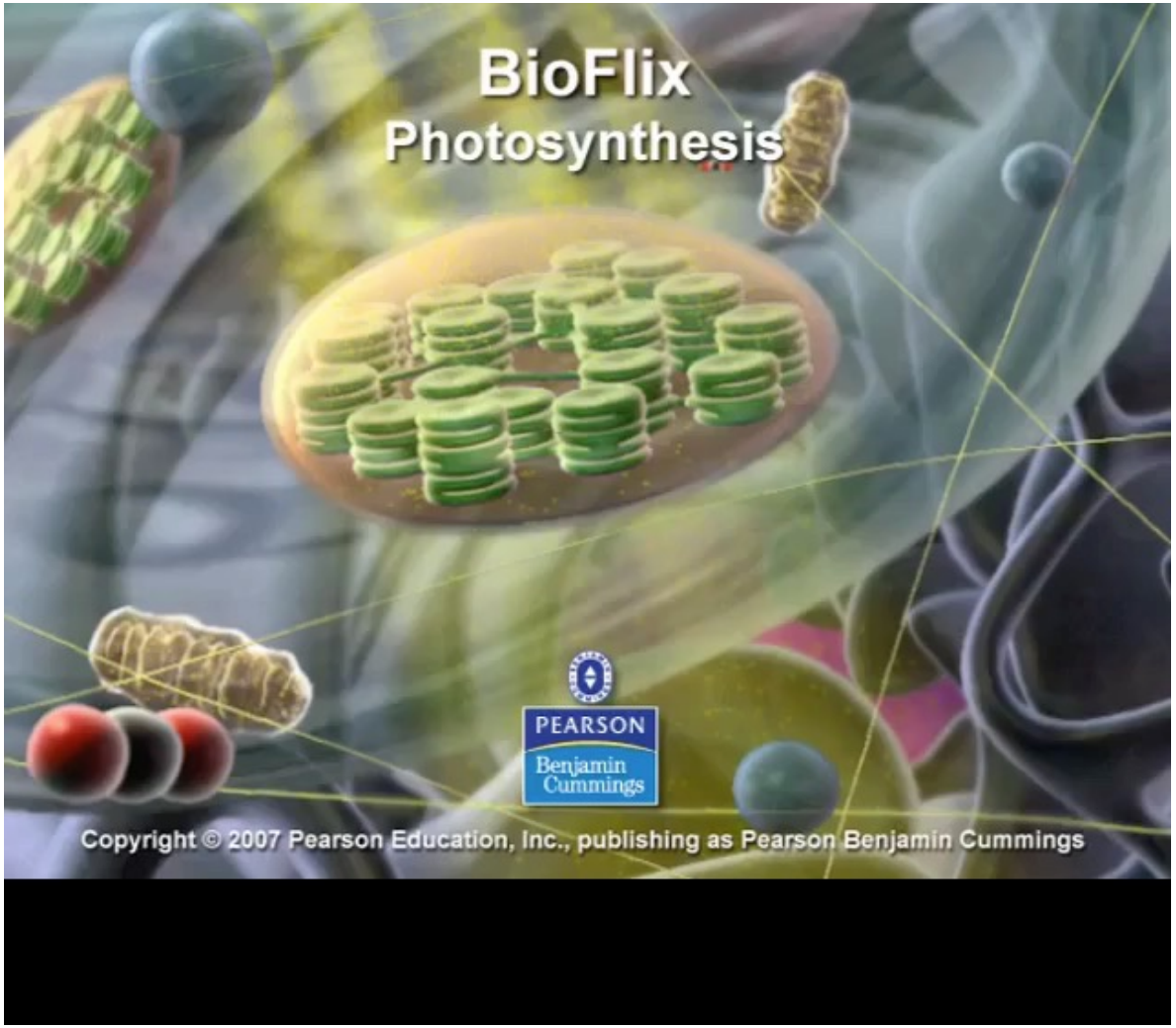
Textbook Figure 25.10

The Origin of Chloroplasts & Mitochondria



Context Slide

Textbook Bioflix Animation



Lecture 7 Summary

- Chloroplast has a three-membrane structure that houses the different stages of photosynthesis.
- The light reactions convert light energy into chemical energy.
- The carbon fixation reactions use the products of the light reactions to fix CO_2 into energy rich sugar molecules.
- Animals and plants both break down sugars in cellular respiration.
- Photosynthesis and cellular respiration have common features.
- The endosymbiotic theory supports chloroplasts and mitochondria originating from independent organisms.

Objective-Based Questions

1. Where is the chloroplast do the light reactions occur?

- A. thylakoid lumen
- B. thylakoid membrane
- C. inner membrane
- D. stroma

2. What products of the light reaction are used in carbon fixation?

- A. oxygen, ATP, NADPH
- B. oxygen, ATP
- C. oxygen, NADPH
- D. ATP, NADPH

3. Which stage in the Calvin cycle is a 5-carbon compound made?

- A. Fixation
- B. Reduction
- C. Oxidation
- D. Regeneration

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Photosynthesis

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