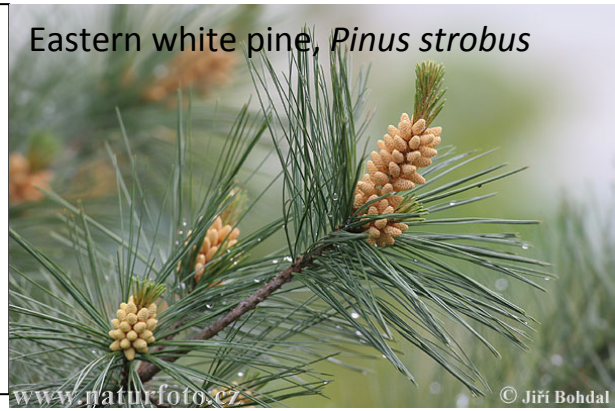


Plant metabolism

Chapter 4, pp. 56-63



Lecture Outline:

Intro to metabolism and energy

Photosynthesis converts solar energy to chemical energy of food

Structure and function of **chloroplasts**

Chlorophyll is the light-absorbing *pigment* in plant chloroplasts

The ***light reactions*** convert solar energy to the chemical energy of ATP and NADPH

The ***Calvin cycle*** uses the chemical energy of ATP and NADPH to make sugar from CO_2

Cellular respiration breaks down food to create usable energy for the cell in the form of ATP

Structure and function of **mitochondria**

The 3 phases of cellular respiration: glycolysis, Kreb's cycle and the electron transport chain

Biofuels: Using enzymes to make corn ethanol



A vial of enzymes for cellulosic ethanol production.
Denmark-based company Novozyme

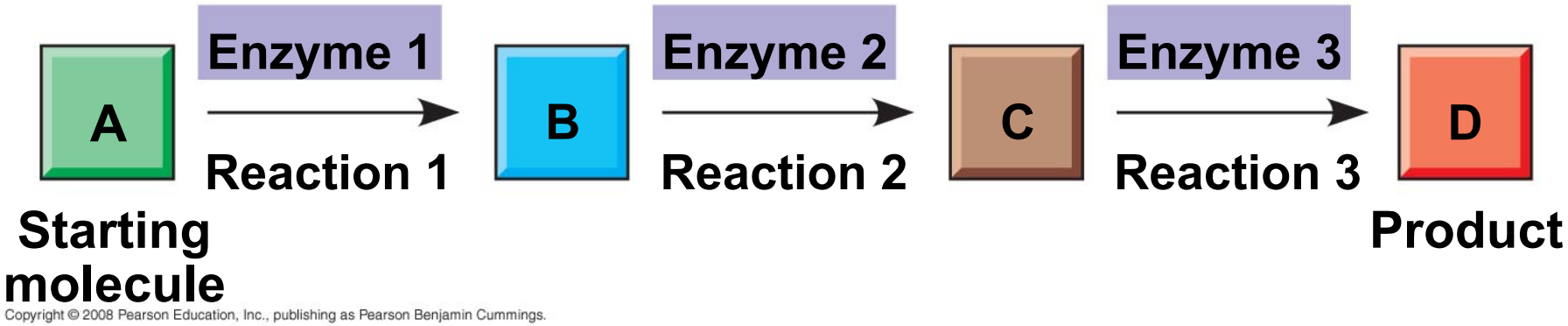
Link to NYT story on Blackboard.

enzyme = a protein catalyst used for a specific chemical reaction

Corn ethanol production has traditionally used enzymes to break down *starch* (e.g., from corn kernel) to make ethanol.

The future → <u>Cellulosic ethanol</u> using enzymes to break down *cellulose* (e.g., from cornstalks) to make ethanol.

Metabolism **–** all chemical reactions in an organism



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A, B, C = REACTANTS → **D = PRODUCT**

Forms of energy

Energy is the capacity to cause change

1. ***Kinetic energy*** – energy of motion
   – eg., thermal energy or light
   – light powers *photosynthesis*
2. ***Potential energy*** – energy possessed by matter due to its location or structure
   – eg., chemical energy stored in bonds of molecules
   – chemical energy in food powers *cellular respiration*

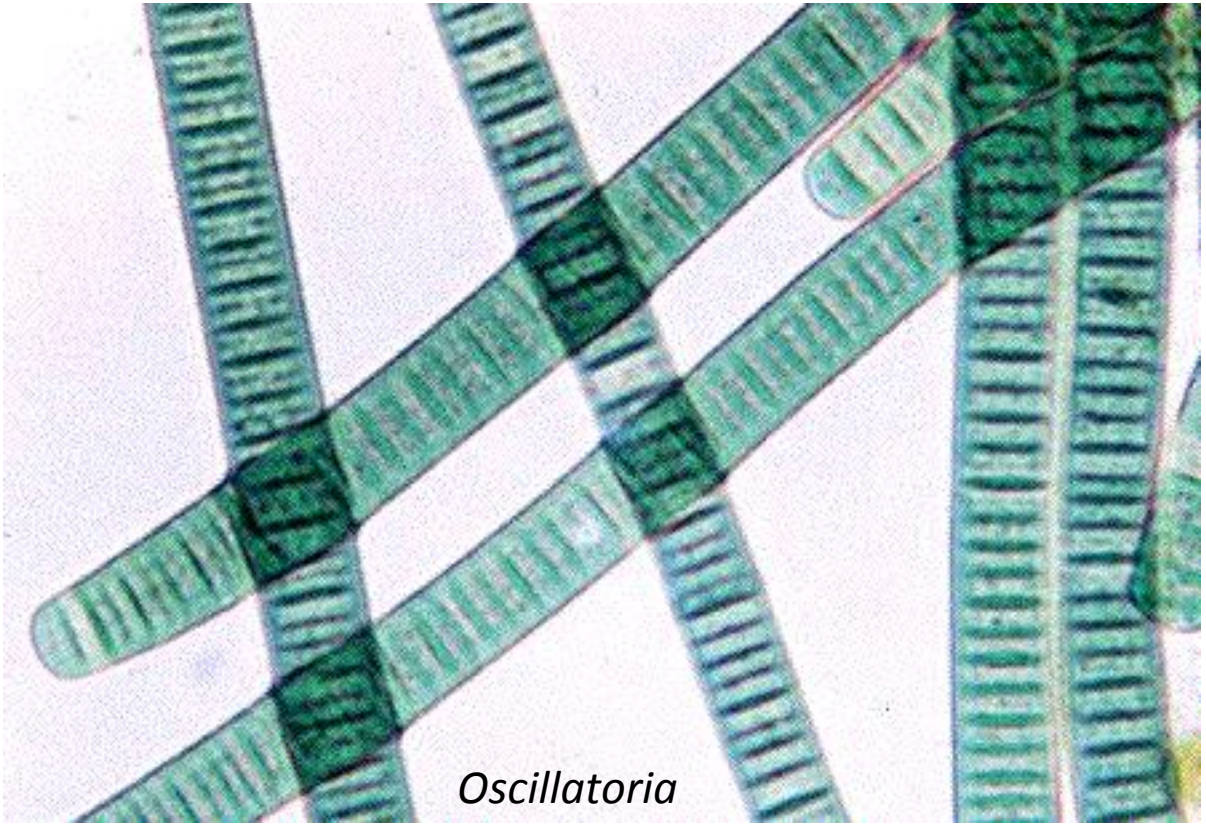


Understanding photosynthesis will help build more efficient photovoltaic panels

"The photosynthetic system of plants is nature's most elaborate nanoscale biological machine. It converts light energy at unrivaled efficiency of more than 95 percent compared to 10 to 15 percent in the current man-made solar technologies. In order to capture that efficiency in solar energy technology, we must first tackle the basic science of photosynthesis by understanding the chemistry behind its ultra-efficient energy conversion process in nature."

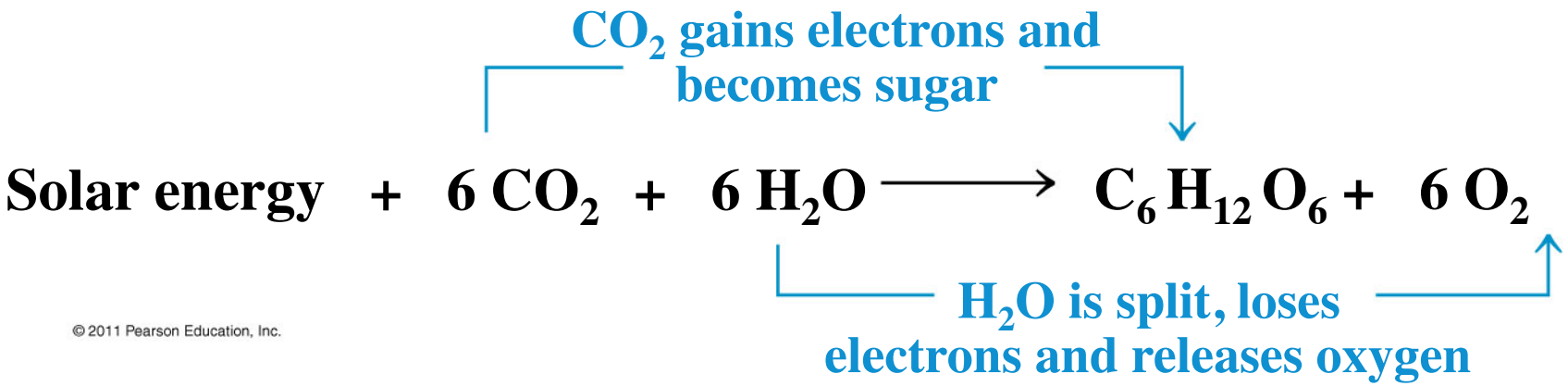
K. V. Lakshmi, assistant professor of chemistry and chemical biology at Rensselaer Polytechnic Institute in Troy, NY

Cyanobacteria ("blue green algae"), 3.5 billion year old photosynthetic prokaryotes



www.ucmp.berkeley.edu

Photosynthesis = The conversion of light energy to chemical energy that is stored in sugars or other organic compounds



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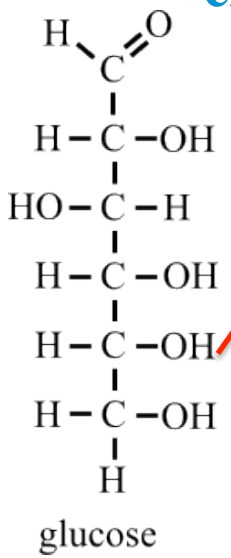
Photosynthesis = The conversion of light energy to chemical energy that is stored in sugars or other organic compounds

CO_2 gains electrons and becomes sugar

$$\text{Solar energy} + 6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$$

H_2O is split, loses electrons and releases oxygen

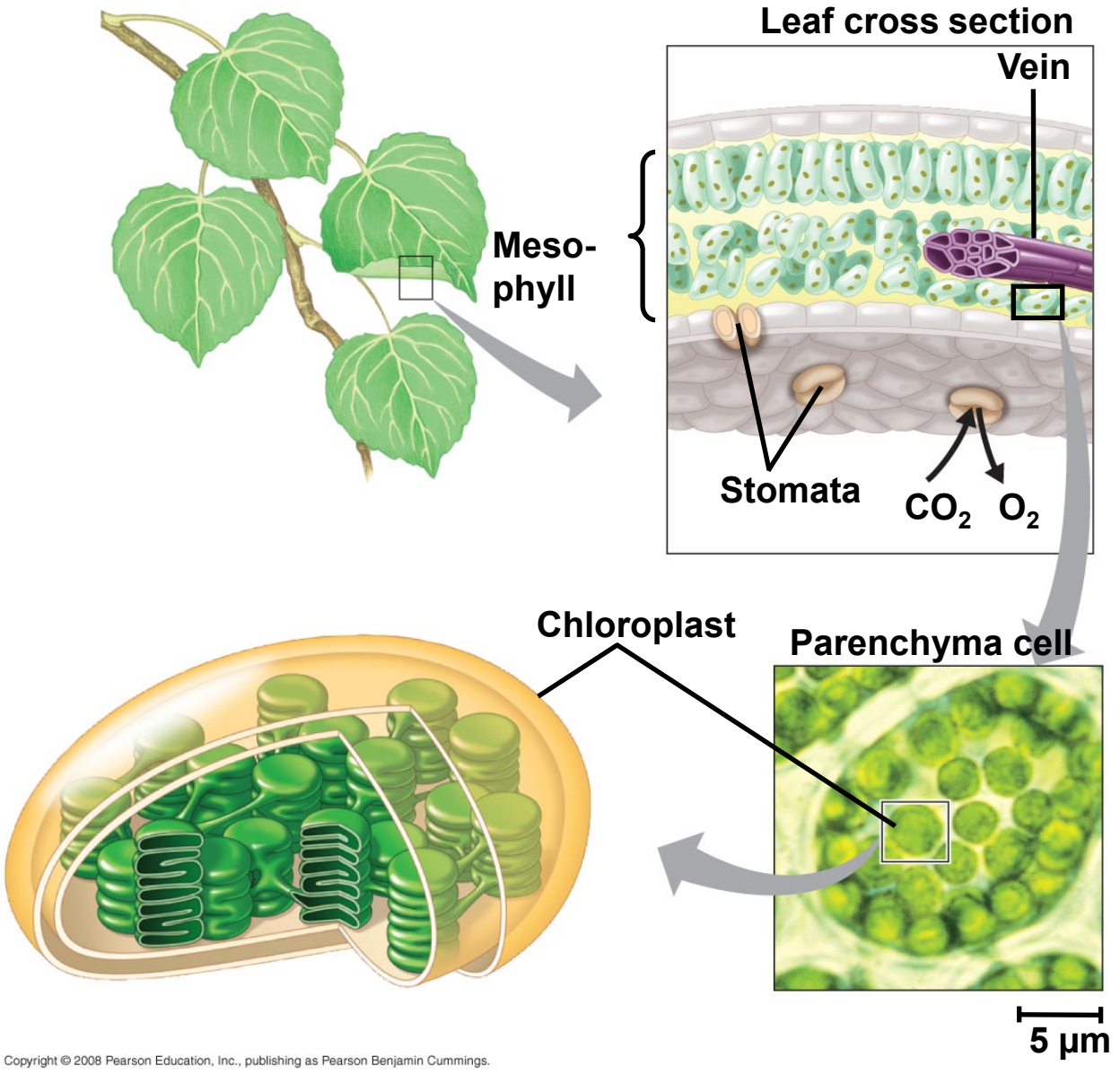
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sugar has lots of *potential energy* because of its chemical structure

Leaves are the plant's major photosynthetic organ

Leaves contain *mesophyll tissue* and parenchyma cells containing many **chloroplasts**



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Overview of photosynthesis

Light reactions

Calvin cycle



H_2O

Thylakoid

Light

Light Reactions



ATP

NADPH

O_2

Chloroplast

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The "energy currency" of the cell:

Sunlight is an energy source that is hard to spend in the cell. It's kind of like having a really big bill in your pocket: you're rich, but you can't use it!



The “energy currency” of the cell:

By contrast, the molecules **ATP** and **NADPH** are easily spent, like pocket change: chemical bond energy stored in these molecules is easily released, making these molecules quick sources of energy for cellular reactions.





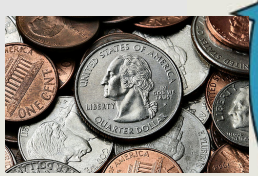
H_2O

Thylakoid

CO_2

Light

Light Reactions



Calvin Cycle

ATP

NADPH

Chloroplast

O_2

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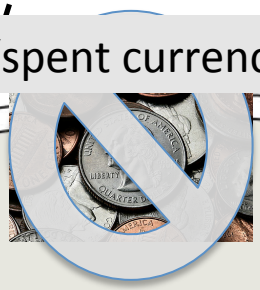


H_2O

Thylakoid

CO_2

"spent currency"



Light

$NADP^+$

ADP + P_i

Light Reactions

Calvin Cycle

ATP

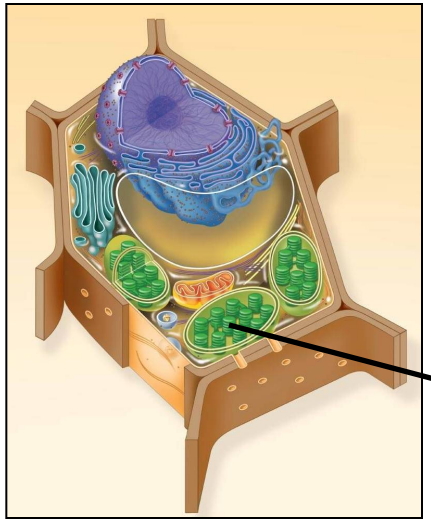
NADPH

Chloroplast

O_2

$[CH_2O]$ (sugar)

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Light

Reflected light

Chloroplast

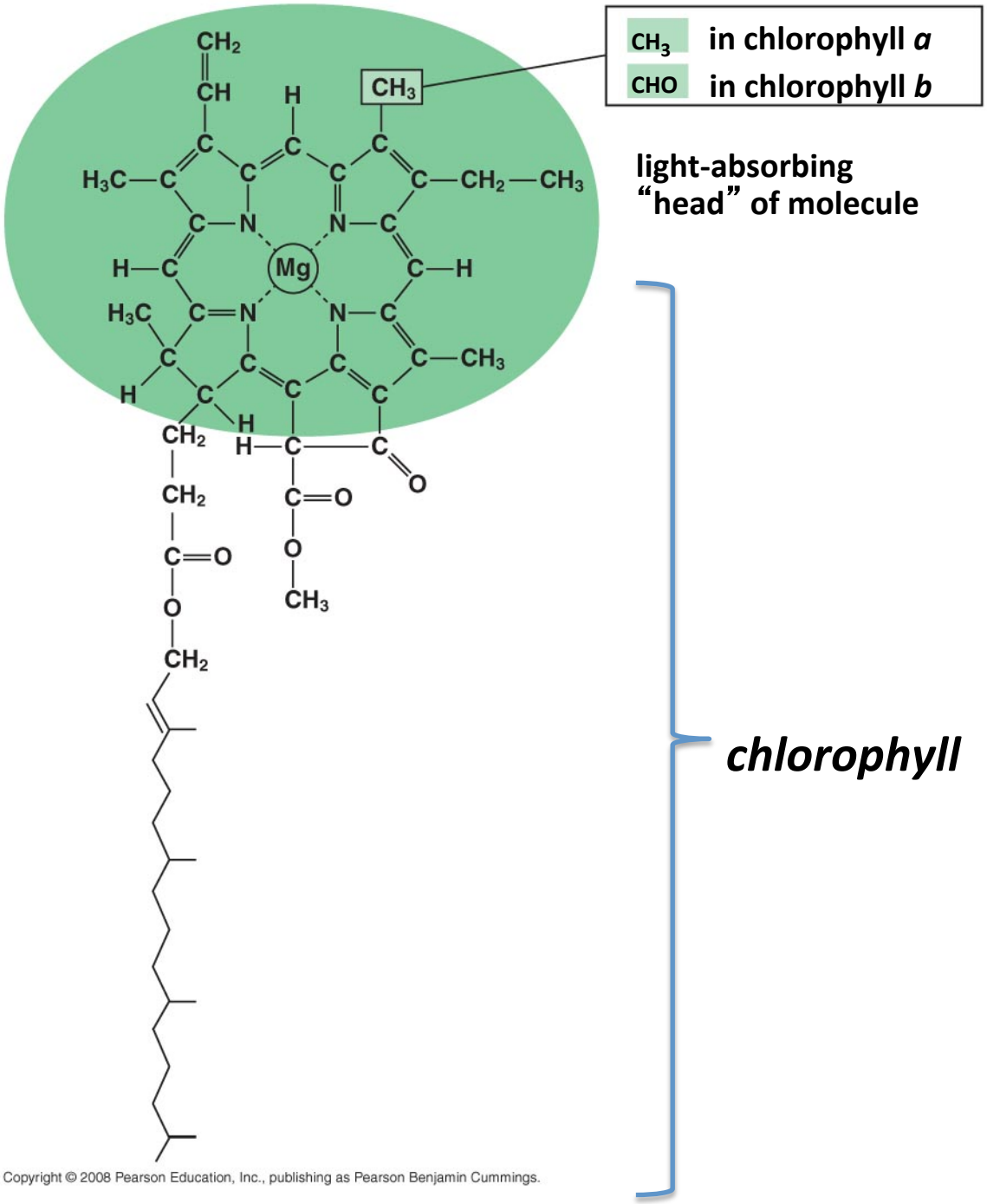
Absorbed light

Transmitted light

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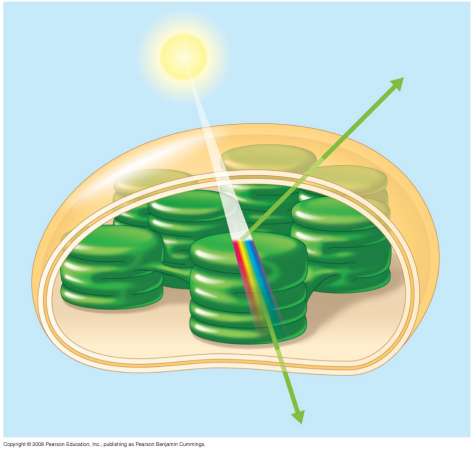
Pigments like *chlorophyll* absorb light of certain wave-lengths

- the other wavelengths are reflected or transmitted
- this is why leaves are green



The **light reactions** convert light energy from the sun to the chemical energy of ATP and NADPH

Photosystems - complexes of proteins and chlorophyll that absorb light energy



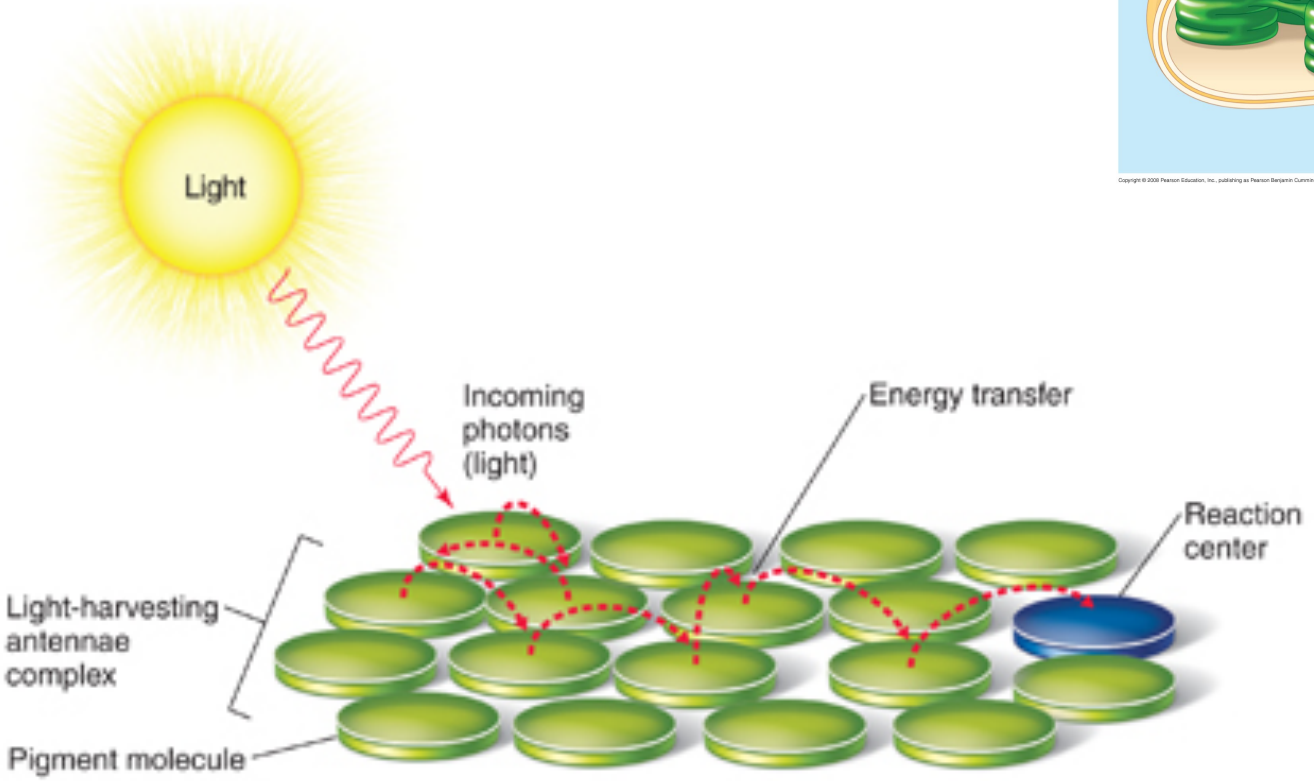


Figure 4.9 Photosystem. Each photosystem is composed of several hundred chlorophyll and carotenoid molecules that make up light-harvesting antennae. When light strikes a pigment molecule, the energy is transferred and funneled into a reaction center.



H_2O

Thylakoid

Light

Light Reactions



ATP

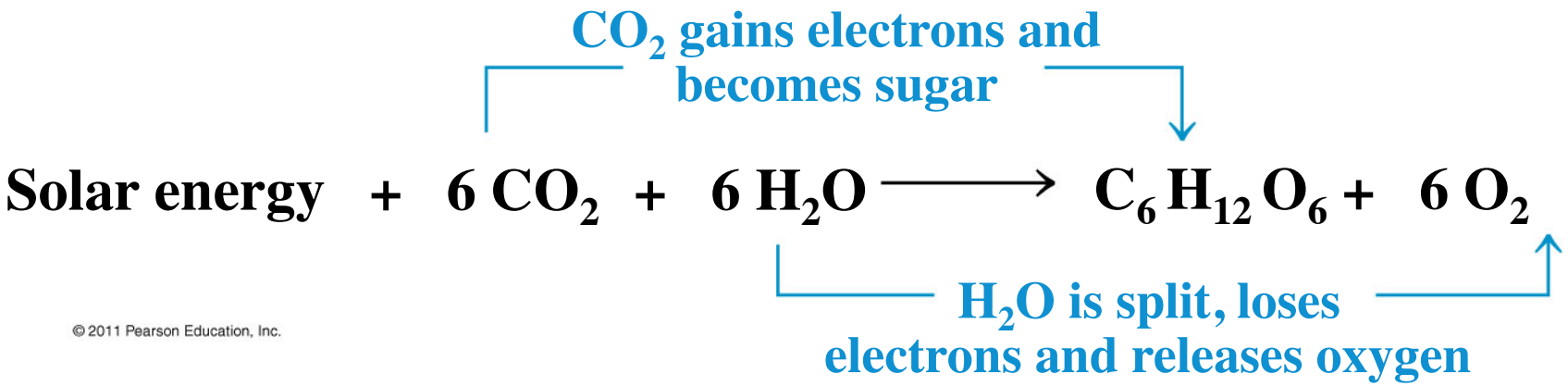
NADPH

O_2

Chloroplast

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Photosynthesis = The conversion of light energy to chemical energy that is stored in sugars or other organic compounds

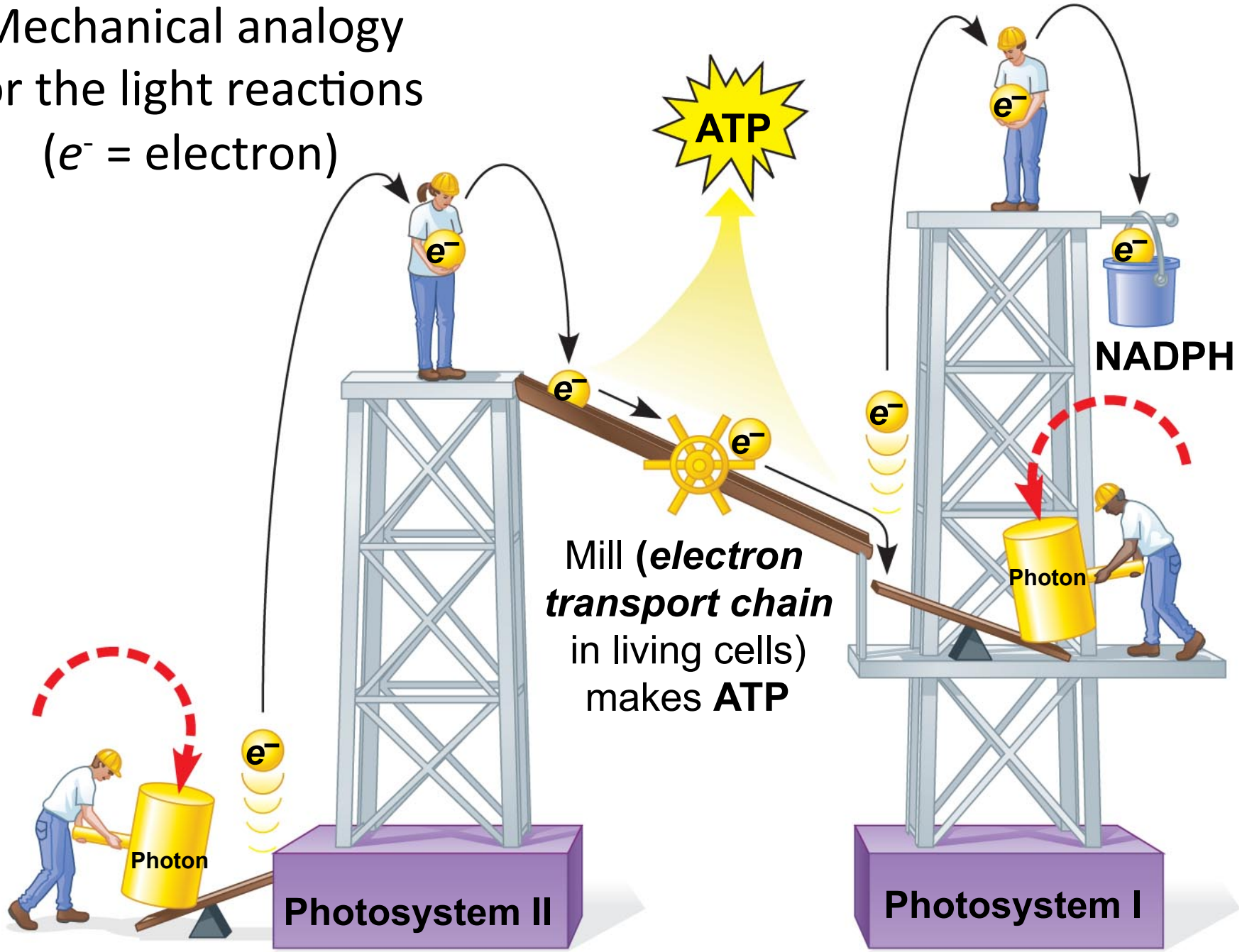


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Details of ***light reactions*** in the ***thylakoid membranes*** of the *chloroplast*

1. Light is absorbed by ***chlorophyll pigments*** in the photosystem II, releasing **electrons**.
2. H_2O is split, releasing a constant stream of **electrons** and **O_2** as a byproduct
3. Electrons release energy as they are passed from photosystem II to photosystem I via an ***electron transport chain.*** This energy is used to make **ATP.**
4. The electrons are passed to *electron carrier molecule* **NADPH**

Mechanical analogy for the light reactions (e^- = electron)



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H_2O

Thylakoid

Light

Light Reactions



ATP

NADPH

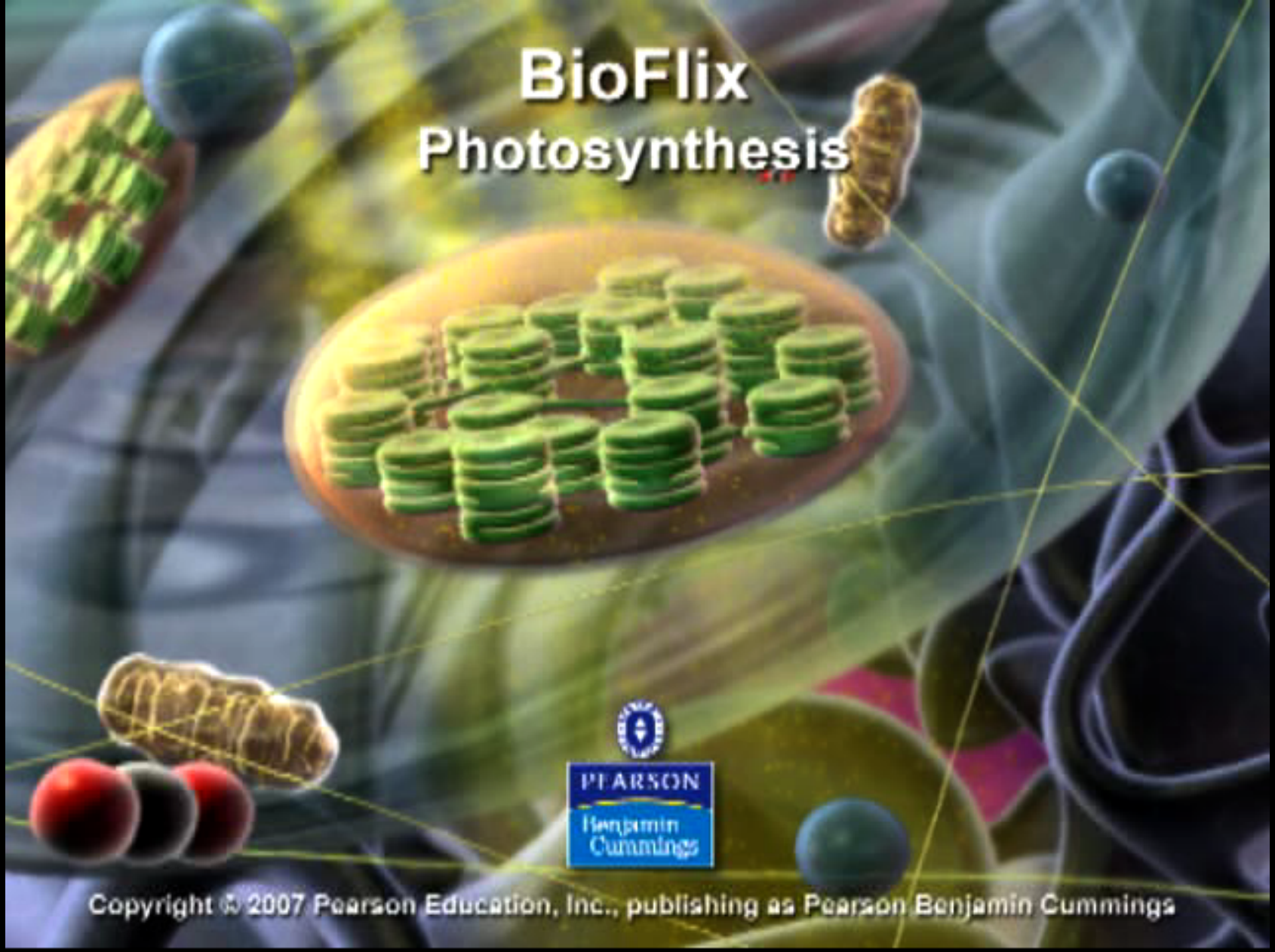
O_2

Chloroplast

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4. The electrons are passed to *electron carrier molecule* **NADPH**
5. NADPH holds onto the electrons and bring them to the **Calvin cycle** (where sugars are made)**.**


BioFlix
Photosynthesis
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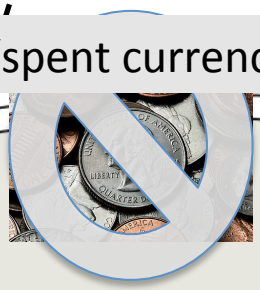


H_2O

Thylakoid

CO_2

"spent currency"



Light

$NADP^+$

ADP + P_i

Light Reactions

Calvin Cycle

ATP

NADPH

Chloroplast

O_2

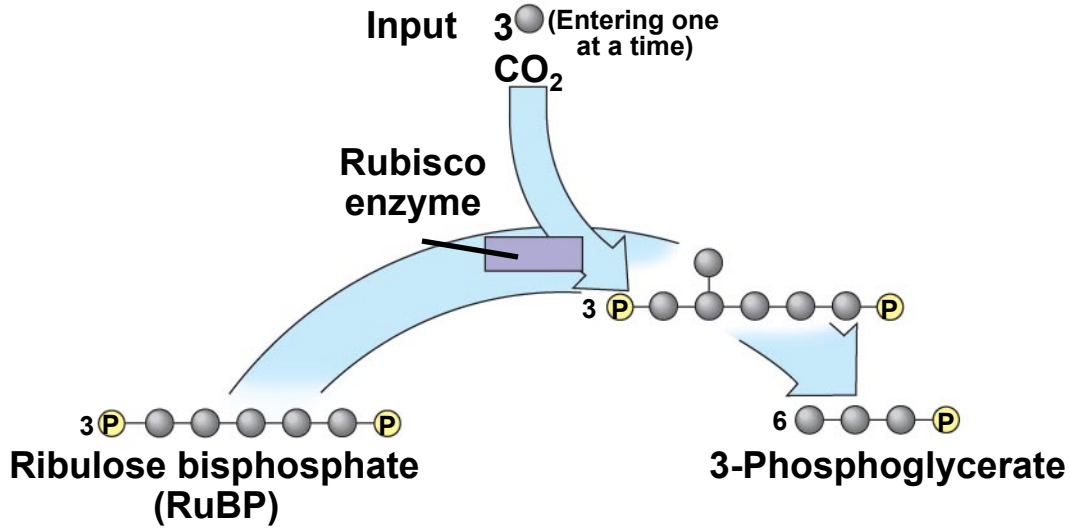
$[CH_2O]$ (sugar)

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The **Calvin cycle** is a series of ***carbon fixation reactions***

- CO_2 is "fixed" (i.e., bonded) to an organic compound
- the chemical energy of ATP and NADPH from the light reactions is used to make ***sugar*** from CO_2

carbon
phosphorus



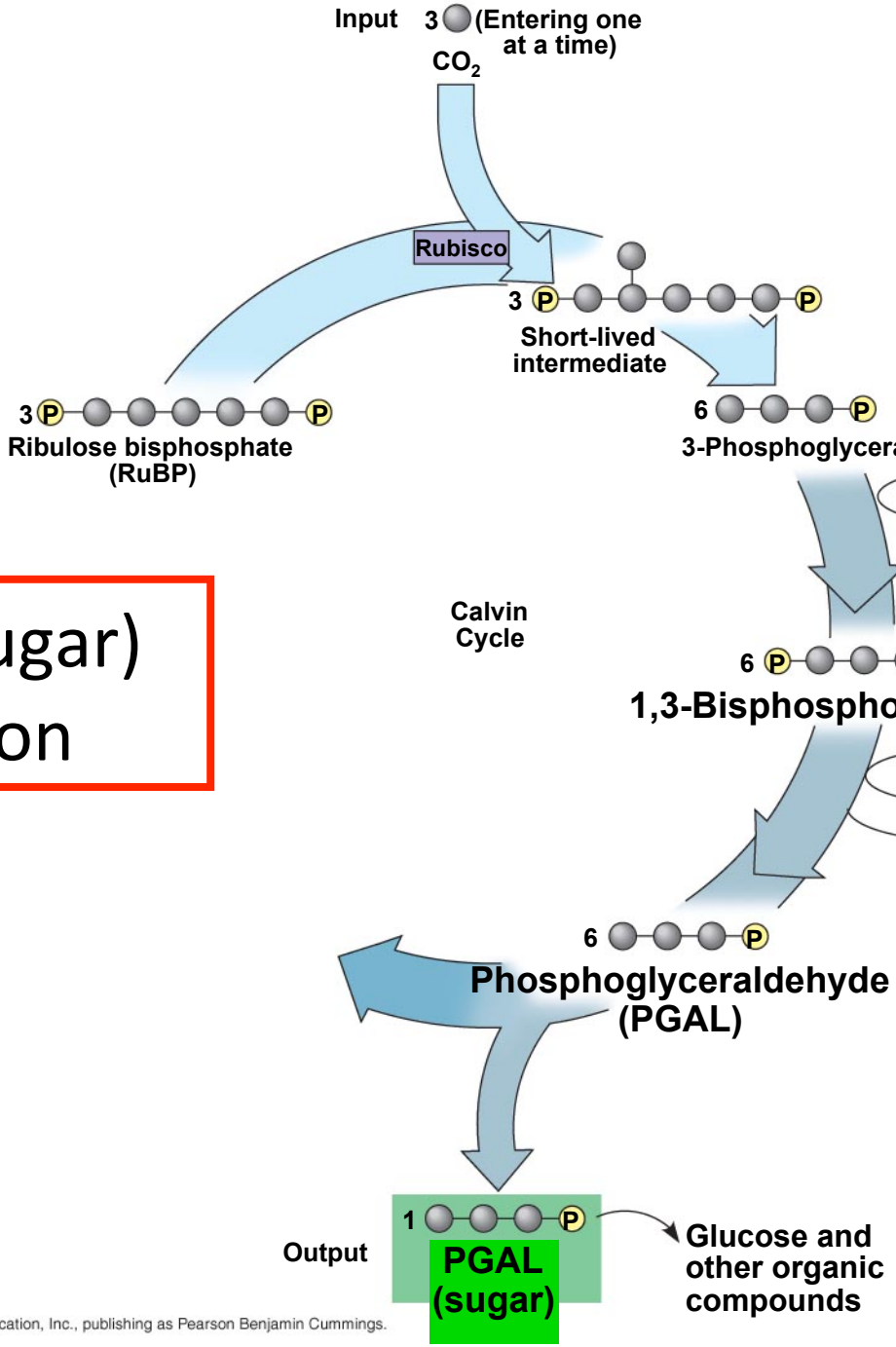
1. Carbon fixation - rubisco enzyme "fixes" CO_2 with RuBP (a 5-C molecule)

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carbon

P phosphorus

2. PGAL (sugar) production



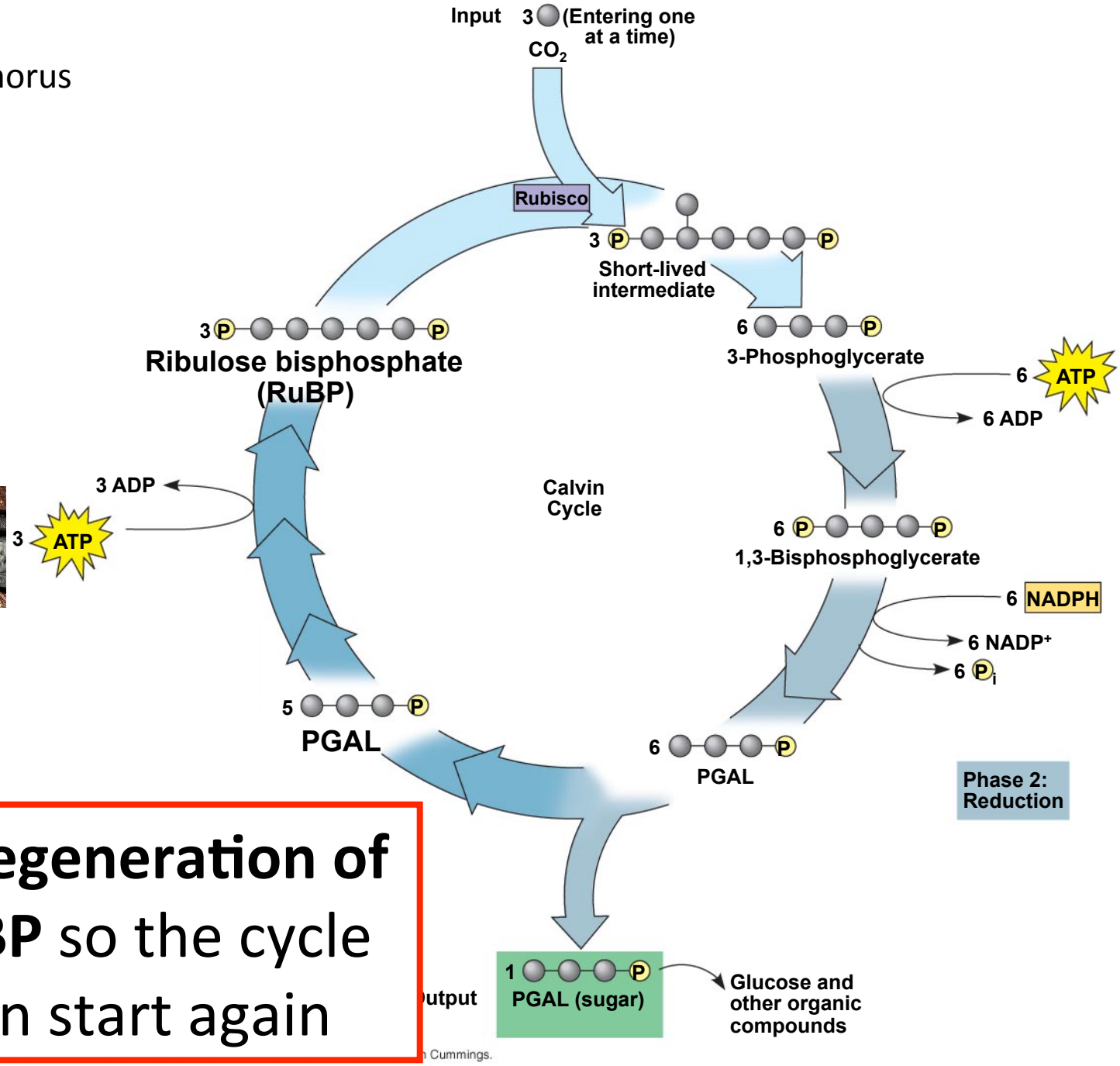




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carbon
phosphorus

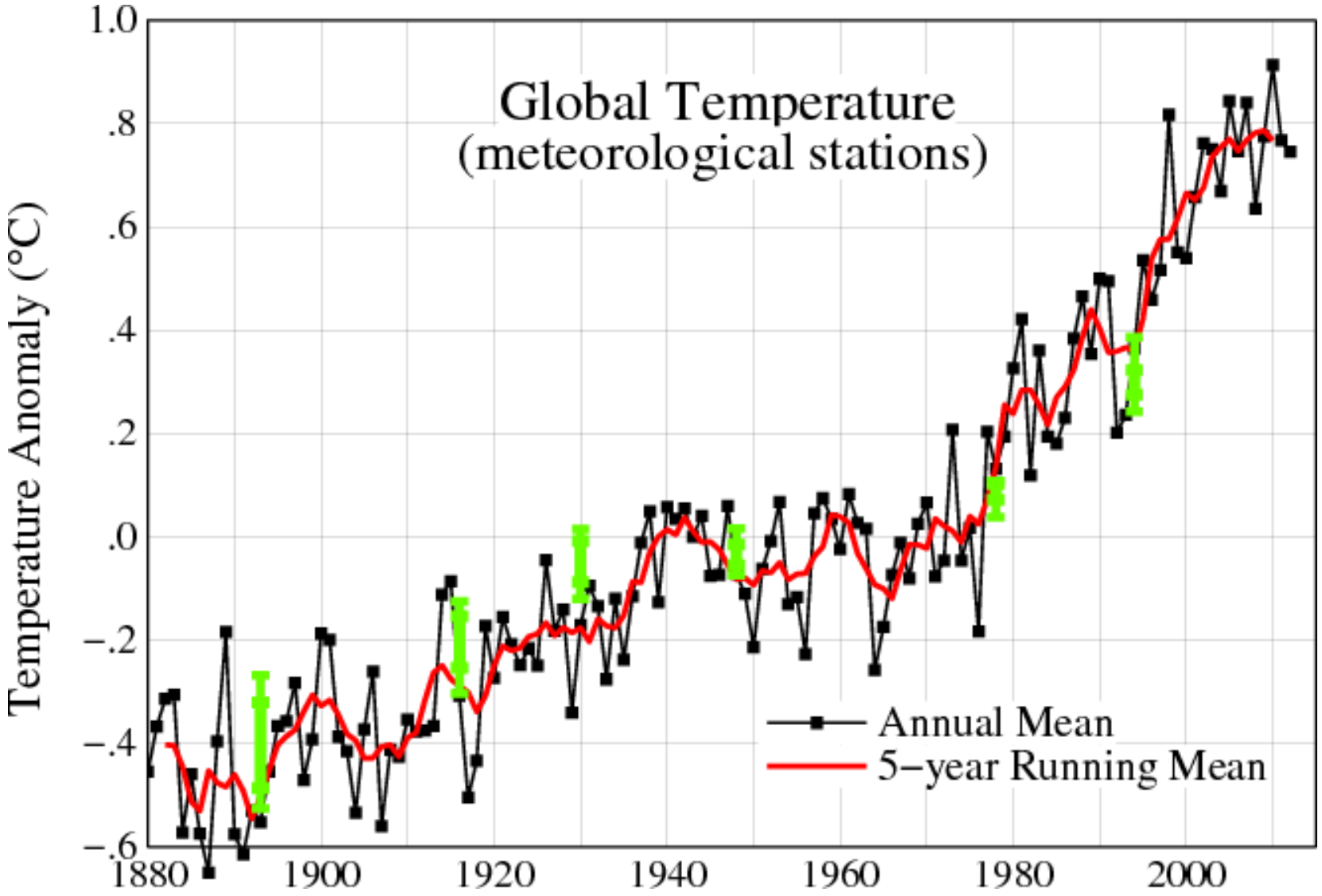




3. Regeneration of RuBP so the cycle can start again

Cummings.

Carbon fixation and climate change



http://data.giss.nasa.gov

Lecture Review, Chap 4 Metabolism

- What is metabolism?
- What is an enzyme? How does an enzyme facilitate metabolism in the cell?
- What is energy? Describe the 2 kinds of energy. What is the energy molecule of the cell produced by the light reactions of photosynthesis?
- Describe the structure and function of a chloroplast.
- What is a pigment? What is the most important pigment in photosynthesis?
- What are the major inputs and products of the light reactions?
- What are the major inputs and products of the Calvin cycle?
- What role do electrons play in producing energy needed to make sugar from CO_2?