Photosynthesis

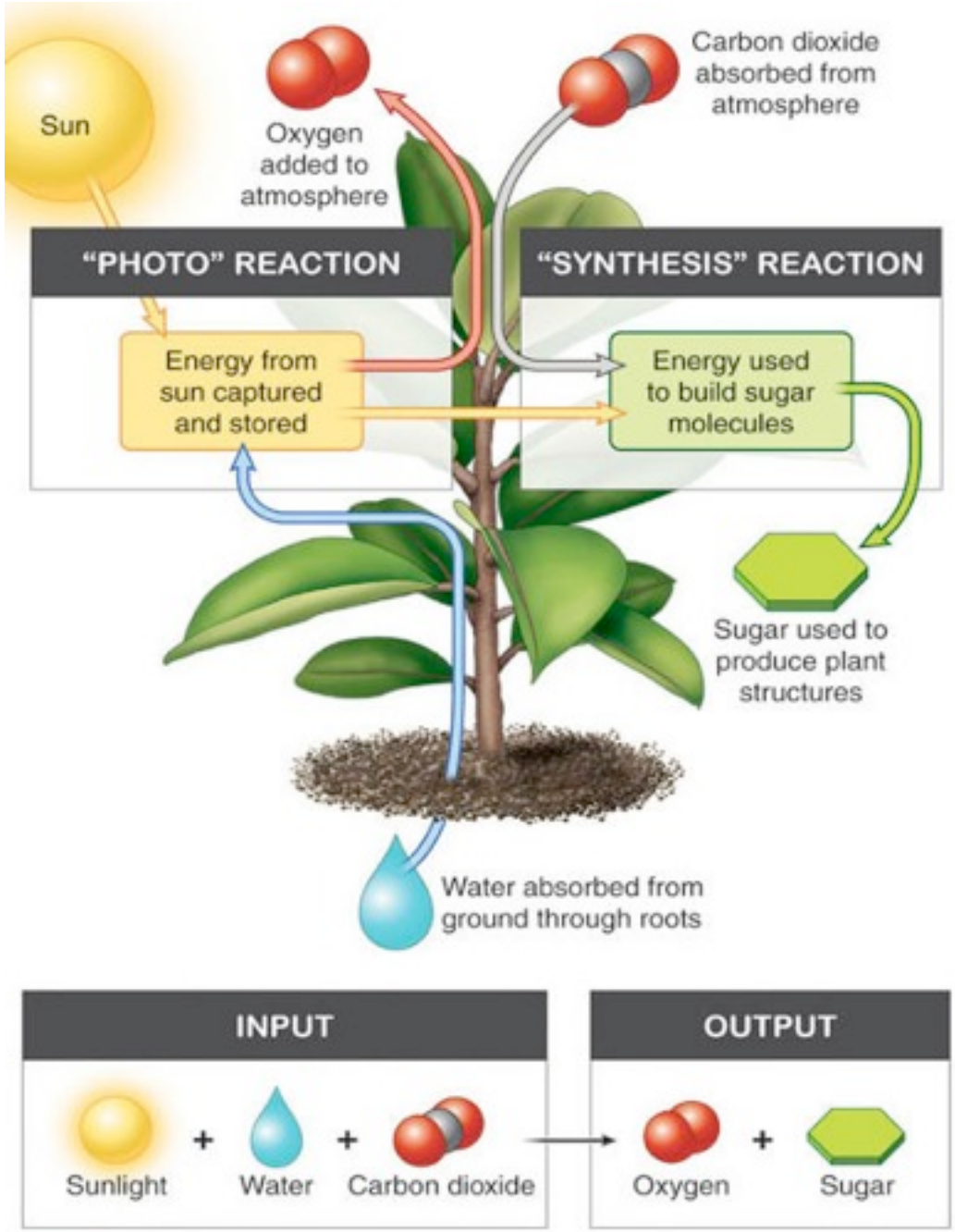


Figure 4-10 Photosynthesis: the big picture.

Photosynthesis in Overview

- Process by which plants and other autotrophs store the energy of sunlight into sugars.
- Requires sunlight, water, and carbon dioxide.
- Overall equation:

$$6\ CO_2 + 6\ H_20 \rightarrow C_6H_{12}O_6 + 6\ O_2$$

- Occurs in the leaves of plants in organelles called chloroplasts.

PHOTOSYNTHESIS!

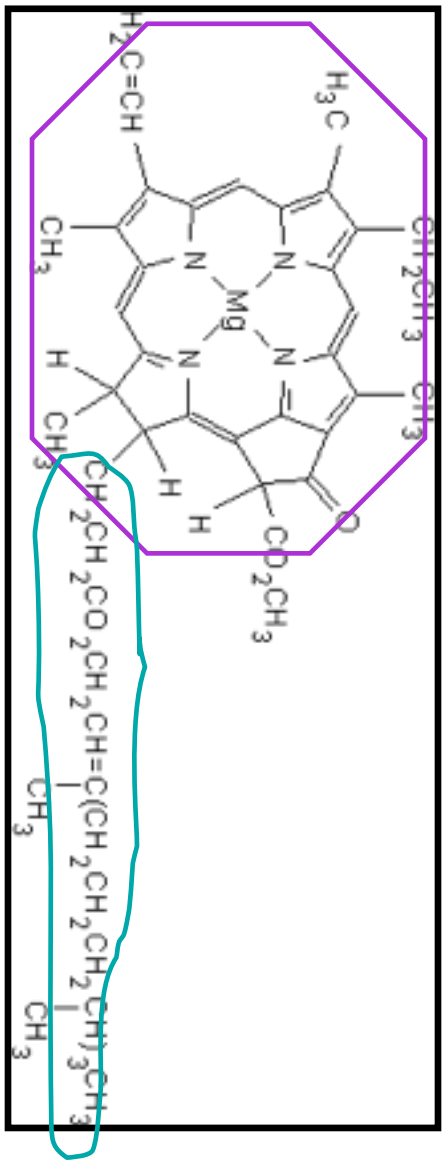
- a reaction whereby **plants** are able to **convert** the **sun's energy** into **glucose**!

- photosynthesis happens in:
  - **plants!**
  - **algae!**
  - **plant-like protists!**
  - **cyanobacteria!**

- Photosynthesis starts when CHLOROPHYLL absorbs light energy and begins the process!

PHOTOSYNTHESIS!

- Chlorophyll molecules contain a **porphyrin ring** and long **hydrocarbon tail**.
- The **tail is hydrophobic** anchors the molecule into a membrane
- The **porphyrin ring contains electrons that absorb light energy** and begin the process of photosynthesis.



PHOTOSYNTHESIS!

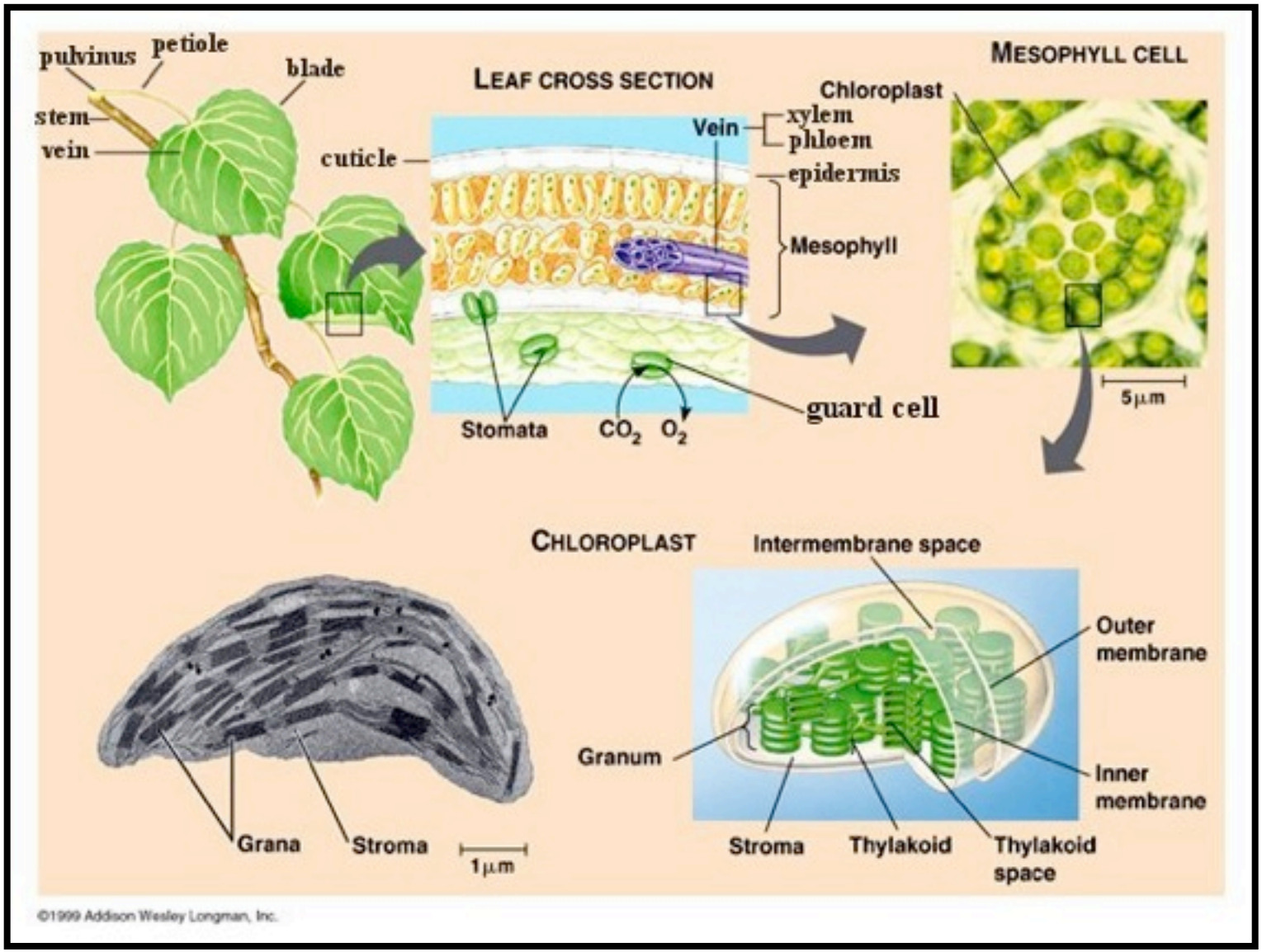
- Where does photosynthesis happen?!?!?!

IN THE LEAVES!!!

The primary function of a leaf is photosynthesis!

Their arrangement on stems and branches maximizes the surface area exposed to sunlight!

PHOTOSYNTHESIS!

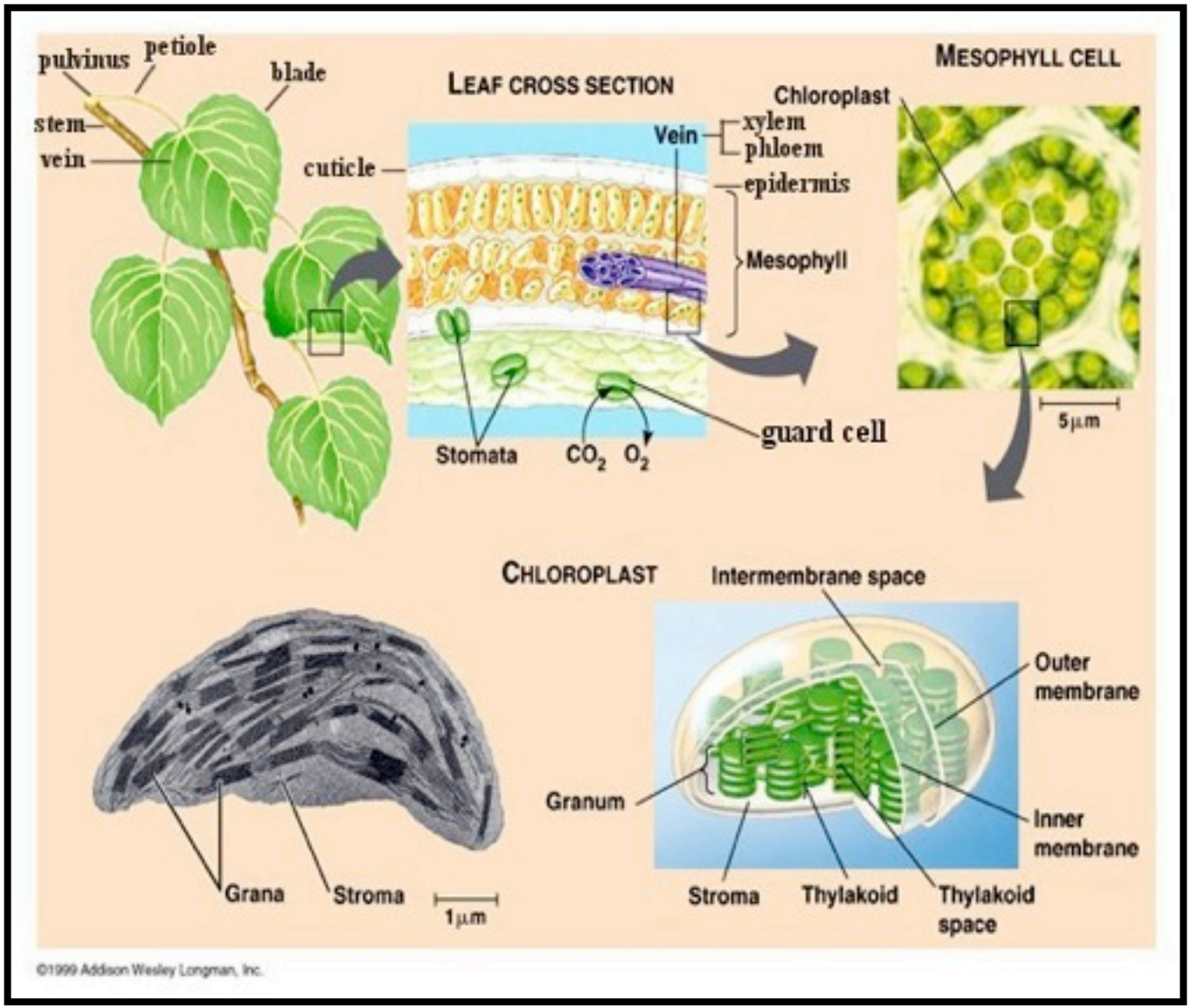


Leaf is coated with a water-resistant **waxy cuticle** layer.

Epidermis layer is transparent and colorless and allows light to pass freely.

Chloroplasts are most abundant in the **mesophyll cells** – this is <u>where most of photosynthesis takes place!</u>

PHOTOSYNTHESIS!



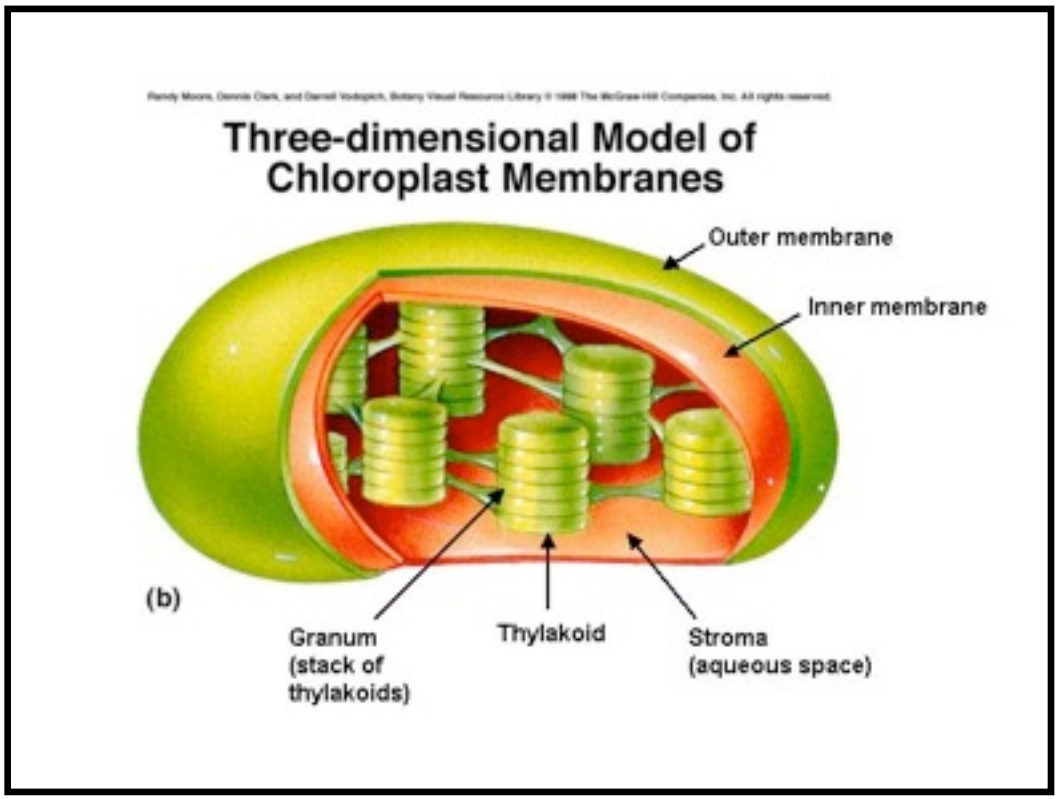
Guard cells create microscopic openings called stomata.

Stomata = openings on the surface of the leaf that **regulate the exchange of CO_2 and O_2** with the atmosphere.

Stomata = also allow water vapour to escape by **transpiration**.

PHOTOSYNTHESIS!

- The **chloroplast** is the photosynthesis factory!!!



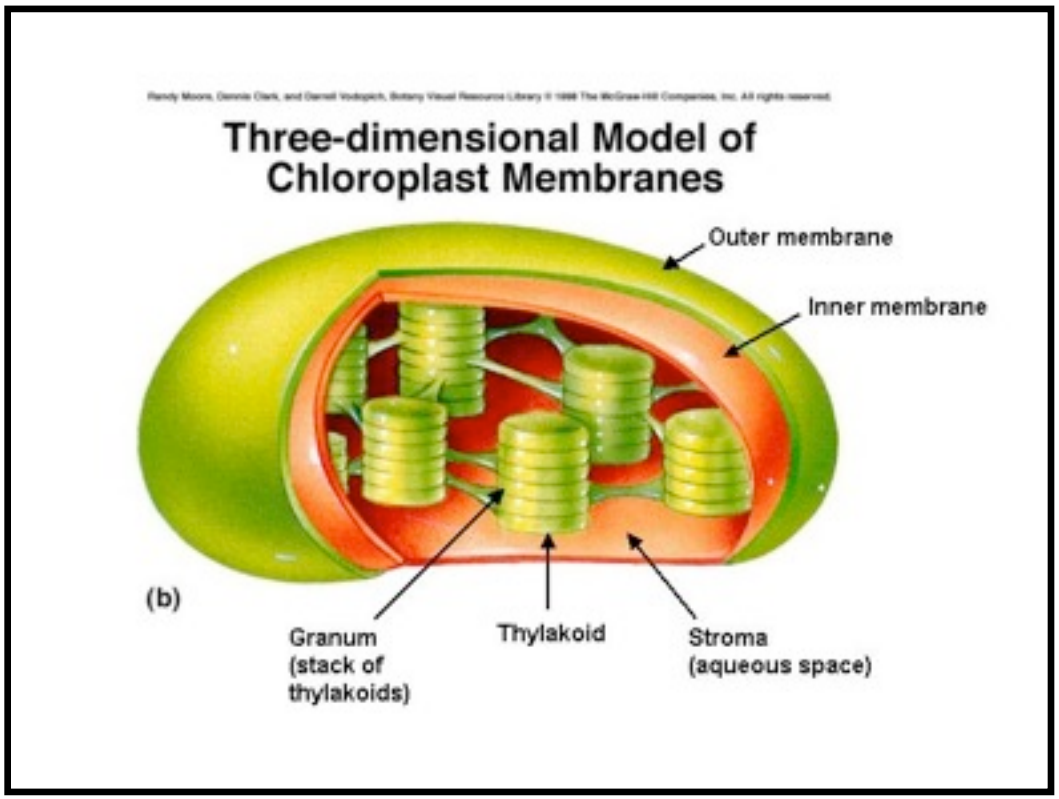
Chloroplasts are surrounded by a **double membrane**.

The membranes enclose an interior space filled with a **protein-rich semiliquid material** called STROMA.

Within the stroma, a system of membrane-bound sacks called **THYLAKOIDS** stack on top of one another to form columns called **GRANA**.

PHOTOSYNTHESIS!

- The **chloroplast** is the photosynthesis factory!!!



Adjacent grana are connected to one another by unstacked thylakoids called LAMELLAE.

Photosynthesis happens partly within the stroma and partly within the thylakoid membrane.

The thylakoid membrane contains CHLOROPHYLL!!!

PHOTOSYNTHESIS!

- The overall process of photosynthesis is summarized in the following chemical equation:

chlorophyll

$$6CO_{2(g)} + 6H_2O_{(l)} + \text{light energy} \rightarrow\rightarrow \rightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)}$$

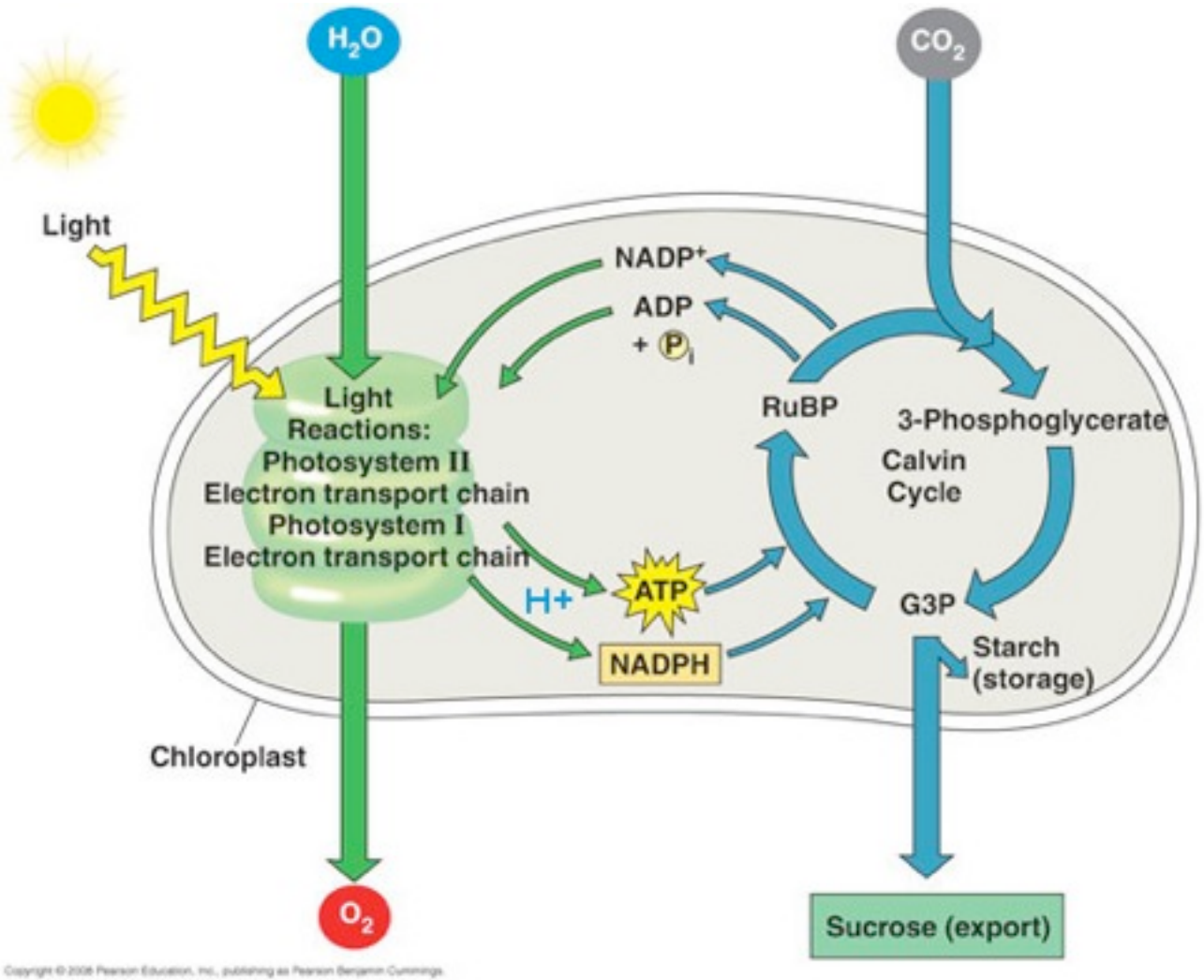
Carbon dioxide — water — glucose — oxygen

In other words, **carbon dioxide** from the atmosphere, and **water** from the soil along with the **sun's light energy** are used by plants to produce **glucose** (plant food) and **oxygen** is released into the atmosphere.

PHOTOSYNTHESIS!

- Photosynthesis can be divided into 2 sequential processes:
  - » 1. THE LIGHT REACTIONS – require **chlorophyll** and occur on the **thylakoid membranes** in chloroplasts
  - » 2. CARBON FIXATION (Calvin Cycle) – takes place in the **stroma** and require the energy of **ATP** and reducing power of **NADPH**.

PHOTOSYNTHESIS!



LIGHT REACTIONS

- The light reactions begin when **photons of light** strike a photosynthetic membrane.
  - There are 3 steps to this process…
    - » **PHOTOEXCITATION** – the absorption of a photon by an electron of chlorophyll
    - » **ELECTRON TRANSPORT** – electrons are pumped through a series of electron carriers, creating an H+ reservoir
    - » **CHEMIOSMOSIS** – the movement of protons (H+) through ATPase complexes to drive ADP to ATP

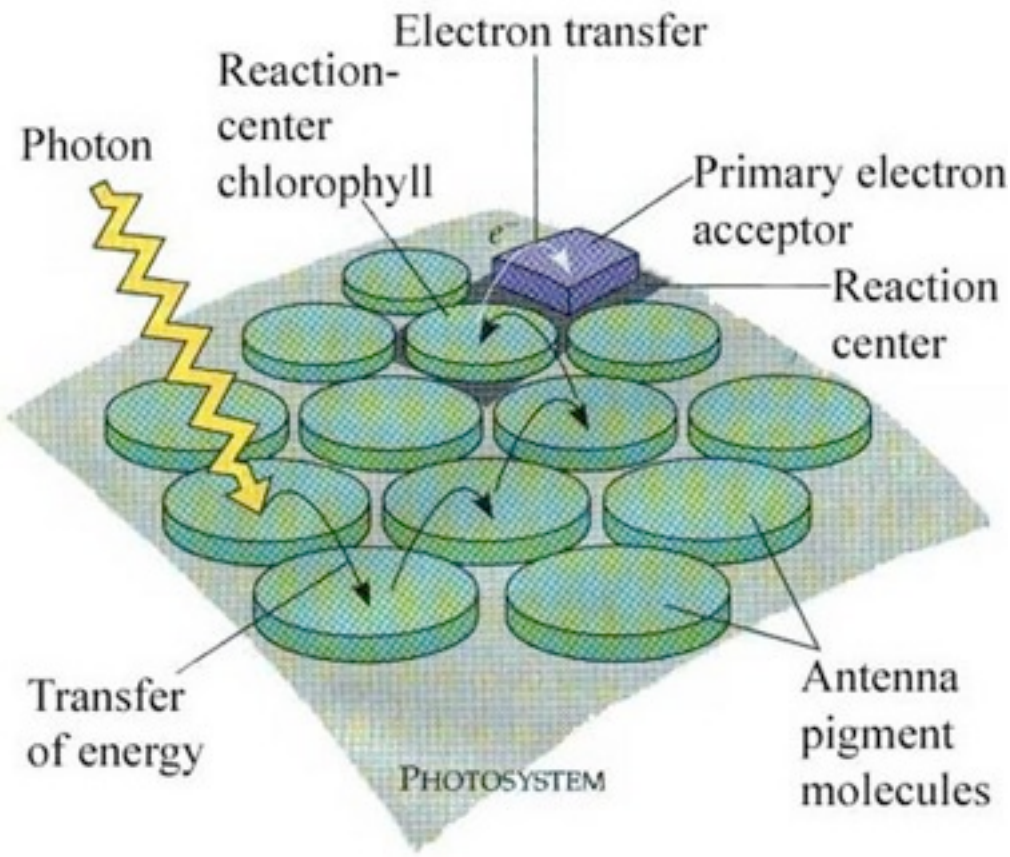
LIGHT REACTIONS

- The major end result of the light reaction is…

The energy of light is transferred to ATP and NADPH

ATP and NADPH head into the next step = CALVIN CYCLE

LIGHT REACTIONS



In a chloroplast molecule, light is not absorbed by independent chlorophyll pigment molecules.

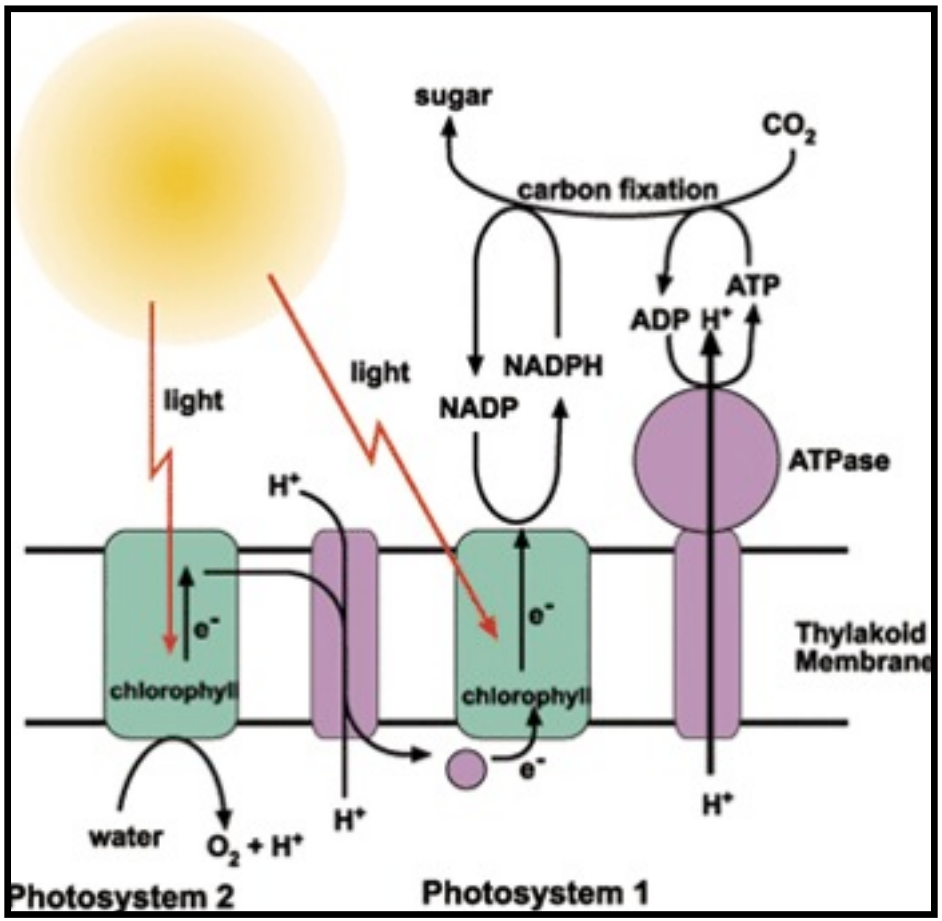
Light is absorbed by a chlorophyll molecule that is associated with proteins in clusters called **PHOTOSYSTEMS**.

Chloroplast thylakoid membranes contain two types of photosystems:

PHOTOSYSTEM I

PHOTOSYSTEM II

LIGHT REACTIONS



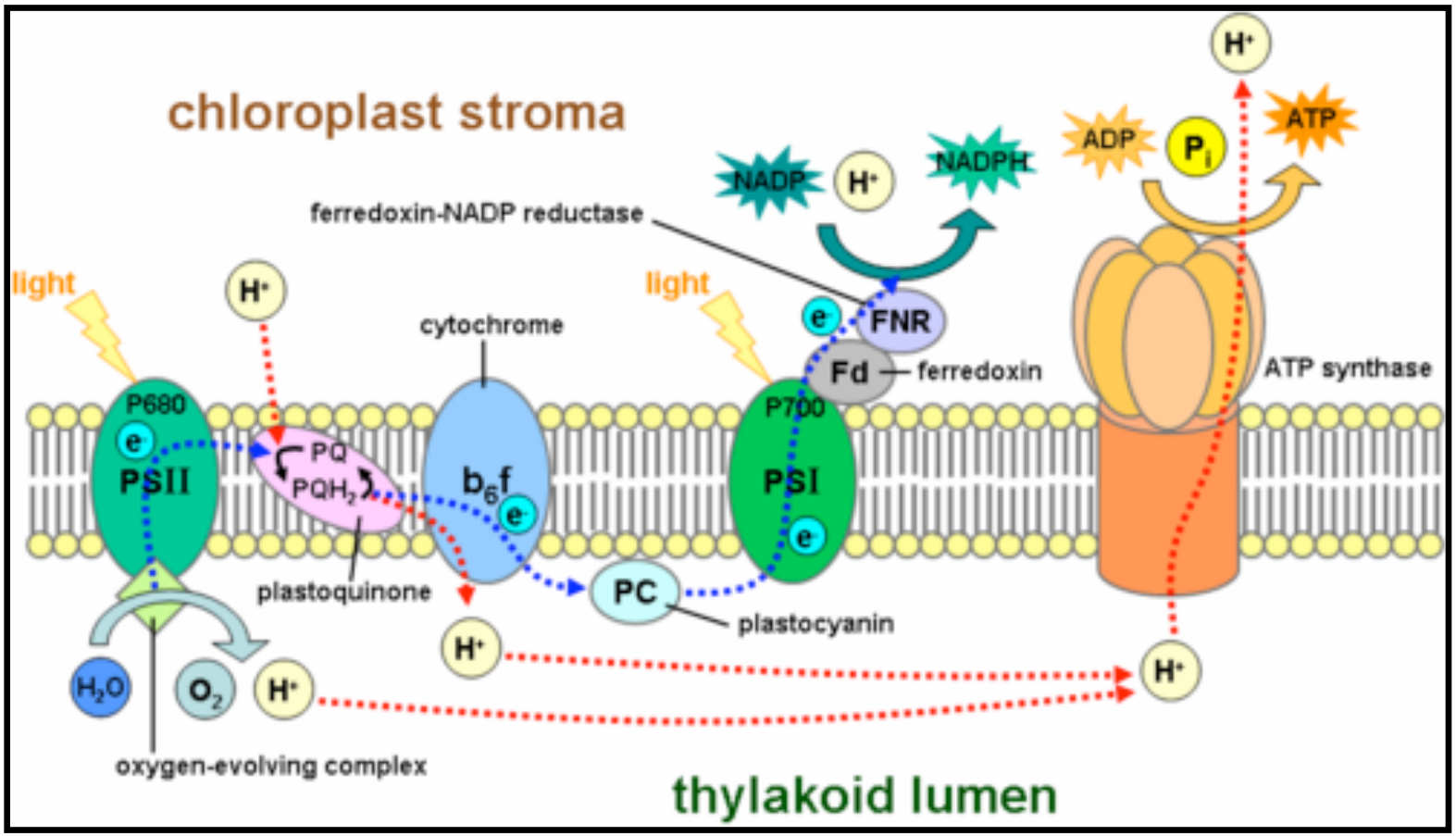
PHOTOSYSTEM 1 – contains **chlorophyll P700** – absorbs red light

PHOTOSYSTEM 2 – contains **chlorophyll P680** – absorbs red light

Photosystem I and II have differing absorption spectrums.

Plants use Photosystems I and II to produce ATP and NADPH via non-cyclic electron flow.

LIGHT REACTIONS

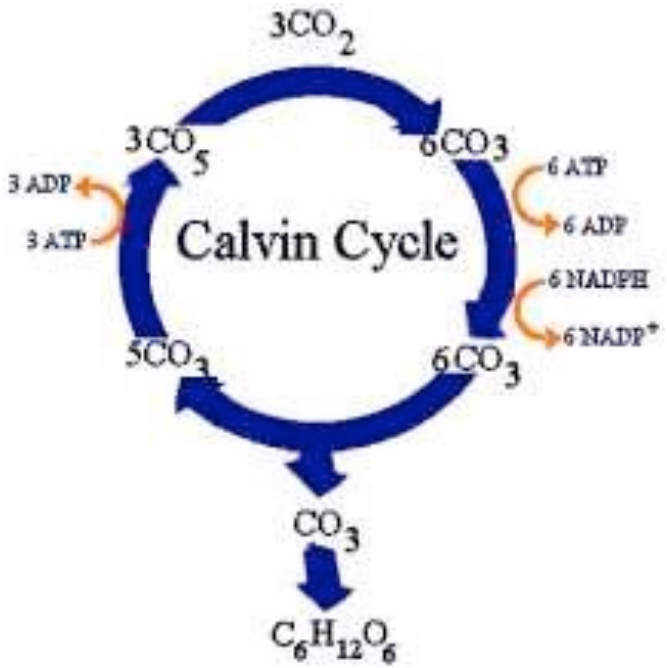


LIGHT REACTIONS

- http://www.youtube.com/watch?v=hj_WKgnL6MI

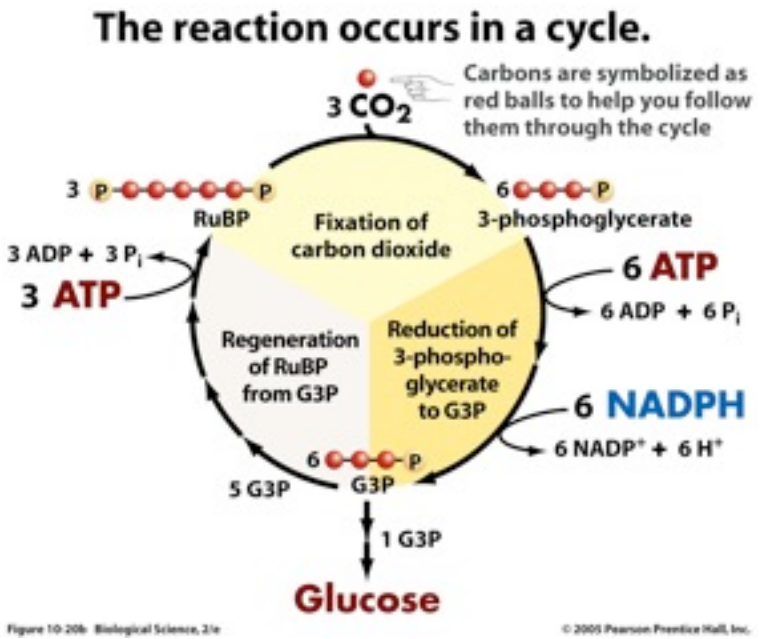
CALVIN CYCLE

- **occurs in the stroma** of the chloroplast
- is a **cyclic series** of reactions
- CO_2 is converted into carbohydrates using NADPH and ATP



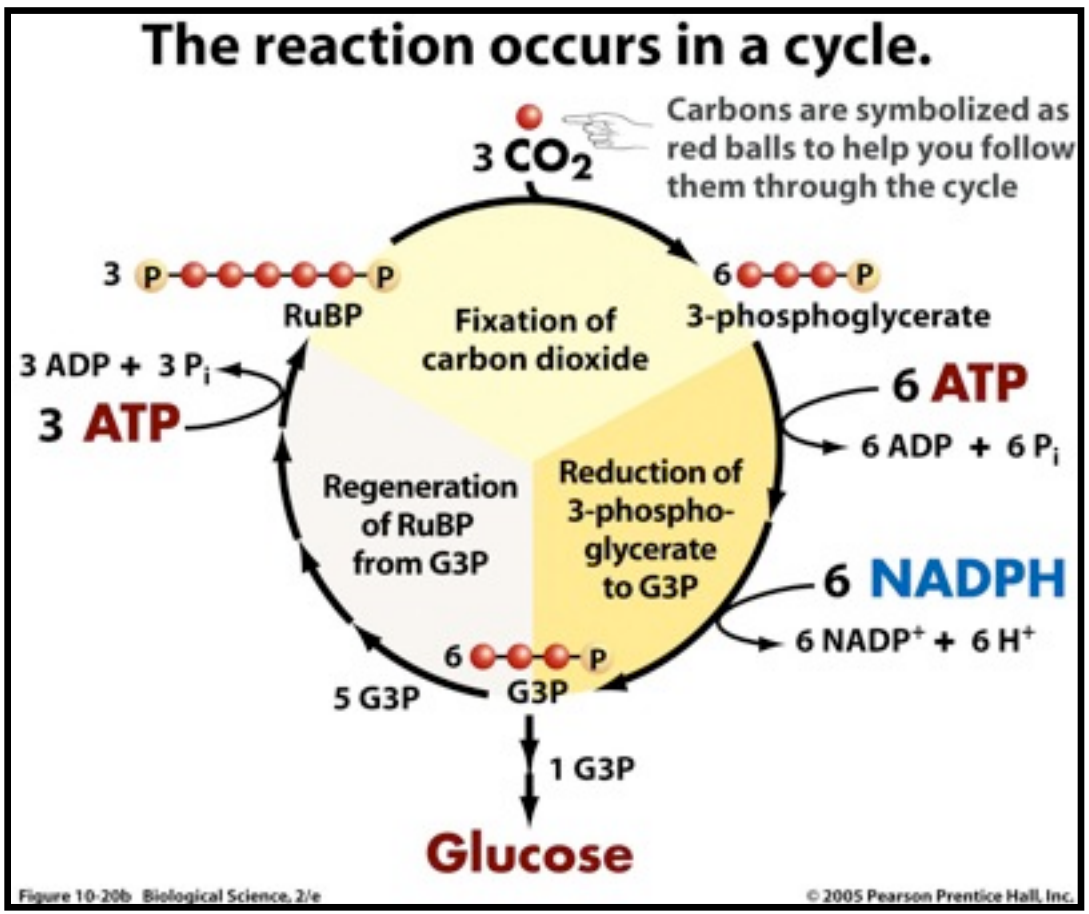
CALVIN CYCLE

- The Calvin Cycle can be divided into **3 phases**:
  - 1. CARBON FIXATION
  - 2. REDUCTION REACTIONS
  - 3. RIBULOSE 1,5 BISPHOSPHATE (RuBP) REGENERATION



CALVIN CYCLE

STAGE ONE: CARBON FIXATION



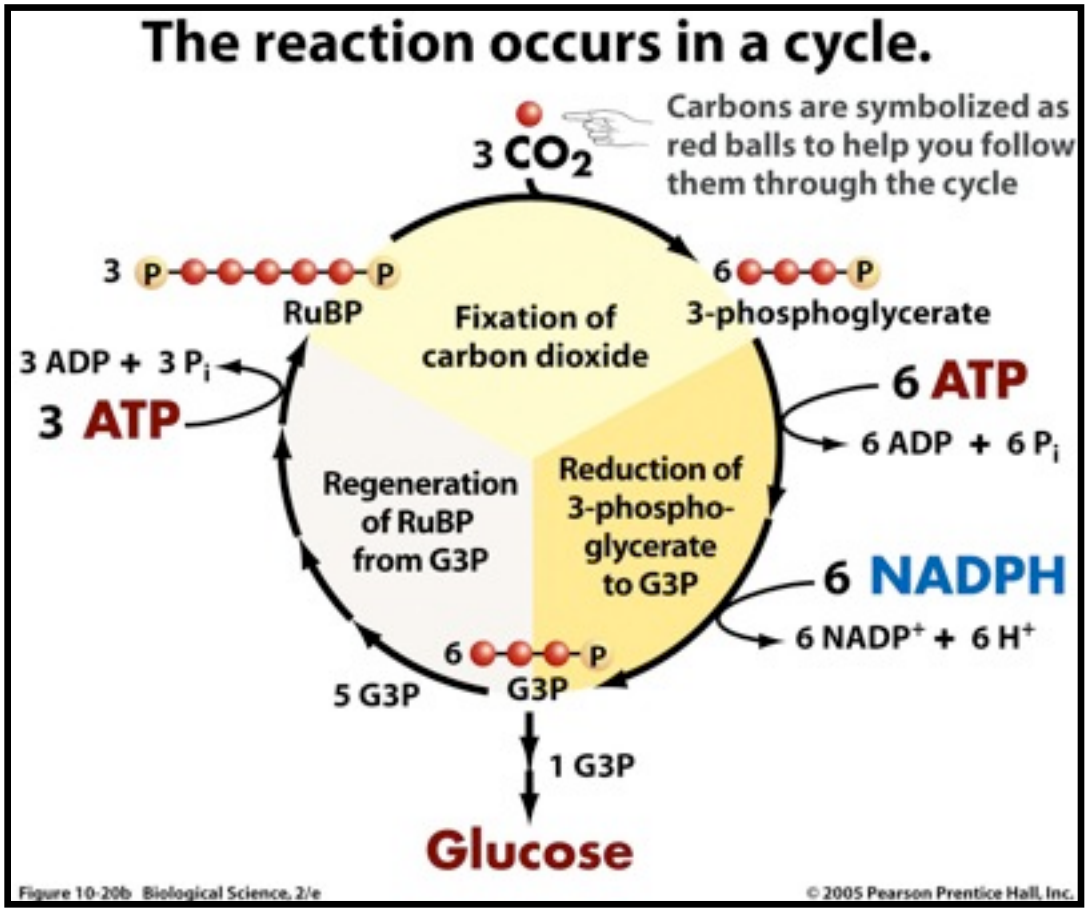
CO_2 adds to an already existing 5-carbon molecule (**RuBP**).

This forms an unstabe 6-carbon intermediate that instantly splits into 3-carbon molecules (**3-PGA**).

These reactions are catalyzed by the enzyme **RUBISCO**.

CALVIN CYCLE

STAGE TWO: REDUCTIONS



Each of the six PGA molecules is phosphorylated by ATP.

This results in 6 molecules of 1,3-BPG.

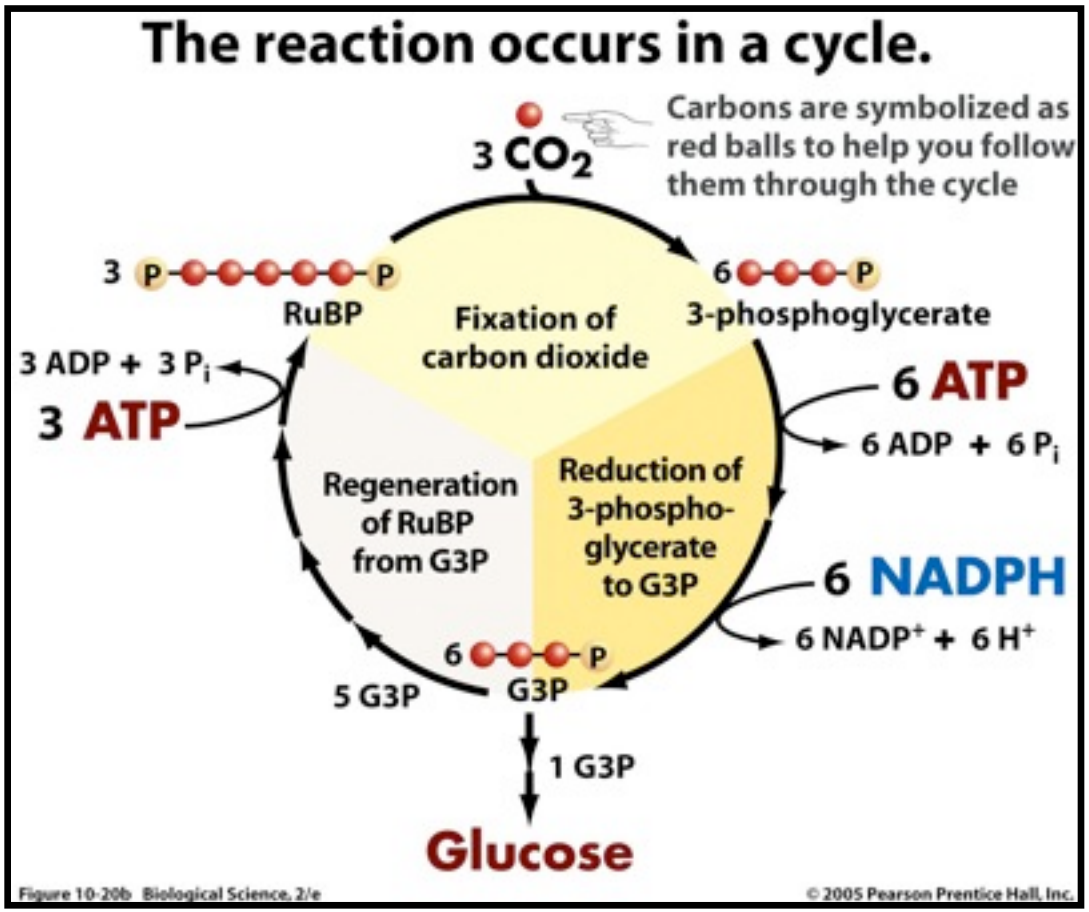
6 electron pairs from 6 NADPH molecules reduces the 6 molecules of 1,3-BPG.

This results in 6 molecules of G3P.

G3P exits as a final product

CALVIN CYCLE

STAGE THREE: REGENERATION OF RuBP



In a series of enzyme-catalyzed reactions, the remaining 5 G3P molecules are rearranged to regenerate 3 molecules of RuBP.

3 molecules of ATP are used in this process!

Once RuBP is regenerated, the cycle can fix more CO_2 molecules.

CALVIN CYCLE

- The G3P molecules that leave the Calvin Cycle are then used to synthesize carbohydrates like glucose.
- **NOTE** It takes the fixation of $3CO_2$ molecules to produce ONE molecule of G3P that can leave the cycle.
- To make glucose, you require 2 molecules of G3P
- Thus, it takes 6 turns of the calvin cycle or $6CO_2$ molecules to synthesize ONE glucose molecule!

CALVIN CYCLE

- http://www.youtube.com/watch?v=CUZXWHoiOSs