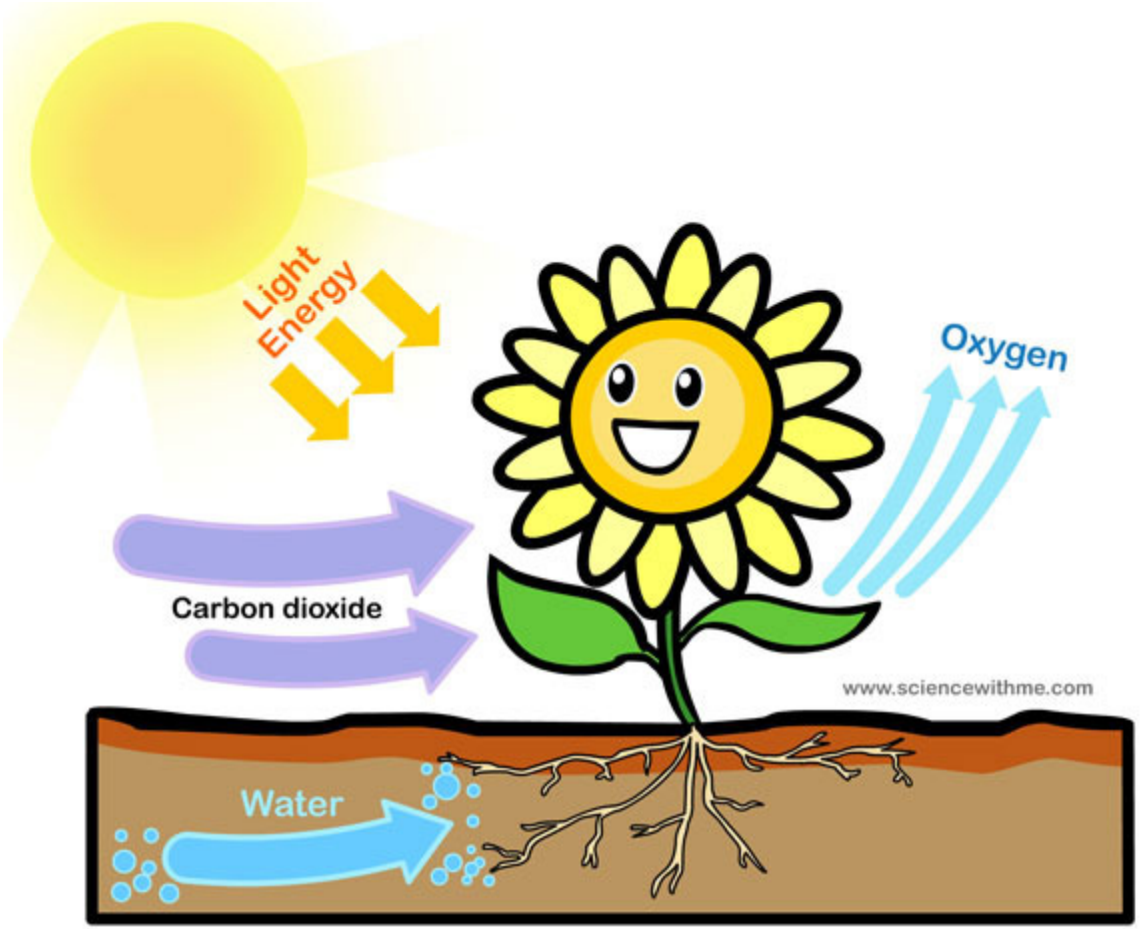
NOTES: 8.2 – 8.3
PHOTOSYNTHESIS!



8.2 - Photosynthesis: Trapping the Sun's Energy

- **Key Concepts:**
  - What did the experiments of van Helmont, Priestley, and Ingenhousz reveal about how plants grow?
  - What is the overall reaction for photosynthesis?
  - What is the role of light and chlorophyll in photosynthesis?
  - How is glucose (a carbohydrate) produced in the light independent reactions?

- **Vocabulary:**

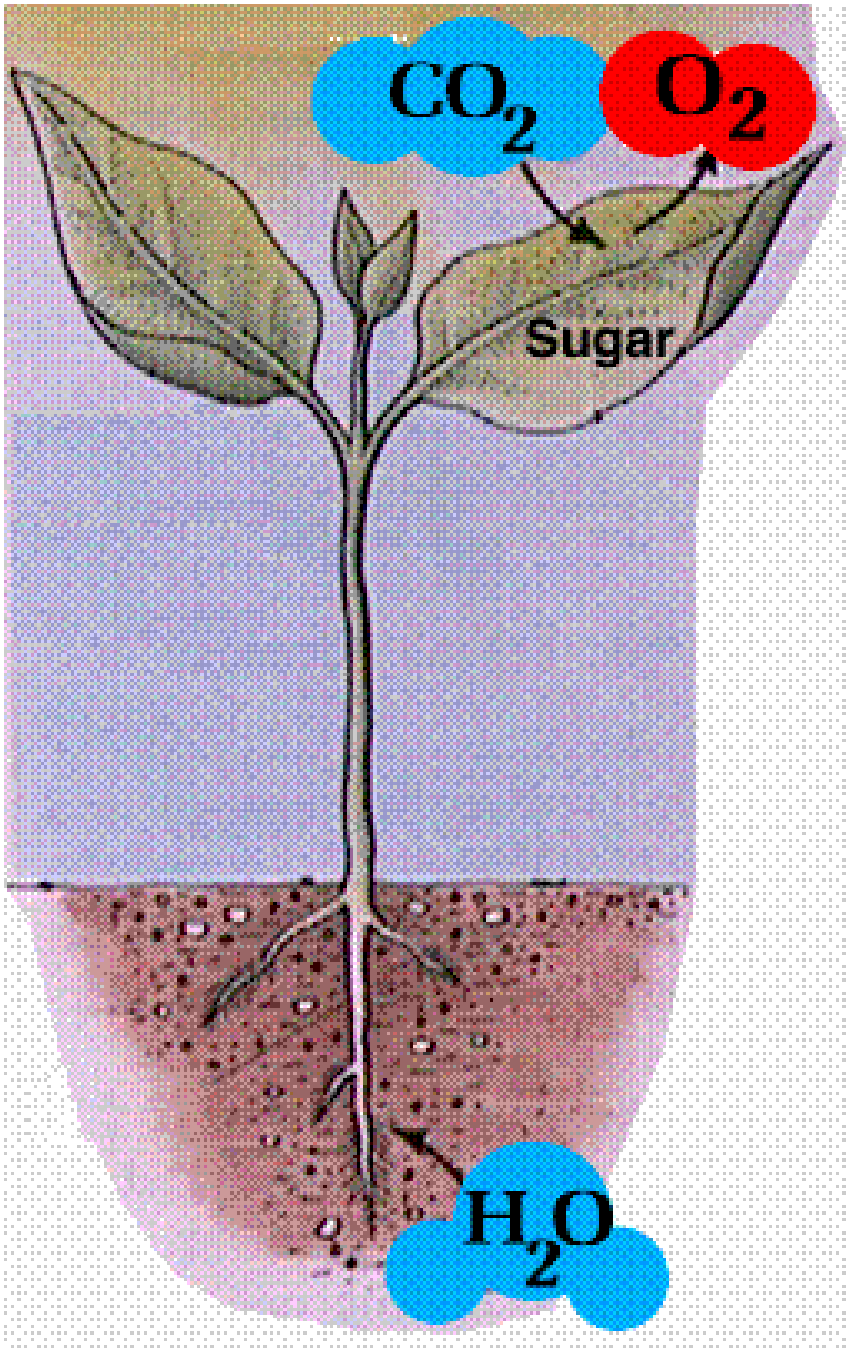
-photosynthesis
-pigment
-chlorophyll
-ATP
-NADPH
-chloroplast

8-2 Photosynthesis: An Overview

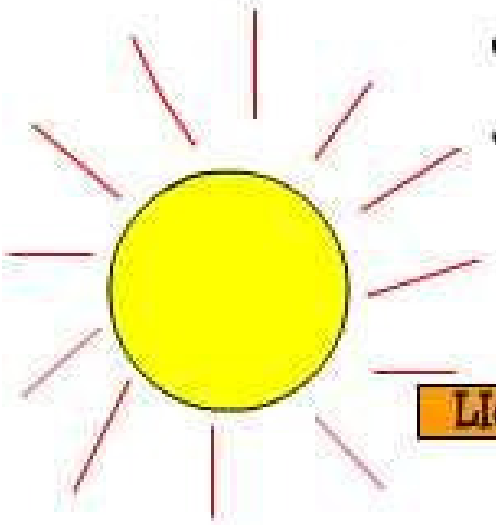
- **Photosynthesis:**
  - Plants use the energy of sunlight to convert water and carbon dioxide into oxygen and high energy carbohydrates (sugars and starches).

Equation (unbalanced):

$$H_2O + CO_2 + \text{Sunlight} \longrightarrow O_2 + \text{carbohydrates (glucose)}$$


CO_2
O_2
Sugar
H_2O

Photosynthesis



LIGHT

oxygen

- given off into air

sugar

converted

STARCH

- stored food in other parts of the plant.
- turns iodine dark blue

Chlorophyll

- traps light energy to make food

water

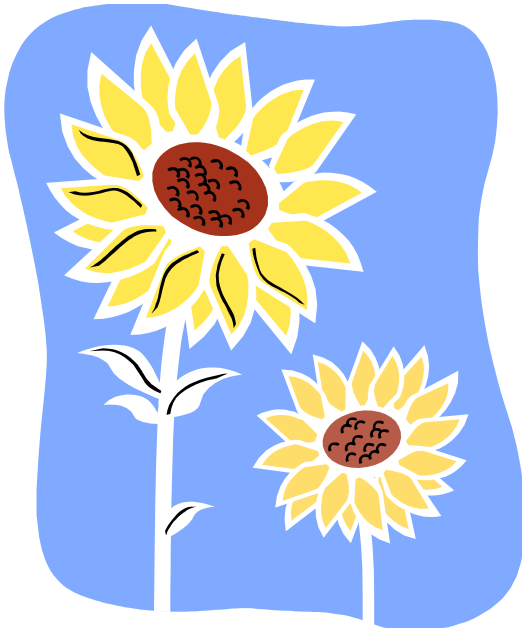
- absorbed from the roots

Carbon dioxide

- enters through the stomataof the leaves.

SCIENCE HISTORY…

- 3 different scientists helped identify the substances involved in photosynthesis
  - Van Helmont
  - Priestley
  - Ingenhousz



Jan Baptiste Van Helmont

17th century

The Von Helmont Problem

QUESTION: Do plants grow by taking material out of the soil?

- He put a 2.3 kg. (5 lb.) willow tree in 90.8 kg (200 lbs). of soil.
- The tree received only rainwater for five years.
- After 5 years, Von Helmont found that the soil only weighed 57 g less than when the experiment began.
- The willow tree now weighed 76.8 kg (169 lbs. 3 oz.).

What did Helmont conclude was responsible for most of the tree weight gain?

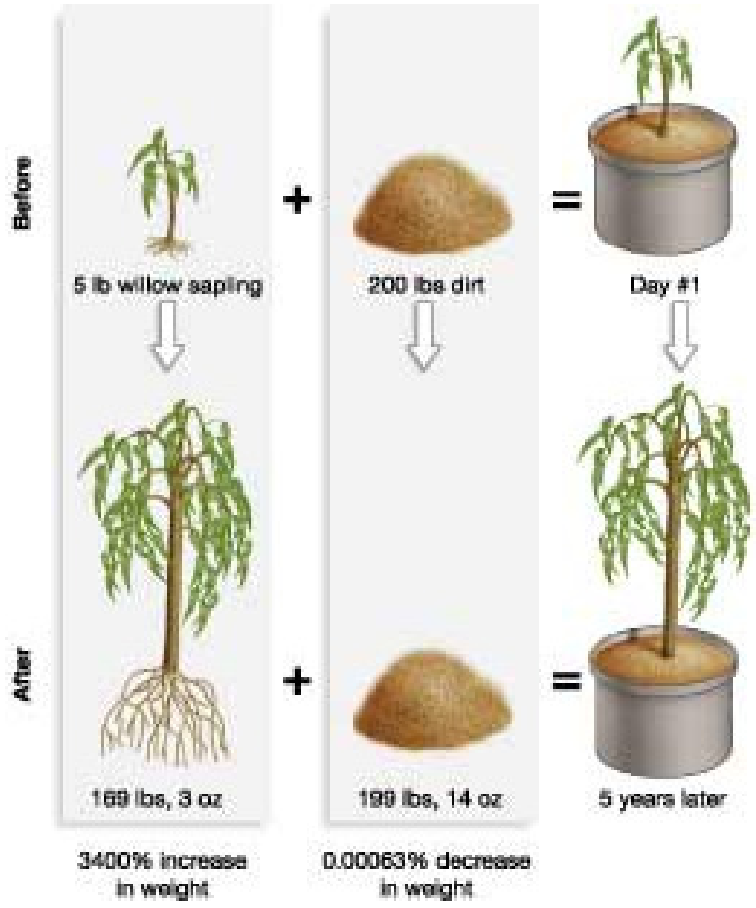
-WATER!

Is this the only thing responsible?

-NO

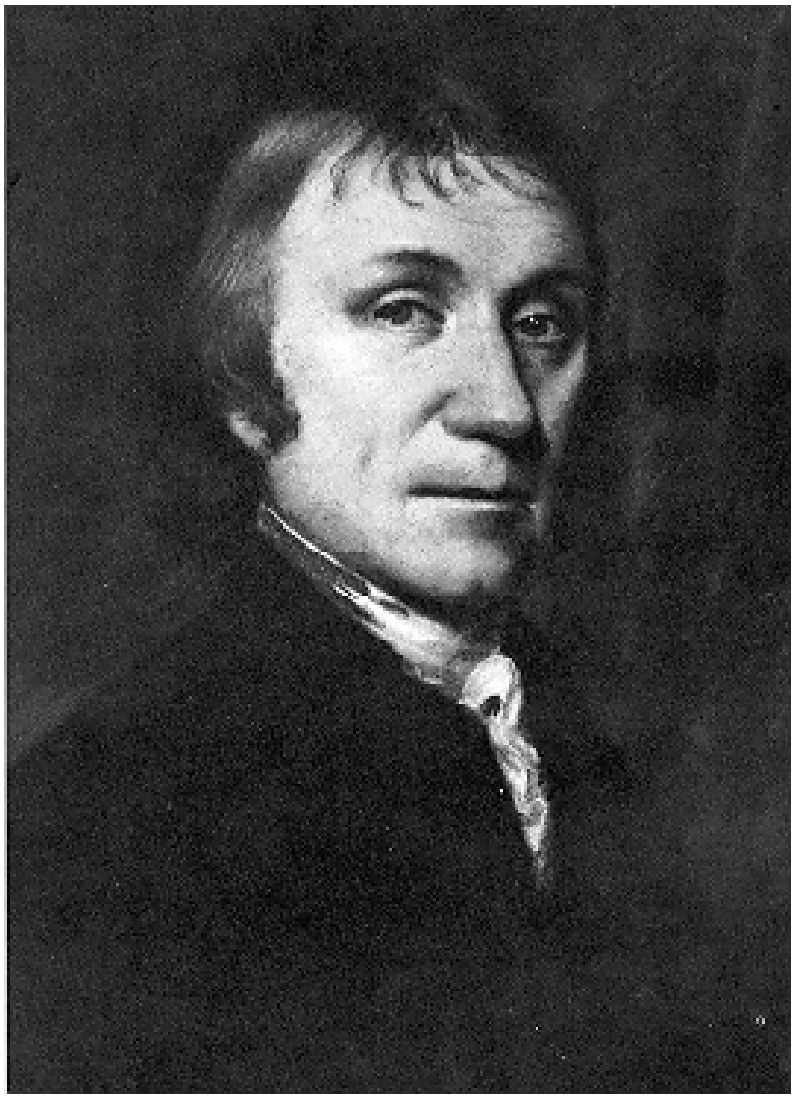
Main fact we learned from Van Helmont's experiments:

- **<u>The mass gained by a plant is NOT from the soil!</u>**



Joseph Priestley

18th century

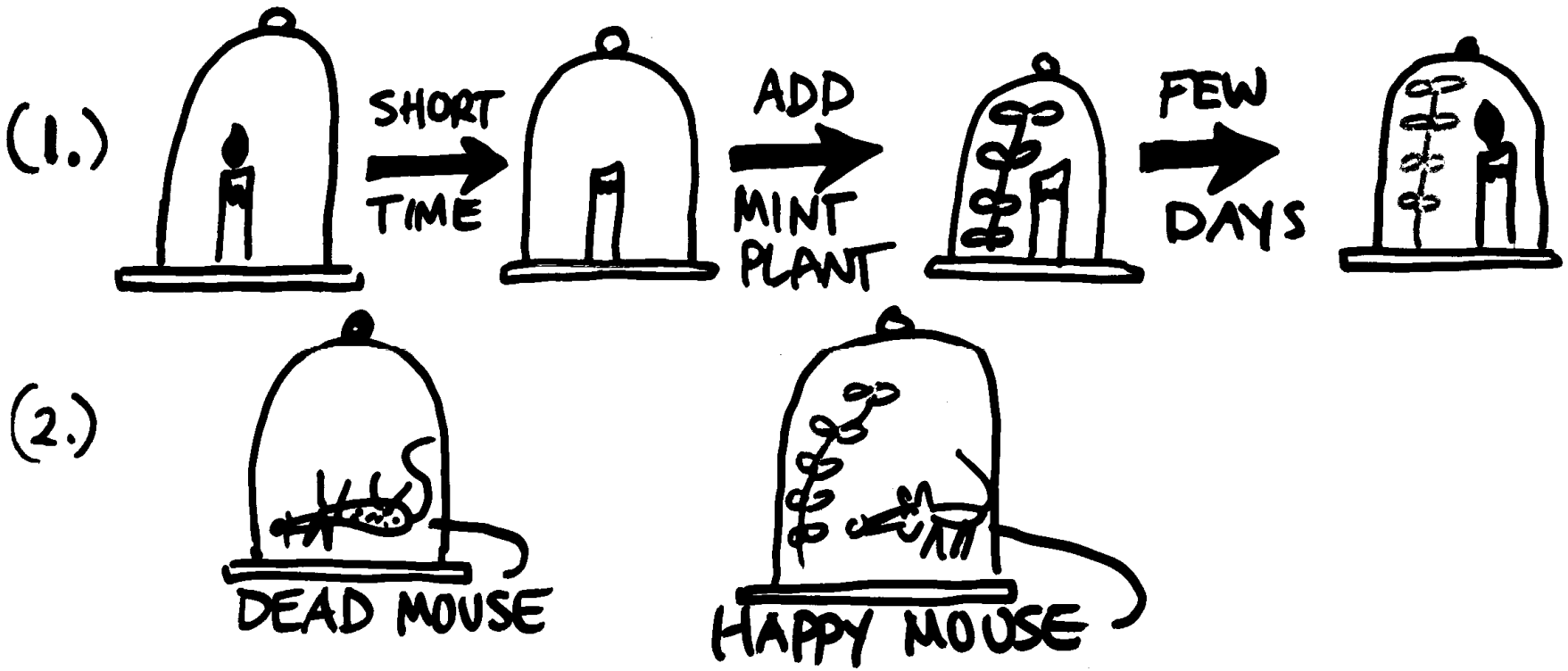


- In 1772 another Englishman, Joseph Priestly (1733-1804), reported the results of an important experiment.
- He found that a sprig of mint would not die when placed in air that had been "spent" (used) by burning a candle in it.
- To the contrary, in such air the plant would grow and the air would then, to his astonishment, again support a candle flame.
- Priestly inferred that the mint produced a substance that was required for burning.

- ***What is that substance?***

Main fact we learned from Priestly's experiments:

- **<u>Plants produce a substance that "refreshes" spent air …OXYGEN!</u>**



J. Ingenhousz

- The Dutch physician, Jan Ingenhousz, published *Experiments on Vegetables*, which supplied experimental evidence stating that the effect observed by Priestly occurred only in **sunlight**.

He also showed that only the **green parts of plants, especially the leaves, have this capacity.

Main fact we learned from Ingenhousz' experiments:

- **Only the green parts of plants produce this "refreshing" substance (O_2), and only when exposed to sunlight**

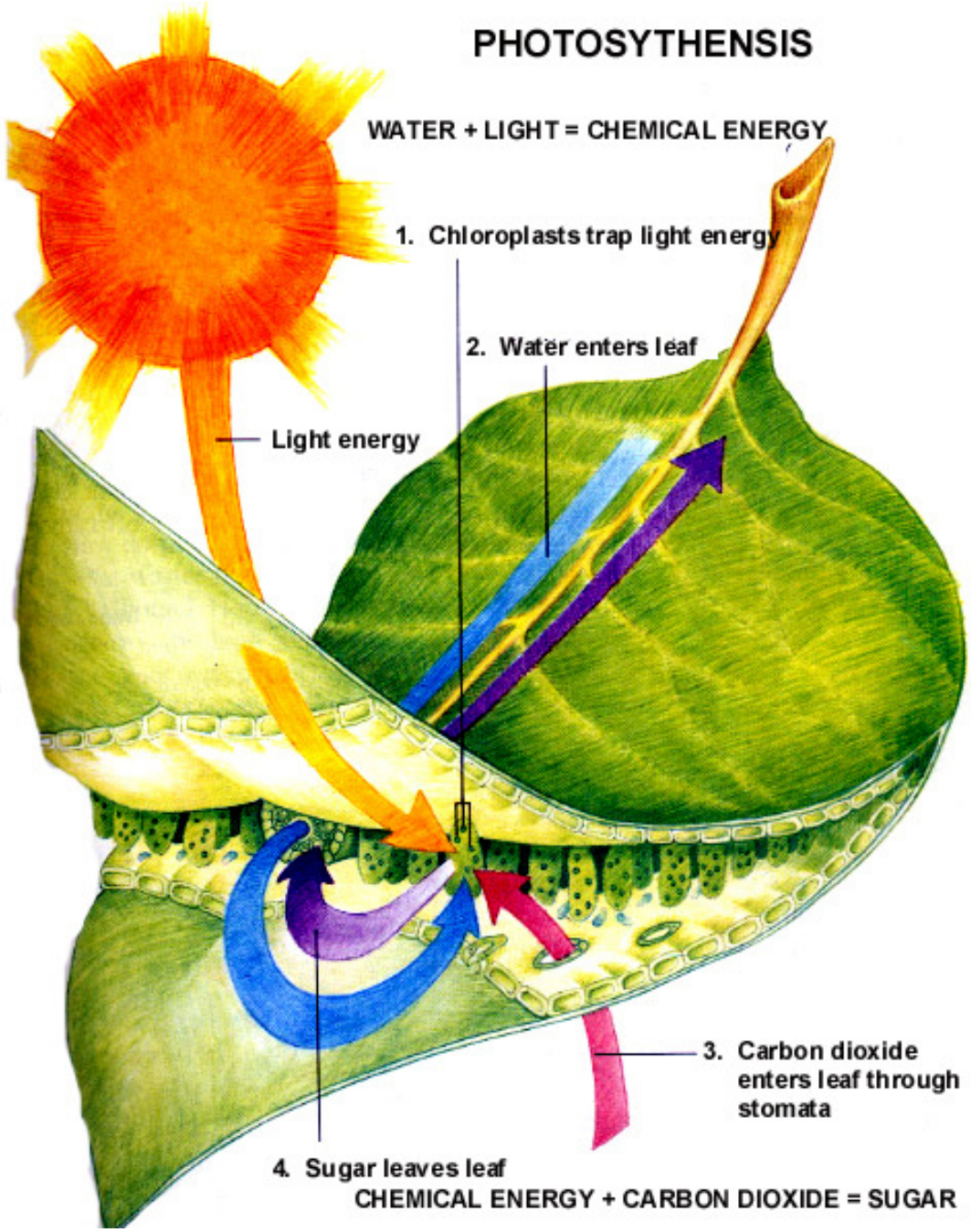
More General Info

(Before the REAL fun begins!)

Photosynthesis overview (8.2)

$$6H_2O + 6CO_2 \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$$

- Photosynthesis uses the energy of sunlight to convert water and carbon dioxide into oxygen and high energy sugars
- $C_6H_{12}O_6$ = **glucose** (a simple sugar)
- Plants use the sugars to produce complex carbohydrates such as **starches**.

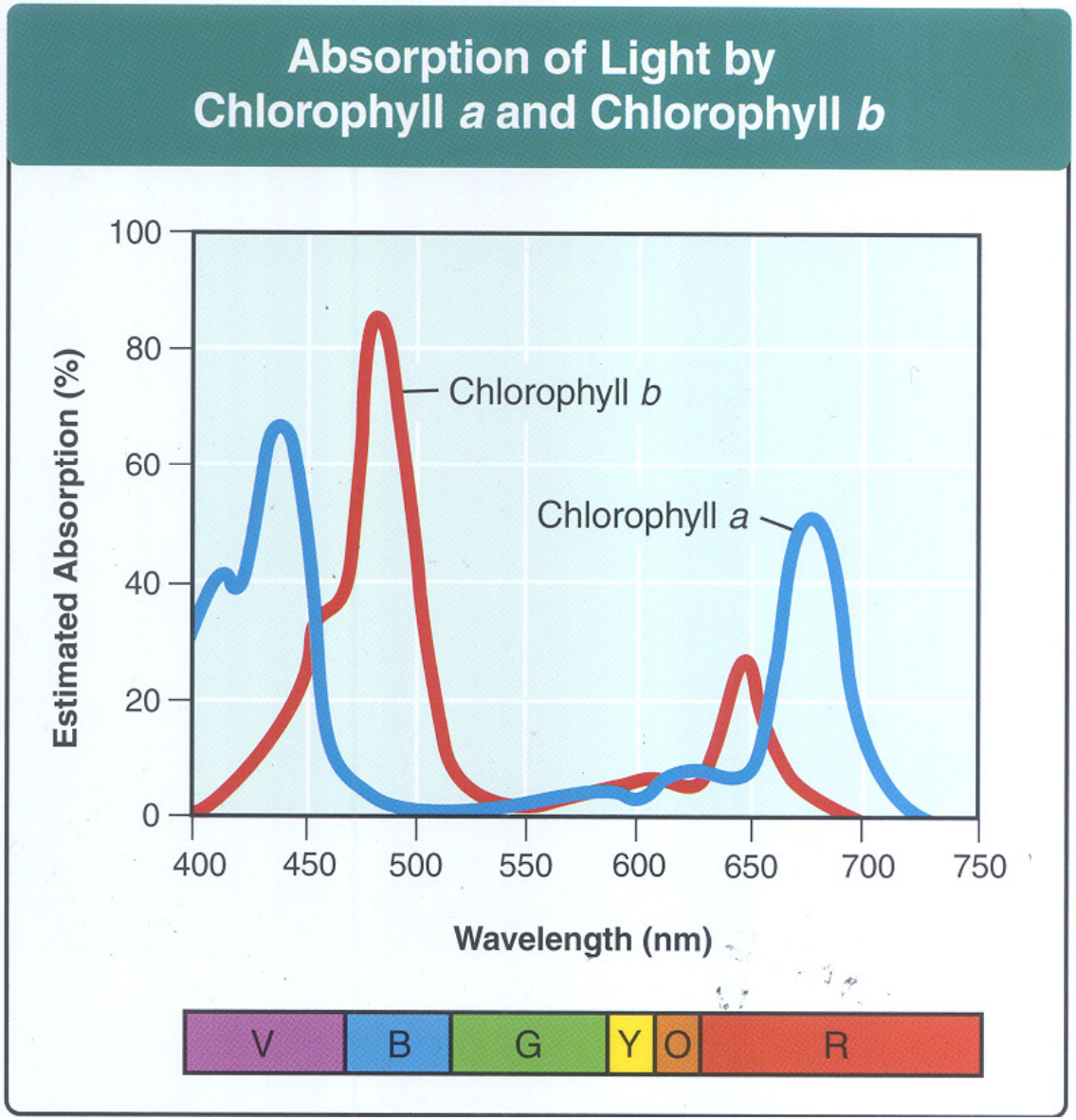

PHOTOSYTHENSIS
WATER + LIGHT = CHEMICAL ENERGY
1. Chloroplasts trap light energy
2. Water enters leaf
Light energy
3. Carbon dioxide enters leaf through stomata
4. Sugar leaves leaf
CHEMICAL ENERGY + CARBON DIOXIDE = SUGAR

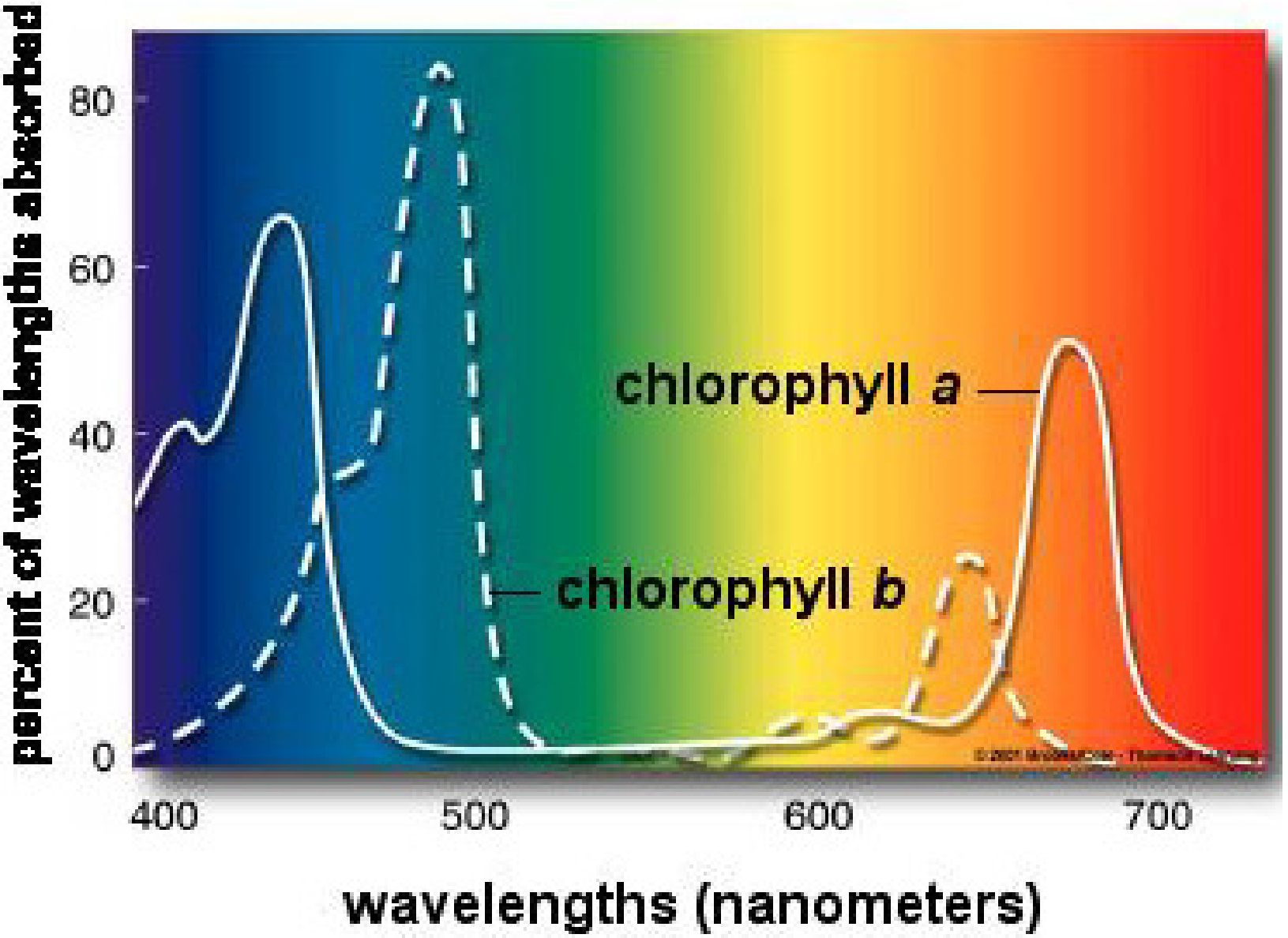
Light & Pigment

- White light is actually a mixture of different wavelengths of light.
- Plants gather the sun's energy with light absorbing molecules called **PIGMENTS**.
- The plant's principle pigment is **chlorophyll** and there are 2 main types: "a" and "b."
  - Plants also contain red and orange pigments such as carotene which absorbs light in other areas of the spectrum.
- Energy absorbed by chlorophyll is transferred directly to electrons in the chlorophyll molecule. These high energy electrons make photosynthesis work!

So why are leaves green?

- Look at the wavelengths of light that chlorophyll absorbs & uses in photosynthesis
- The colors that are left are reflected back and that is what you see.




percent of wavelengths absorbed
80
60
40
20
0
chlorophyll a
chlorophyll b
400
500
600
700
wavelengths (nanometers)

Check for understanding…

- ***Would a plant grow well in green light? Explain!***

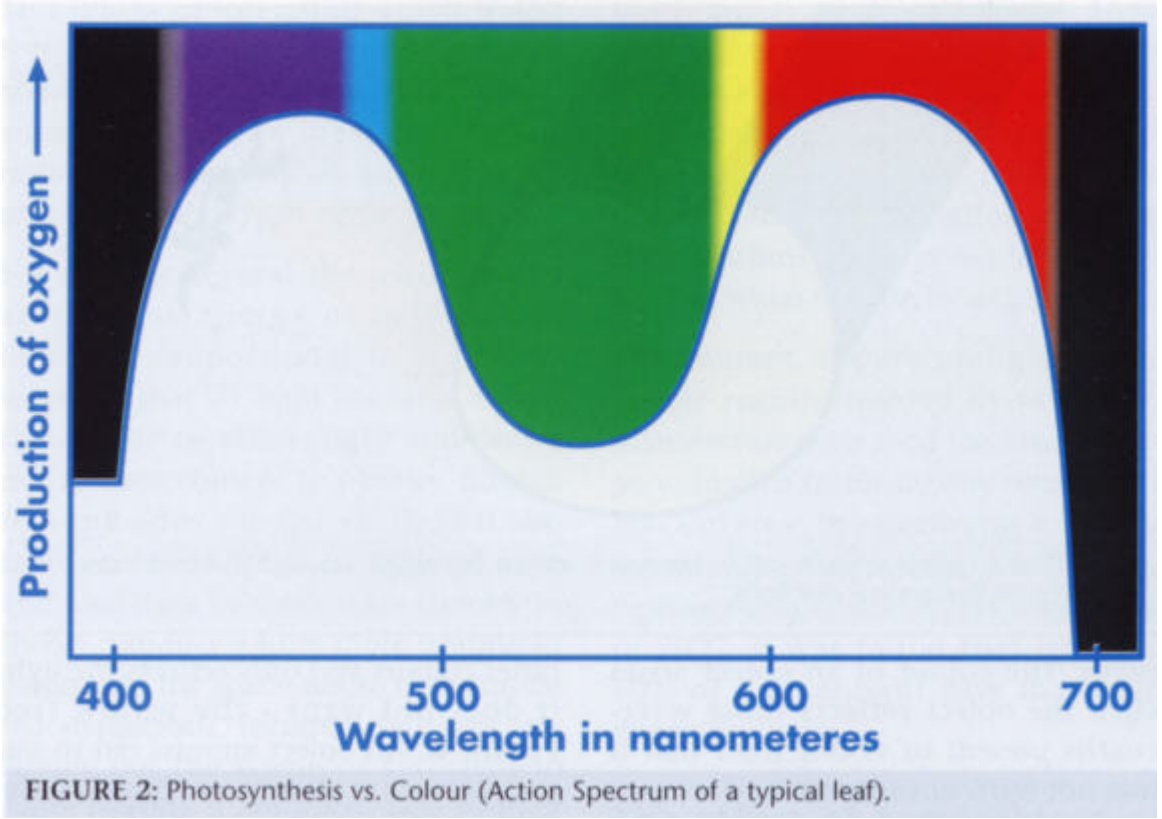
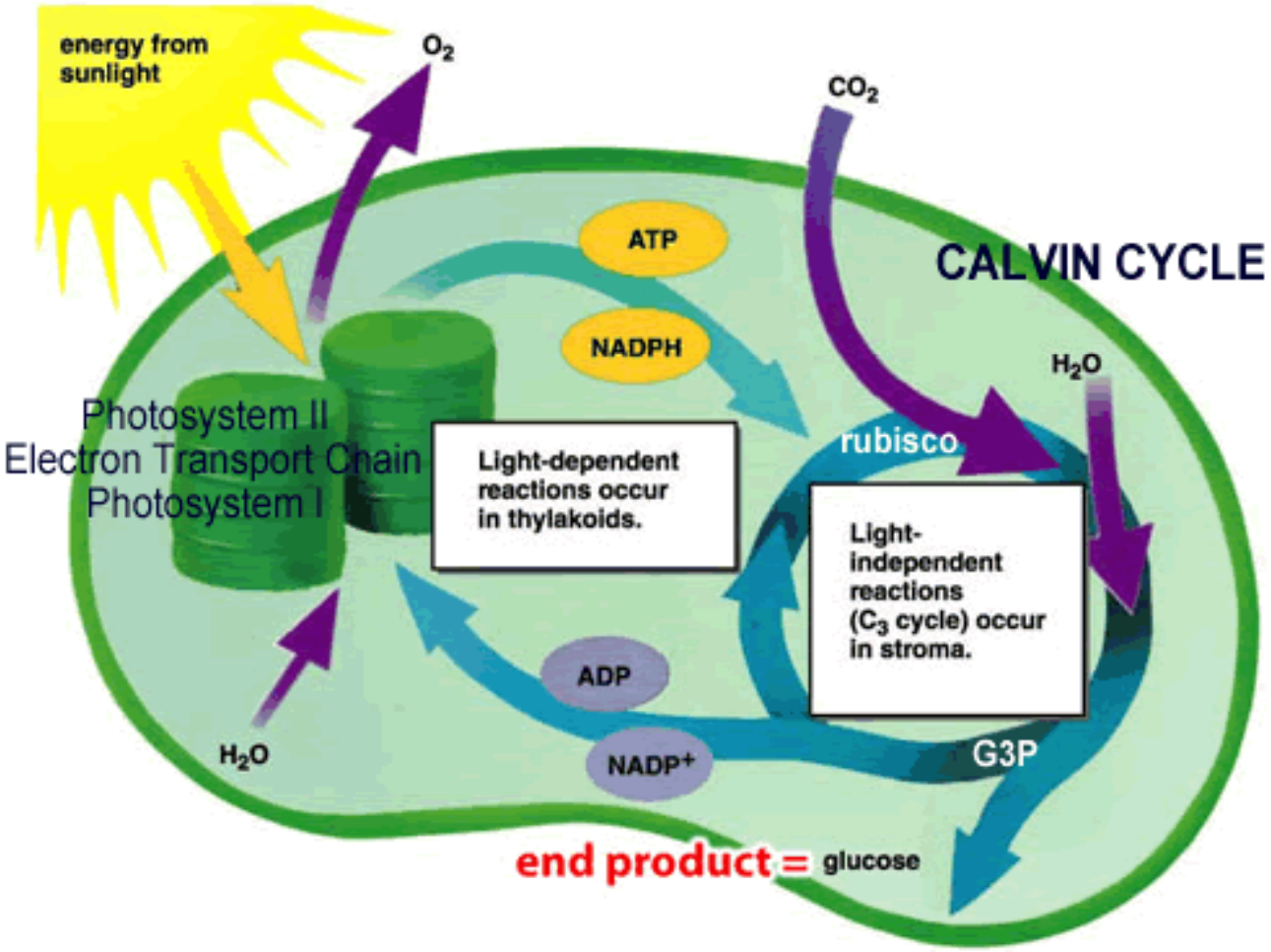


FIGURE 2: Photosynthesis vs. Colour (Action Spectrum of a typical leaf).

8.3: The Process of Photosynthesis



Inside a Chloroplast:

➔ Thylakoids:

-cluster of proteins and pigments that capture the sun's energy

➔ Thylakoid membrane:

-**light-dependent** reactions take place here.

➔ Stroma:

-**space** on the interior of a chloroplast;

the **light-independent** (Calvin Cycle) reactions take place here

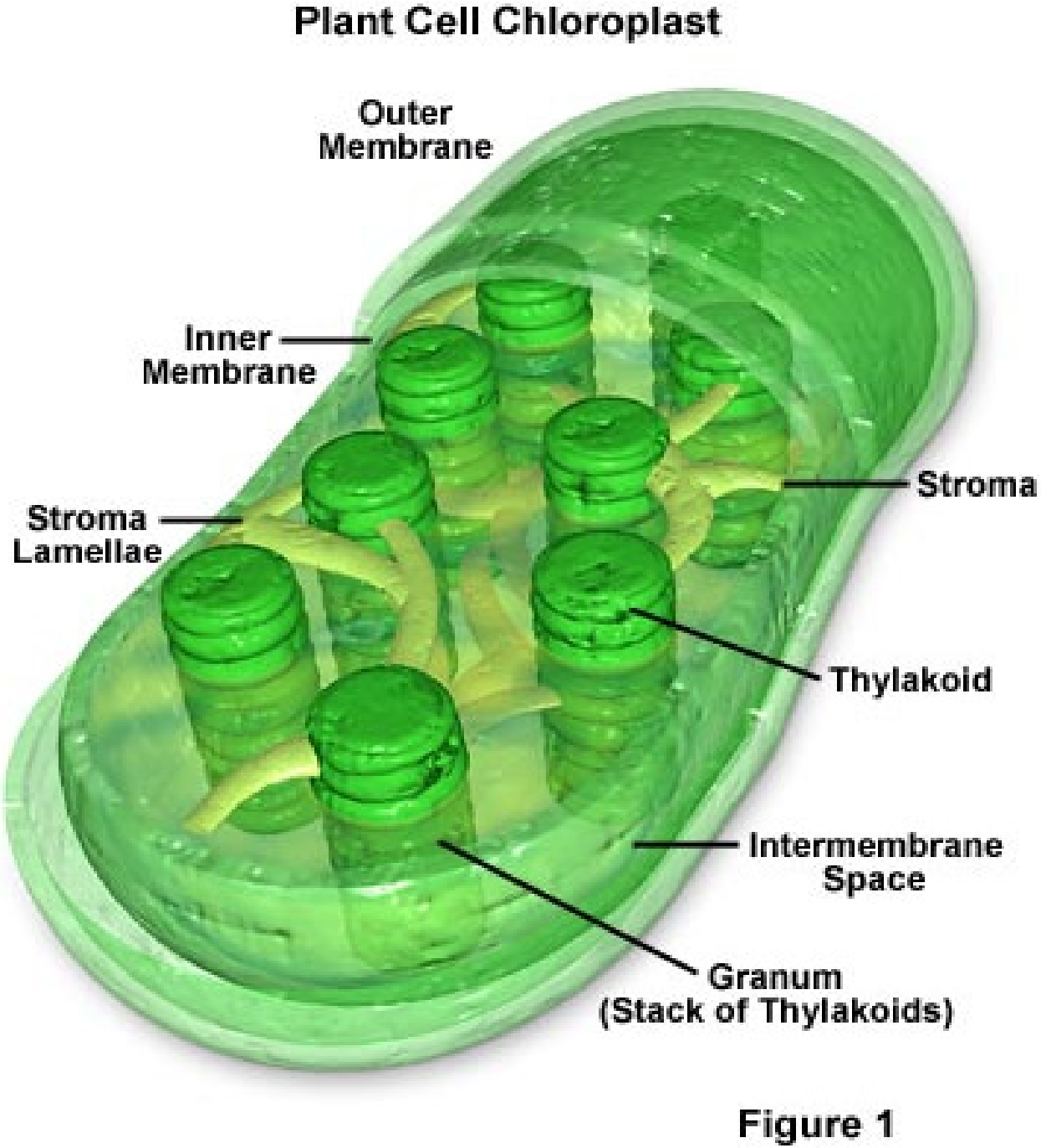
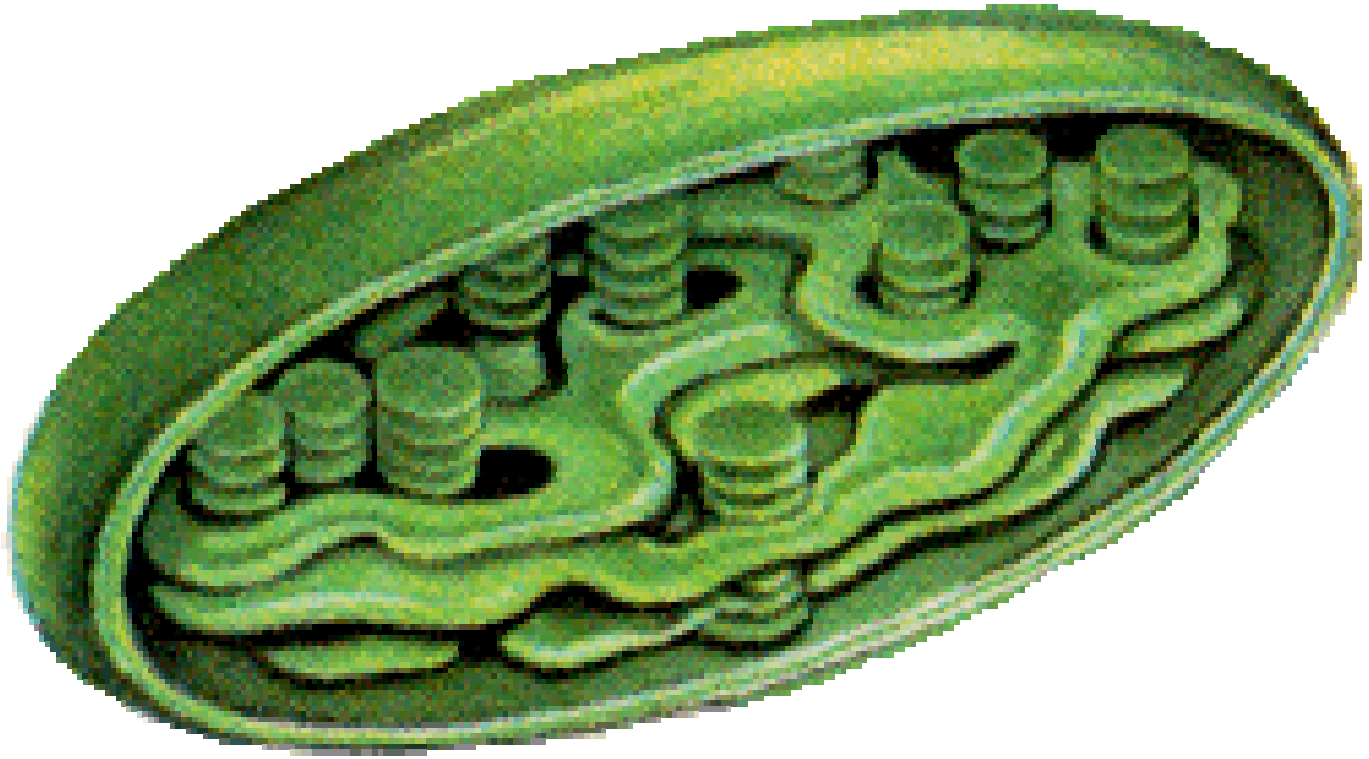

Plant Cell Chloroplast
Outer Membrane
Inner Membrane
Stroma
Stroma Lamellae
Thylakoid
Intermembrane Space
Granum (Stack of Thylakoids)

Figure 1

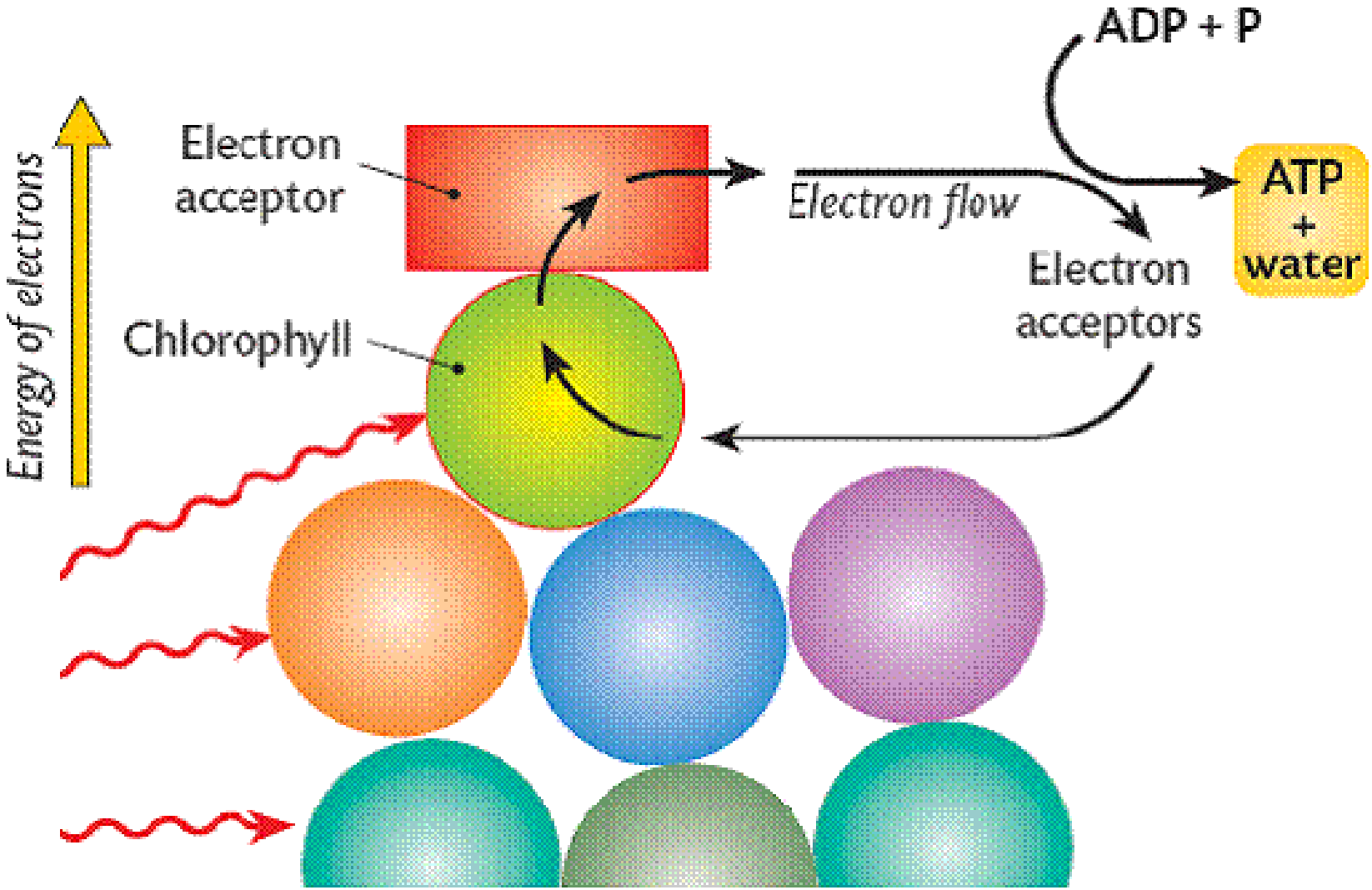
CHLOROPLAST CROSS-SECTION



This is where photosynthesis occurs…

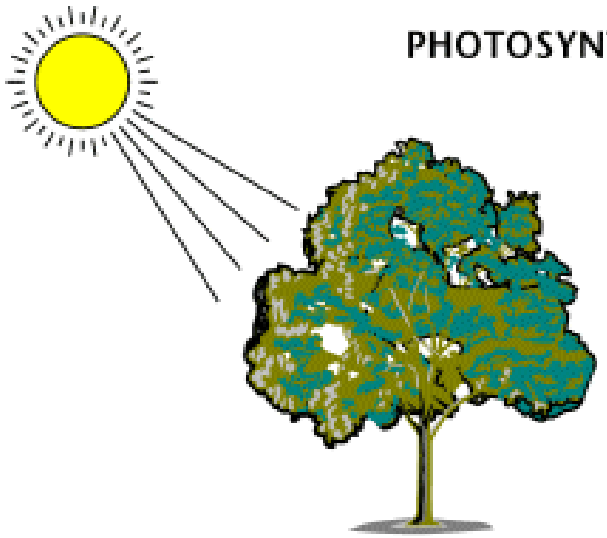
Before we get to the hard stuff…

- When energy from the sun excites electrons, they increase in energy
- They are so "hot" that they need an electron carrier
- An **electron carrier** moves high energy electrons from chlorophyll to other molecules (without using much energy itself)
  - ***In photosynthesis, this electron carrier is:***
    $NADP^+$


ADP + P
Energy of electrons
Electron acceptor
Electron flow
ATP + water
Electron acceptors
Chlorophyll

Equation for Photosynthesis

$$6H_2O + 6CO_2 \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

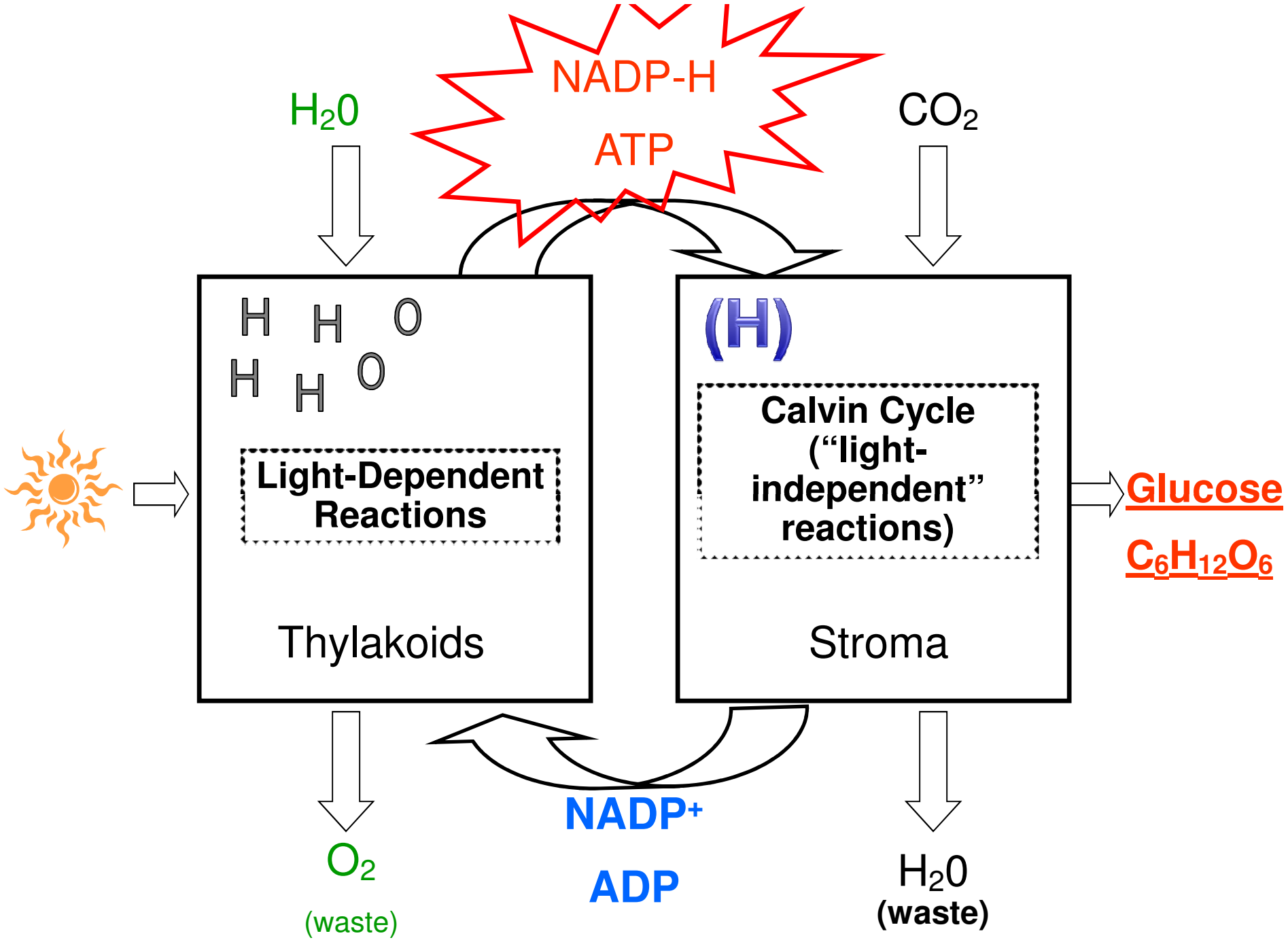


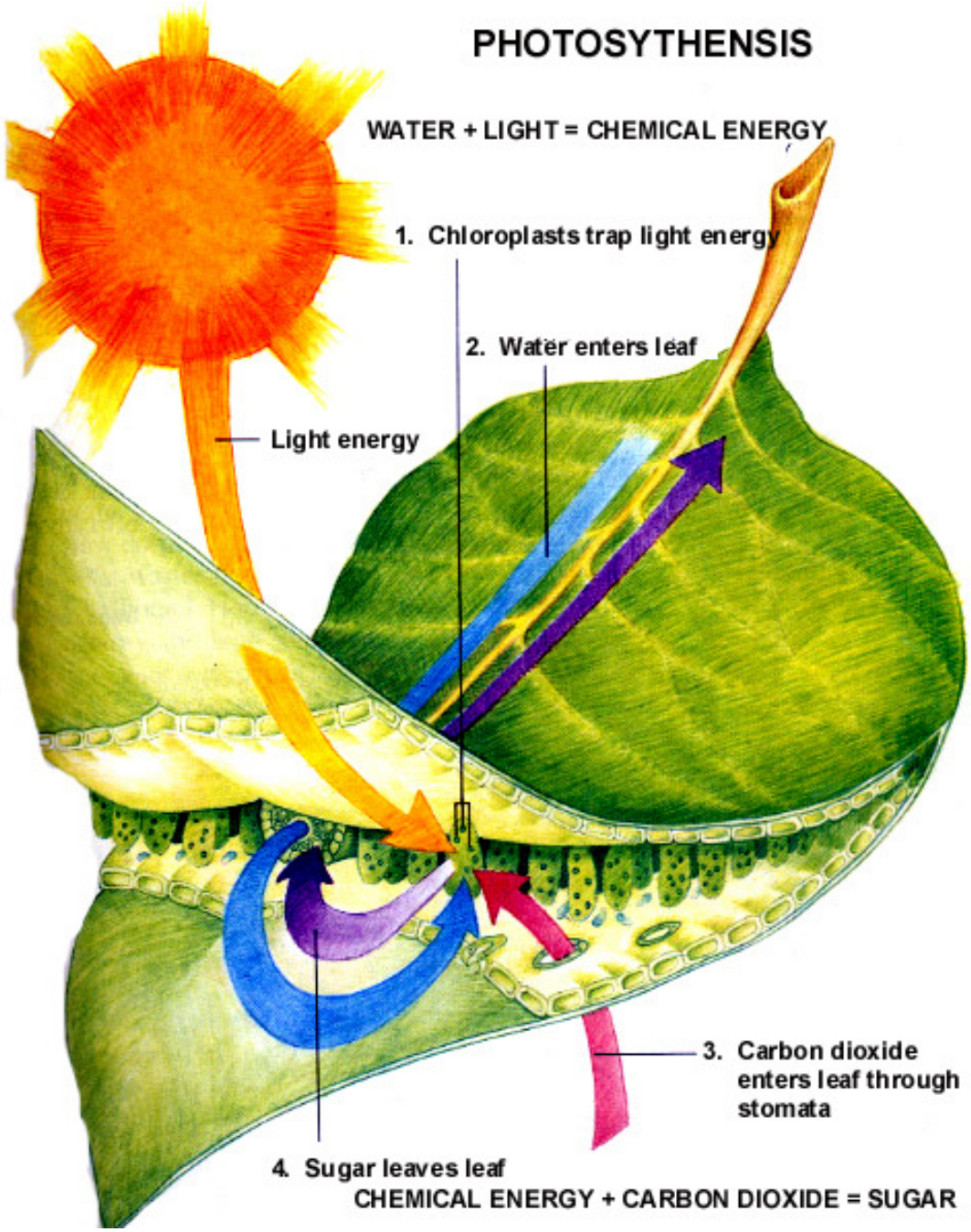
In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose - or sugar.

water + carbon dioxide + sunlight → glucose + oxygen

$6\ H_2O$ + $6\ CO_2$ + radiant energy → $C_6H_{12}O_6$ + $6\ O_2$

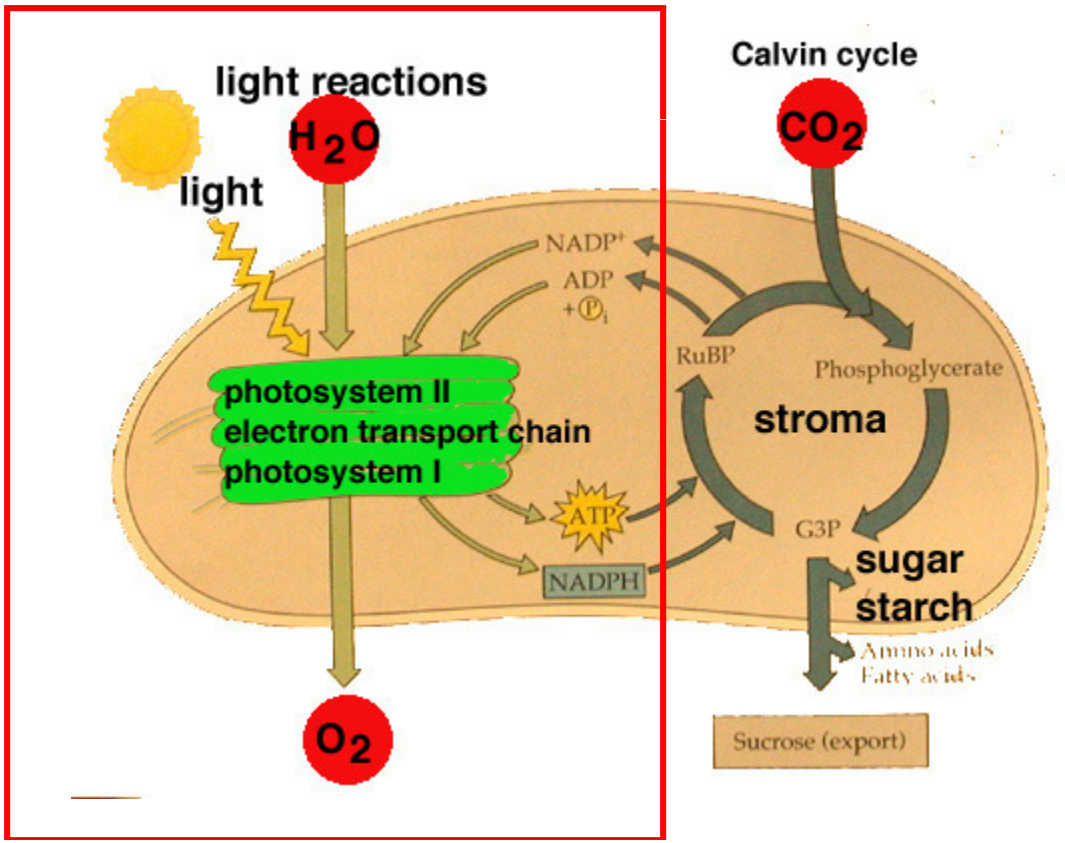
To simplify the very complex process of photosynthesis, we are going to set up the 2 reactions (“Light” and “Dark”) ***as a chart in our notes.***

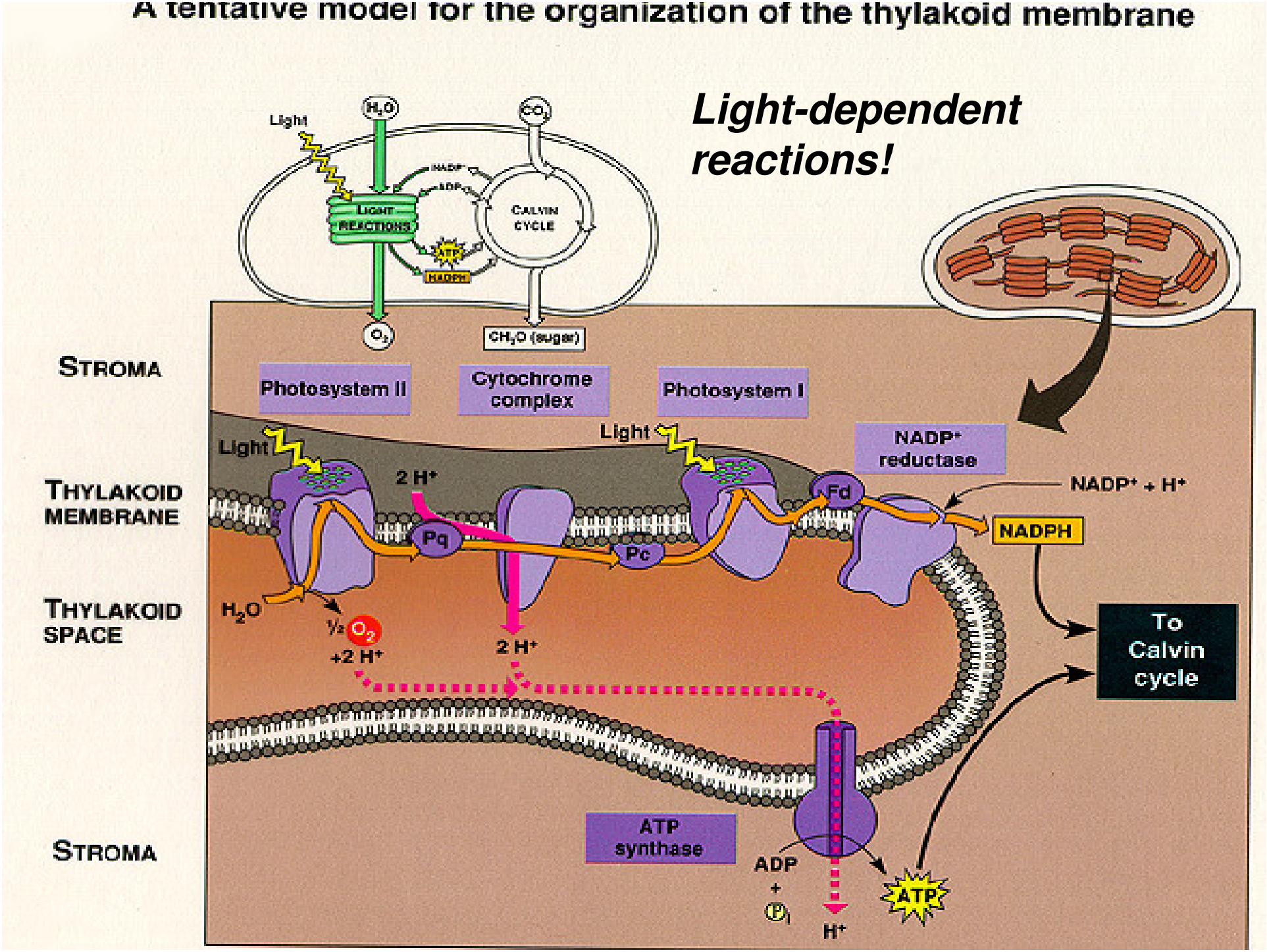

NADP-H
ATP
H_20
CO_2
H H O
H H O
(H)
Light-Dependent Reactions
Calvin Cycle ("light-independent" reactions)
Glucose
$C_6H_{12}O_6$
Thylakoids
Stroma
O_2
(waste)
NADP+
ADP
H_20
(waste)


PHOTOSYTHENSIS
WATER + LIGHT = CHEMICAL ENERGY
1. Chloroplasts trap light energy
2. Water enters leaf
Light energy
3. Carbon dioxide enters leaf through stomata
4. Sugar leaves leaf
CHEMICAL ENERGY + CARBON DIOXIDE = SUGAR

Light-Dependent Reactions:

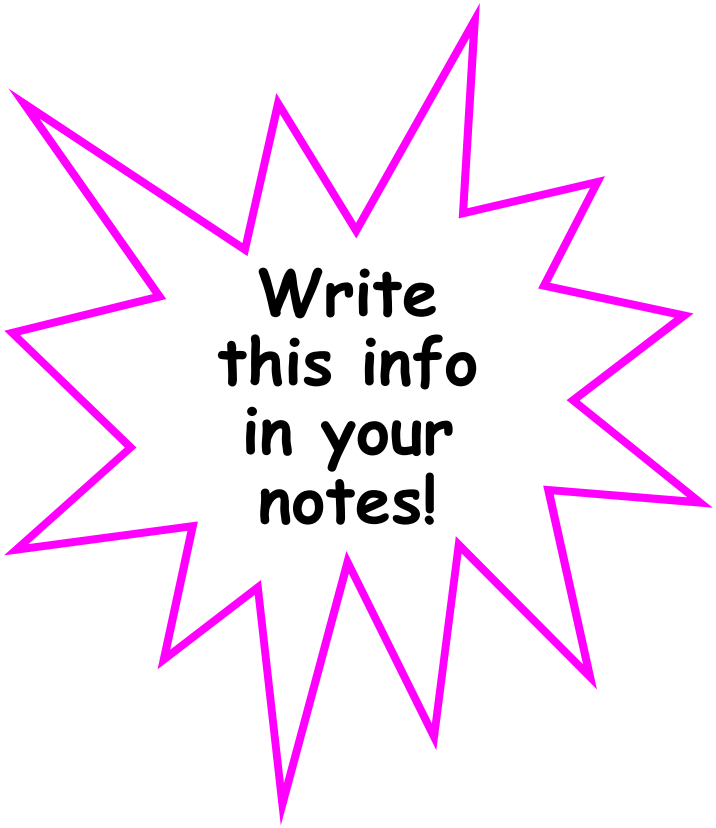
- Produce oxygen gas and convert ADP and $NADP^+$ into the energy carriers ATP and NADPH.

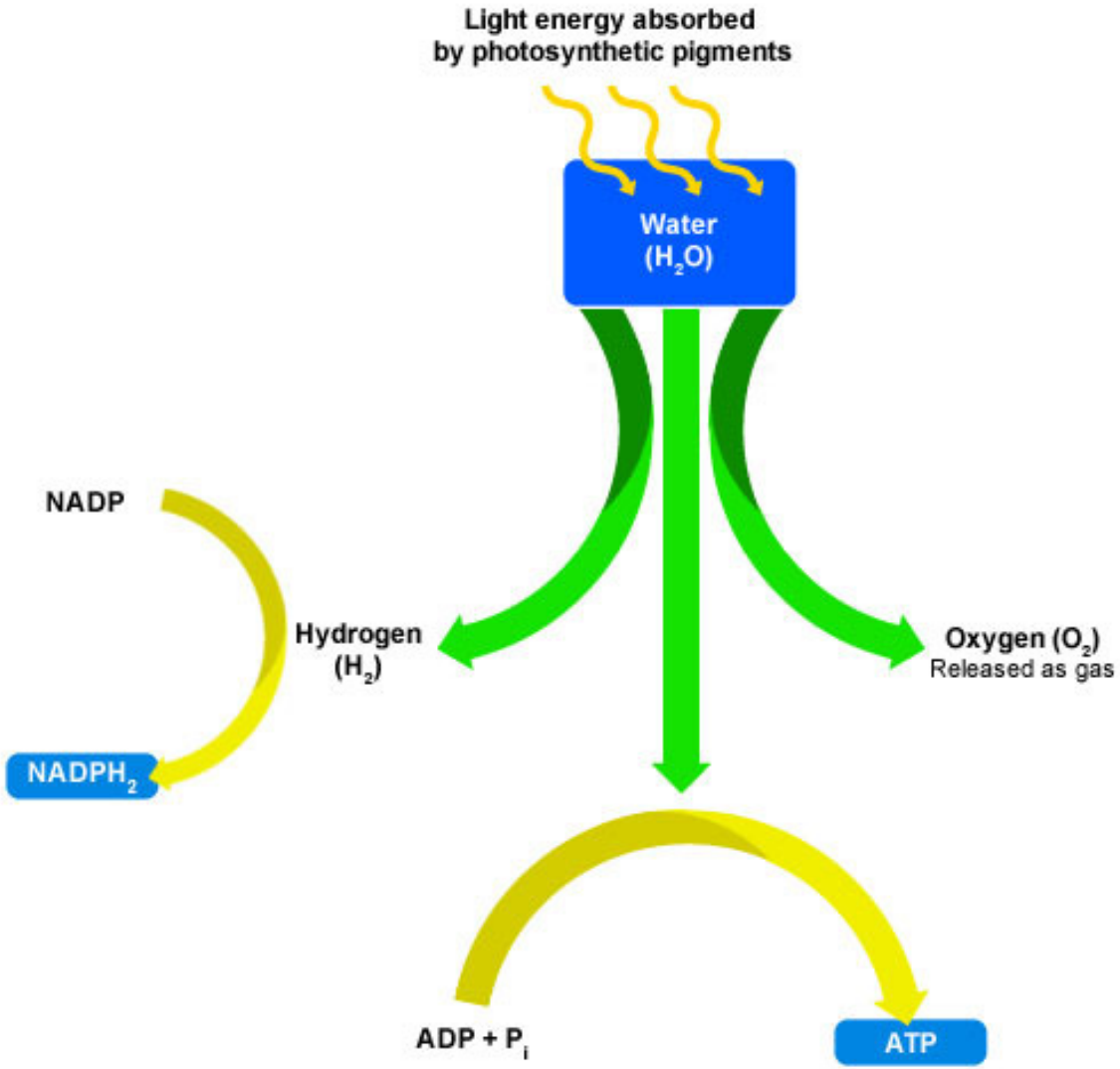



A tentative model for the organization of the thylakoid membrane
Light-dependent reactions!
Light
H_2O
CO_2
NADP+
ADP
Light reactions
Calvin cycle
ATP
NADPH
O_2
CH_2O (sugar)
Stroma
Photosystem II
Cytochrome complex
Photosystem I
Light
Light
NADP+ reductase
$NADP^+ + H^+$
Thylakoid membrane
$2\ H^+$
Pq
Pc
Fd
NADPH
Thylakoid space
H_2O
$\frac{1}{2}\ O_2$
$+2\ H^+$
$2\ H^+$
To Calvin cycle
ATP synthase
ADP
+
P_i
H^+
ATP
Stroma

The Light-Dependent Reactions:

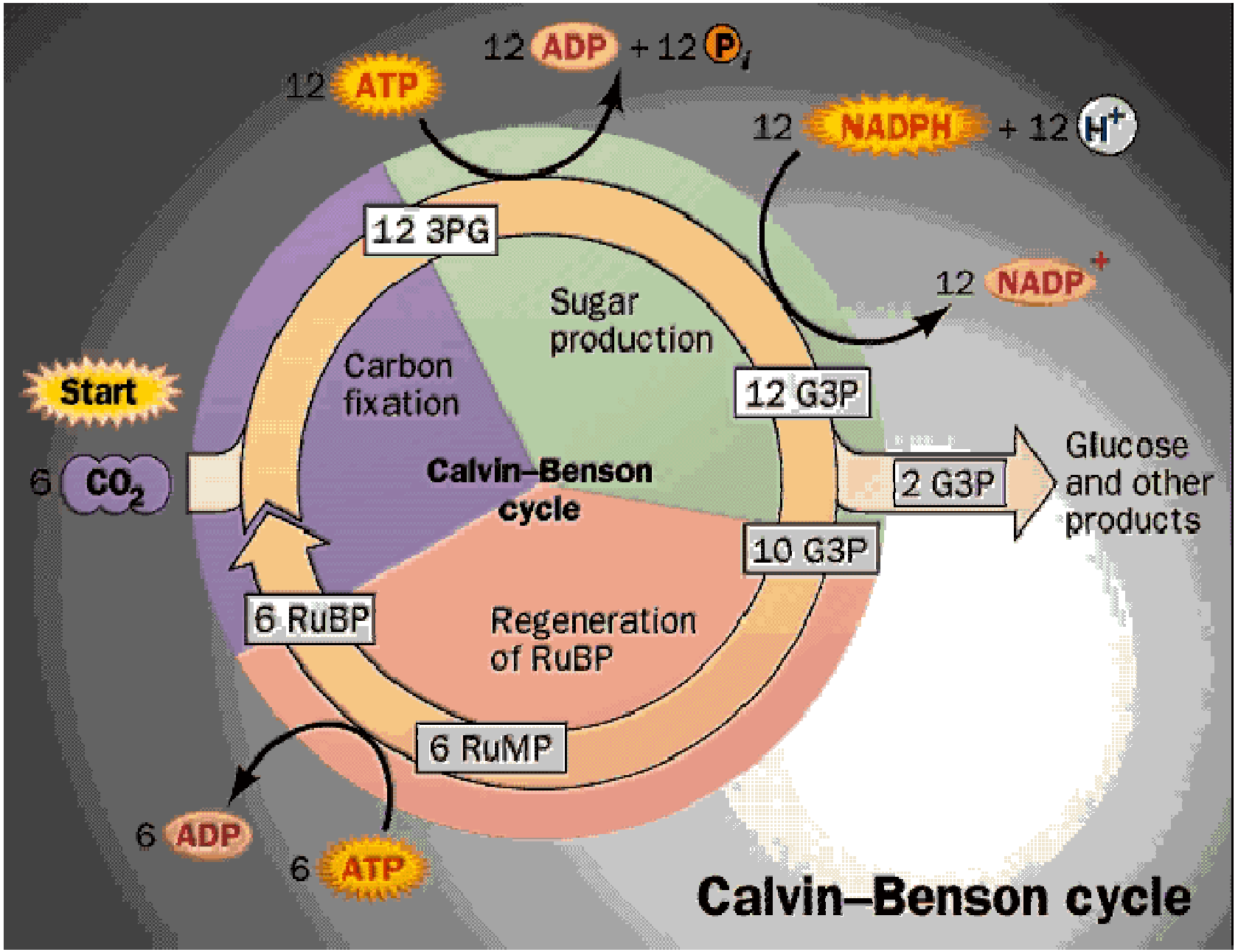
USE	**PRODUCE**
Water	Oxygen (O_2)
ADP	ATP
$NADP^+$	NADPH
Light Energy	




Light energy absorbed
by photosynthetic pigments
Water
(H_2O)
NADP
Hydrogen
(H_2)
Oxygen (O_2)
Released as gas
$NADPH_2$
ADP + P_i
ATP

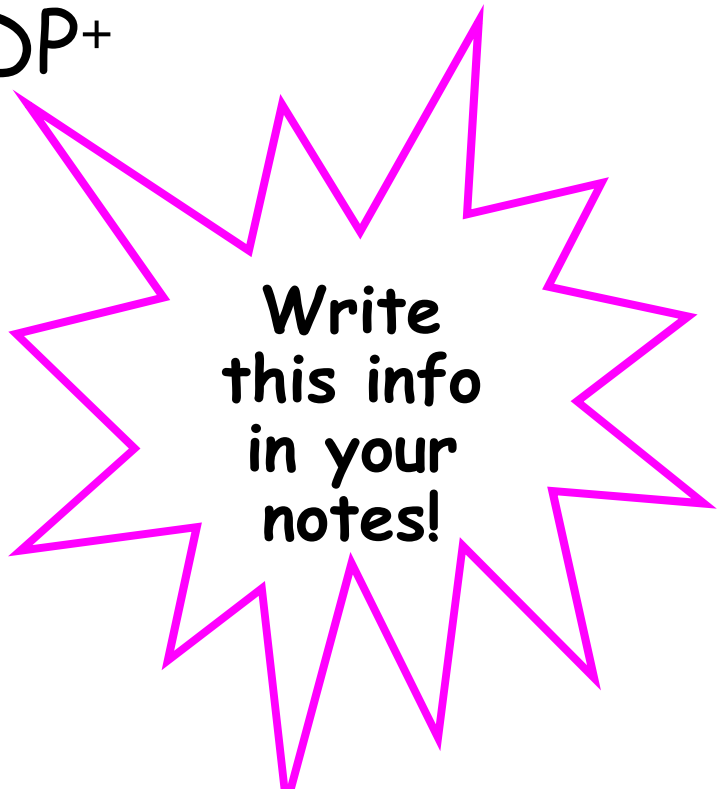
CALVIN CYCLE
(the "Light-Independent" Reactions!)

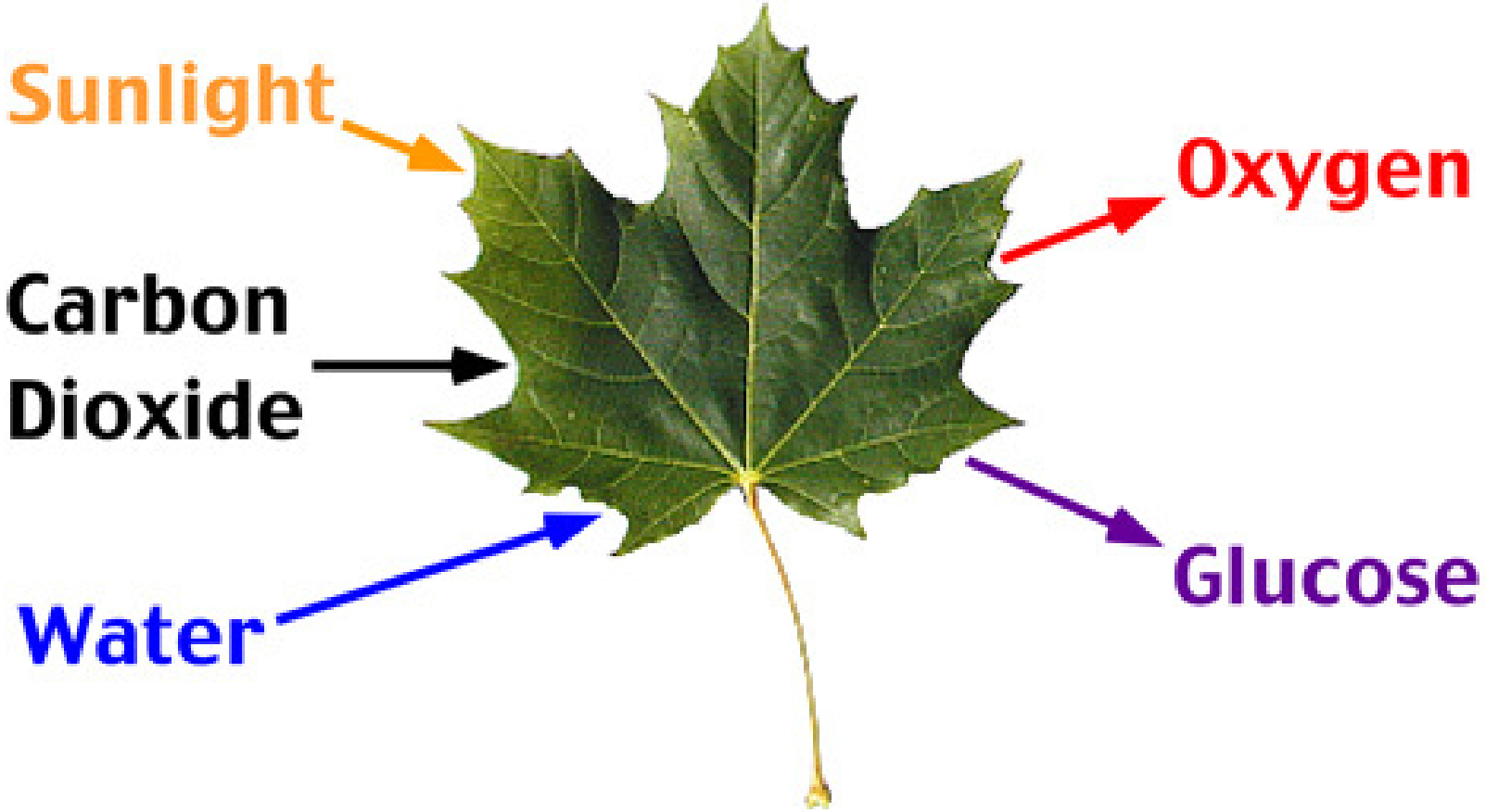
- Plants use the energy that ATP and NADPH contain to build high-energy compounds (**carbohydrates**!) that can be stored for a long time.

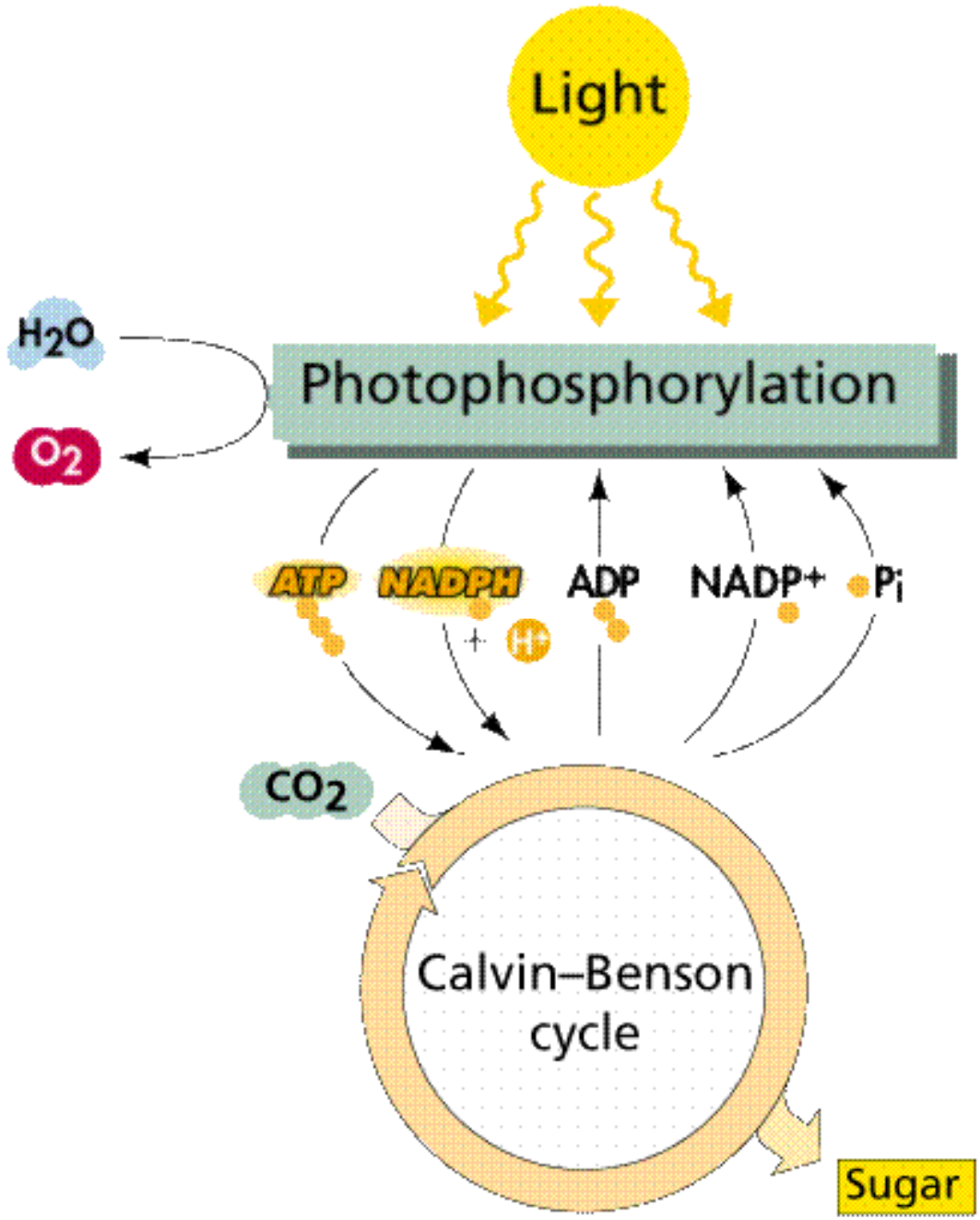

12 ADP + 12 Pi
12 ATP
12 NADPH + 12 H+
12 3PG
12 NADP+
Sugar production
Carbon fixation
Start
12 G3P
6 CO2
Calvin–Benson cycle
2 G3P
Glucose and other products
10 G3P
6 RuBP
Regeneration of RuBP
6 RuMP
6 ADP
6 ATP
Calvin–Benson cycle

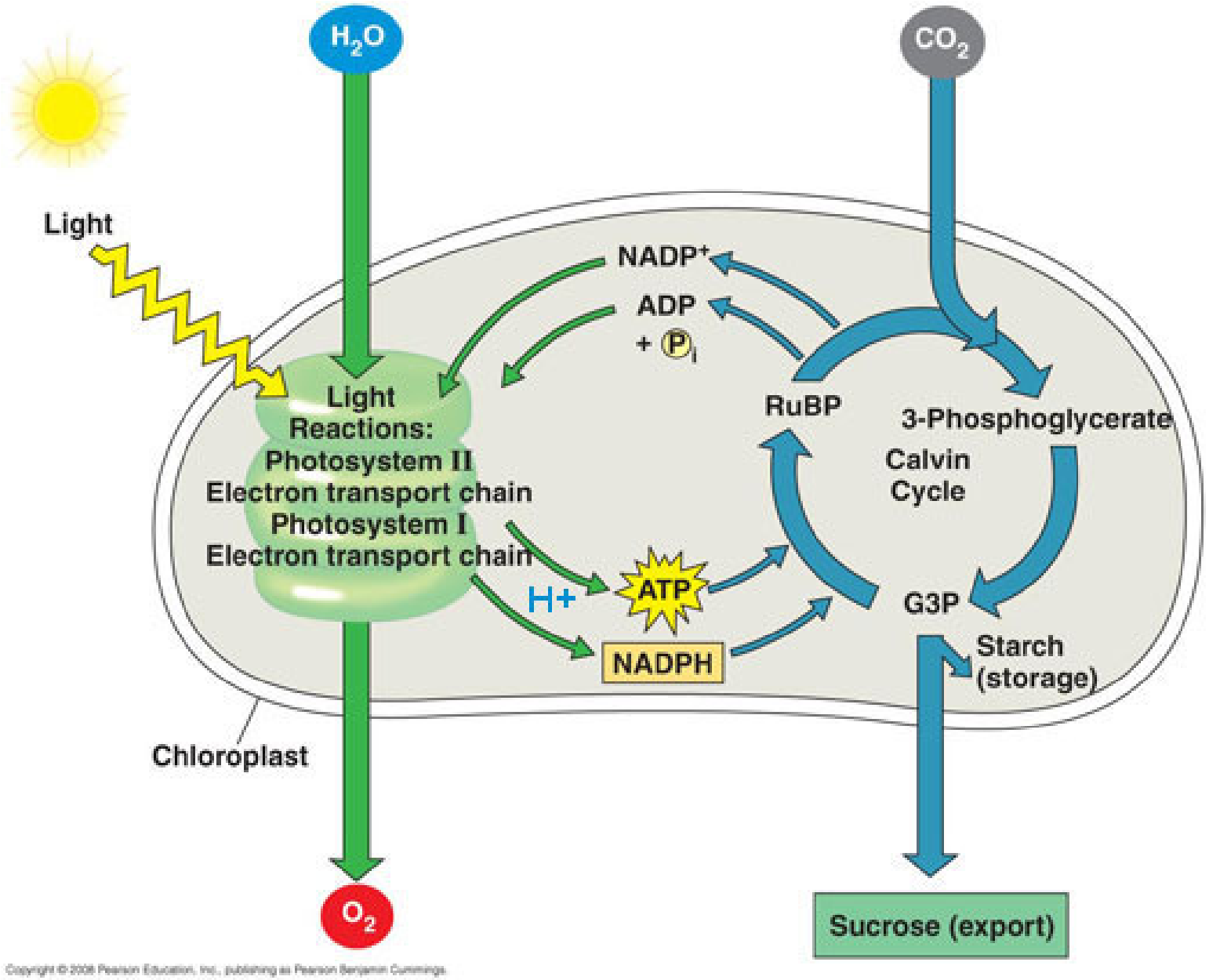
The Calvin Cycle (Light-Independent) Reactions:

USE	PRODUCE
Carbon Dioxide (CO_2)	Glucose
ATP	ADP
NADPH	$NADP^+$




Sunlight
Carbon Dioxide
Water
Oxygen
Glucose


Light
H_2O
O_2
Photophosphorylation
ATP
NADPH
H^+
ADP
NADP+
P_i
CO_2
Calvin–Benson cycle
Sugar



Factors Affecting Photosynthesis:

- **Water supply**
- **Temperature**

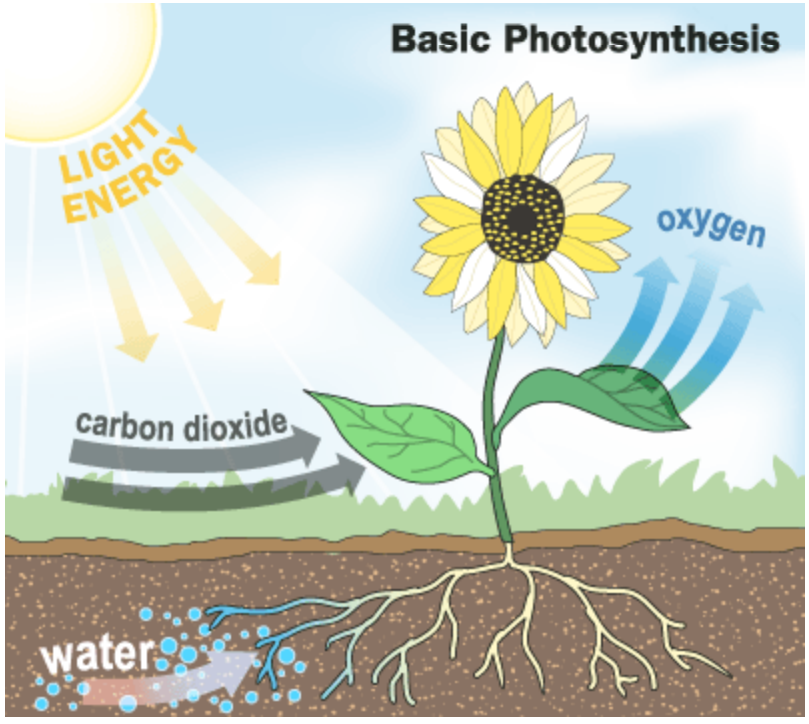
  -Some of the enzymes function best between 0-35 degrees Celsius.

- **Intensity of light**

  -As light intensity increases, so does the rate of photosynthesis (to a point)

Review

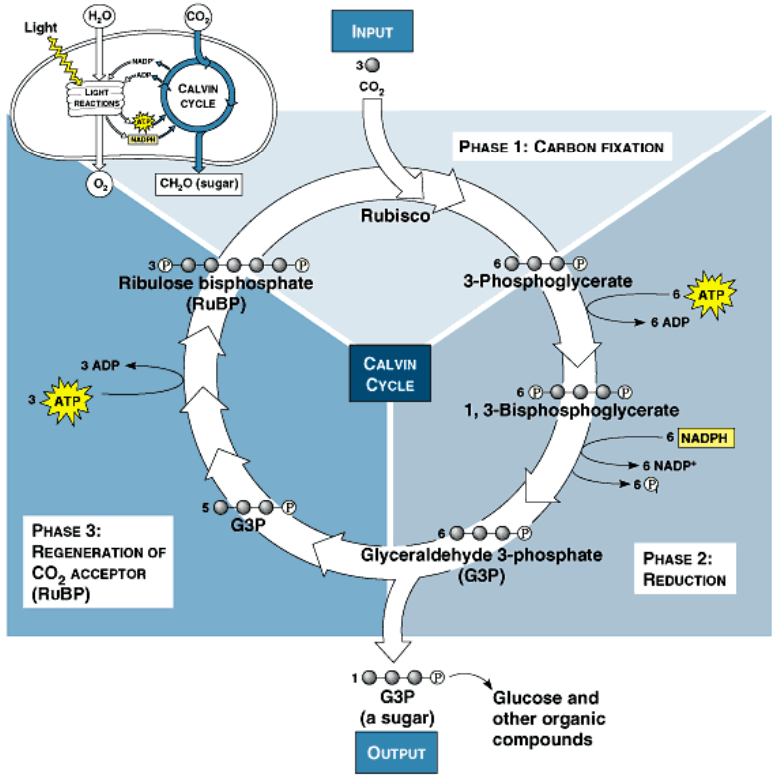
- Which reaction is “light independent”?
- What is the name of the electron carrier in photosynthesis?
- What are the 3 things needed for the “Dark” reactions to occur?
- What is the main product of photosynthesis?
- What 2 things are “recycled” back to the light reaction?



Review

- Which reaction is “light independent”?

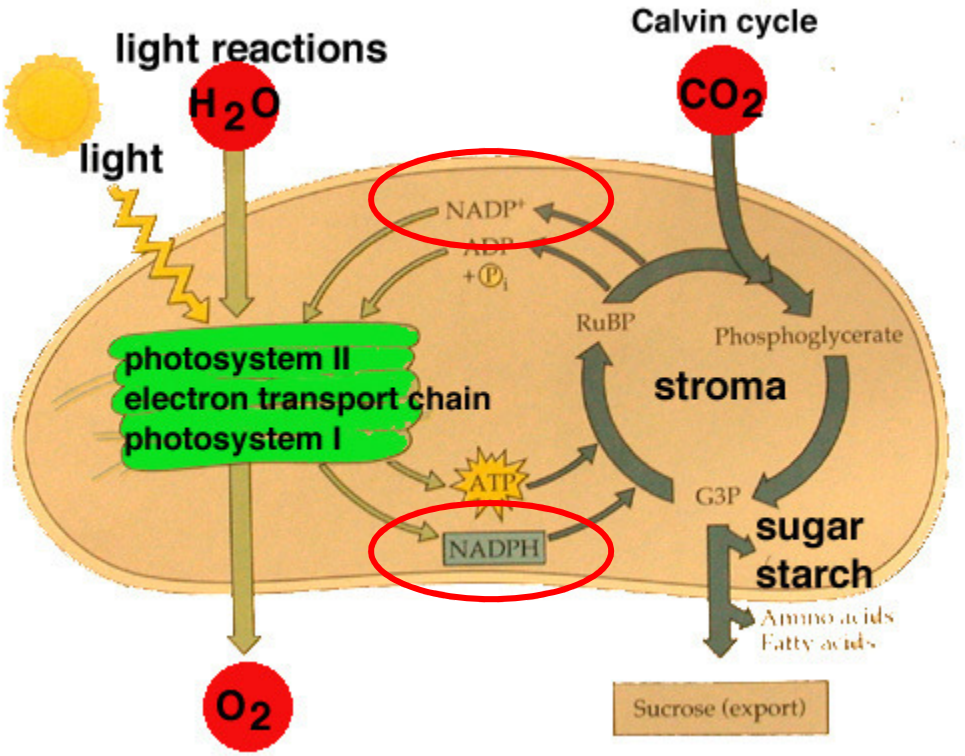
  the CALVIN CYCLE



Review

- What is the name of the electron carrier in photosynthesis?

  NADP+ (becomes NADPH)



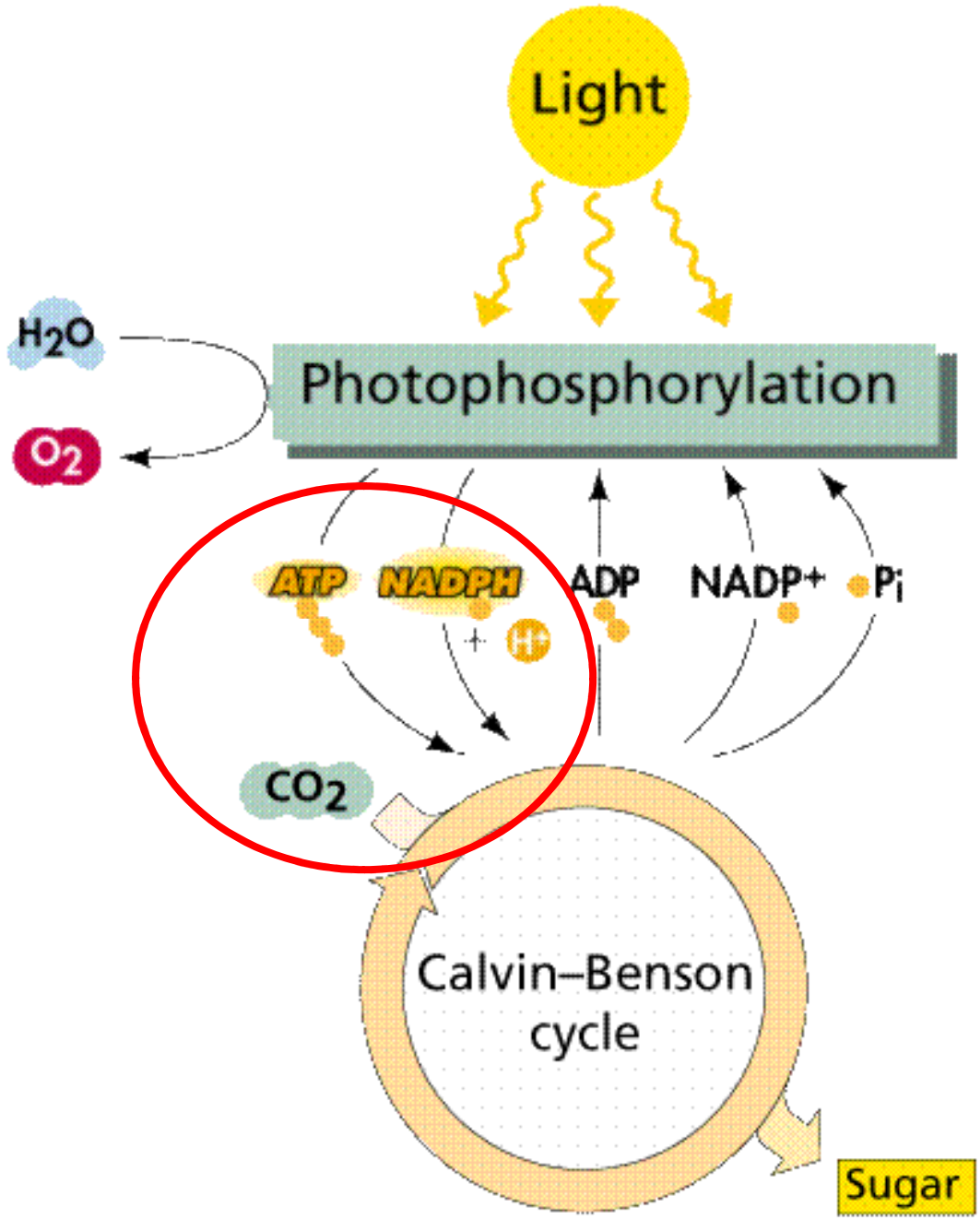
Review

- What are the 3 things needed for the "Dark" Reactions to occur?

  1) PRESENCE OF CO_2;

  2) ATP from LIGHT REACTIONS;

  3) NADPH from LIGHT REACTIONS.

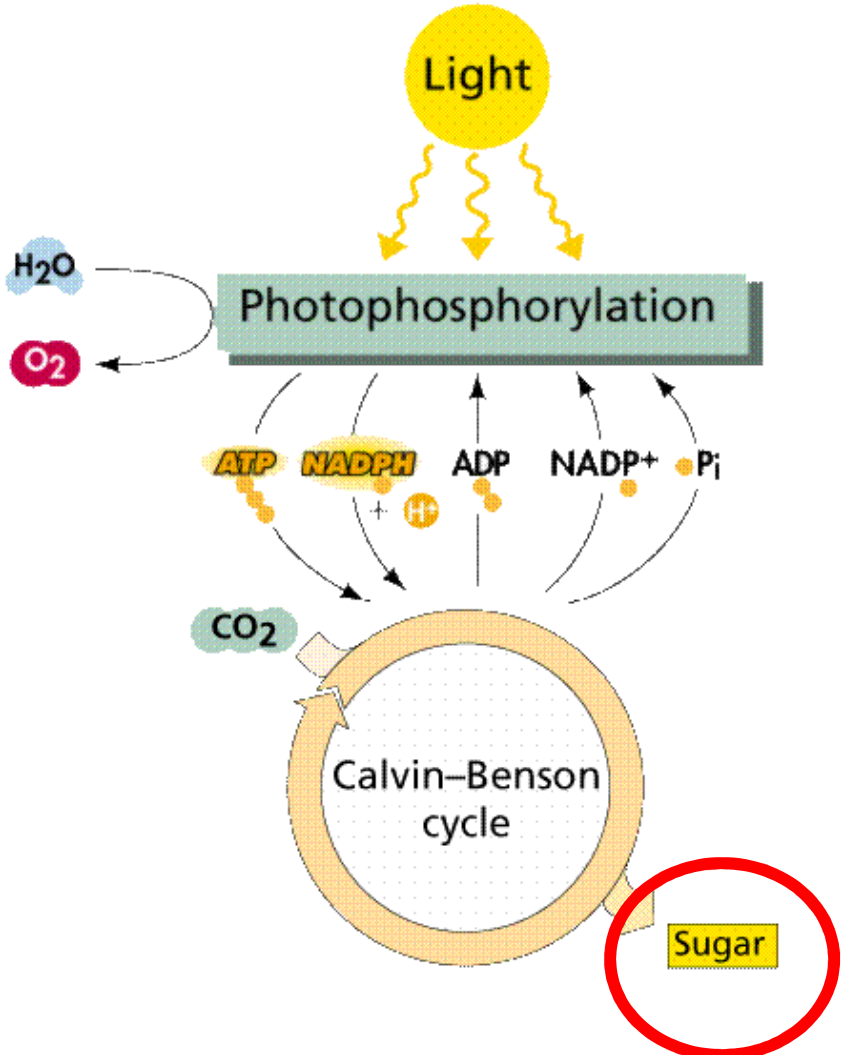

Light
H_2O
O_2
Photophosphorylation
ATP
NADPH
H^+
ADP
NADP+
Pi
CO_2
Calvin–Benson cycle
Sugar

Review

- What is the main product of photosynthesis?

  GLUCOSE!!

  (and OXYGEN, O_2)



Review

- What 2 things are “recycled” back to the light reaction?

  ATP → ADP;

  and NADPH → NADP+