NOTES: 8.2 – 8.3
PHOTOSYNTHESIS!

[Diagram showing a plant with arrows indicating the flow of light energy, carbon dioxide, water, and oxygen.]
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):**

\[ \text{H}_2\text{O} + \text{CO}_2 + \text{Sunlight} \rightarrow \text{O}_2 + \text{carbohydrates} \quad \text{(glucose)} \]
Photosynthesis

- Light (energy from the sun)
  - Chlorophyll (traps light energy to make food)
    - Water (absorbed from the roots)
    - Carbon dioxide (enters through the stomata of the leaves)

- Oxygen (given off into air)
  - Converted into starch (stored food in other parts of the plant)
    - Turns iodine dark blue
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:

• **The mass gained by a plant is NOT from the soil!**
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:

- Plants produce a substance that "refreshes" spent air ... OXYGEN!

(1.) Short time → Add mint plant → Few days

(2.) Dead mouse → Happy mouse
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.
(Before the REAL fun begins!)

More General Info
Photosynthesis uses the energy of sunlight to convert water and carbon dioxide into oxygen and high energy sugars.

- \[ \text{C}_6\text{H}_{12}\text{O}_6 = \text{glucose} \] (a simple sugar)

- Plants use the sugars to produce complex carbohydrates such as starches.
PHOTOSYNTHESIS

1. Chloroplasts trap light energy
2. Water enters leaf
3. Carbon dioxide enters leaf through stomata
4. Sugar leaves leaf

WATER + LIGHT = CHEMICAL ENERGY

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.
Check for understanding...

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

![Diagram showing photosynthesis vs. colour (Action Spectrum of a typical leaf).](image)
8.3: The Process of Photosynthesis

Light-dependent reactions occur in thylakoids.

Light-independent reactions (C₃ cycle) occur in stroma.

End product = glucose
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
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**


Equation for Photosynthesis

\[ 6\text{H}_2\text{O} + 6\text{CO}_2 \xrightarrow{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]

chlorophyll

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

Thylakoids

(light-independent)

Calvin Cycle

Stroma

NADP-H

ATP

CO₂

Glucose

C₆H₁₂O₆

H₂O

O₂

(waste)

(waste)

NADP⁺

ADP
WATER + LIGHT = CHEMICAL ENERGY

1. Chloroplasts trap light energy
2. Water enters leaf
3. Carbon dioxide enters leaf through stomata
4. Sugar leaves leaf

CHEMICAL ENERGY + CARBON DIOXIDE = SUGAR

PHOTOSYNTHESIS
Light-Dependent Reactions:

- Produce **oxygen gas** and convert **ADP** and **NADP**\(^+\) into the energy carriers **ATP** and **NADPH**.
Light-dependent reactions!
The Light-Dependent Reactions:

**USE**
- Water
- ADP
- NADP+
- Light Energy

**PRODUCE**
- Oxygen ($O_2$)
- ATP
- NADPH

Write this info in your notes!
Light energy absorbed by photosynthetic pigments

Water (H₂O)

NADP

NADPH₂

Hydrogen (H₂)

Oxygen (O₂) Released as gas

ADP + P₁

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.
The Calvin Cycle (Light-Independent)

Reactions:

**USE**
- Carbon Dioxide ($CO_2$)
- ATP
- NADPH

**PRODUCE**
- Glucose
- ADP
- NADP$^+$

Write this info in your notes!
Sunlight → Leaf → Oxygen
Carbon Dioxide → Leaf → Glucose
Water → Leaf → Oxygen

Glucose is produced by photosynthesis in the leaves of plants. Sunlight, carbon dioxide, and water are required to produce glucose and oxygen.
Light Reactions:
Photosystem II
Electron transport chain
Photosystem I
Electron transport chain

Water ($H_2O$) enters on the left, and Carbon Dioxide ($CO_2$) enters the Calvin Cycle from the right.

The light reactions occur in the thylakoid membranes of the chloroplasts, where chlorophyll absorbs light energy and converts it into chemical energy.

The electron transport chain generates ATP and NADPH, which are used in the Calvin Cycle to synthesize glucose.

NADP$^+$ is reduced to NADPH, and ATP is synthesized.

The Calvin Cycle occurs in the stroma of the chloroplasts:
- RuBP (Ribulose 1,5-bisphosphate) is converted to 3-phosphoglycerate (3-PGA).
- 3-PGA is then oxidized to produce 3-phosphoglycerate (3-PGA) and AMP.
- The AMP is then converted to ADP and ATP.

Oxygen ($O_2$) is released as a byproduct of the light reactions.

Sucrose is exported from the chloroplasts and stored in the vacuoles of the plant cells.

Energy is stored in ATP and NADPH, which are used to reduce the inorganic phosphate ($P_i$) to ATP and to reduce NAD$^+$ to NADPH.
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.
• What is the main product of photosynthesis?

GLUCOSE!! (and OXYGEN, O$_2$)
What 2 things are “recycled” back to the light reaction?

**ATP ➔ ADP;**
**and NADPH ➔ NADP**