PHOTOSYNTHESIS

Chapter 6

5.1 Matter and Energy Pathways in Living Systems

Chapter 5 – Photosynthesis & Cellular Respiration

5.1 Matter and Energy Pathways in Living Systems

- In this section you will:
  - **Compare** and **summarize** the essential features of chloroplast and mitochondria in relation to the role of photosynthesis in storing energy and the role of cellular respiration in releasing energy
  - **Summarize** and **explain** the role of ATP in cellular metabolism.

Photosynthesis & Cellular Respiration

- Both cellular respiration and photosynthesis are examples of biological processes that involve matter and energy
- During photosynthesis, energy from the sun is stored in the chemical bonds of glucose
- This energy is released during cellular respiration

Photosynthesis

- A process that converts **solar energy** into **chemical energy**
- Meaning: 'Light" and "to make or build".
- Remember the chemical formula!?

5

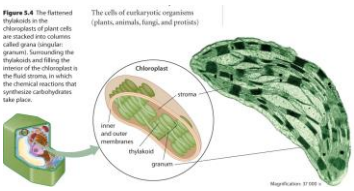
Chloroplasts

- Clusters of **CHLOROPHYLL** are found in plant organelles called **CHLOROPLASTS**
- yep… they're green!
- Site of photosynthesis
- Structure of a chloroplast:
- Outer & Inner Membrane

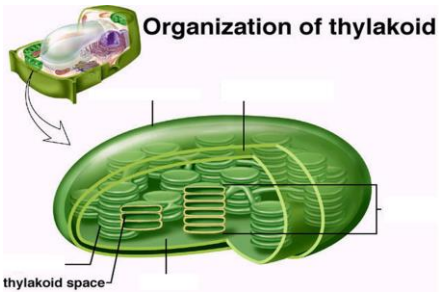
Thylakoid Membranes (Discs): contain **chlorophyll**

Grana: Stacks of Thylakoid Discs

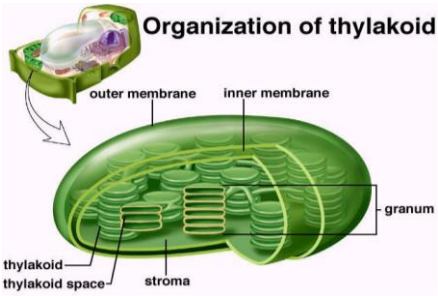
Stroma: gel-like enzyme-rich substance filling the chloroplast



6



7



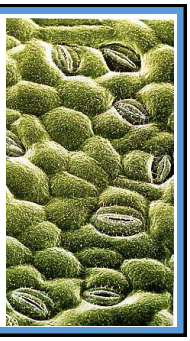
8

Leaf structure

- Most **chloroplasts** are found in a layer of cells at the **TOP** of a leaf

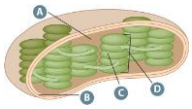
The **PALISADE MESOPHYLL LAYER**

- Why?
- The sun first passes through the waxy cuticle, then through the upper epidermis, then finally to the Palisade Mesophyll layer



Check Your Understanding:

1. What is chlorophyll?
2. Identify the regions of the chloroplast indicated on this diagram. Describe what happens in C.



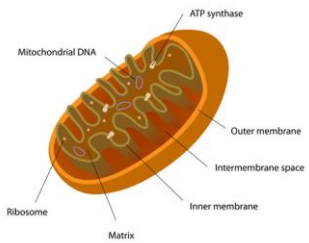
3. Describe the major function of photosynthetic pigments.

10

Mitochondria

- Site of **Cellular Respiration**
- Found in organelles
- Two membranes
- Fluid-filled space within the membrane is known as the **matrix**
- Matrix contains many chemicals and proteins requires to break down carbohydrates

11



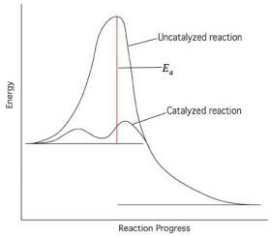
12

Role of Enzymes

- Metabolism – Chemical process- Necessary chemical reactions
- **Anabolic reactions-** Create larger membranes from small subunits
- **Catabolic reactions-** Break down large molecules into smaller pieces
- Reactions require energy
- Energy requirements are known as activation energy
- Catalysts and enzymes reduce the activation energy allowing reactions to occur more rapidly
- Enzymes are protein catalysts within cells

13

Activation Energy- Catalyzed vs. Unanalyzed



14

Energy Containing Molecules Formed During Photosynthesis

Molecule	Function
■ATP (adenosine triphosphate)	■**Principal energy** – supply molecule for cellular functions of all cells ■Provides an immediate source of energy for cellular processes ■Formed by addition of ADP and P (phosphate)

15

ATP (adenosine triphosphate)

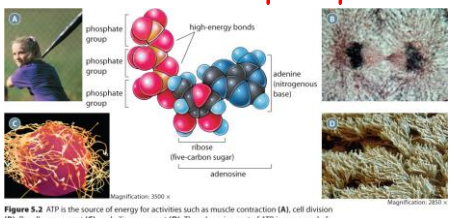
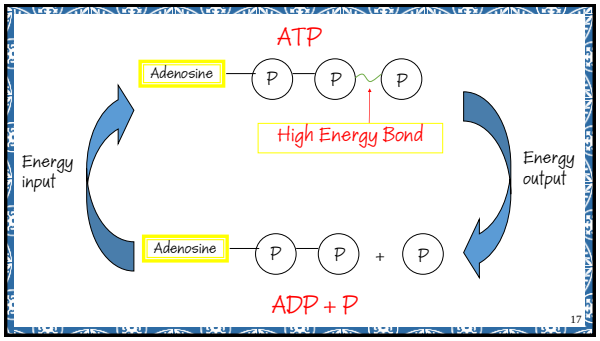


Figure 5.2 ATP is the source of energy for activities such as muscle contraction **(A)**, cell division **(B)**, flagella movement **(C)**, and cilia movement **(D)**. The adenosine part of ATP is composed of a molecule called adenine, which is bonded to a five-carbon sugar called ribose. Our bodies use about 40 kg of ATP daily. The amount of ATP available at any moment is enough to meet only immediate cellular needs. Thus, ATP must be synthesized constantly.

16



Energy Containing Molecules Formed During Photosynthesis

Molecule	Function
■NADPH ▪(FYI - nicotinamide dinucleotide phosphate)	▪During photosynthesis, $NADP^+$ accepts 1 H^+ ion and 2 e- to form NADPH ▪NADPH is an electron donor, thus becomes $NADP^+$ again ▪Involved in energy transfers

18

5.2 Photosynthesis Stores Energy in Organic Compounds

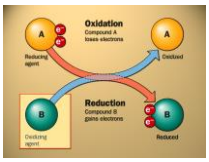
- In this section you will:
  - **Describe** how pigments absorb light energy and transfer it as reducing power in NADPH
  - **Explain** how absorbed light energy is transferred to the chemical potential energy of ATP by chemiosmosis
  - **Describe** where the energy transfer processes take place in chloroplasts
  - **Explain** how scientific knowledge may lead to the development of new technologies
  - **Collect** and **interpret** data and calculate Rf values from chromatography experiments
  - Conduct investigations in print and electronic resources on C3 and C4 photosynthetic mechanisms

19

Oxidation – Reduction Reactions of Photosynthesis

•Oxidation

- A reaction in which an atom or molecule loses electrons
- Example:
  - Hydrogen undergoes oxidation to form hydrogen ions or we say hydrogen is **"oxidized"** to form hydrogen ions



20

•Reduction

- A reaction in which an atom or molecule gains electrons

- Electron transfers between 2 substances always involve both oxidation / reduction reactions

21

Oxidation / reduction example

NADPH

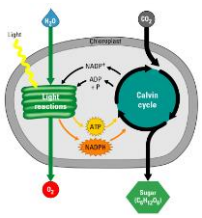
- Reduction of $NADP^+$
  - $NADP^+ + H^+ \rightarrow NADPH$
    - NADPH is now stable and can release energy to the next electron acceptor
- Oxidation of NADPH
  - $NADPH \rightarrow NADP^+ + H^+$
    - $NADP^+$ can be reused in future reduction reactions

22

Photosynthesis is a two step process:

1.Light Dependent Reactions - energy from the sun is captured in energy carrying molecules. Since it must take place in sunlight it is often called the "light" reaction.

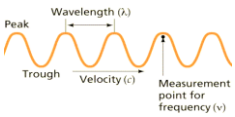
2.Light Independent Reactions - The energy from the "light" reactions is used to fix the carbon from atmospheric carbon dioxide into organic compounds. It does not have to take place in the light so it is often called the "dark" reactions(s), aka: carbon-fixation reactions, Calvin Cycle.



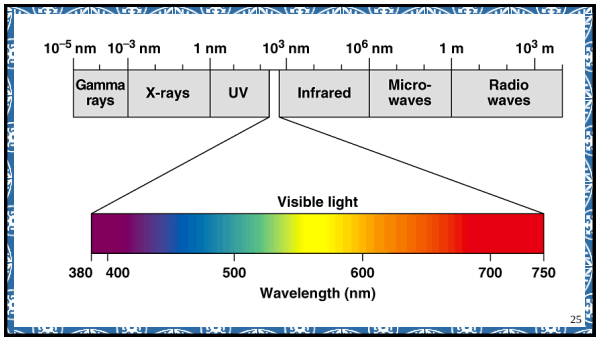
23

Light

- Light travels in waves called **PHOTONS**
- Each photon is a small unit of **energy**
- Photons with **short wavelengths** have **HIGH energy** (bad for us!)
  Ex. UV rays, x-rays, gamma rays.
- Photons with **long wavelengths** have **LOW energy**
  Ex. infrared, microwaves, radio waves



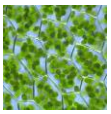
24

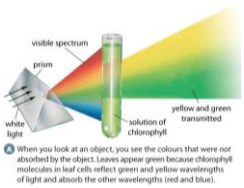


25

Chlorophyll

- Green colored **PIGMENT**
- Found in plants, algae, protists, and cyanobacteria
- chlorophyll **absorbs** the **PHOTONS** and begins the process of **photosynthesis**
- **CHLOROPHYLL A.** (bright green) is the MOST IMPORTANT PIGMENT
- other pigments like chlorophyll b (dull green), carotene (orange), etc.
- - Accessory pigments





A When you look at an object, you see the colours that were not absorbed by the object. Leaves appear green because chlorophyll molecules in leaf cells reflect green and yellow wavelengths of light and absorb the other wavelengths (red and blue).

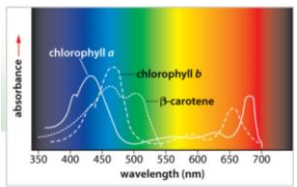
26

Accessory pigments

- Help absorb other photon wavelengths and pass energy to chlorophyll a.
- Why do leaves turn many different colors in the fall?
- a **SPECTROPHOTOMETER** can accurately show which pigments absorb which wavelengths (colors)

27

The Absorption Spectrum of Chlorophyll a and Chlorophyll b



B This absorbance spectrum for three photosynthetic pigments shows that each pigment absorbs a different combination of colours of light.

28

Chromatography

- Technique used to separate a mixture into its component molecules.
- The molecules migrate, or move up the paper, at different rates because of differences in solubility, molecular mass, and hydrogen bonding with the paper.
- Migration of pigment relative to migration of solvent is expressed as a constant, R_f (Reference front). It can be calculated by using the formula:
- R_f = distance pigment migrated/distance solvent front migrated

29

Chromatography

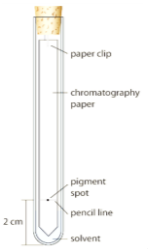
- **Solute**- A substance that is dissolved in a solution.
- **Solvent-** The dissolving agent of a solution. Water is the most versatile solvent known.
- **Solvent front-** leading edge of the solvent moving along the paper.
- **Rf**- Defined as the ratio of the distance traveled by the substance to the distance traveled by the solvent.

30

Chromatography Lab – Thursday 265

- Filter paper is placed in solvent
- As solvent moves up the paper it will carry pigments
- Size: Smaller pigments travel further up paper
- Solubility: More soluble pigments travel further up paper

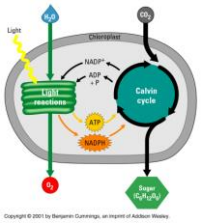
- Mslis.weebly.com



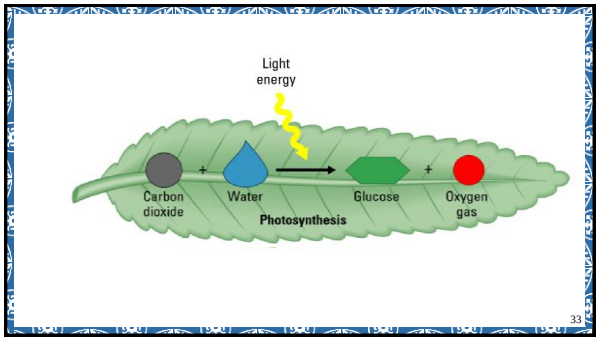
31

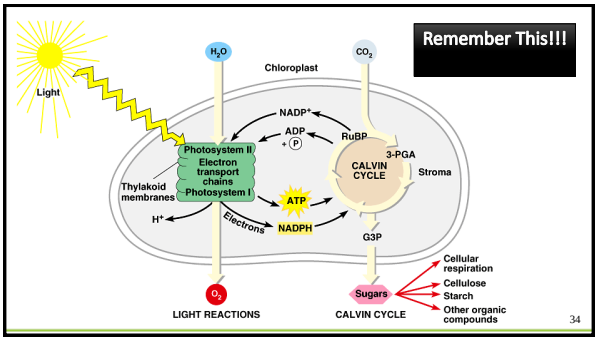
An Overview of Photosynthesis

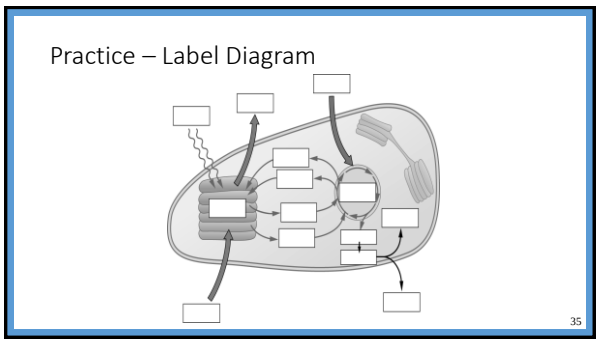
- **Photo** - light required
  - Light reactions - in thylakoid membrane
  - Energy from sun converted to chemical energy
    - ATP
    - NADPH
- **Synthesis** - Calvin Cycle
  - Makes sugar in stroma
  - No light required
  - CO_2 to $C_6H_{12}O_6$
  - Uses ATP and NADPH

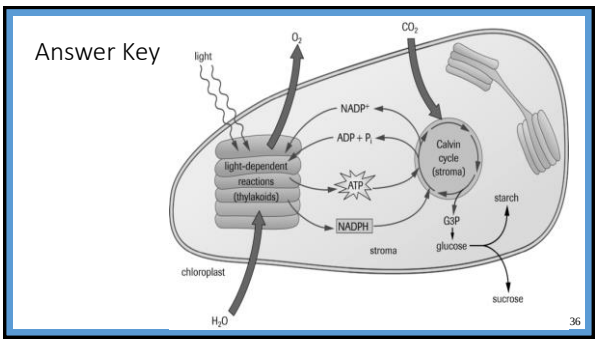


32


Light energy
Carbon dioxide
Water
Glucose
Oxygen gas
Photosynthesis
33


Remember This!!!
Light
H_2O
CO_2
Chloroplast
$NADP^+$
ADP + P
RuBP
3-PGA
CALVIN CYCLE
Stroma
Photosystem II
Electron transport chains
Photosystem I
Thylakoid membranes
ATP
H^+
Electrons
NADPH
G3P
O_2
Sugars
Cellular respiration
Cellulose
Starch
Other organic compounds
LIGHT REACTIONS
CALVIN CYCLE
34


Practice – Label Diagram
35


Answer Key
light
O_2
CO_2
$NADP^+$
$ADP + P_i$
light-dependent reactions (thylakoids)
ATP
NADPH
Calvin cycle (stroma)
G3P
starch
glucose
sucrose
stroma
chloroplast
H_2O
36

Photosystems

- **Photosystems**: The arrangement of chlorophyll and other pigments along the **thylakoid membrane**.
- Two photosystems: PSII and PSI
- Named in the order of discovery- **1. PSII 2. PSI**
- Pigments absorb light from various wavelengths
- Energy is passed along to one specialized electron-acceptor chlorophyll *a* - **reaction center**.
- Electron is passed to another **electron acceptor**.

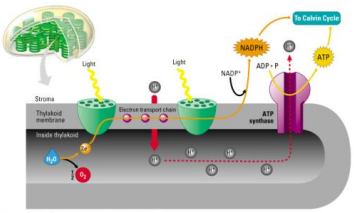
37

Photosynthesis: Light Dependent Reactions

- It all begins with the **sun** striking a **water molecule** and **breaking it apart**

Called photolysis

- $H_2O \rightarrow 2H^+ + 2e^- + \frac{1}{2} O_2$
- The O_2 is released (ahh! Inhale!)
- The H+ build up inside the thylakoid disc
- The electrons get "**excited!**" on 2 **PHOTOSYSTEMS**



38

- **PHOTOSYSTEM II** then **I:**

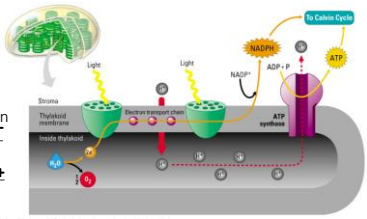
Clusters of chlorophyll that **capture** the **energy** from **photons**

Located **ON** the **thylakoid membrane**

- Then the **excited!** electrons get passed down an **ELECTRON TRANSPORT CHAIN (ETC)**

The energy pumps **more H+ INTO** the **Thylakoid Disc, and**

NADP+ becomes reduced to **NADPH**



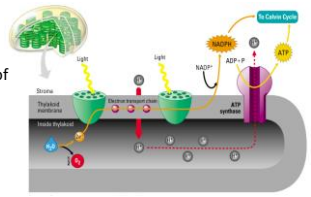
39

- **CHEMIOSMOSIS** now occurs:

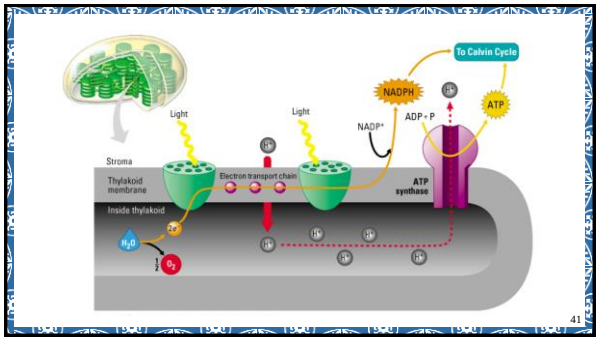
The **H+** flow through the **ATP Synthase** to create **ATP**

- Note: the **ATP** and the **NADPH** (both produced in the **STROMA**) will be needed for the next part of Photosynthesis…

(DARK REACTION)

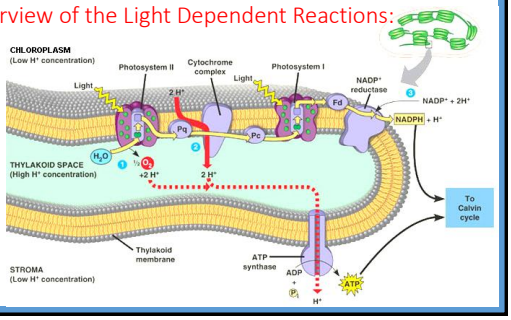


40



41

A Overview of the Light Dependent Reactions:



Check Your Understanding:

1. What are the two sets of reactions that are involved in photosynthesis?
2. Predict why most green plants contain more than one photosynthetic pigment.
3. What is a photosystem? Where do you find photosystems?
4. Describe or sketch what happens to electrons in the ETC.
5. How are electrons replaced in photosystem I, and what is the source of the replacement electrons?
6. Identify the source of oxygen released from the chloroplast during photosynthesis. Explain the main function of the reaction in which oxygen is released.

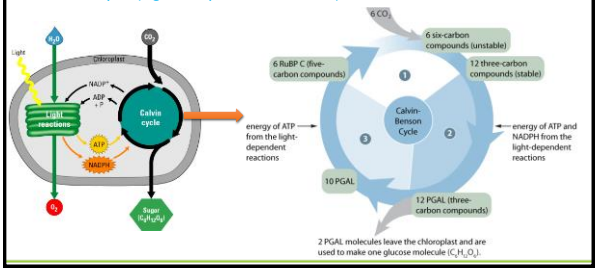
43

7. How does NADP+ become converted to NADPH?
8. Is NADPH an oxidized or reduced molecule? Explain.
9. How are electrons replaced in photosystem I, and what is the source of the replacement electrons?
10. What is the effect of having a greater concentration of hydrogen ions in the thylakoid space (lumen), than in the stroma?
11. What is ATP synthase, and what is its significance?
12. The membranes of the thylakoids is impermeable to hydrogen ions (H+), meaning that these ions cannot diffuse across the membranes from the inner space of the thylakoid to the stroma.
    a. Identify the only path by which H+ ions can move down their concentration gradients across the membrane to the stroma.
    b. Identify the process that is associated with the movment of H+ through the pathway and identify the end product of this process.

44

Photosynthesis: Part 2

The Calvin cycle (Light Independent Reactions)



- This **LIGHT INDEPENDENT** reactions happens in the **STROMA**:

ATP from the light reactions **+**

NADPH from the light reactions **+**

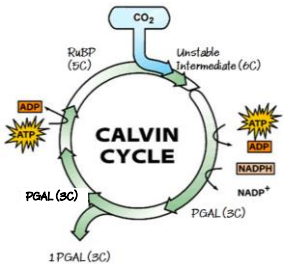
CO_2 from the air space in the leaf

- React to produce:

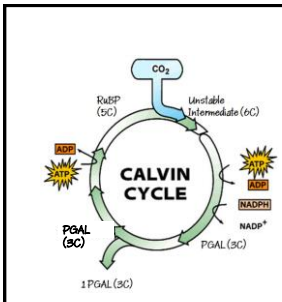
$C_6H_{12}O_6$ (GLUCOSE)

(sucrose, starch, cellulose, etc.) and some **WATER VAPOUR**

- Note: PGAL also called G3P



46



47

Calvin Cycle

- Each turn of the Calvin Cycle fixes one carbon
- For the net synthesis of one glucose molecule the cycle must take place 6 times fixing 6 carbons.
- The Calvin Cycle has three phases.

48

Phase 1: Carbon Fixation

- CO2 attaches to a five-carbon sugar, ribulose biphosphate (RuBP)
  - Rubisco
- The six-carbon intermediate splits in half to form two molecules of PGA

49

Phase 2: Reduction

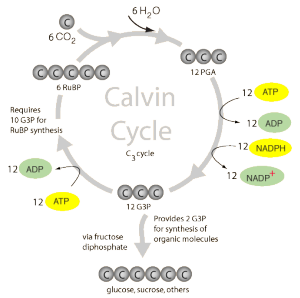
- PGA received a phosphate from ATP to form ADP and a pari of electrons from NADPH
- PGA is reduced to form G3P (2)

50

Phase 3: Regeneration

- 2 G3P are used to form 1 glucose molecule (6 carbons)
- The remaining 10 G3P (30 carbons) are rearranged to form 6 new (5 carbon) rubiscos to maintain the cycle.

51



52

Calvin Cycle

- https://www.youtube.com/watch?v=0UzMaoaXKaM
- http://www.uic.edu/classes/bios/bios100/lectures/calvin.htm

53

Review Photosynthesis: Crash Course Biology

Photosynthesis: Crash Course Biology #8

- http://www.youtube.com/watch?v=sQK3Yr4Sc_k (13:15 min)

54

Check Your Understanding

1. What does the term carbon dioxide fixation mean?
2. Identify the source of ATP and NADPH required to synthesize glucose.
3. Where in the chloroplast does the Light Independent reactions take place?
4. Outline the Calvin Cycle in terms of carbon dioxide fixation, reduction, and regeneration

55

Reminder

- Photosynthesis Quiz

56