Photosynthesis and Cellular Respiration

Chapter 8-9

Warm Up

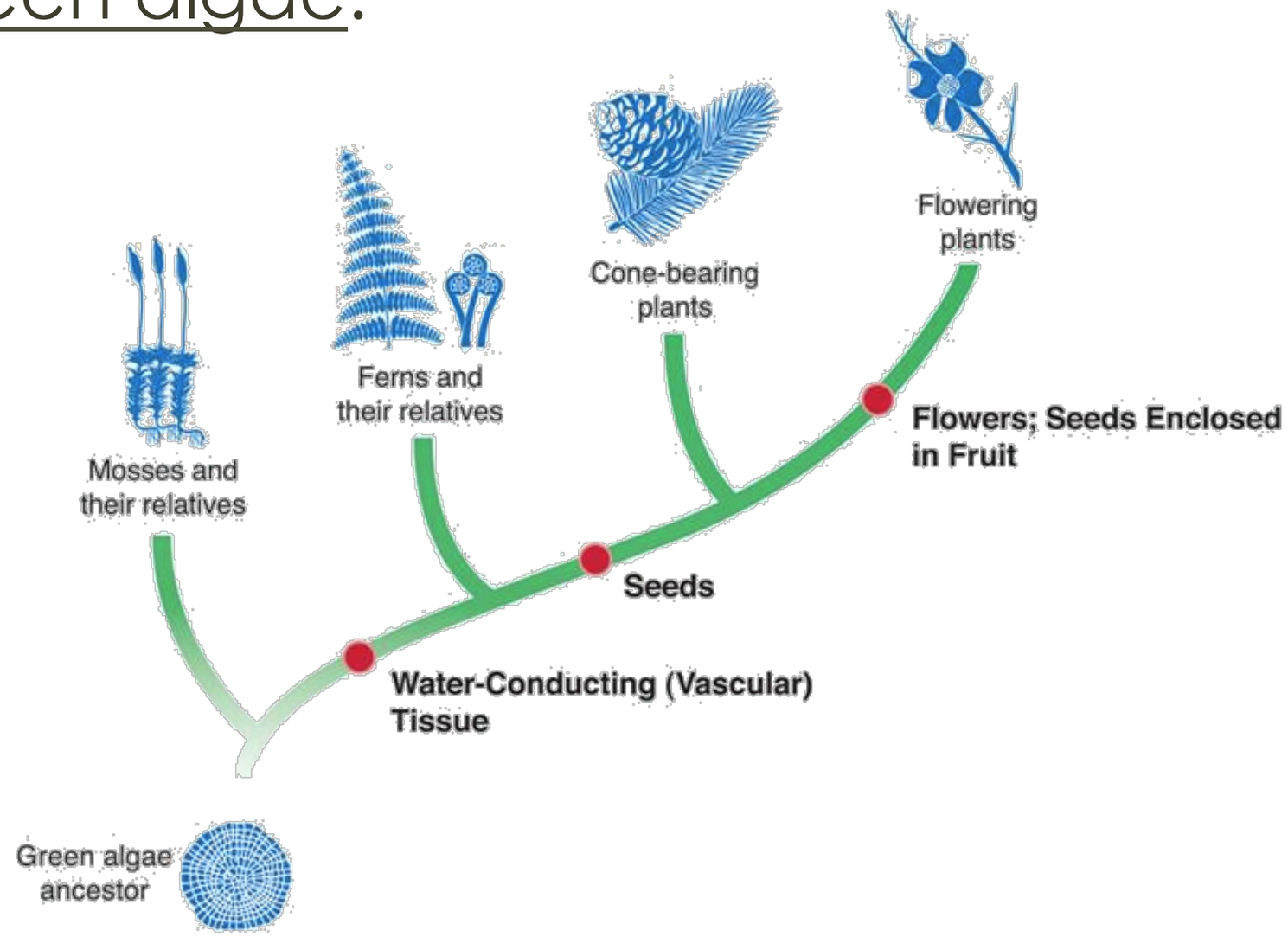
- Please complete the pretest that you picked up when you came in.

What are plants?

- Plants are members of the kingdom Plantae.
- Plants are multicellular eukaryotes that have cell walls made of cellulose. They carry out photosynthesis using the green pigments, chlorophyll a and b.

What are plants?

- The first plants evolved from an organism much like green algae.

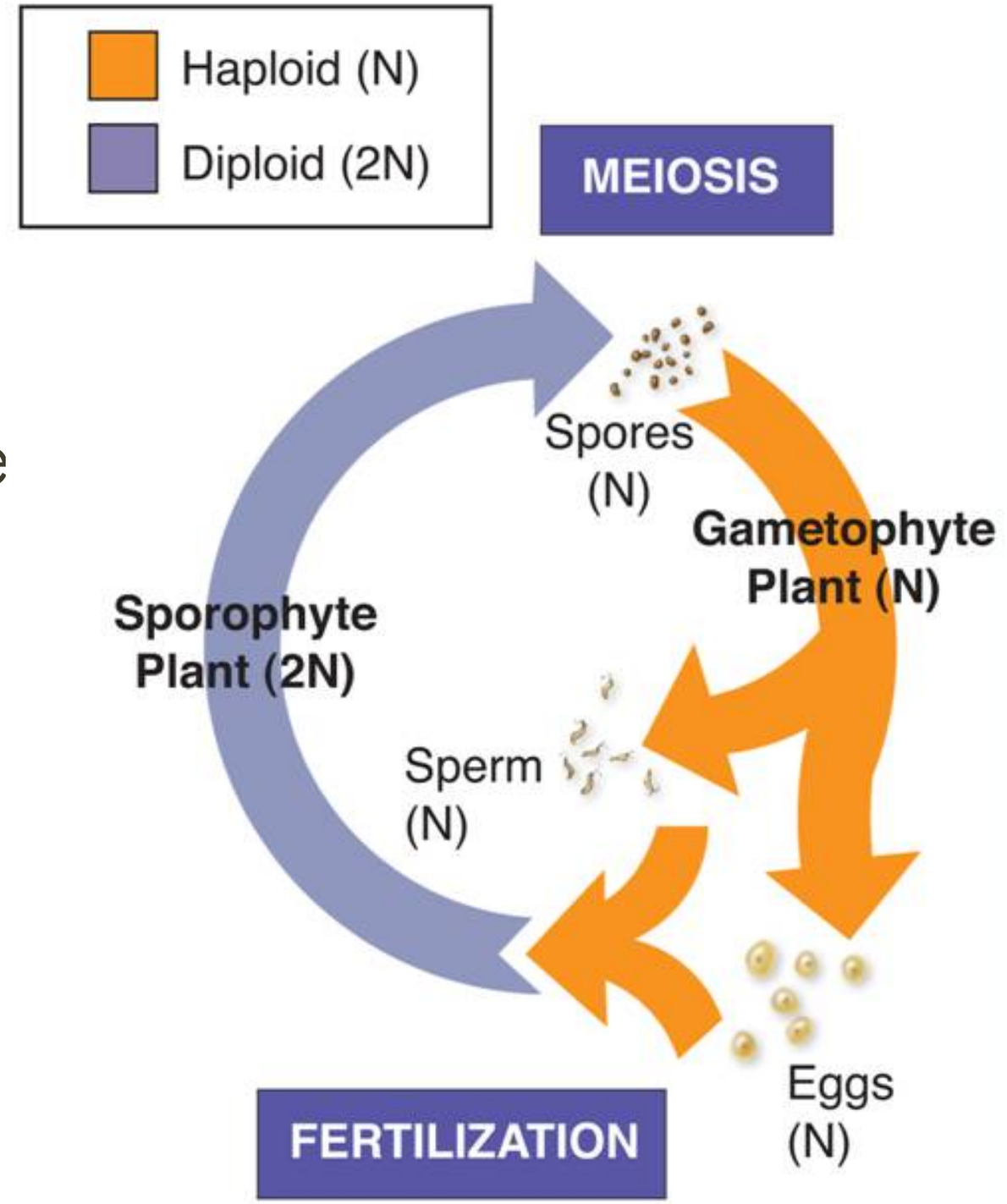


The Plant Life Cycle

- Plant life cycles have alternating phases, called alternation of generations, which alternates between a haploid and diploid phase.
- The two cycles alternate to produce the two types of reproductive cells- gametes and spores.

Alternation of Generations

- The diploid (2N) phase is the sporophyte- or spore producing plant.
- The haploid (N) phase is the gametophyte- or gamete producing plant.



What Plants Need To Survive

- Sunlight- used to carry out photosynthesis.
- Water and Minerals- plants need a continual supply of water, and minerals, which come from the soil.
- Gas Exchange- oxygen for cellular respiration and carbon dioxide for photosynthesis.
- Movement of Water and Nutrients- water is absorbed in their roots but distributed throughout the plant.

Groups of Plants

- Plants can be categorized as either vascular plants, or non-vascular plants (called bryophytes).
- Vascular plants have tracheids- specialized cells that conduct water.

Vascular Transport Systems

- **Xylem**- carries water upward from the roots to every part of a plant.
  - The main cells in the xylem tissue is the tracheid.
- **Phloem**- transports solutions of nutrients and carbohydrates produced by photosynthesis.
- **Lignin**- substance that makes cell walls rigid; enables vascular plants to grow upright.

Vascular Plant Structures

- **Roots**- underground organs that absorb water and minerals.
- **Leaves**- photosynthetic organs that contain one or more bundles of vascular tissue.
- **Veins**- made of xylem and phloem.
- **Stems**- supporting structures that connect roots and leaves, carrying water and nutrients.

Exit Slip

- What is the function of the xylem and the phloem?
- Explain the difference between the gametophyte and the sporophyte.
- What type of plant was the most primitive?

Warm Up

- What was the scientific name for nonvascular plants?
- What are the names of the specialized cells that conduct water?

Four Groups of Plants

Seedless Plants

- **Vascular**
  - Have xylem and phloem
- **Nonvascular** (Bryophytes)
  - lack xylem and phloem (conduct water via osmosis)

Seed Plants

- **Gymnosperms**
  - Bear seeds directly on their cones.
    (non-enclosed seed)
- **Angiosperms**
  aka: flowering plants)
  - Bear seeds within a layer of tissue that protects the seed. (enclosed seed)

Seed Plants

Gymnosperms

- Includes four classes: conifers, cycads, ginkgoes, and gnetophytes.
- Gymnosperms contain structures called cones that house their seeds.

Angiosperms

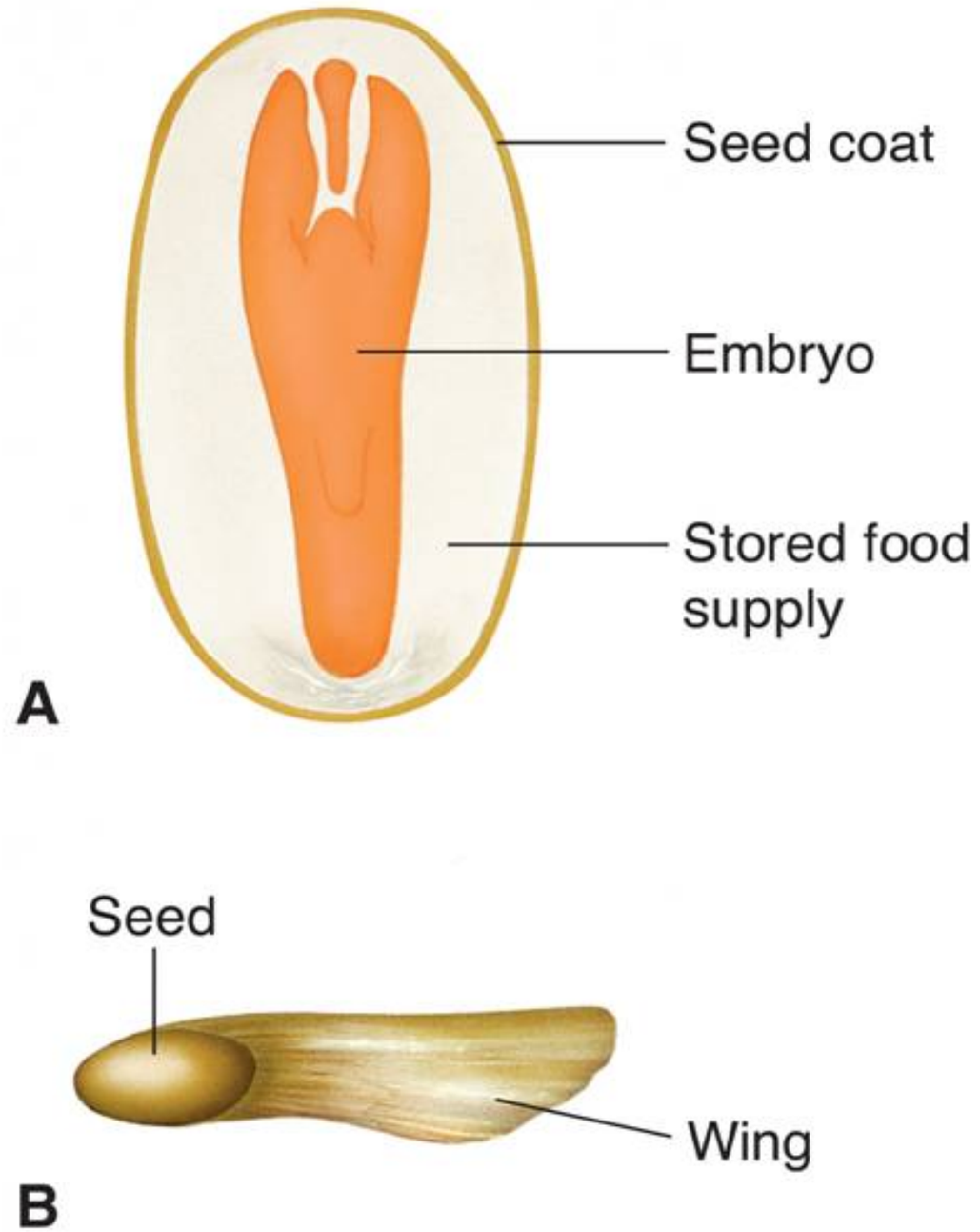
- Include grasses, flowering trees and shrubs, wildflowers, and other flowers.
- Angiosperms contain structures called flowers that house their seeds.

Gymnosperms

- Do not require water for reproduction- so they can live almost anywhere!
- **Pollen Grains**- contain the entire male gametophyte in seed plants. Pollen grains are transferred to the female through the process of pollination.
- **Seeds**- an embryo of a plant that is encased in a protective covering and surrounded by a food supply.
- **Embryo**- an organism in its early stage of development.

Gymnosperms

- **Seed Coat**- surrounds and protects embryo- keeps the seed from drying out.



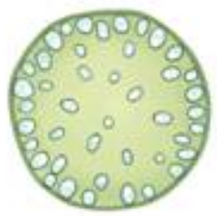
Angiosperms (flowering plants)

- Develop reproductive organs known as flowers, which contain ovaries that surround and protect the seed.
- After pollination, the ovary develops into a fruit- a wall of tissue surrounding the seed. This protects the seed and aids in its dispersal.

Diversity of Angiosperms

- There are two classes within the angiosperms: monocots and dicots.
  - Monocots and dicots are named for the number of seed leaves, or cotyledons, in the plant embryo. Monocots have one seed leaf, and dicots have two.

Characteristics of Monocots and Dicots

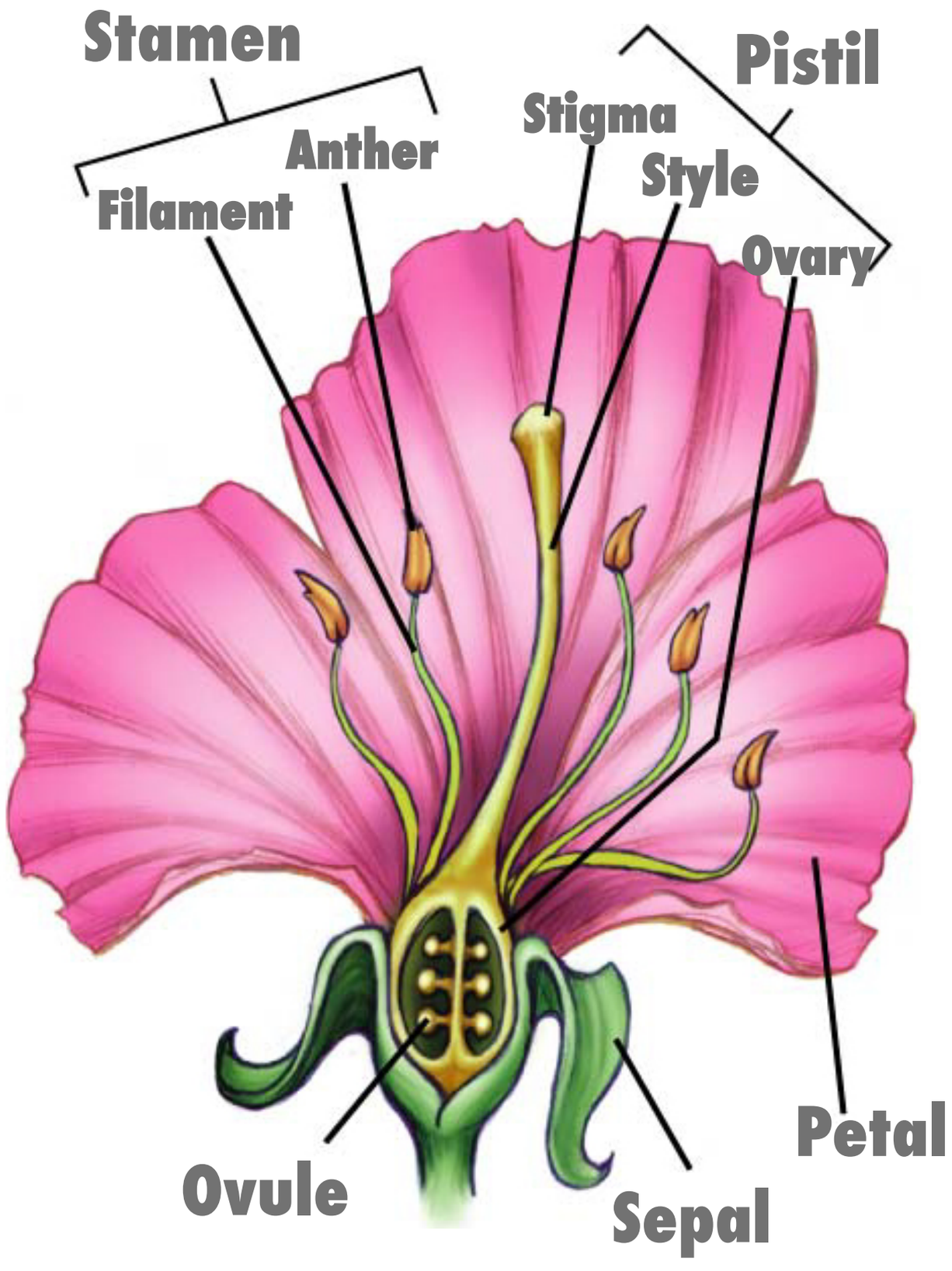
	Monocots	Dicots
Seeds	Single cotyledon 	Two cotyledons 
Leaves	Parallel veins 	Branched veins 
Flowers	Floral parts often in multiples of 3 	Floral parts often in multiples of 4 or 5 
Stems	Vascular bundles scattered throughout stem 	Vascular bundles arranged in a ring 
Roots	Fibrous roots 	Taproot 

Plant Life Spans

- **Annuals**- are plants that complete a life cycle in one growing season.
- **Biennials**- complete their life cycle in two years. In the first year, they germinate and grow roots, short stems, and sometimes leaves. In the second year, they grow new stems and leaves, produce flowers and seeds, and die.
- **Perennials**- live for more than two years.

Structure of Flowers

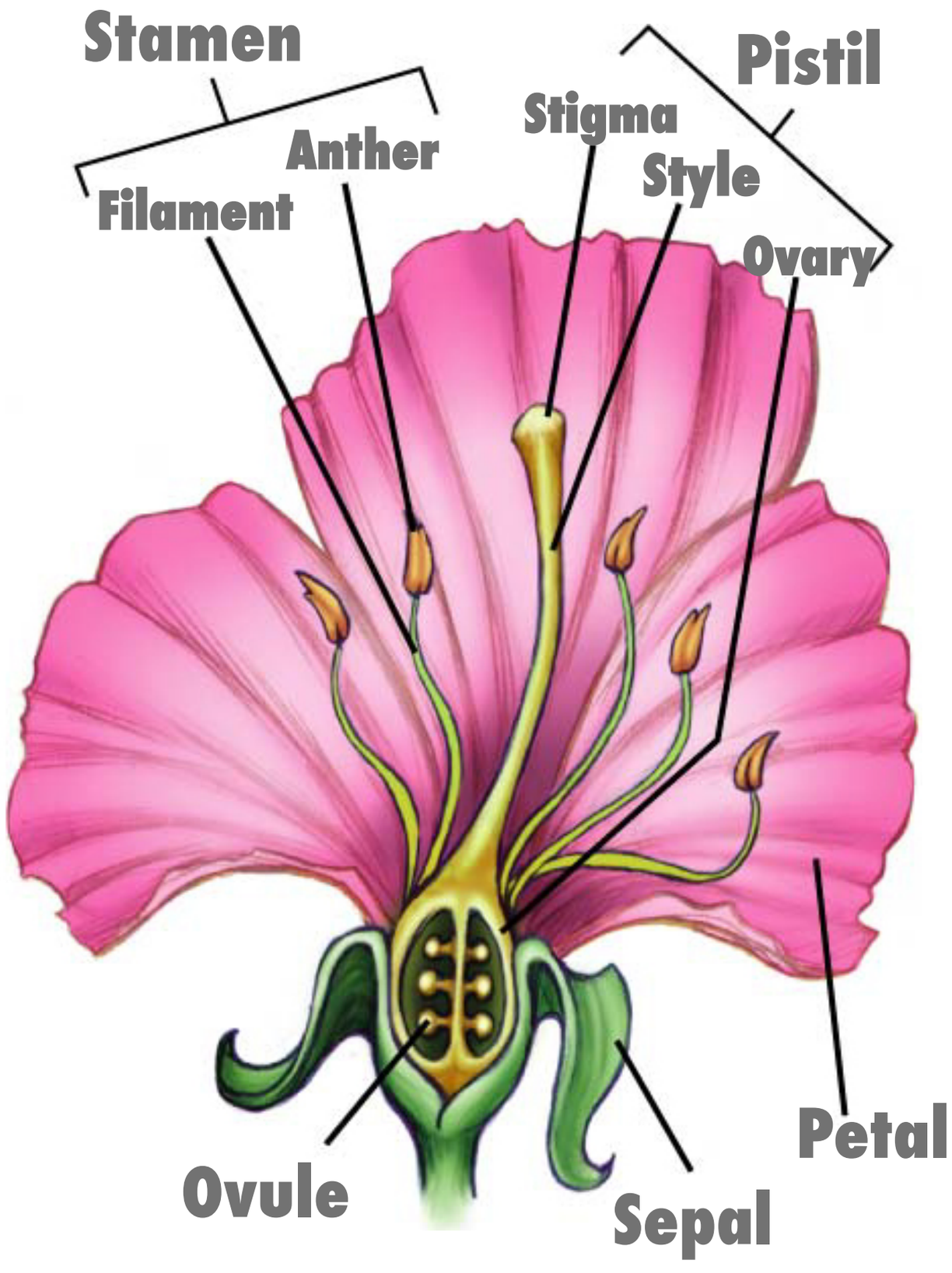
1. **Pistil**:female reproductive structure
   - **Stigma**: sticky tip; traps pollen
   - **Style**: slender tube; transports pollen from stigma to ovary
   - **Ovary**: contains ovules; ovary develops into fruit
   - **Ovule**: contains egg cell which develops into a seed when fertilized



Structure of Flowers

2. Stamen: male reproductive structure

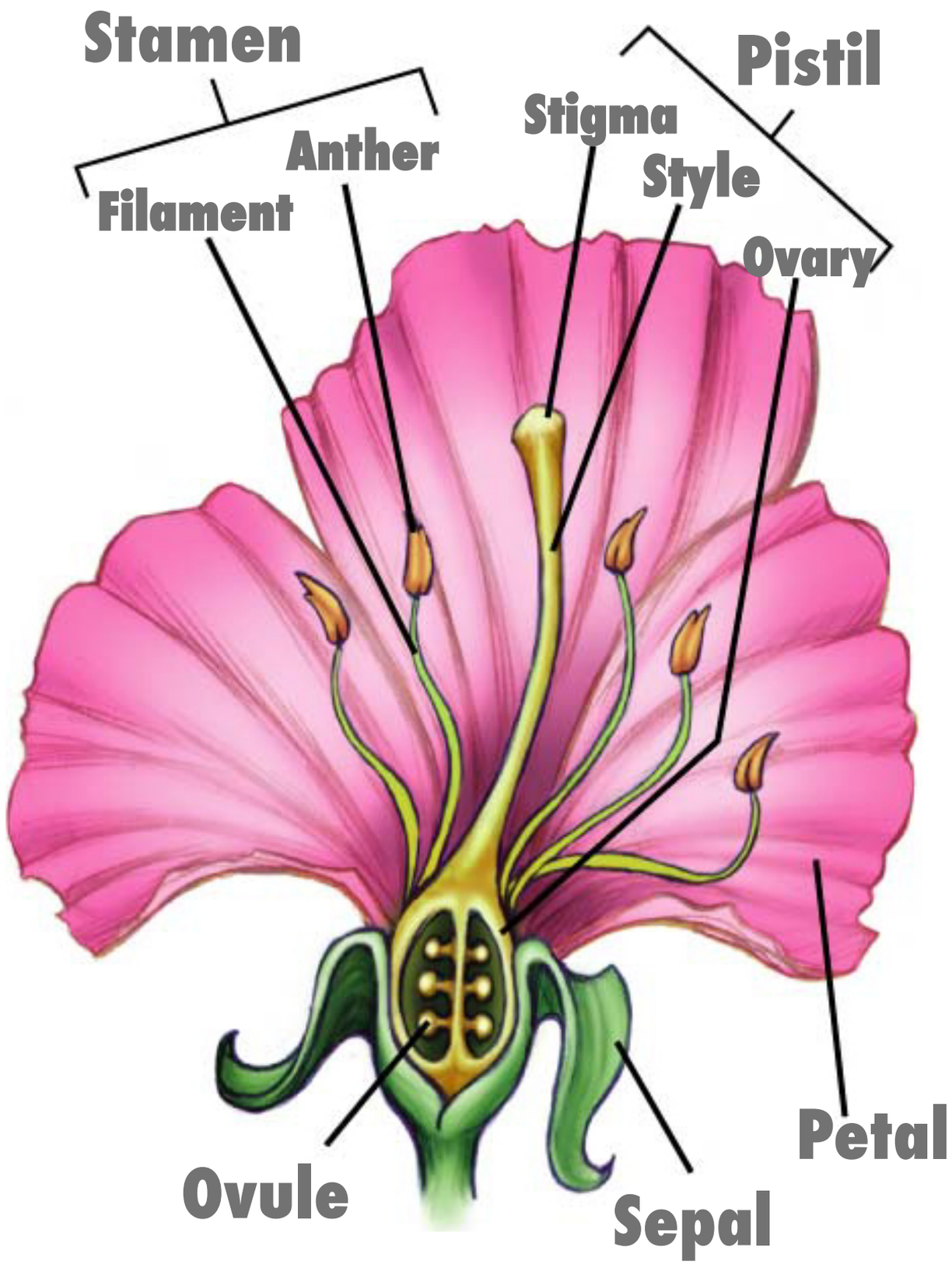
- **Filament**: thin stalk; supports anther
- **Anther**: knob-like structure; produces pollen
- **Pollen**: contains microscopic cells that become sperm cells



Structure of Flowers

3. **Sepals**: encloses & protects flower before it blooms

4. **Petals**: usually colorful & scented; attracts pollinators



Flashback Exercise

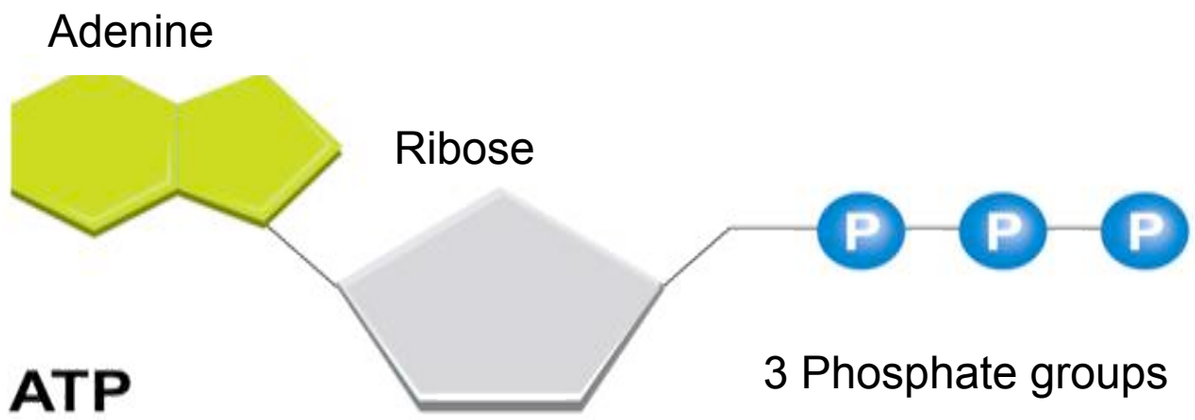
1. During replication, which sequence of nucleotides would bond with the DNA sequence TATGA?
2. In what ways does RNA differ from DNA?
3. Which nucleotide(s) bond(s) with adenine?
4. Where are anticodons found?
5. The process of decoding mRNA into a polypeptide chain is known as what?

Energy and Life

- **Energy**- the ability to do work.
  - Autotrophs- organisms that make their own food.
  - Heterotrophs- organisms that cannot use the sun's energy directly, thus they obtain energy from the foods they consume.
- **Chemical Energy**- stored within chemical bonds and is released when these bonds are broken.

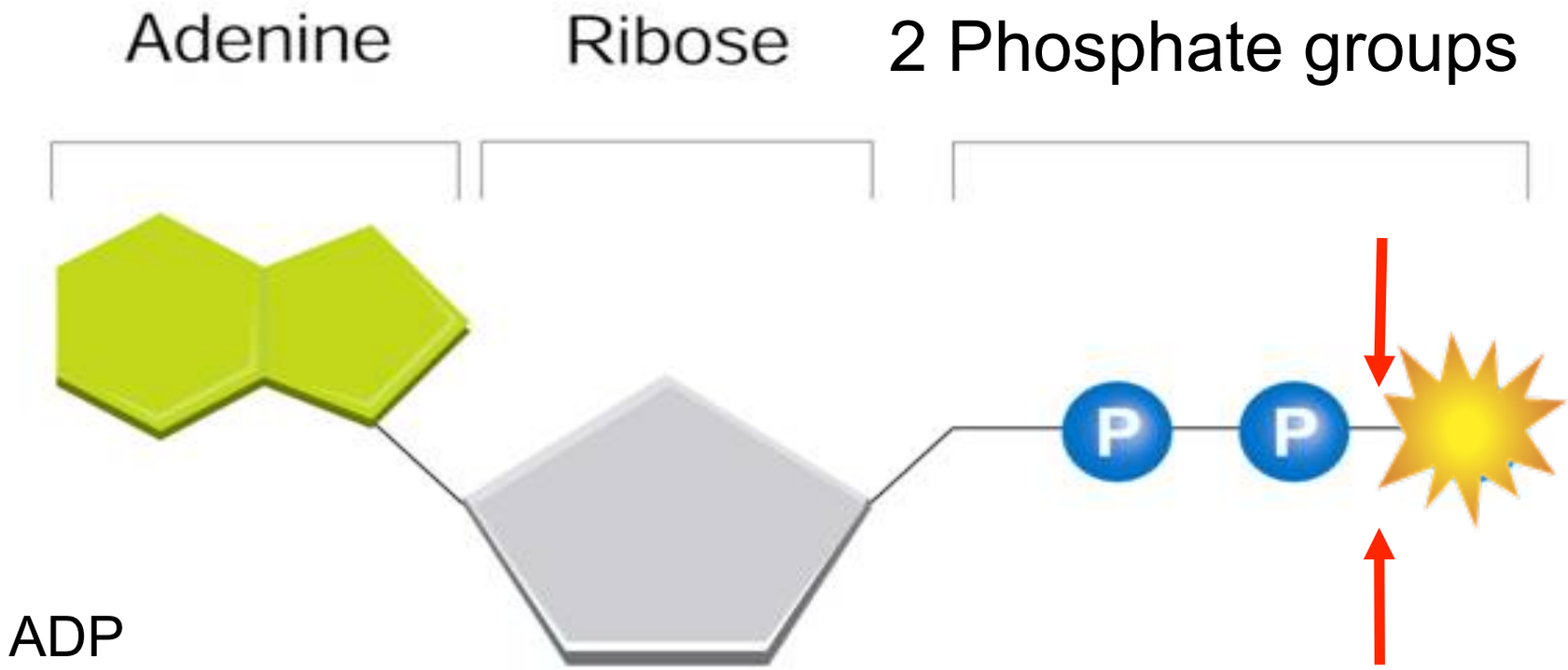
Chemical Energy and ATP

- **<u>Adenosine Triphosphate</u>** (<u>ATP</u>)- consists of adenine, ribose (a 5-carbon sugar), and 3 phosphate groups.
  - The 3 phosphate groups are the key to ATP's ability to store and release energy.



ADP

- **<u>Adenosine Diphosphate</u>** (<u>ADP</u>)- a compound similar to ATP, except it has 2 phosphate groups.



Using Biochemical Energy

- ATP is used for active transport. Many cell membranes use a sodium-potassium pump which pumps sodium ions (Na+) out of the cell and potassium ions (K+) into the cell. ATP provides the energy that keeps the pump working and maintaining a balance of both ions on each side of the cell membrane.

ATP and Glucose

- ATP is a great molecule for transferring energy but not good for storing large amounts of energy for a long term.
- To store energy for long periods of time, the cell relies on glucose, which has 90x the chemical energy of ATP.

Exit Slip

- See handout

Warm-Up Exercise

- How do autotrophs obtain energy? How do heterotrophs obtain energy?
- With respect to energy, how are ATP and glucose similar? How are they different?

Photosynthesis

- **Photosynthesis**- the process where plants use the energy from sunlight to convert water and carbon dioxide into high energy carbohydrates, such as sugars and starches, and oxygen, a waste/byproduct.

Van Helmont's Experiment

- **1600s- Van Helmont plans experiment to find if plants grow by taking material from the soil.**
- He determined the mass of a pot soil and seedling and planted the seedling in the soil and watered regularly for 5 years.
- The seedling grew into a small tree and now weighed about 75 kg, but the mass of the soil was almost unchanged.
- Van Helmont concluded that most of the gain of mass had come from **water**, as that was the only thing he had added.

Priestley's Experiment

- **1700s- Priestley took a candle, placed a glass jar over it, and watched as the flame gradually died out.**
- Priestly reasoned something in the air was necessary to keep the flame burning, and when this substance ran out, the candle went out. **The substance was _?_**
- Priestley found that if he placed a live sprig of mint under the jar and allowed a few days to pass, the candle would remain lighted for a while. The **mint had produced the substance required for burning**. In other words, it released O_2.

Ingenhousz

- Later, Ingenhousz showed that the effect observed by Priestley only occurred when the plant was exposed to light. The results of Priestley's and Ingenhousz's experiments showed that **light is necessary for plants to produce O_2**.
- These early experiments led other scientists to discover that in presence of light, plants transform carbon dioxide and water into carbohydrates and they also release oxygen.

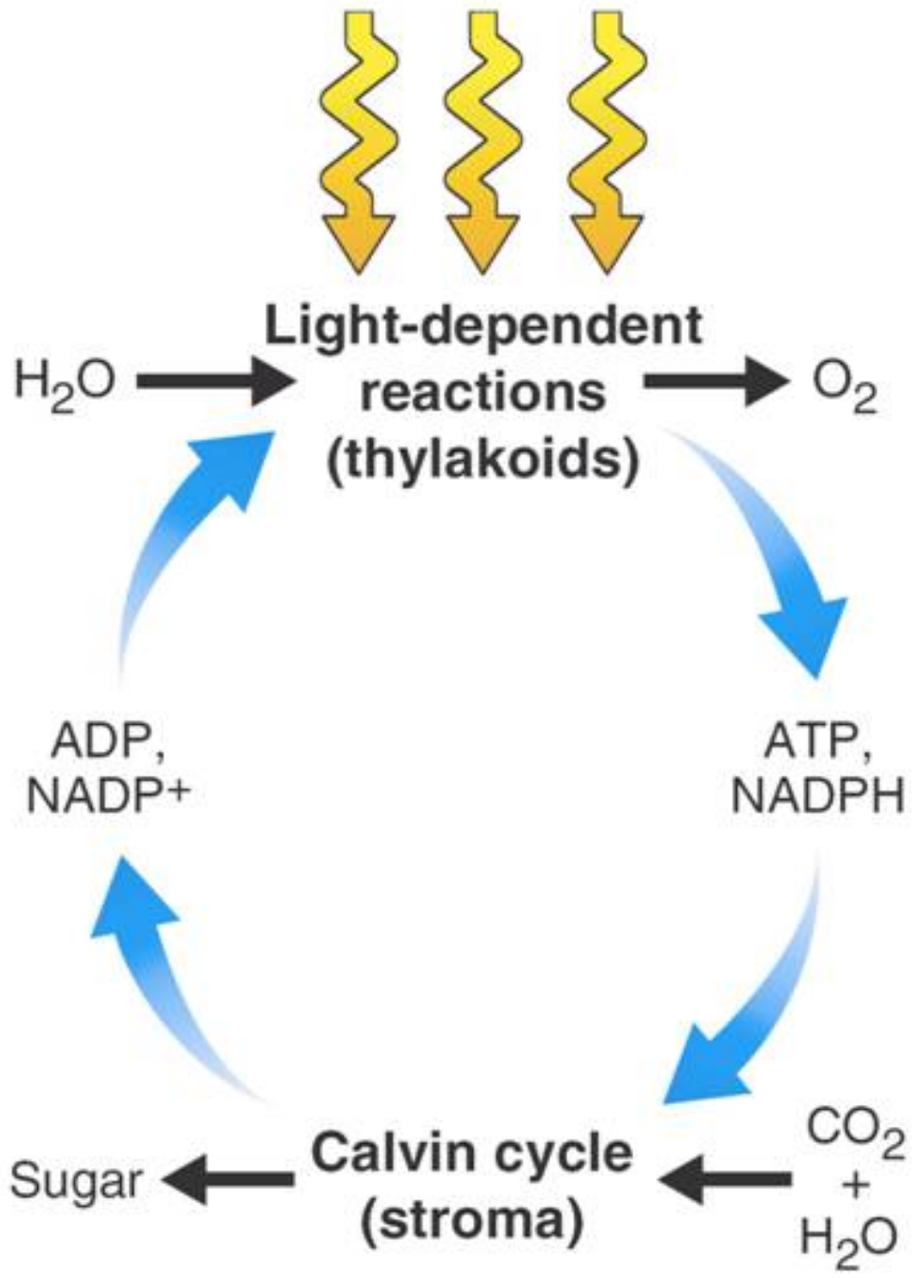
The Photosynthesis Equation

$$CO_2 + H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + O_2$$

carbon dioxide + water $\xrightarrow{\text{light}}$ sugars + oxygen

- Photosynthesis uses the energy of sunlight to convert water and carbon dioxide into high energy sugars and oxygen. Plants use the sugars to produce complex carbohydrates such as starches. Plants obtain carbon dioxide from the air in which they grow.

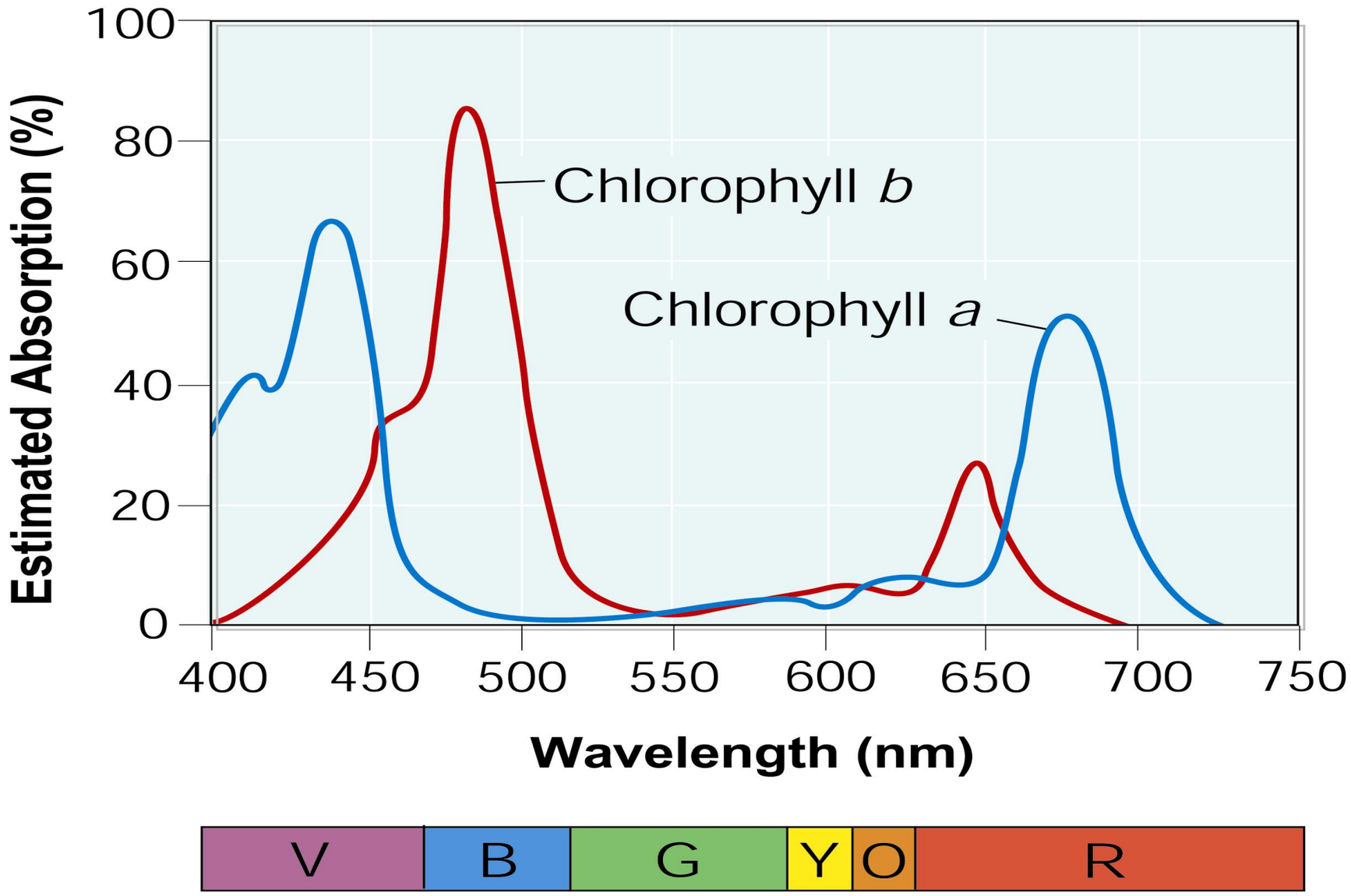
Photosynthesis



Light and Pigments

- Photosynthesis requires 4 components:
  1. carbon dioxide
  2. water
  3. light
  4. chlorophyll- a molecule found in chloroplasts
- Energy from the sun travels to the Earth in the form of light, which plants gather with light-absorbing molecules called pigments.
- The plant's main pigment is chlorophyll.
  - There are 2 types of chlorophyll: chlorophyll *a* and chlorophyll *b*.

Chlorophyll Absorption



Exit Slip

- See handout

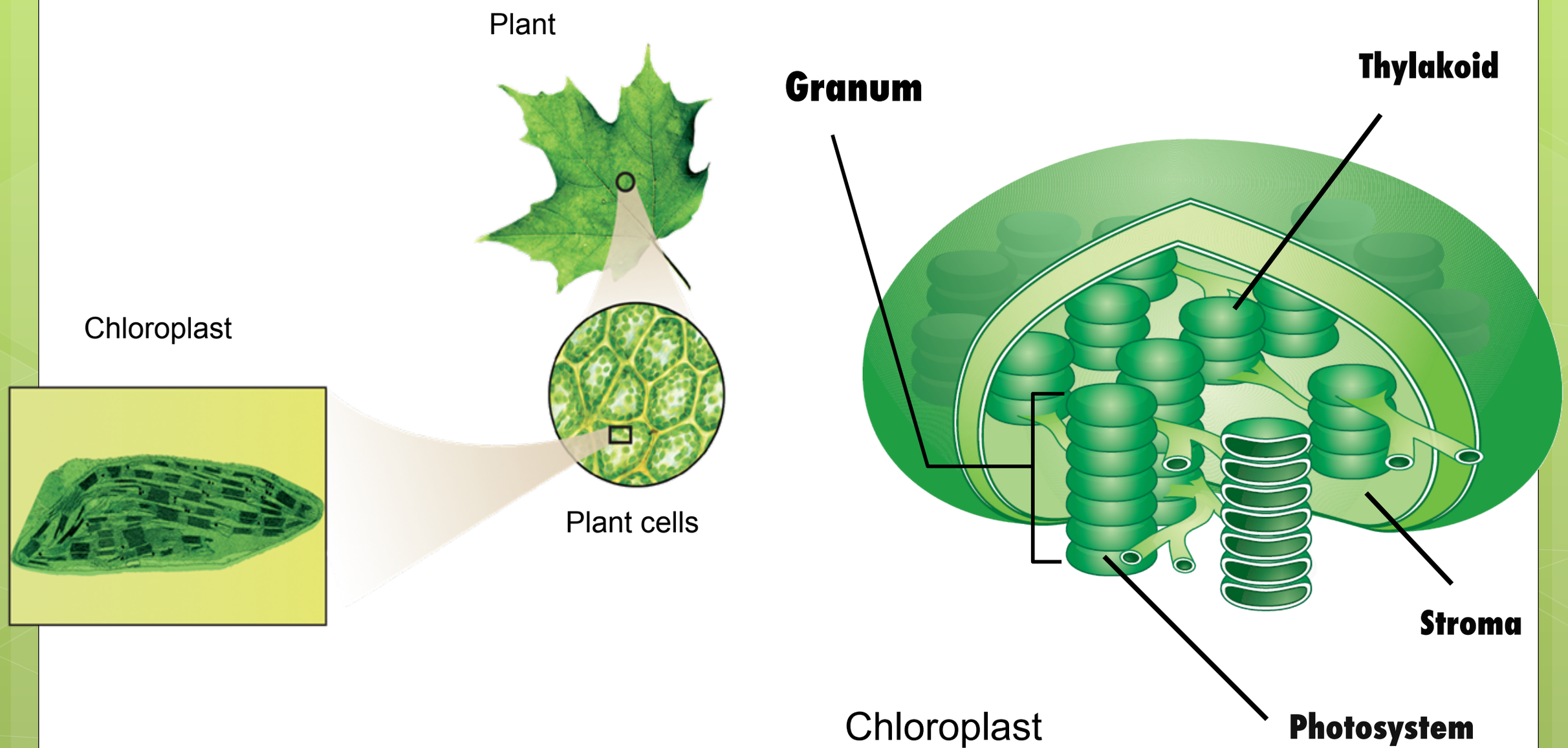
Warm-Up Exercise

- Write a couple of sentences describing the overall process of photosynthesis, including the reactants and products.

The Reactions of Photosynthesis

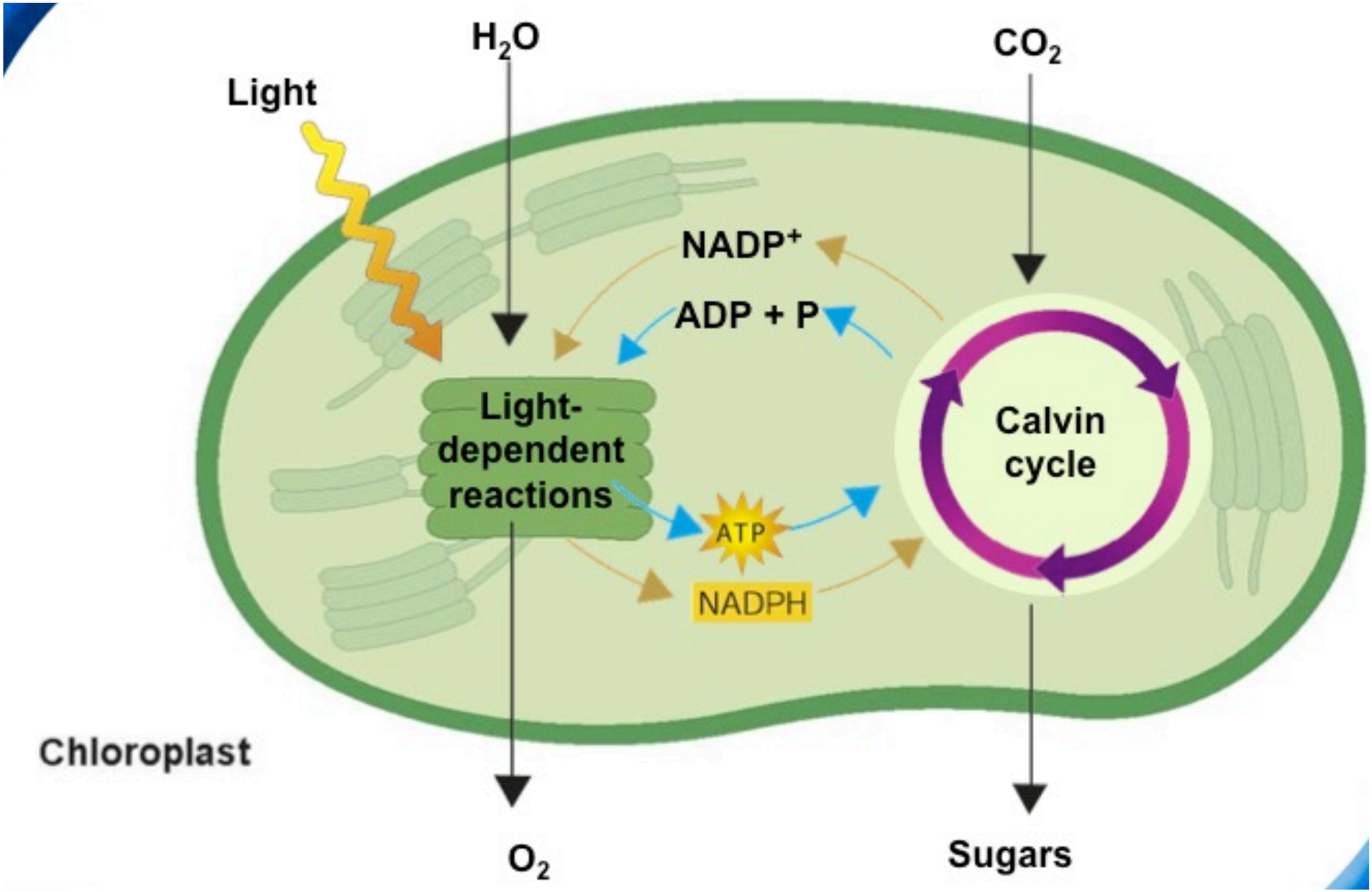
- Photosynthesis takes place inside chloroplasts.
- Within the chloroplast, there are saclike photosynthetic membranes called thylakoids, which are arranged in stacks known as grana.
- Proteins in the thylakoid membrane organize chlorophyll and other pigments into clusters known as photosystems, which are the light-collecting units of the chloroplast.

Inside A Chloroplast



Photosynthesis

- Photosynthesis unfolds into two parts: the light-dependent reactions and the light-independent reactions also known as the Calvin Cycle.
- The light dependent reactions take place within the thylakoid membranes. The Calvin cycle takes place in the stroma, the region outside the thylakoid membranes.


H_2O
CO_2
Light
$NADP^+$
ADP + P
Light-dependent reactions
Calvin cycle
ATP
NADPH
Chloroplast
O_2
Sugars

Electron Carriers

- Cells use electron carriers to transport high-energy electrons from chlorophyll to other molecules.
- A carrier is a compound that can accept a pair of high-energy electrons and transfer them and their energy to another molecule.
- This process is called electron transport and the string of carriers are known as the electron transport chain.

NADP+

Nicotinamide Adenine Dinucleotide Phosphate

- Accepts and holds 2 high energy electrons and a hydrogen- converting $NADP^+$ to NADPH. This is one way that some energy from the sun can be trapped in a chemical form.
- NADPH can then act as an electron carrier between chlorophyll and other cell locations.

Light Dependent Reactions

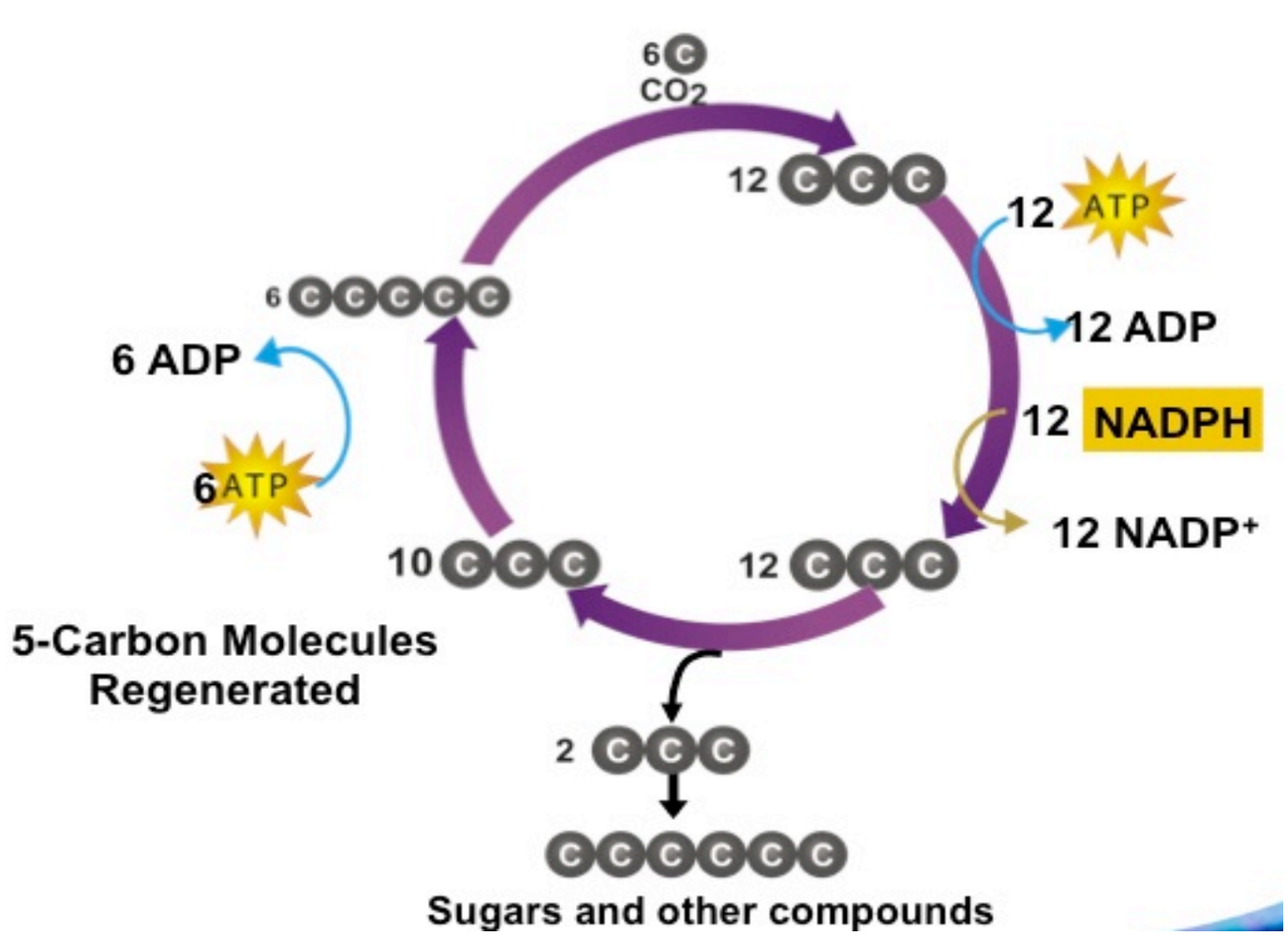
- Light-dependent reactions produce oxygen gas and convert ADP and $NADP^+$ into ATP and NADPH.

Steps of Light Dependent Reactions

- Photosynthesis begins when pigments in PS II (in chlorophyll) absorb light.
- The light energy is absorbed by the electrons, boosting their energy, and these electrons are passed along to the ETC from PS II to PS I.
- Pigments in PS I use energy from light to reenergize the electrons released by PS II. $NADP^+$ picks up these high energy electrons along with H+ ions and becomes NADPH.
- As these H+ ions are pumped across the thylakoid membrane, they pass through a protein channel called ATP synthase, which uses the energy from the hydrogen ions to convert ADP to ATP.

The Calvin Cycle

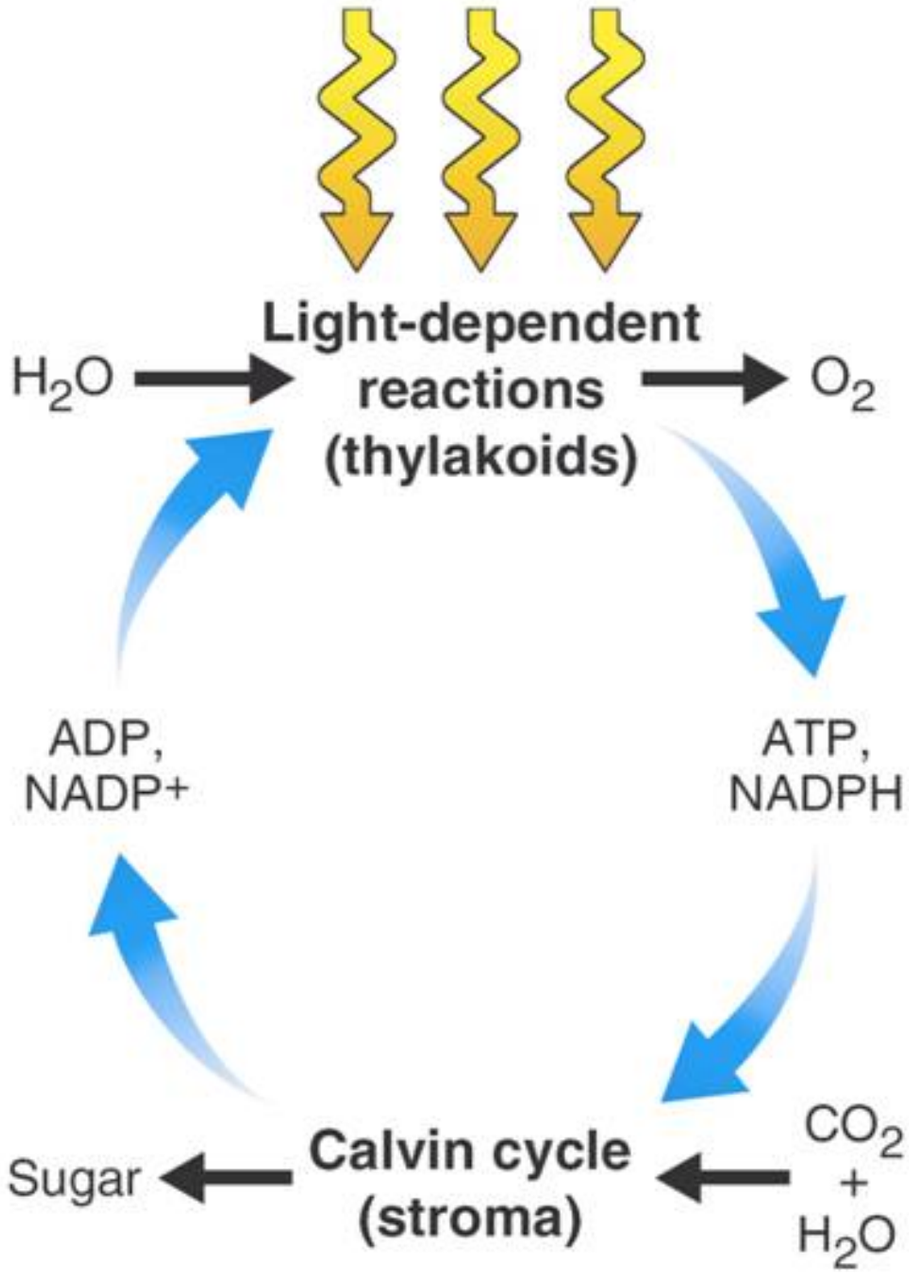
- The Calvin Cycle uses ATP and NADPH from the light-dependent reactions to produce high-energy sugars that can be stored for a long time.



Steps of the Calvin Cycle

- Six CO_2 molecules enter the cycle from the atmosphere. These CO_2 combine with six 5-C molecules resulting in twelve 3-C molecules.
- These molecules are converted to higher energy forms using energy from ATP a and high energy electrons from NADPH.
- Two of the twelve 3-C molecules are removed from the cycle and used by the plant to produce sugars, lipids, amino acids, etc.
- The remaining ten 3-C molecules are converted back into six 5-C molecules which combine with six CO_2 molecules from the air to begin the cycle again.

Photosynthesis



Factors Affecting Photosynthesis

- The amount of water.
- Temperature.
- Intensity of light.

Exit Slip

- See handout

Warm Up

- Please complete the pretest that you picked up when you came in.

Chemical Energy and Food

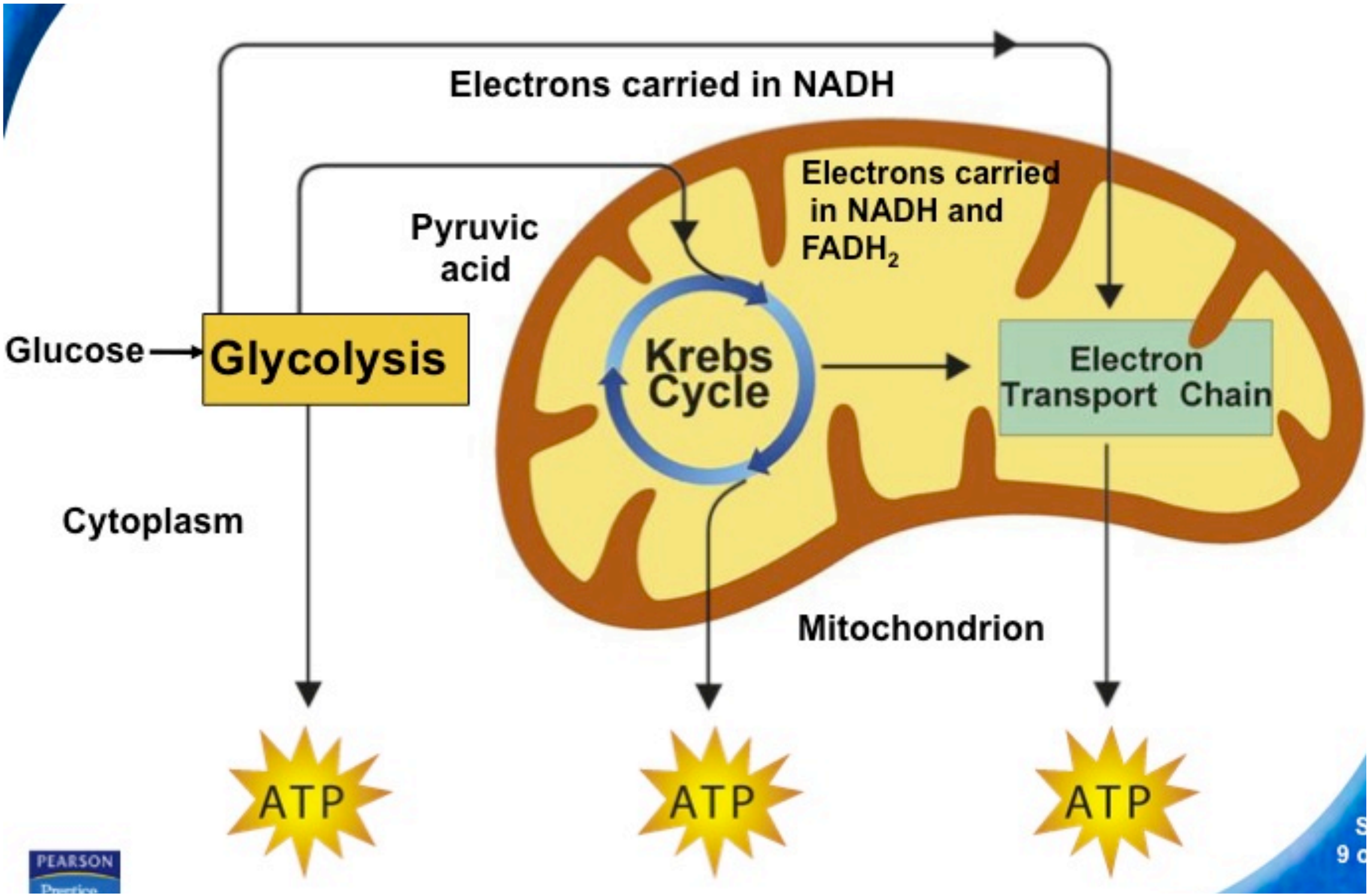
- **Calorie**- (C) - the amount of energy needed to raise the temperature of 1 gram of water by 1 degree Celsius.
- **Glycolysis**- process where glucose is broken down to release a small amount of energy.
  - When oxygen is present, glycolysis leads to 2 other pathways that release a lot of energy- the Kreb's Cycle and the Electron Transport Chain- together these make up the process known as cellular respiration.
  - If oxygen is not present, another pathway proceeds- fermentation.

Cellular Respiration

- **<u>Cellular Respiration</u>**- process that releases energy by breaking down glucose and other food molecules in the presence of oxygen.

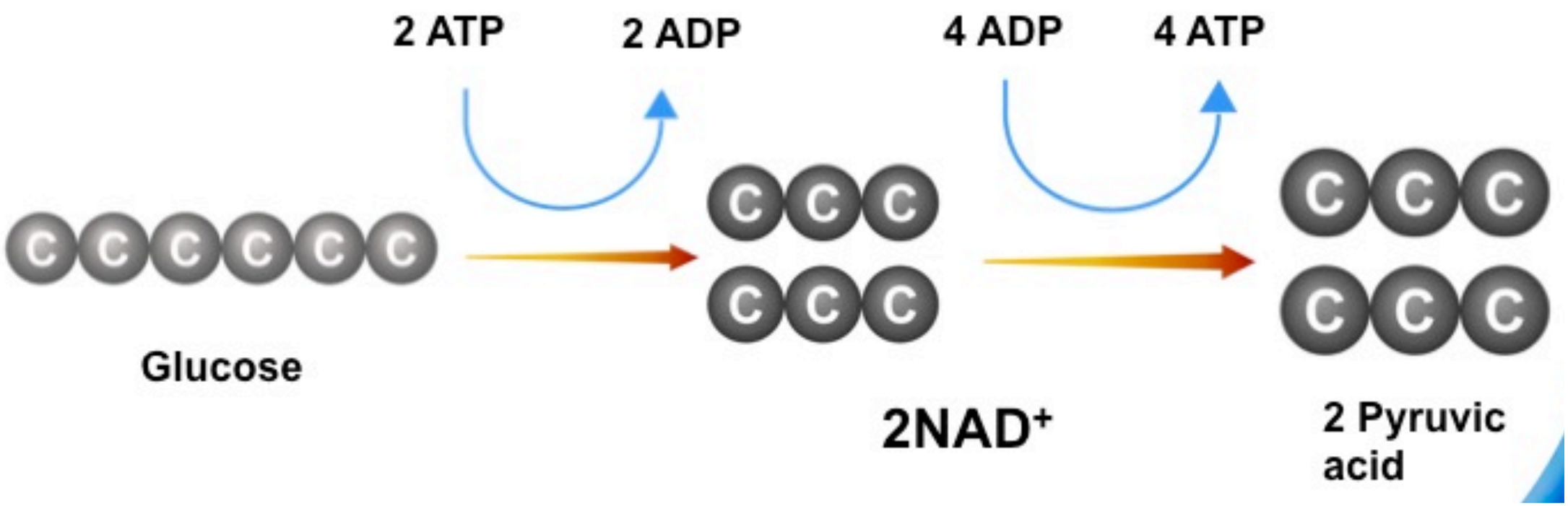
$$6CO_2 + C_6H_{12}O_6 \longrightarrow 6CO_2 + H_2O + \text{Energy}$$

Oxygen + Glucose $\longrightarrow$ Carbon Dioxide + Water + Energy


Electrons carried in NADH
Electrons carried in NADH and $FADH_2$
Pyruvic acid
Glucose
Glycolysis
Krebs Cycle
Electron Transport Chain
Cytoplasm
Mitochondrion
ATP
ATP
ATP

Glycolysis

- Glycolysis is the process in which one molecule of glucose is broken in half, producing 2 molecules of pyruvic acid, a 3-C compound.



Glycolysis

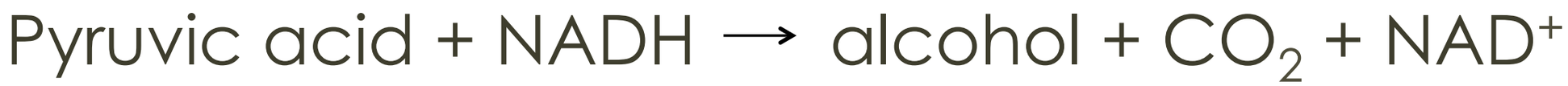
- ATP Production
  - 2 ATP molecules are used to get glycolysis started. When glycolysis is complete, 4 ATP molecules have been released, netting 2 total ATP.
- NADH Production
  - One reaction of glycolysis removes 4 high energy electrons and passes them to an NAD+ carrier, forming NADH. The NADH holds the electrons until the energy can be transferred to another pathway in the cell.

Fermentation

- When oxygen is not present, glycolysis is followed by fermentation, which releases energy from food molecules by producing ATP in the absence of oxygen.
- During fermentation, cells convert NADH to NAD+ by passing high-energy electrons back to pyruvic acid, allowing glycolysis to continue producing a steady supply of ATP.
- Because fermentation does not require oxygen, it is said to be anaerobic.
- There are 2 main types of fermentation: alcoholic fermentation and lactic acid fermentation.

Alcoholic Fermentation

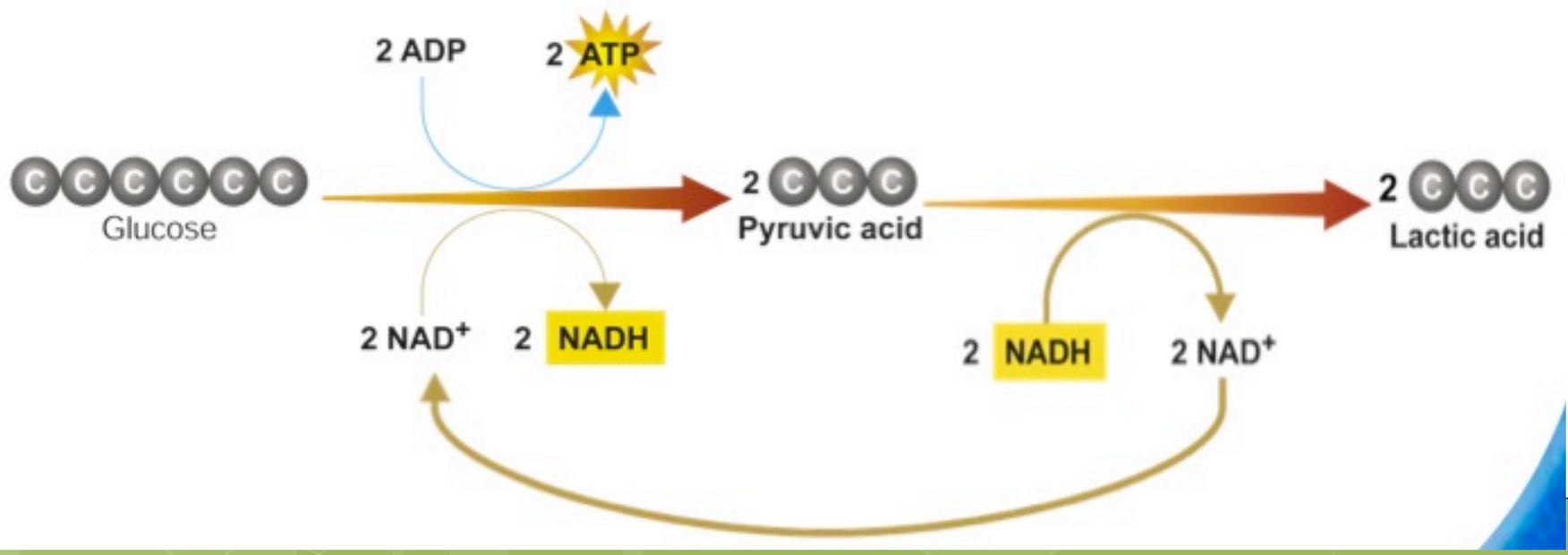
- Yeasts and other microorganisms use alcoholic fermentation, which forms ethyl alcohol and carbon dioxide as wastes.



Lactic Acid Fermentation

- In many cells, the pyruvic acid that is produced in glycolysis can be converted into lactic acid. This process generates NAD+ so that glycolysis can continue.

Pyruvic Acid + NADH $\longrightarrow$ lactic acid + NAD+



Exit Slip

- How are lactic acid fermentation and alcoholic fermentation similar? How are they different?

Warm Up Exercise

- What is the equation for cellular respiration?
- What are the products of glycolysis?
- In the presence of oxygen, which process follows glycolysis? In the absence of oxygen, which process follows glycolysis?

The Kreb's Cycle

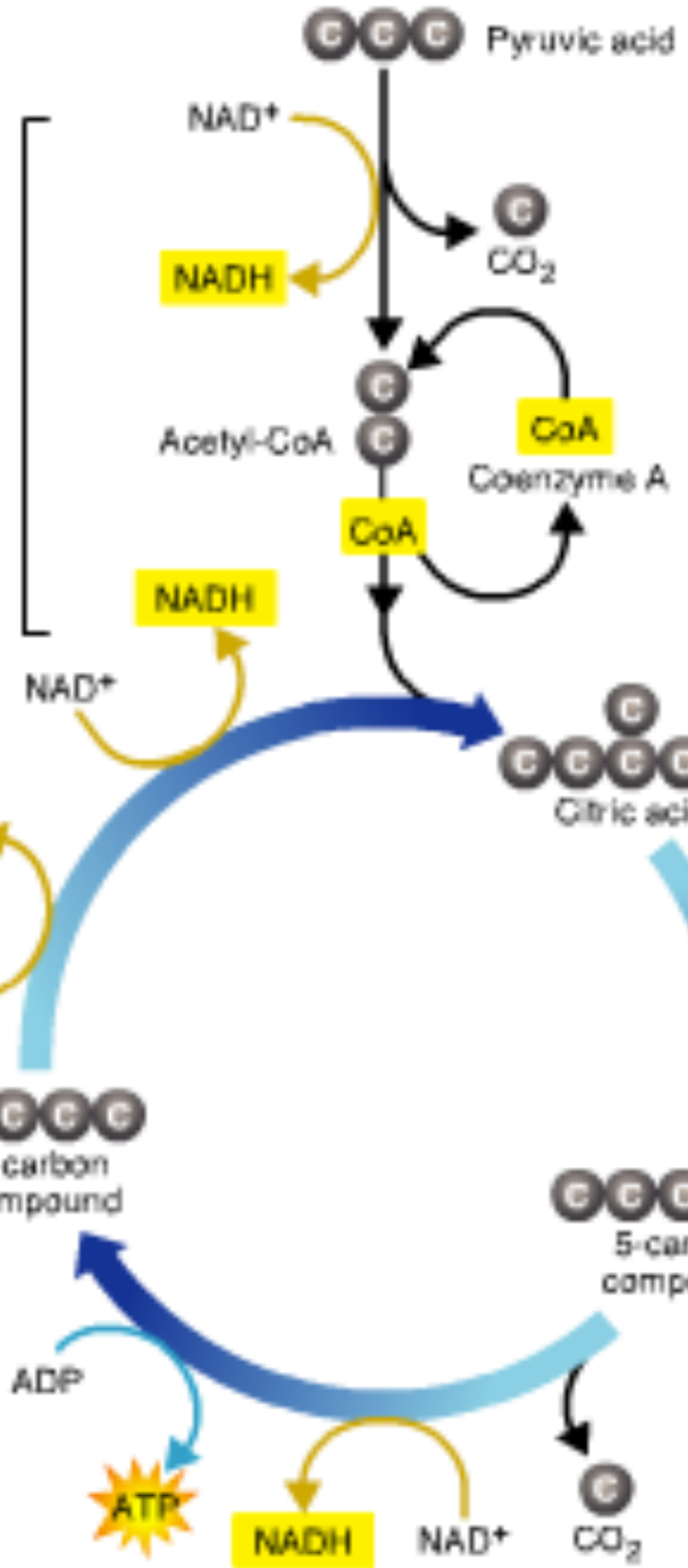
- In the presence of oxygen, pyruvic acid produced in glycolysis passes on to the second stage of cellular respiration, the Kreb's Cycle, where it is broken down into CO_2.
  - The Kreb's Cycle begins when pyruvic acid enters the mitochondria. One carbon joins with oxygen to become CO_2 and is released into the air. The other 2 carbons join with Coenzyme A to produce Acetyl CoA. The molecules in Acetyl CoA are rearranged and combined with a 4-C molecule to produce to produce the compound citric acid.

A Citric Acid Production

As pyruvic acid enters the mitochondrion, a carbon is removed, forming CO_2, and electrons are removed, changing NAD^+ to NADH. Coenzyme A joins the 2-carbon molecule, forming acetyl-CoA. Acetyl-CoA then adds the 2-carbon acetyl group to a 4-carbon compound, forming citric acid.

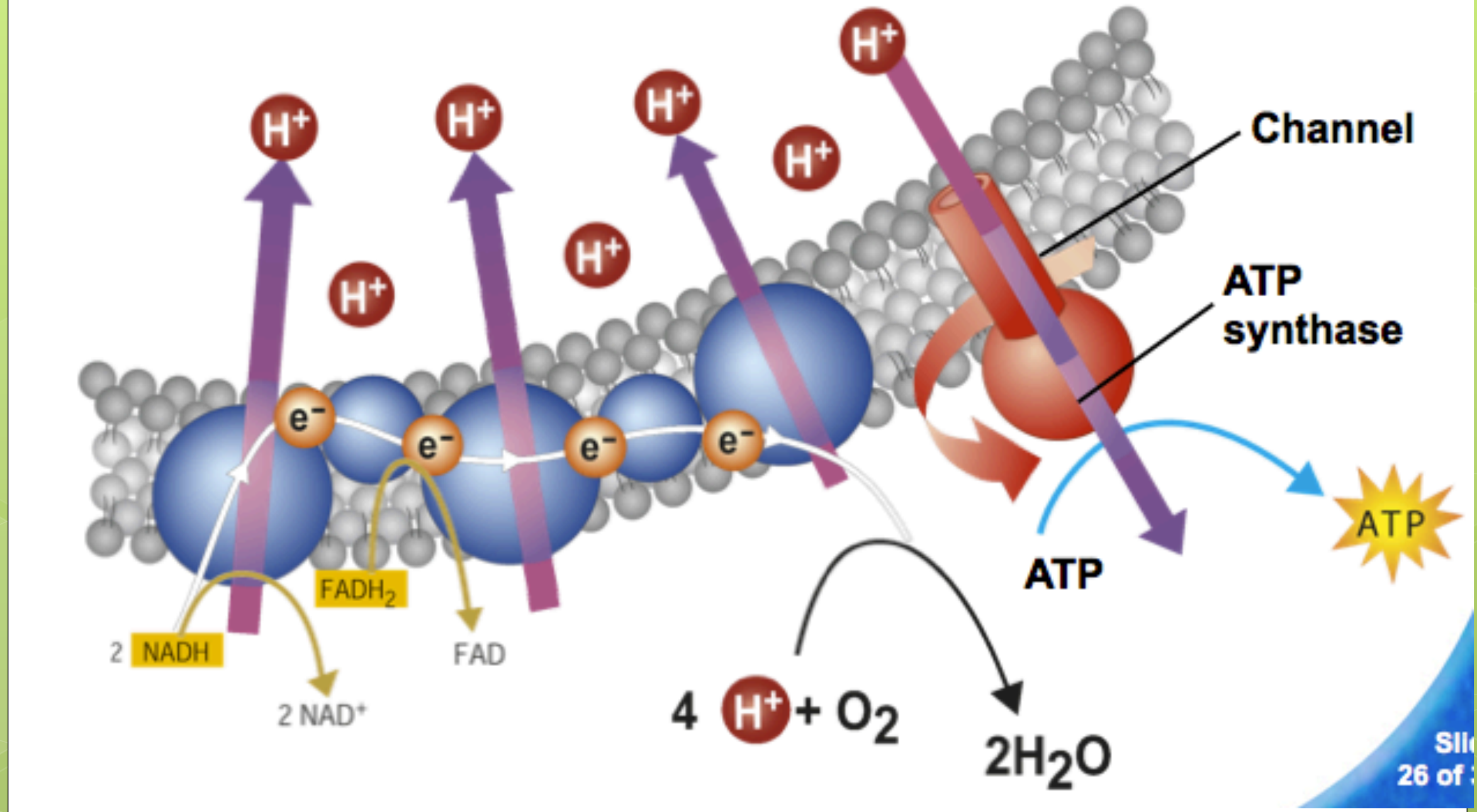
B Energy Extraction

Citric acid is broken down into a 5-carbon compound, then into a 4-carbon compound. Along the way, two more molecules of CO_2 are released, and electrons join NAD^+ and FAD, forming NADH and $FADH_2$. In addition, one molecule of ATP is generated. The energy tally from one molecule of pyruvic acid is 4 NADH, 1 $FADH_2$, and 1 molecule of ATP.



Electron Transport

- High energy electrons from NADH and $FADH_2$ are passed along the ETC where they are paired with oxygen and hydrogen to form water.
  - In eukaryotes, the ETC is located in the inner membrane of the mitochondria. In prokaryotes, it is in the cell membrane.
- Every time 2 high-energy electrons are transported down the ETC, their energy is used to move H^+ ions across the cell membrane. This process allows ADP to be converted to ATP.


H+
H+
H+
H+
H+
H+
Channel
ATP
synthase
e−
e−
e−
e−
FADH2
2 NADH
FAD
2 NAD+
ATP
ATP
4 H+ + O2
2H2O

The Totals

- **Glycolysis**- produces 2 ATP per molecule of glucose. (in the absence of O_2)
- **Kreb's Cycle/ETC**- produces 36 ATP per molecule of glucose. (in the presence of O_2)

Energy and Exercise

- **First 10 seconds**: energy from ATP already stored in cells.
- **First 90 seconds**: energy from lactic acid fermentation.
- **Longer**: Cellular respiration- the only way to generate a continuing supply of ATP.
  - At first, body breaks down stored glycogen. After 15-20 minutes, body breaks down other stored molecules, including fats, for energy.
  - Releases energy slower than lactic acid fermentation, this is why athletes must pace themselves.

Comparing Photosynthesis and Cellular Respiration

	Photosynthesis	Cellular Respiration
Function	Energy capture	Energy release
Location	Chloroplasts	Mitochondria
Reactants	CO_2 and H_2O	$C_6H_{12}O_6$ and O_2
Products	$C_6H_{12}O_6$ and O_2	CO_2 and H_2O
Equation	$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$	$6O_2 + C_6H_{12}O_6 \longrightarrow 6CO_2 + 6H_2O$

Exit Slip

- Compare the energy flow in photosynthesis to the energy flow in cellular respiration.

Warm Up Exercise

Digestion

- The digestive system includes: the mouth, pharynx, esophagus, stomach, small intestine, and large intestine.
- Accessory structures include: the salivary glands, pancreas, and the liver.
- The function of the digestive system is to help convert food into simpler molecules that can be absorbed and used by the cells of the body.

Digestion

- Teeth- aid in mechanical digestion (the physical breakdown of large pieces of food into smaller pieces)
  - As you chew, digestive enzymes break down carbohydrates into smaller molecules (chemical digestion).