**Chapter 4: Photosynthesis and Cellular Respiration**

Why It’s Important: Every cell in your body needs \_\_\_\_\_\_\_\_\_\_\_\_\_\_ to function. This energy is acquired through photosynthesis and cellular respiration

|  |  |  |
| --- | --- | --- |
| Objectives | Vocabulary | |
| * **Analyze** the flow of energy through living systems. * **Compare** the metabolism of autotrophs with that of heterotrophs. * **Describe** the role of ATP in metabolism. * **Describe** the experiments that led to an understanding of photosynthesis * Summarize how energy is captured from sunlightin the first stage of photosynthesis. * **Analyze** the function of electron transport chains in the second stage of photosynthesis. * **Relate** the Calvin cycle to carbon dioxide fixation in the third stage of photosynthesis. * **Identify** three environmental factors that affect the rate of photosynthesis. | Section 4.1   * ATP * ADP * Chemosynthesis * Photosynthesis * Autotroph * Heterotroph * Cellular respiration   Section 4.2   * Pigment * Chlorophyll * Carotenoid * NADP+ * NADPH | * Thylakoid * Granum / grana * Stroma * Thylakoid * Light-dependent reactions * Light-independent reactions   Section 4.3   * Photosystem * Electron Transport chain * ATP synthase * Calvin Cycle |

* What is metabolism?

|  |  |
| --- | --- |
| Energy in Living Systems | |
| Untitled-1 copy | Directly or indirectly, almost all of the energy in living systems needed for metabolism comes from the \_\_\_\_\_\_\_\_\_\_\_\_ |

* **Metabolism** involves either \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ molecules or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ down molecules in which energy is stored.
* **Photosynthesis** is the process by which \_\_\_\_\_\_\_\_\_\_\_ energy is converted to \_\_\_\_\_\_\_\_\_\_\_\_\_ energy
  + This chemical energy is stored in the organic compound \_\_\_\_\_\_\_\_\_\_\_\_\_, which is a plant’s \_\_\_\_\_\_\_
  + Often, plants convert glucose to \_\_\_\_\_\_\_\_\_\_\_, which can be stored in \_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_ for later use
  + Organisms that carry out photosynthesis are called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

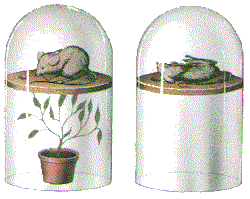
**Equation for Photosynthesis**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_

* What are the reactants? What are the products? Which substance acts a catalyst?
* How did we learn about photosynthesis?
  + The work of three major scientists has led to our understanding of photosynthesis
    1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
       - \_\_\_\_\_\_ century Dutch physician who devised an experiment to find out where the \_\_\_\_\_\_\_ of a growing tree comes from





* + - * Carefully found the mass of a pot of dry \_\_\_\_\_\_ and a small \_\_\_\_\_\_\_\_\_\_\_
      * Planted the seedling in the pot of soil, took care of it and \_\_\_\_\_\_\_\_\_ it for five years.
      * At the end of five years, the seedling had grown into a small tree. The tree gained a mass of about 75 kg, while the mass of the soil was almost unchanged
      * Conclusion 🡪 The mass of a tree comes from \_\_\_\_\_\_\_\_ because it was the only thing he added to the soil
    1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
       - English scientist who conducted an experiment nearly \_\_\_\_\_\_\_ years after Van Helmont
       - Placed a glass jar over a burning candle & watched as the flame gradually \_\_\_\_\_\_\_ out and concluded that something in the air was needed for the candle to continue burning
       - Priestley ran the experiment again with a small \_\_\_\_\_\_\_\_\_\_ in the container
       - After a few days, Priestley attempted to relight the candle with a burning \_\_\_\_\_\_\_\_\_\_\_.
       - It \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_!
       - Conclusion🡪 Plants produce \_\_\_\_\_\_\_\_\_\_\_\_\_, which allowed the candle to burn
       - Priestley did similar experiments with plants and \_\_\_\_\_\_\_\_…he discovered that oxygen is also necessary to sustain animal life. While unintentionally cruel, this discovery was very important. Previously, scientists believed that “air” was an element and did not know that it contained \_\_\_\_\_\_\_\_\_\_\_\_\_\_ gases
    2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
       - Dutch scientist who conducted Priestley’s experiment in the presence and absence of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
       - Observed similar results only in the presence of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
       - Conclusion🡪 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is necessary for plants to produce oxygen
  + The work of Van Helmont, Priestley, and Ingenhousz constructed part of the chemical equation for photosynthesis

Light Energy

\_\_\_\_ + H20 ------------------- > C6H1206 + O2

* + What reactant(s) was/were contributing to the carbon and oxygen and in glucose?
  + In the 1950s, scientists placed radioactive \_\_\_\_\_\_\_, or tags on the \_\_\_\_\_\_\_\_\_\_\_\_ in CO2 and H20 to track their reactions during photosynthesis
  + Result 🡪 The oxygen in CO2 was incorporated into \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and the oxygen in H20 was released as a \_\_\_\_\_\_
* The **chemical energy** in organic compounds can be transferred to other organic compounds or to organisms that \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ food.
* Organisms that must get energy by consuming other organisms are called **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
* Examples… Rabbits consume \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ & A fox consumes \_\_\_\_\_\_\_\_\_\_\_\_\_
* Both plants and animals need a way to \_\_\_\_\_\_\_\_\_\_\_ down their food so that it can be \_\_\_\_\_\_\_ to carry out cellular activities. Organisms do so in a process called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + This process converts the chemical energy stored in glucose or starch into a \_\_\_\_\_\_\_\_\_\_\_\_\_ form of energy called \_\_\_\_\_\_\_\_\_

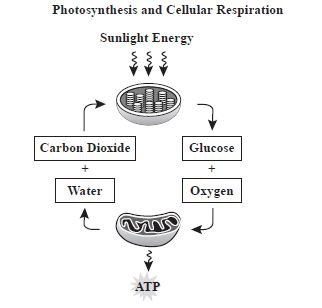
**Cellular Respiration Equation**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_

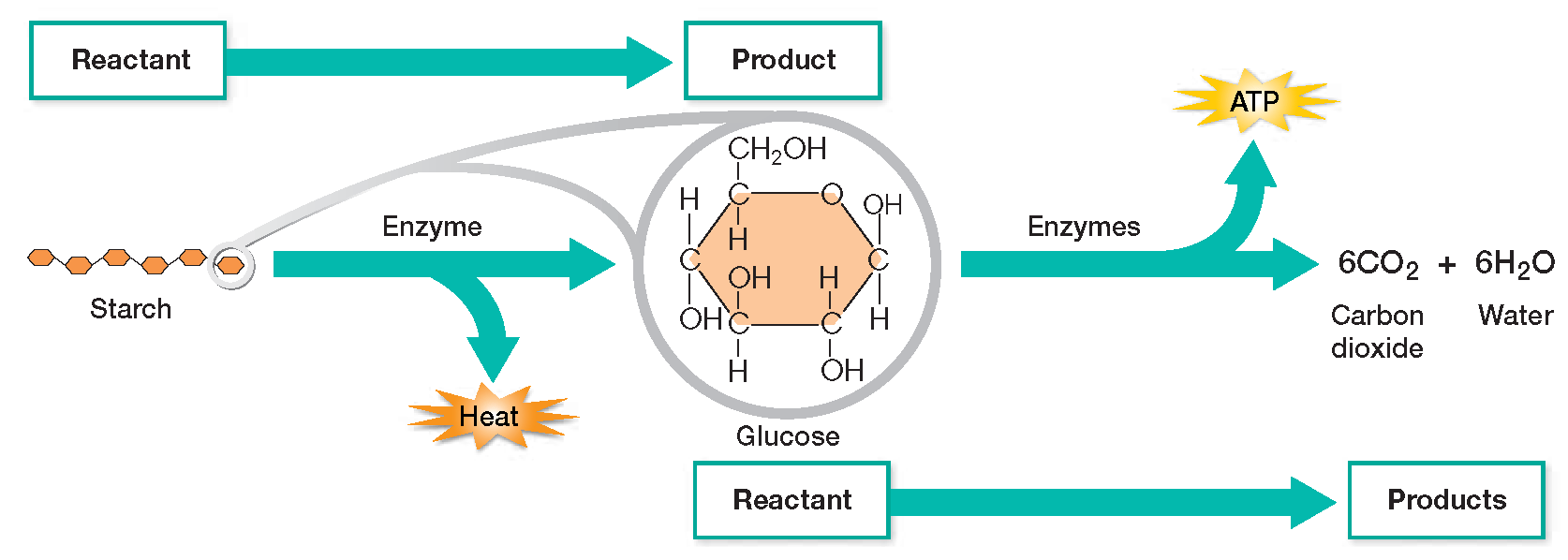
\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_

* What are the reactants?
* What are the products?
* Which substance acts as a catalyst?

How are the equations for cellular respiration and photosynthesis related?

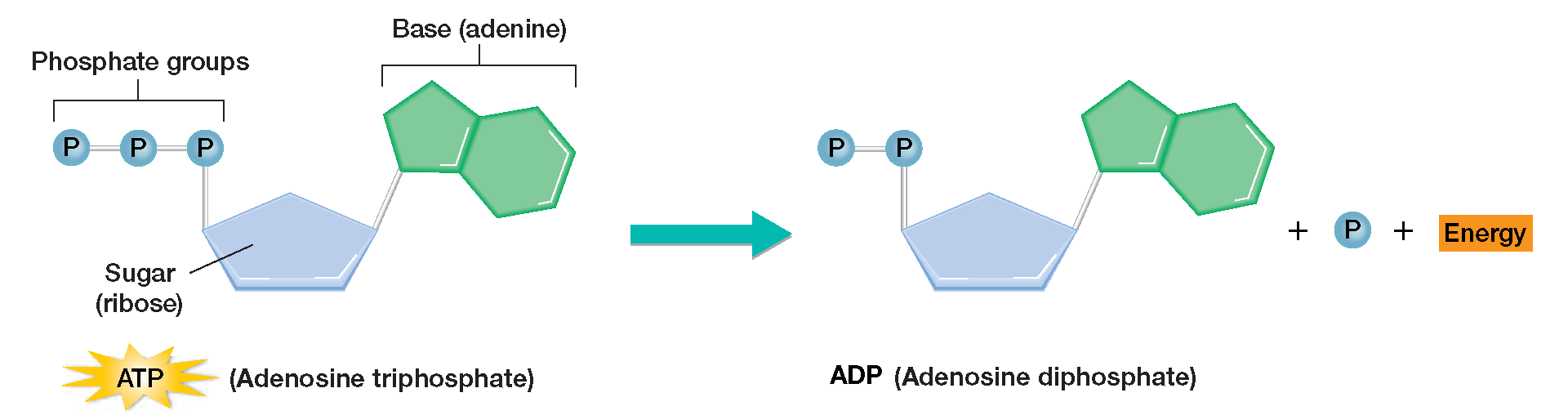


* **Transfer of Energy to ATP**
  + When cells break down food molecules, some of the energy in the molecules is released as \_\_\_\_\_\_\_, while the remaining energy is stored in ATP.
  + Like money, ATP is a portable form of energy \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ inside cells
  + It delivers energy wherever energy is needed in a cell
* Breakdown of Starch



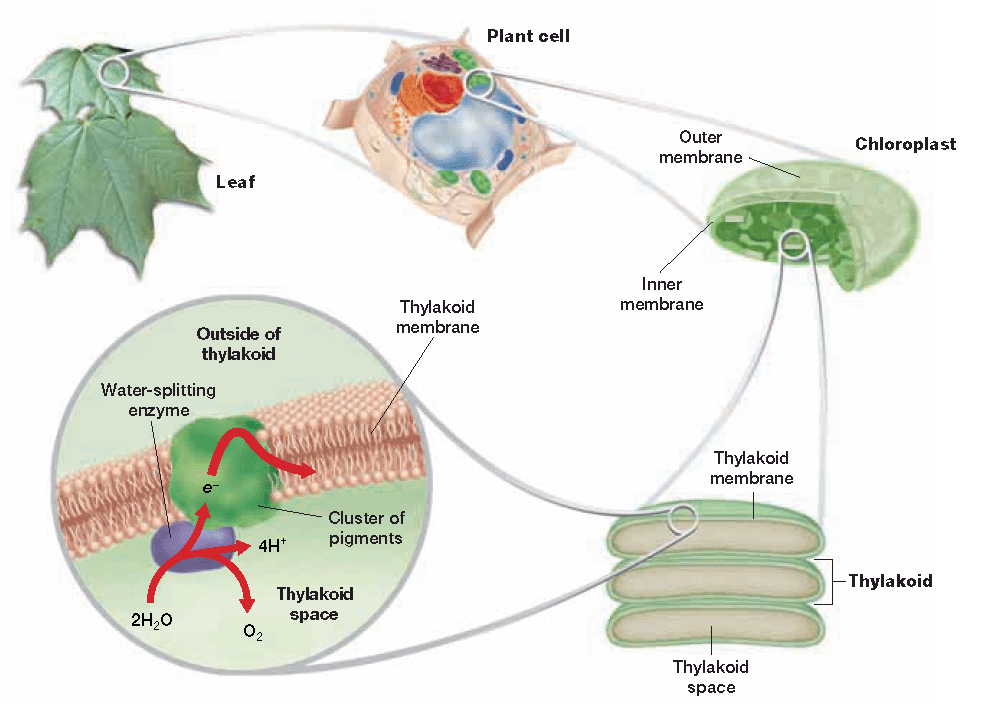
**ATP**: , which stands for \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, is actually a \_\_\_\_\_\_\_\_\_\_\_ with \_\_\_\_\_\_\_\_\_\_ extra energy-storing phosphate groups.

* **What are the three basic parts of a nucleotide?**
* Where is energy stored in ATP?
* So ATP is made up of a….
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(ribose)
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_ phosphate groups
* Energy is released when the bonds that hold the phosphate groups together are \_\_\_\_\_\_\_\_\_\_\_\_\_
* The removal of a phosphate group from ATP produces ADP, which stands for \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* H2O + ATP 🡪 ADP + P + energy
* ATP Releases Energy



**Photosynthesis occurs in three stages**

* **The Light-dependent reactions**
  + **Stage 1** Energy is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ from sunlight.
  + **Stage 2** Light energy is converted to chemical energy, which is temporarily stored in \_\_\_\_\_\_\_\_\_\_\_ and the electron carrier molecule \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* **The Light-Independent reactions/Calvin cycle**
  + **Stage 3** The chemical energy stored in ATP and NADPH powers the formation of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_, using \_\_\_\_\_\_\_\_\_\_\_\_.



These stages occur in different parts of the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Each green stack inside the chloroplast is called a

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

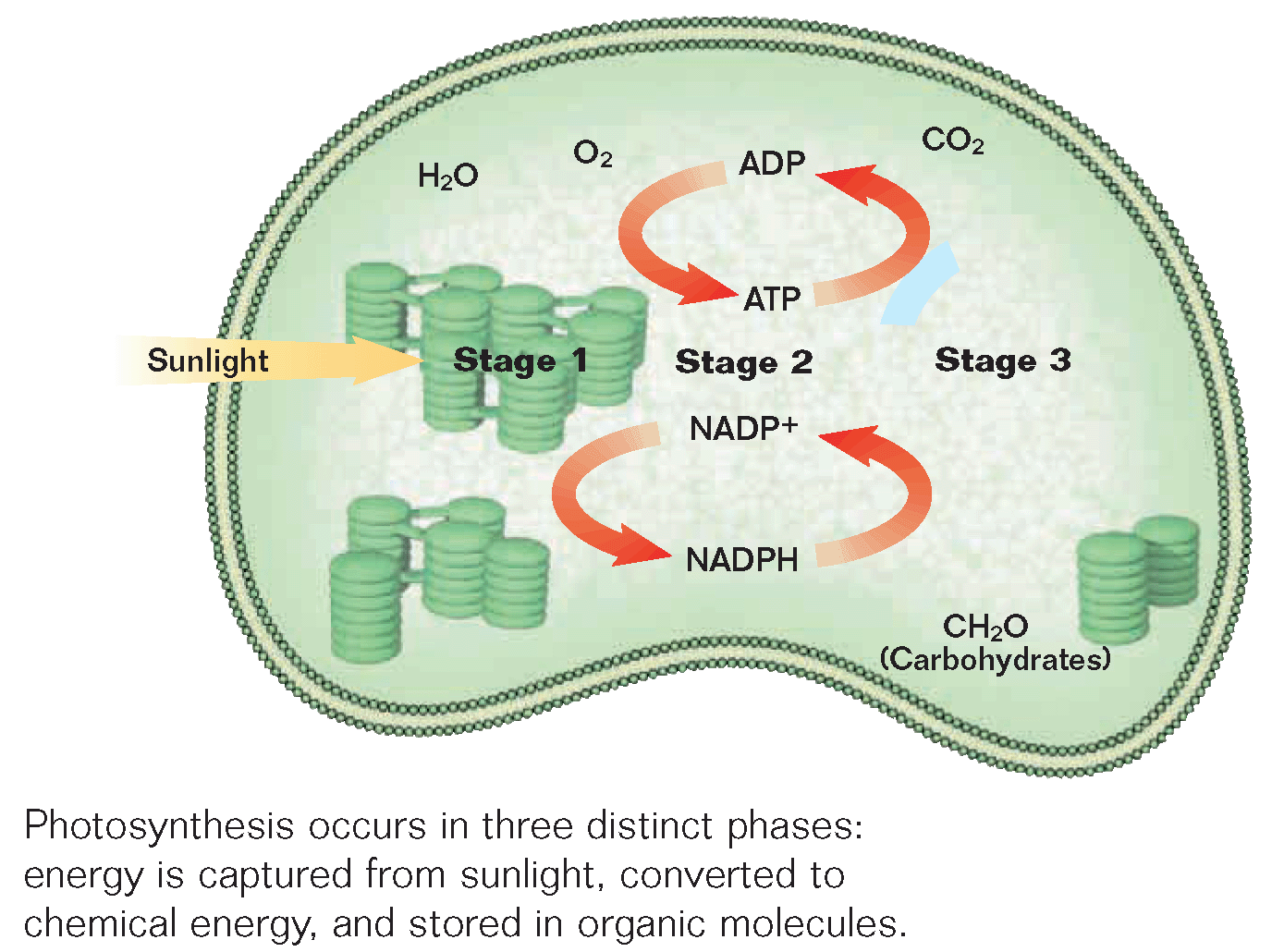
The grana are made up of individual

\_\_\_\_\_\_\_\_\_\_\_\_\_ which have their own membranes

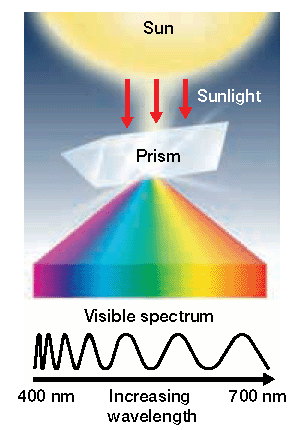
called \_\_\_\_\_\_\_\_\_\_\_\_\_\_membranes

**Photosynthesis**

Stages 1 & 2 occur in the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_,while stage 3 occurs outside of the grana in the space called the \_\_\_\_\_\_\_\_\_\_\_



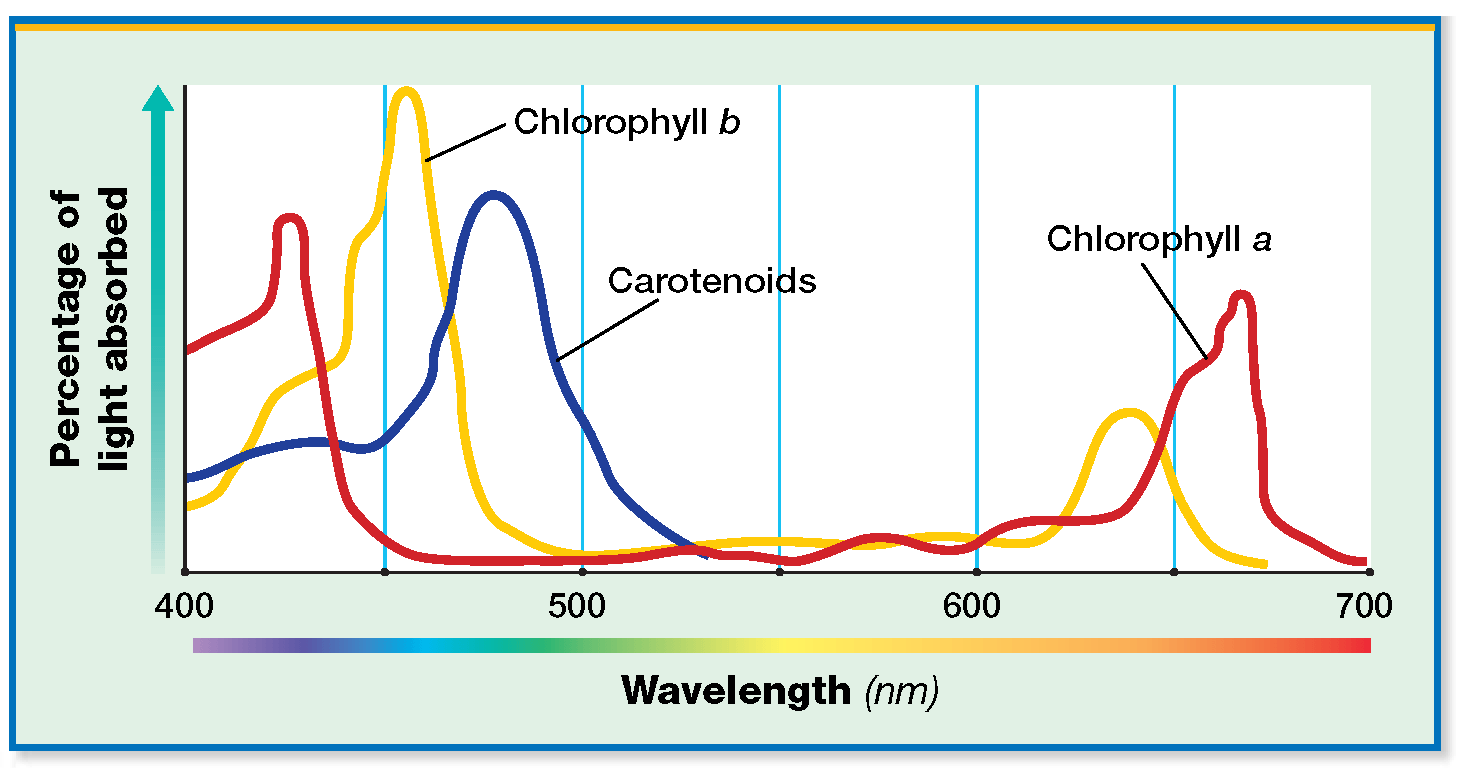
* **Stage One: Capture of Light Energy**
  + Sunlight contains a mixture of all the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (colors) of visible light
  + When sunlight passes through a \_\_\_\_\_\_\_\_\_, the prism separates the light into different colors.
  + According to increasing frequency, the wavelengths are…



* + - Red
    - Orange
    - Yellow
    - Green
    - Blue
    - Indigo
    - Violet
  + Hint…\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Wavelengths that are seen are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
    - Think of mirror…what is the image called that you see?

Increasing frequency (energy)

* + - Wavelengths that are not seen are \_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Leaves contain light-absorbing substances called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
    - Chlorophyll \_\_\_\_
    - Chlorophyll \_\_\_\_
      * \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



* What colors do chlorophyll b and a absorb?
* So chlorophyll reflects…
* What colors do carotenoids reflect that chlorophyll does not?
* These pigments are embedded in the \_\_\_\_\_\_\_\_\_\_\_\_\_ membrane which surround the \_\_\_\_\_\_\_\_\_\_\_\_When light strikes the membrane, energy is transferred to \_\_\_\_\_\_\_\_\_\_\_\_\_ in chlorophyll molecules. This energy transfer causes the electrons to jump to a \_\_\_\_\_\_\_\_\_ energy level.
  + When electrons are at the lowest energy level they are at the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ state
  + When they absorb energy, they become \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and move to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ energy levels
  + Plants first \_\_\_\_\_\_\_\_\_\_\_\_ the sun’s energy when electrons in their chlorophyll molecules absorb its wavelengths
  + Excited electrons eventually move back \_\_\_\_\_\_\_ to the ground state
  + As they do, they release their absorbed \_\_\_\_\_\_\_

Question 1: What molecule that contains chemical energy is produced in photosynthesis?

A. O2

B. CO2

C. C6H12O6

D. H20

Question 2: What is the difference between autotrophs and heterotrophs?

Question 3: An ATP molecule is a nucleotide with two more…

A. Nitrogenous bases

B. Phosphate groups

C. Sugars

D. Glycerol molecules

Question 4: Do chlorophyll molecules reflect or absorb green light?

Question 5: In order of increasing frequency, what do the first letter of each color in visible light spell?

Question 6: Which scientist determined that the process of photosynthesis requires light?

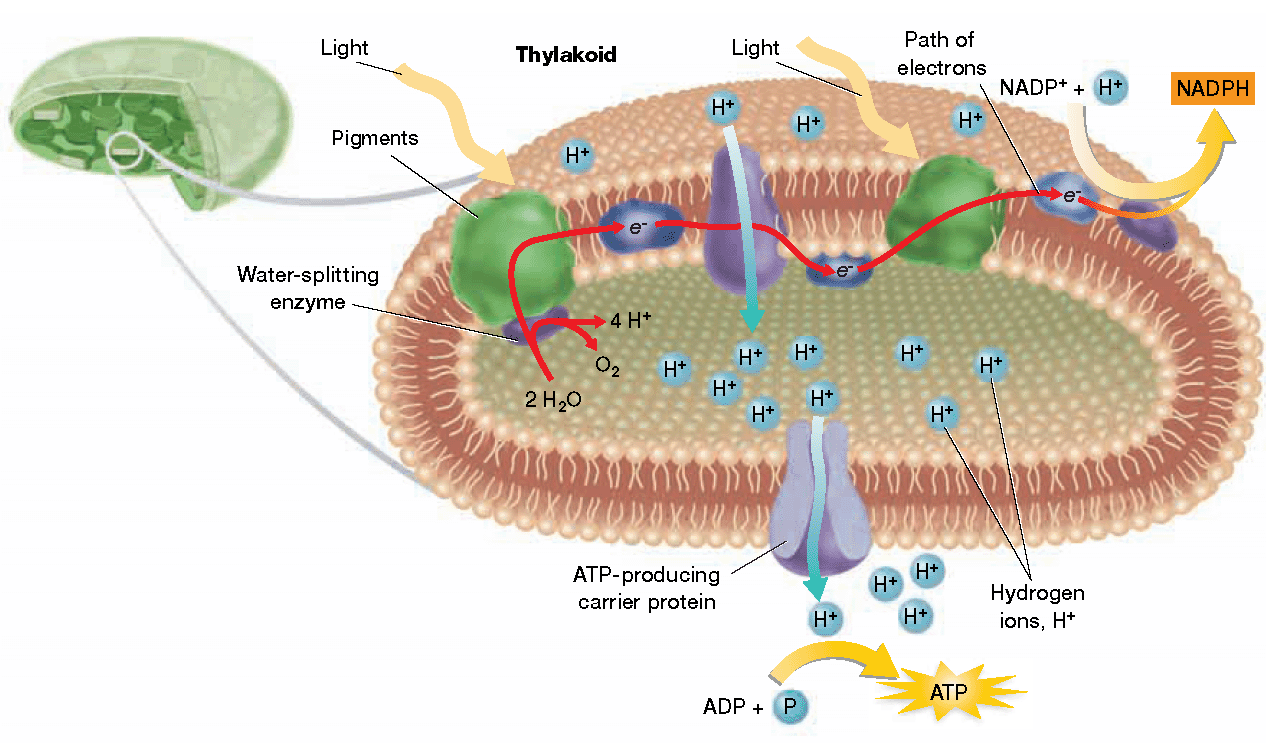
A. Jan van Helmont

B. Joseph Priestley

C. Jan Ingenhousz

**Stage Two: Conversion of Light Energy**

* The absorbed light energy in electrons is used to make three different products…
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Since these substances need light to be produced, stage two is referred to as the \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ reactions
  + First an excited electron \_\_\_\_\_\_\_ to a nearby molecule in the thylakoid membrane.
  + Then the electron is passed down a series of molecules along the membrane called an \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_ (ETC)
  + As electrons move down the molecules, they release \_\_\_\_\_\_\_\_\_\_\_\_…
  + Similar to how a bucket brigade loses water



The first electron

transport chain lies between the two green \_\_\_\_\_\_\_\_\_\_\_ of pigment molecules

The first pigment cluster is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (PSII) because it was the second one discovered

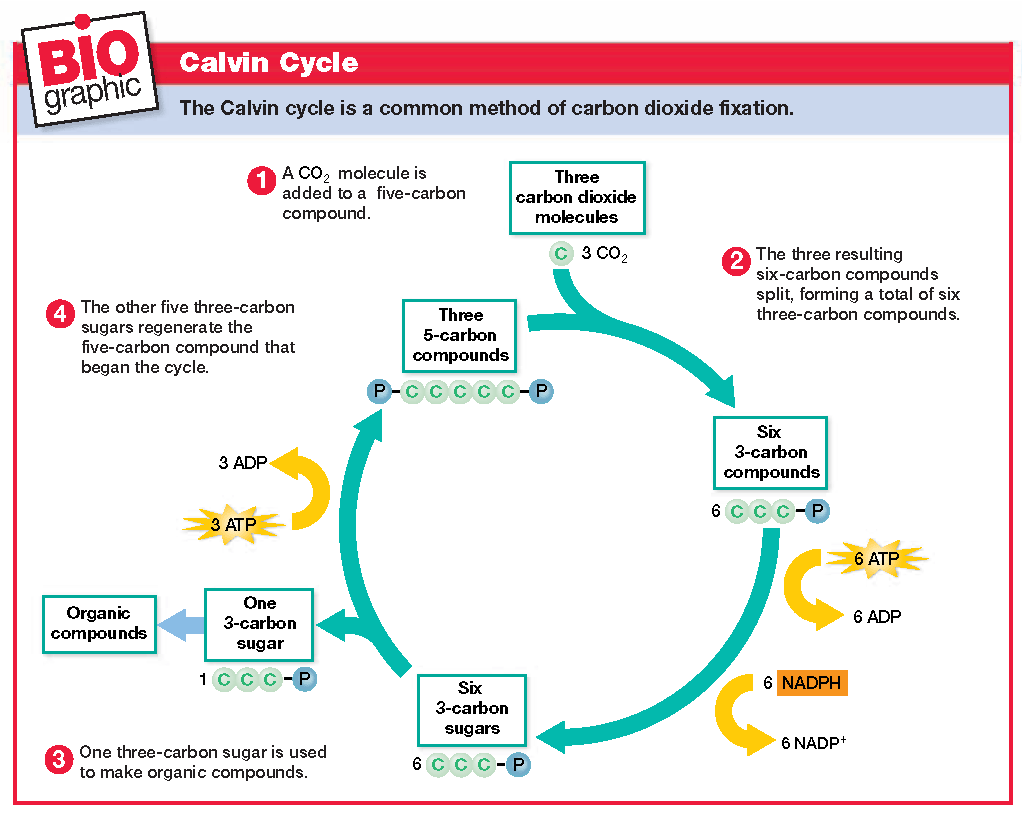
-It absorbs energy and releases an excited \_\_\_\_\_\_

* The excited electron jumps to the next molecule in the electron transport chain, releasing \_\_\_\_\_\_\_\_\_\_\_\_. This energy is used by a membrane pump that pumps \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ions \_\_\_\_\_\_\_ the thylakoid. This creates a \_\_\_\_\_\_\_\_\_\_ \_\_\_\_ of hydrogen ions inside the thylakoid
* This concentration gradient causes hydrogen ions to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ through a transport protein \_\_\_\_\_ of the thylakoid into the \_\_\_\_\_\_\_\_\_\_\_
* The flow of hydrogen ions causes the transport protein to \_\_\_\_\_\_\_\_\_\_
* The spinning action creates a \_\_\_\_\_\_\_\_\_\_ that binds a phosphate group to ADP, producing \_\_\_\_\_\_\_
* Since this transport protein produces ATP, it is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* The energy released from the electrons also allows an enzyme to split a \_\_\_\_\_\_ molecule into hydrogen atoms and the gas \_\_\_
* Chlorophyll molecules replace their excited electrons by taking an electron from hydrogen atoms, leaving them as \_\_\_\_\_\_\_. This allows light energy to excite \_\_\_\_\_\_\_\_\_\_\_ electron in PSII
* The second cluster of pigments is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_ (PSI) because it was the first one discovered
* The original excited electron from \_\_\_\_\_\_ is eventually passed to PSI, where chlorophyll molecules will absorb light energy and \_\_\_\_\_\_\_\_\_\_ the electron again
* These excited electrons move down a \_\_\_\_\_\_\_\_ electron transport chain, releasing energy
* The released energy is used to bind a \_\_\_\_\_\_\_\_\_\_\_ ion to NADP+, which forms \_\_\_\_\_\_\_\_\_\_\_
* **NADPH** is an electron \_\_\_\_\_\_\_\_\_\_\_ that provides the high-energy electrons needed to make \_\_\_\_\_\_\_in the third stage of photosynthesis

Review…What three products are made during the light-dependent reactions?

**Stage Three: Formation of Organic Compounds**

* In the third (final) stage of photosynthesis, carbon atoms from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in the atmosphere are used to make organic compounds, such as \_\_\_\_\_\_\_\_\_\_\_\_\_\_, in which chemical energy is stored.
* The transfer of carbon dioxide to organic compounds is called **carbon dioxide \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
* **These reactions do not require light energy, so stage three is referred to as the light \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ reactions**



Sugars are formed in the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, which is named after \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_, the scientist who discovered it

\*\*\*Occurs in the \_\_\_\_\_\_\_\_\_\_\_\_

First \_\_\_\_ CO2 molecules are added to \_\_\_\_ 5-carbon compounds called

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(\_\_\_\_\_\_\_\_\_\_\_\_\_\_)

* These form 3 unstable \_\_\_-carbon compounds that immediately split into \_\_\_\_ 3-carbon compounds called \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_
* Next, the ATP and NADPH made during the \_\_\_\_\_\_\_\_\_ reactions supply \_\_\_\_\_\_\_ for \_\_\_ 3-carbon sugars, called \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_, to be made
* One PGAL is used by the plant to synthesize \_\_\_\_\_\_\_\_\_\_\_,while the others regenerate RuBP, which began the cycle
* As shown in the diagram, RuBP needs another phosphate before the cycle can begin again… where does it come from?
* What organic compound does a plant need to make for itself?
  + What is its formula?
  + How many carbon atoms does it contain?
* How many carbons are in the initial sugar produced?
  + So while this diagram shows 3 CO2 molecules, photosynthesis really needs \_\_\_\_\_
* Fill in the coefficients in the equation for photosynthesis below…

\_\_ CO2 + \_\_ H20 ------------ > C6H1206 + \_\_ O2

* Photosynthesis is directly affected by various environmental factors such as…
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* The rate of photosynthesis will increase with light intensity and CO2 concentration, until all of the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ are being used or the \_\_\_\_\_\_\_\_\_\_\_\_\_\_ cycle cannot process CO2 any faster
* Because photosynthesis involves \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, it is most \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ within a specific temperature range

Question 1: In what part of the chloroplast are the electron transport chains located?

Question 2: Which of the following is not a product of the light-dependent reactions?

A. O2

B. glucose

C. ATP

D. NADPH

Question 3: Which molecule is necessary to start the Calvin cycle?

A. O2

B. glucose

C. CO2

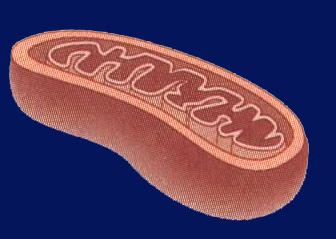
D. ADP

Question 4: What two other names are used to describe the Calvin cycle?

**Cellular Respiration**

|  |  |
| --- | --- |
| Objectives | Vocabulary |
| * **Summarize** how glucose is broken down in the first stage of cellular respiration. * **Describe** how ATP is made in the second stage of cellular respiration. * **Identify** the role of fermentation in the second stage of cellular respiration (next class) * **Evaluate** the importance of oxygen in aerobic respiration. | * Aerobic * Anaerobic * Glycolysis * Krebs Cycle * NADH * FADH2 * Fermentation |

* What type of organic compounds are made during photosynthesis?
* Before organisms use the energy in organic compounds, they must convert this energy to \_\_\_\_\_\_\_\_\_ during the process of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Remember, \_\_\_\_\_\_\_\_ organisms respire…even plants. If they don’t respire, they \_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in the air you breathe makes the production of ATP more efficient, although some ATP is made \_\_\_\_\_\_\_\_\_\_\_\_\_\_ oxygen.
  + Metabolic processes that require oxygen are called **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.**
  + Metabolic processes that do not require oxygen are called **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_,**
* In the process of cellular respiration, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is broken down to produce \_\_\_\_\_\_\_\_\_\_\_\_ within \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



**Structure of the mitochondrion**

* \_\_\_\_\_ membranes
* Inner membrane is \_\_\_\_\_\_\_\_\_
* Space between the two membranes is called the \_\_\_\_\_\_\_\_\_\_\_\_\_\_ space
* Space inside the inner membrane is called the mitochondrial \_\_\_\_\_\_\_\_\_\_\_\_

**The equation for cellular respiration is…**

C6H12O6 + 6O2 → 6CO2 + 6H2O + ATP

Which reactant is needed for cellular respiration to be efficient?

In addition to energy, what other products are made?

**The Stages of Cellular Respiration**: Cellular respiration occurs in three main stages:

**Stage 1** Glycolysis: occurs in the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Stage 2** Krebs Cycle: occurs in the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Stage 3** Electron Transport Chain: occurs along the folded \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ membrane

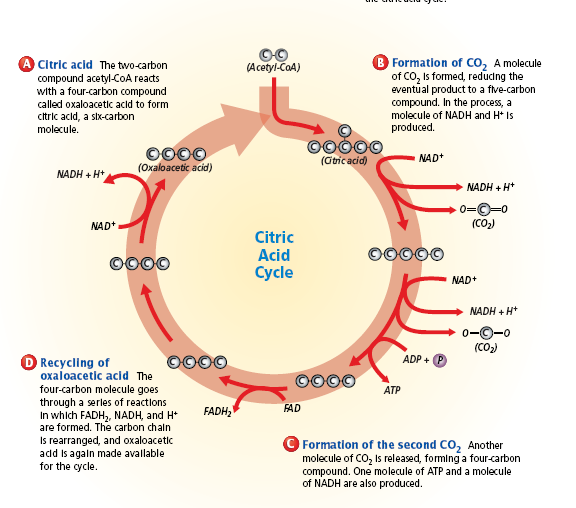
|  |  |
| --- | --- |
| Untitled-11 copy | **Glycolysis**   * Process in which \_\_\_\_\_\_\_\_\_\_\_ is broken down into \_\_\_\_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_ acid * Occurs in the \_\_\_\_\_\_\_\_\_\_\_\_\_\_ * Does \_\_\_\_\_\_\_\_\_ need oxygen! * 4 steps   + Glycolysis: Step 1     - \_\_\_\_\_ ATP jumpstart glycolysis     - \_\_\_\_ phosphates from ATP join \_\_\_\_\_\_\_\_\_\_ to form an unstable 6-carbon compound   + Glycolysis: Step 2: This unstable 6-carbon compound immediately breaks into \_\_\_\_\_\_\_\_ 3-carbon compounds called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_   + Glycolysis: Step 3 * As glucose is broken down some of its \_\_\_\_\_\_\_\_\_\_\_ atoms join \_\_\_\_\_\_\_\_\_ to form \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, which is an energy storing molecule. The hydrogen atoms are replaced by two more \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ groups * Glycolysis: Step 4   + The \_\_\_\_\_\_\_ phosphates bond with 4 molecules of ADP to make 4 \_\_\_\_\_\_\_\_\_\_\_\_ molecules   + The remaining products are two 3-carbon pyruvates, which are ions of \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_   + Remember that 2 ATP are needed to start the process, so glycolysis produces a net gain of \_\_\_\_\_\_ ATP |

**Entering the Mitochondria**



The 3-carbon pyruvates are small enough to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ through the mitochondrial membranes, where they are each broken down into….

* + One \_\_\_\_\_\_\_\_
  + & One 2-carbon compound called an \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* This process releases another hydrogen atom which joins NAD+ to make one more molecule of \_\_\_\_\_\_\_\_\_\_
* The acetyl group is attached to a molecule called \_\_\_\_\_\_\_\_\_\_\_\_\_\_, (\_\_\_\_\_\_) forming the compound \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



* Each acetyl CoA enters the \_\_\_\_\_\_\_\_\_ cycle to start stage 2 of cellular respiration
  + It turns \_\_\_\_\_\_\_\_\_\_, once for each acetyl CoA
  + This cycle is name after \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, the scientist who discovered it
  + Occurs in \_\_\_\_\_\_\_\_ main steps
* Stage Two: Krebs Cycle (Step 1)
  + Acetyl-CoA enters the Krebs cycle by joining a 4-carbon compound called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. The new 6-carbon compound is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Since this is the first product of the Krebs cycle, it also often called the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ cycle
* Stage Two: Krebs Cycle (Step 2)
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_is released from citric acid, resulting in a \_\_\_\_\_\_\_ carbon compound
* Stage Two: Krebs Cycle (Step 3)
  + \_\_\_\_\_\_\_\_ is released from the 5-carbon compound, forming a \_\_\_\_\_\_\_\_ carbon compound
  + So how many molecules of CO2 are made during the Krebs cycle?
* Stage Two: Krebs Cycle (Step 4)
  + The 4-carbon compound is \_\_\_\_\_\_\_\_\_\_\_\_\_, making oxaloacetic acid available for the cycle again

This cycle also makes energy storing compounds…

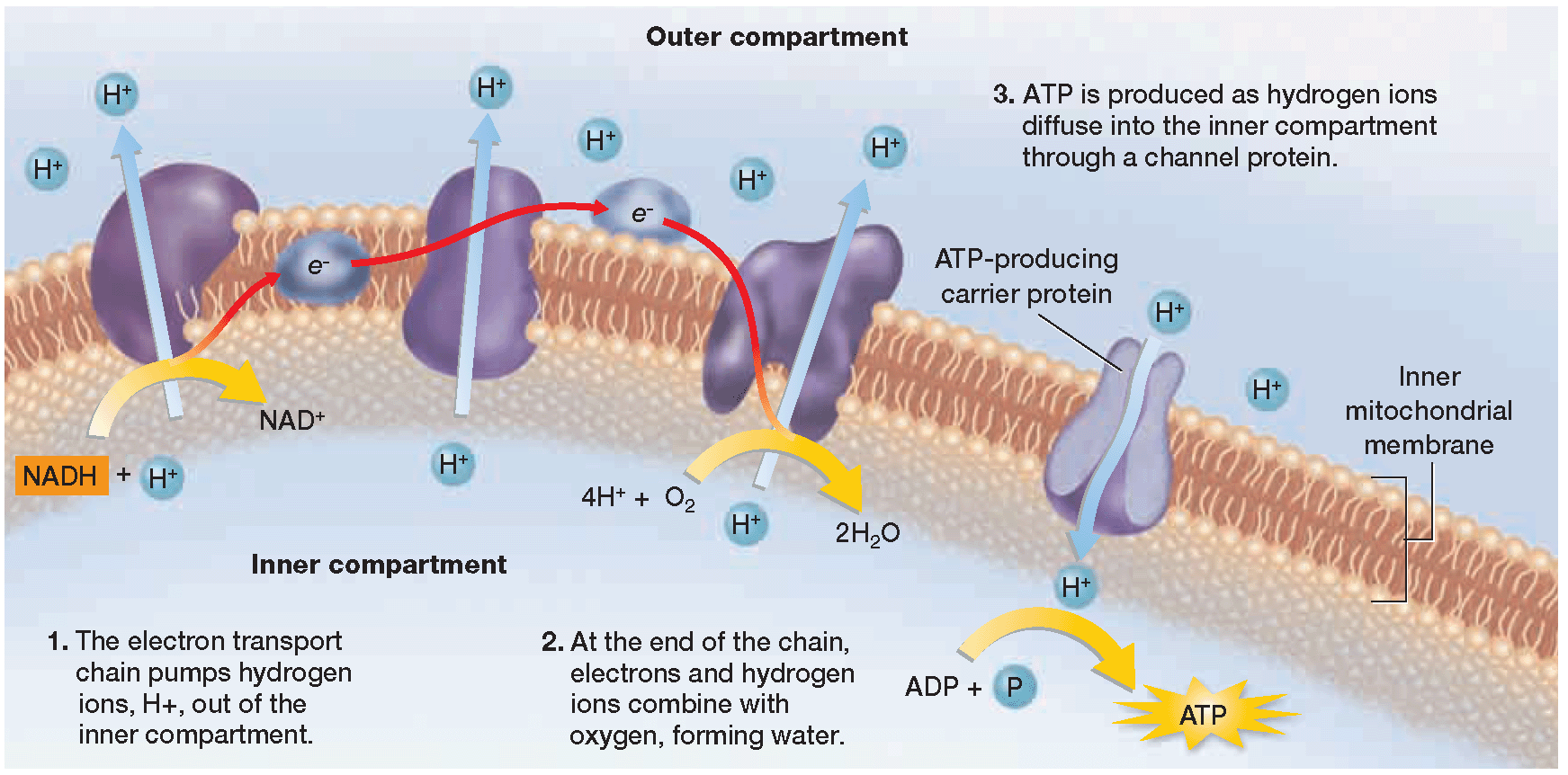
* \_\_\_\_ NADH
* \_\_\_\_ ATP
* \_\_\_\_ FADH2

The cycle turns twice for each molecule of glucose that undergoes glycolysis, so it is really…

* \_\_\_\_ NADH
* \_\_\_\_ ATP
* \_\_\_\_ FADH2

**Stage Three: Electron Transport Chain**

* \_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_ carry high energy \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to the inner membrane of the mitochondria, where they pass through an \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ chain
* The energy released from the moving electrons is used to pump \_\_\_\_\_\_\_\_\_\_\_\_\_ ions from mitochondrial matrix to the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ space. This creates a build-up of hydrogen ions which will \_\_\_\_\_\_\_\_\_\_\_\_\_ through the ATP \_\_\_\_\_\_\_\_\_\_\_\_\_ pump, producing \_\_\_\_\_\_\_\_\_\_ amounts of ATP. As the diffusion of water is called osmosis, the diffusion of chemicals, like H+, is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ . The last molecule in the electron transport chain to receive an electron is oxygen gas \_\_\_\_\_\_\_. It binds with hydrogen ions to make \_\_\_\_\_\_\_\_\_



Without \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, the electron transport chain cannot pass along electrons and it easily gets \_\_\_\_\_\_\_\_\_\_\_\_\_ or clogged up.

This is why oxygen is so essential for most organisms…without it the electron transport chain will \_\_\_\_\_\_\_\_ working and \_\_\_\_\_\_\_\_ will no longer be produced

* The process of making large amounts of ATP in the electron transport chain is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Oxidation results when \_\_\_\_\_\_\_\_\_\_\_ are lost or donated to other molecules
    - Electrons are \_\_\_\_\_\_\_\_\_ from molecule to molecule in the electron transport chain
  + Phosphorylation occurs when a \_\_\_\_\_\_\_\_\_\_\_\_ group is added to a molecule
    - Phosphates are added to \_\_\_\_\_
* Summary of ATP made during cellular respiration
  + Glycolysis = \_\_\_\_ ATP
  + Krebs Cycle = \_\_\_\_ ATP
  + Electron Transport Chain = \_\_\_\_ ATP to \_\_\_ ATP
  + Total… = \_\_\_\_ ATP to \_\_\_ ATP

Question 1: What substance is broken down during cellular respiration?

* 1. CO2 (carbon dioxide) c) O2 (oxygen)
  2. H2O (water) d) C6H12O6 (glucose)

Question 2: Why must glucose be converted to 2 pyruvates in the cytoplasm, before these molecules cross through the mitochondrial membranes?

Question 3: What is the first compound made during the Krebs cycle?

* 1. Oxaloacetic acid c) Acetyl CoA
  2. Citric acid d) Pyruvate

Question 4: Which energy storing compound is **not** made during the Krebs cycle?

* 1. ATP c) NADPH
  2. NADH d) FADH2

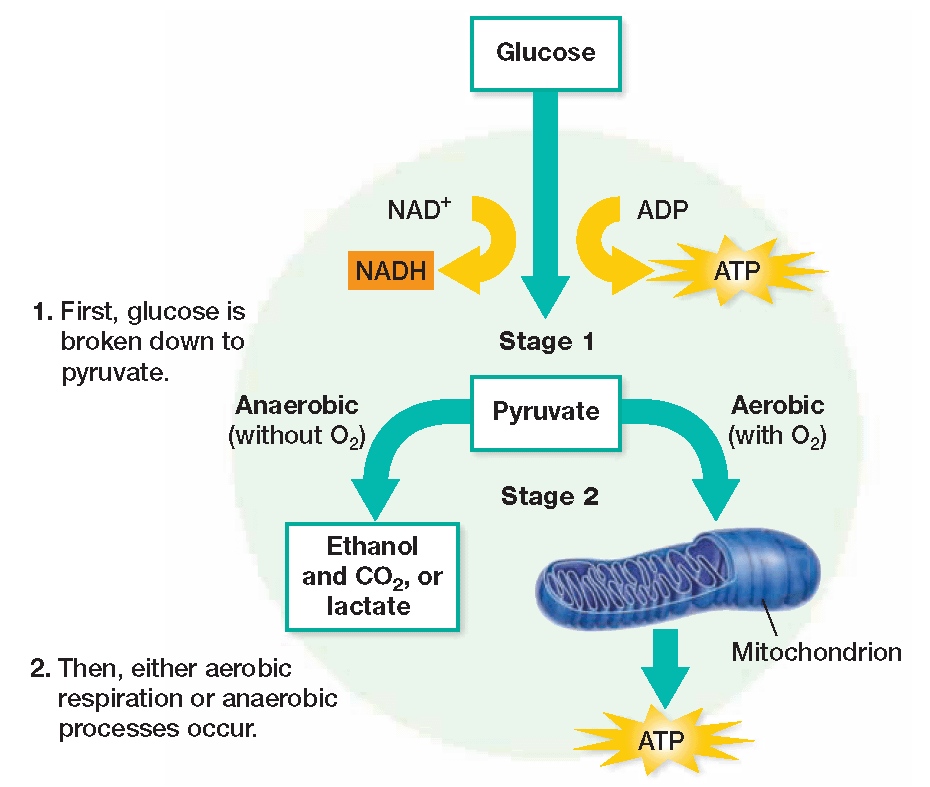
Question 5: Which molecule is necessary to prevent the electron transport chain from becoming clogged or backed up?

* 1. CO2 (carbon dioxide) c) O2 (oxygen)
  2. H2O (water) d) C6H12O6 (glucose)

**Fermentation**

|  |  |
| --- | --- |
| Objectives | Vocabulary |
| * + **Identify** the role of fermentation in the second stage of cellular respiration.   + **Evaluate** the importance of oxygen in aerobic respiration. | Fermentation  Anaerobic respiration |

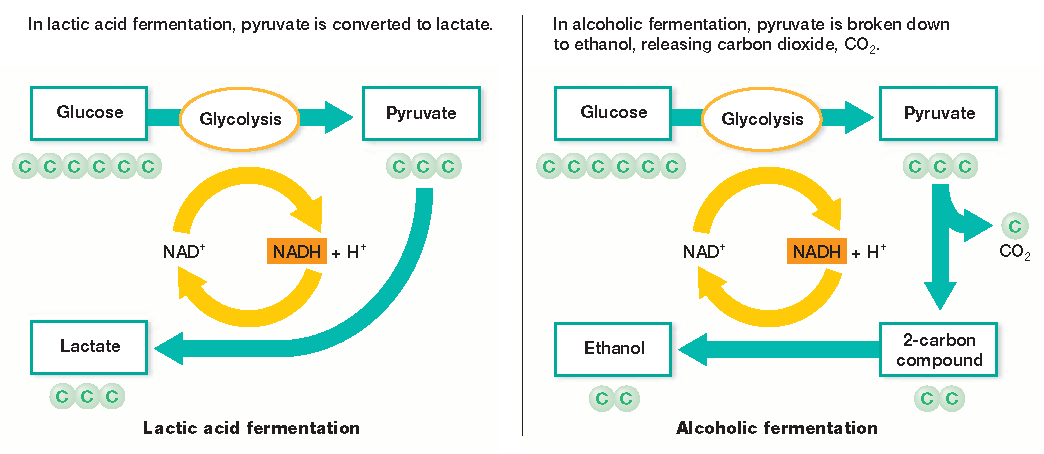
* Recall that glycolysis is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* As shown in the diagram, its final product is two molecules of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



* Once pyruvate is made, either aerobic or anaerobic respiration will continue
* What determines which type of respiration will occur?

**Fermentation**

* When oxygen is not present, cells must produce energy through anaerobic processes called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* There are two types of fermentation
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Both follow \_\_\_\_\_\_\_\_\_\_\_\_\_\_ because they need one of its products
* Look back at this step in glycolysis…what energy storing compound was made?



Both types use NADH to make different \_\_\_\_\_\_\_\_.

When NADH breaks apart, \_\_\_\_\_\_\_\_ may recycle back to glycolysis, which gains \_\_\_\_ ATP

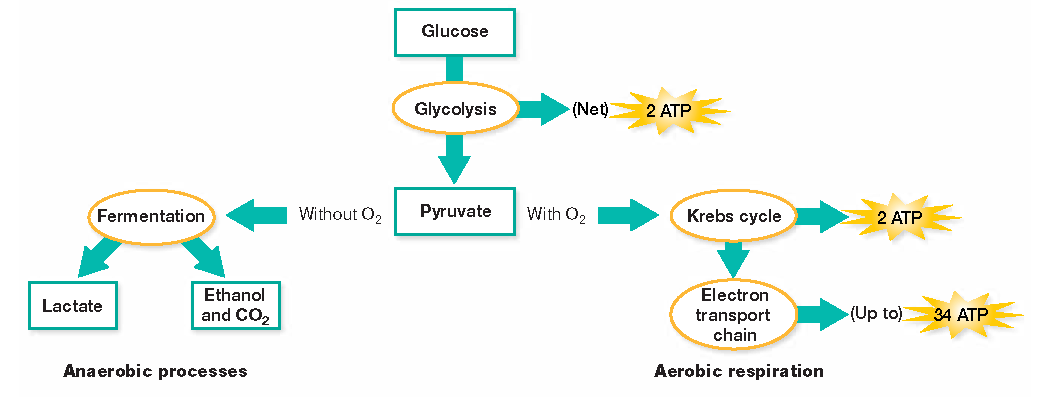
Look at glycolysis again…what ions are needed to make NADH?

Glycolysis and fermentation constantly \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ NAD+ and NADH back and forth, so that they may both continue

Fermentation makes much \_\_\_\_\_\_\_\_\_\_\_ energy than aerobic respiration, but this is sufficient for simple, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ life forms

|  |  |
| --- | --- |
| **Alcoholic Fermentation** | **Lactic Acid Fermentation** |
| * Carried out by organisms such as yeast * Produces…   + \_\_\_\_\_\_\_\_\_\_\_   + \_\_\_\_\_\_\_\_\_\_\_   + \_\_\_\_\_\_\_\_\_\_\_ * Used to produce wine, beer, and bread * CO2 results in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in the bread | * Carried out by some \_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ * Produces…   + \_\_\_\_\_\_\_\_\_\_\_   + \_\_\_\_\_\_\_\_\_\_\_ * What type of food does “lactate” bring to mind? * Fermenting \_\_\_\_\_\_\_\_ with anaerobic bacteria produces \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ * Lactic acid may also build up in \_\_\_\_\_\_\_\_\_\_\_ cells * When the average person is exercising and they start to cramp, what do they do? * This allows your body to take in more \_\_\_\_\_\_\_\_\_\_\_, and resume aerobic respiration |

ATP production



* Fermentation allows \_\_\_\_\_ ATP molecules to be made,
* Aerobic respiration allows up to \_\_\_\_\_\_ ATP molecules to be made

Question 1: Fermentation recycles what molecule back to glycolysis?

* 1. Lactic acid
  2. NAD+
  3. ethanol
  4. CO2

Question 2: List the products of each type of fermentation below.

Alcoholic Lactic Acid