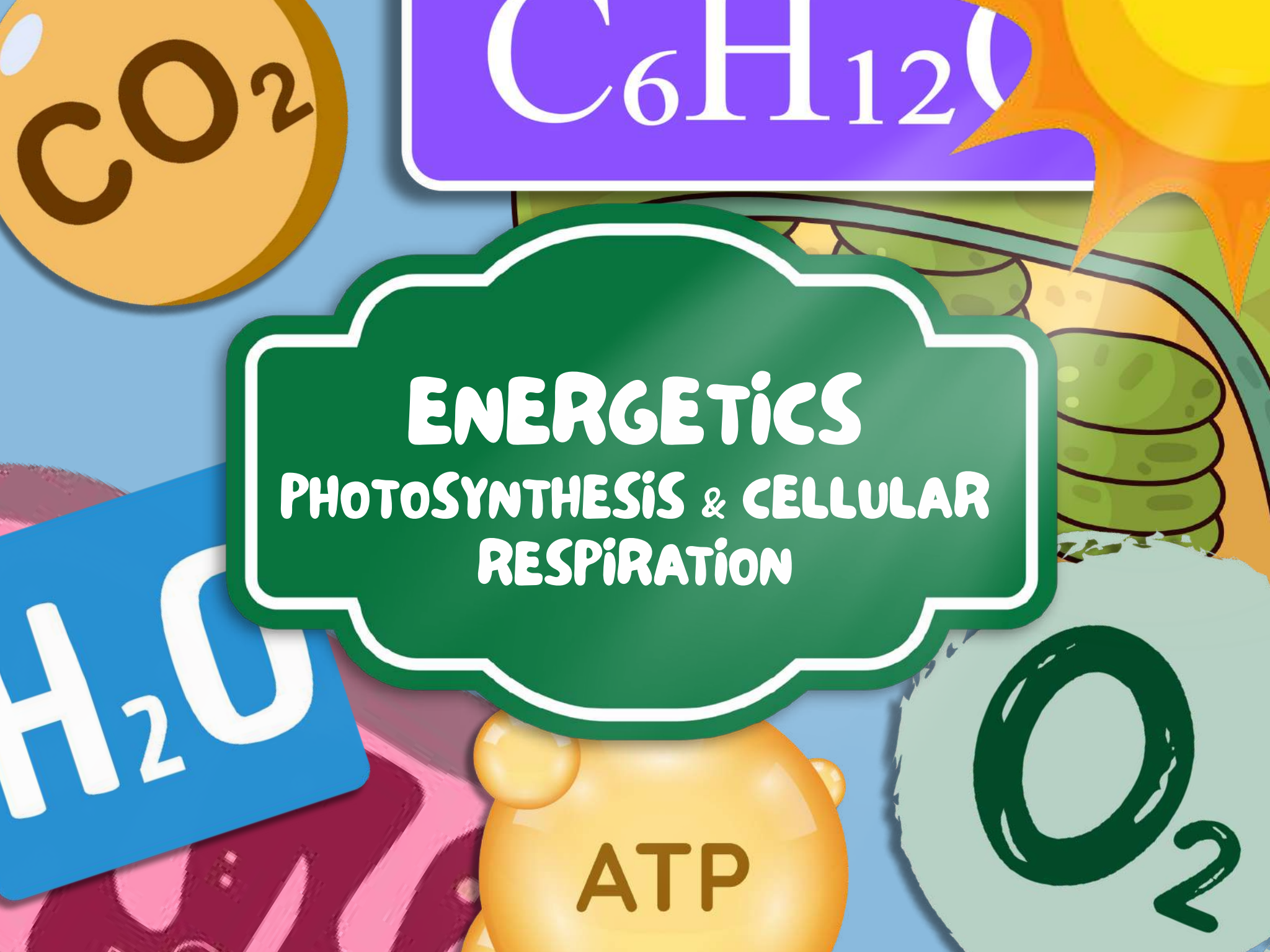

CO_2
$C_6H_{12}O$
ENERGETICS
PHOTOSYNTHESIS & CELLULAR RESPIRATION
H_2O
ATP
O_2

INTRODUCTION

How Cells Make and Use Energy

All living things need energy to stay alive. In this unit, you'll learn how plant and animal cells make and use energy to grow, move, and stay healthy.

We'll start with photosynthesis, the process plants use to make their own food. Plants have special parts in their cells called chloroplasts. Inside the chloroplast, light from the sun helps the plant change water and carbon dioxide into sugar (glucose) and oxygen. This happens in two steps:

The light-dependent reactions happen in the thylakoid membranes, where sunlight is used to make energy.

The Calvin Cycle happens in the stroma, where the plant uses that energy to make sugar.

Then, we'll learn about cellular respiration, the process that both plants and animals use to get energy from food. This happens inside a part of the cell called the mitochondria, sometimes called the "powerhouse" of the cell. In this process, sugar and oxygen are broken down to make ATP, the energy cells use.

Cellular respiration happens in 3 steps:

- Glycolysis breaks sugar into smaller parts (this happens in the cytoplasm).
- The Krebs Cycle happens in the middle of the mitochondria.
- The Electron Transport Chain happens in the inner wall of the mitochondria and makes most of the ATP.

We'll also talk about two types of respiration:

- Aerobic respiration happens when oxygen is available. It makes a lot of energy.
- Anaerobic respiration happens without oxygen. It makes less energy and can cause things like lactic acid in muscles after hard exercise

You'll also learn the difference between:

- Autotrophs – like plants – that make their own food
- Heterotrophs – like animals – that eat food to get energy

Finally, you'll see how cells use ATP to power everything they do, like building new parts, fixing damage, moving, and staying balanced. Plant and animal cells both use ATP, but in different ways depending on what they need. By the end of this unit, you'll understand how energy moves through living things and why it's so important for life.

VOCABULARY

Vocabulary Word	Definition
photosynthesis	
autotroph	
heterotroph	
cellular respiration	
pigment	

Vocabulary Word	Definition
chlorophyll	
electron transport chain	
carbon dioxide fixation	
aerobic	
anaerobic	
glycolysis	
fermentation	
stoma (plural: stomata)	

Vocabulary Word	Definition
Stroma	
Calvin cycle	
Kreb's Cycle	

PHENOMENON

Mission Log – Sol 68

The red lights are still flashing. It's been five sols since Dr. Ruiz was infected, and now another problem is growing worse—the HAB's oxygen levels are dropping. The emergency system is running low on power. The solar panels are barely giving enough energy to charge your tools. And the air scrubbers are no longer removing carbon dioxide like they should.

You check the HAB's oxygen-producing algae pods, a small system of plant cells designed to perform photosynthesis, just like plants do on Earth. They use light, carbon dioxide, and water to make oxygen and sugar. But now? The leaves look faded. The lights in the growth chamber are flickering. Without strong light, there's not enough energy for the algae to run the light-dependent reactions in their chloroplasts. That means less sugar, and less oxygen.

Meanwhile, your own body is feeling the pressure. You haven't had a full meal in two days, and the oxygen shortage is forcing your cells to work harder. You remember your training: when there's not enough oxygen, your cells switch from aerobic respiration to anaerobic respiration, a backup system that gives you some energy—but causes that painful lactic acid burn in your muscles.

You review the facts on your datapad:

- Plant cells need working thylakoid membranes to catch light and make energy.
- The Calvin Cycle turns that energy into glucose for later use.
- Your own mitochondria take that glucose and, with oxygen, break it down to make ATP, the energy your body uses.
- But when there's no oxygen, your mitochondria make less ATP, and more waste builds up.

Your mission is now about more than just research—it's survival. To keep the crew alive, you'll need to:

- Boost the light for the algae so they can restart photosynthesis.

- Find ways to manage your energy while your cells make less ATP.
- Track how your body is using energy differently than the plants in the HAB.

The life systems here were built to last—but the cells inside you and the cells around you are running out of power. What happens next depends on whether you understand how life runs on energy... and how to protect it.

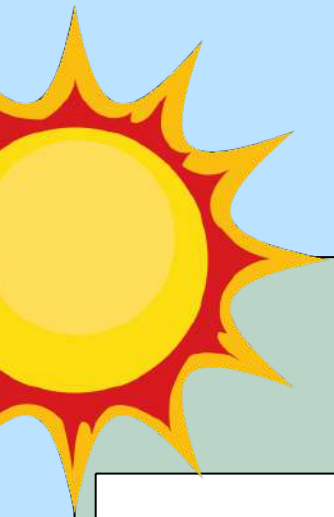
1. Why aren't the algae making enough oxygen anymore?
   - "The algae are not making enough oxygen because _____."
2. How do the plant cells normally make oxygen and sugar?
   - "They use a process called photosynthesis, where they take in _____ and produce _____."
3. What part of the plant cell helps capture light, and what does it do with that energy?
   - "The _____ in the chloroplasts capture sunlight and use it to _____."
4. Why do your muscles hurt when there isn't enough oxygen?
   - "Without oxygen, my cells switch to _____, which makes less energy and causes _____."
5. How do plant and animal cells use glucose differently?
   - "Plant cells make glucose using _____, and animal cells use glucose by _____."
6. Why is ATP so important in the Mars HAB right now?
   - "ATP gives energy to cells so they can _____, and without enough ATP, the crew _____."

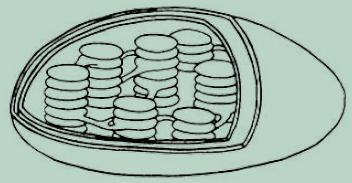
CELLS AND ENERGY

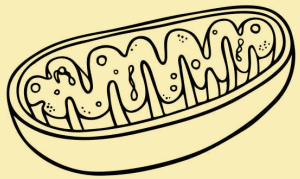
Cells Using Energy

- Purpose of Energy in Cells
- Function: Energy is needed for various cell activities such as movement, growth, repair, and maintaining homeostasis.
- Key Processes
  - Photosynthesis: Process by which plants make food using sunlight. Autotrophs only!
    - Equation: **$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$.**
    - **Reactants**: Carbon dioxide, water, light energy.
    - **Products**: Glucose, oxygen.
  - Cellular Respiration: Process by which cells use oxygen to break down food and release energy. Autotrophs & Heterotrophs
    - **Equation**: **$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$**.
    - **Reactants**: Glucose, oxygen.

CELLS AND ENERGY



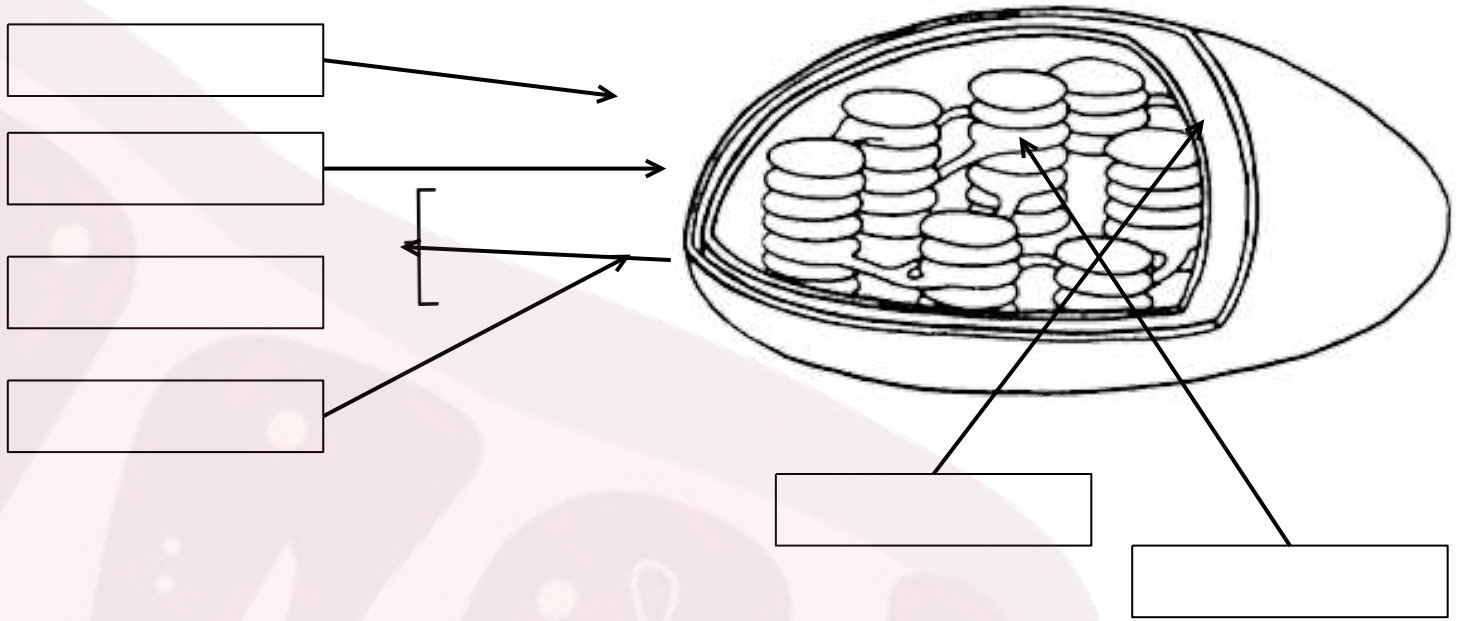




CHLOROPLAST

Roles of Chloroplasts and Mitochondria

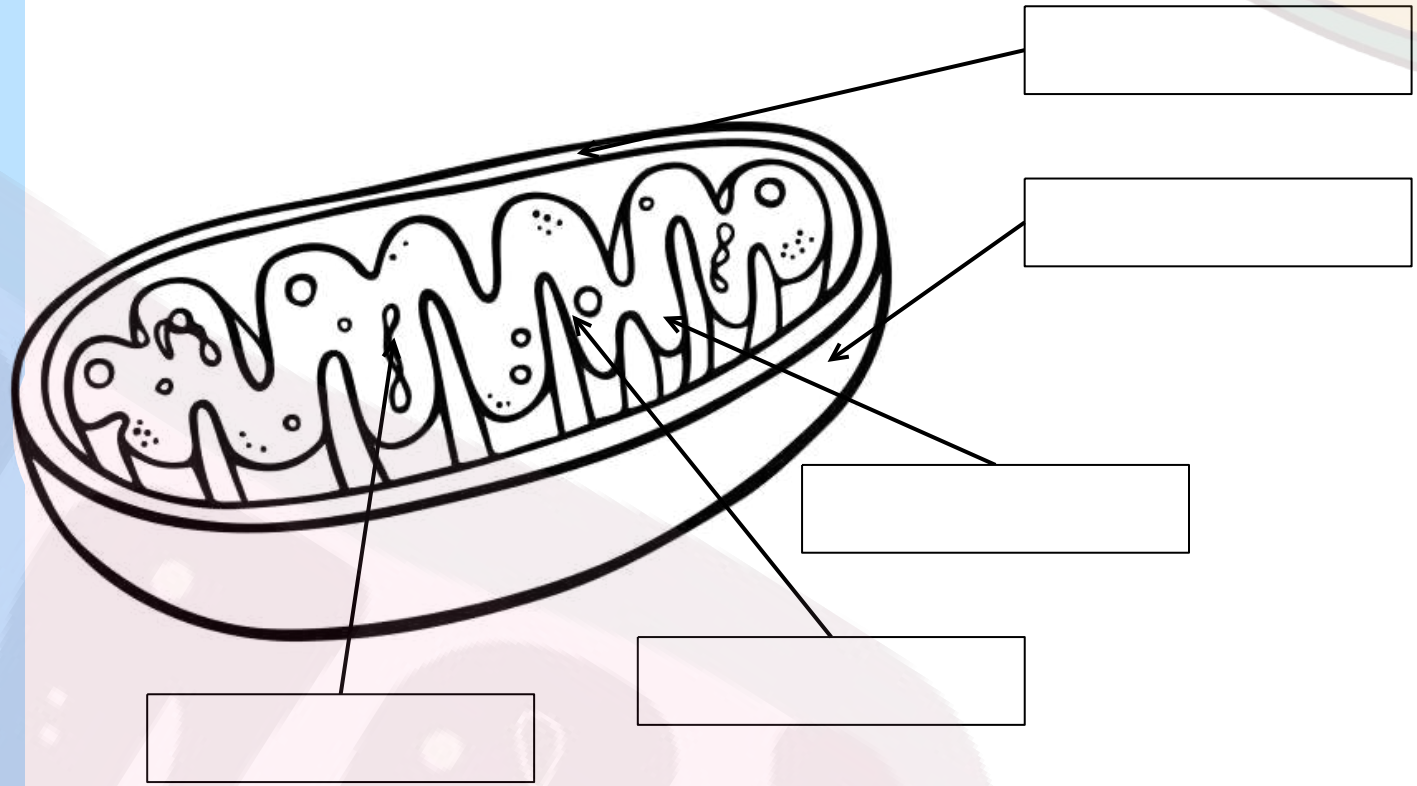
- **Chloroplasts**
  - **Function**: Capture sunlight and make food through photosynthesis.
  - Key Parts:
    - **Thylakoid** Membranes: Convert light energy into chemical energy during the light-dependent reactions.
    - **Stroma**: Where the Calvin Cycle occurs, producing glucose from carbon dioxide and energy molecules



MITOCHONDRIA

Mitochondria

- **Function**: Release energy (ATP) from food through cellular respiration.
- Key Parts:
  - **Inner Mitochondrial Membrane**: Site of the electron transport chain, producing ATP.
  - **Matrix**: liquid portion in the center, where the Krebs Cycle takes place



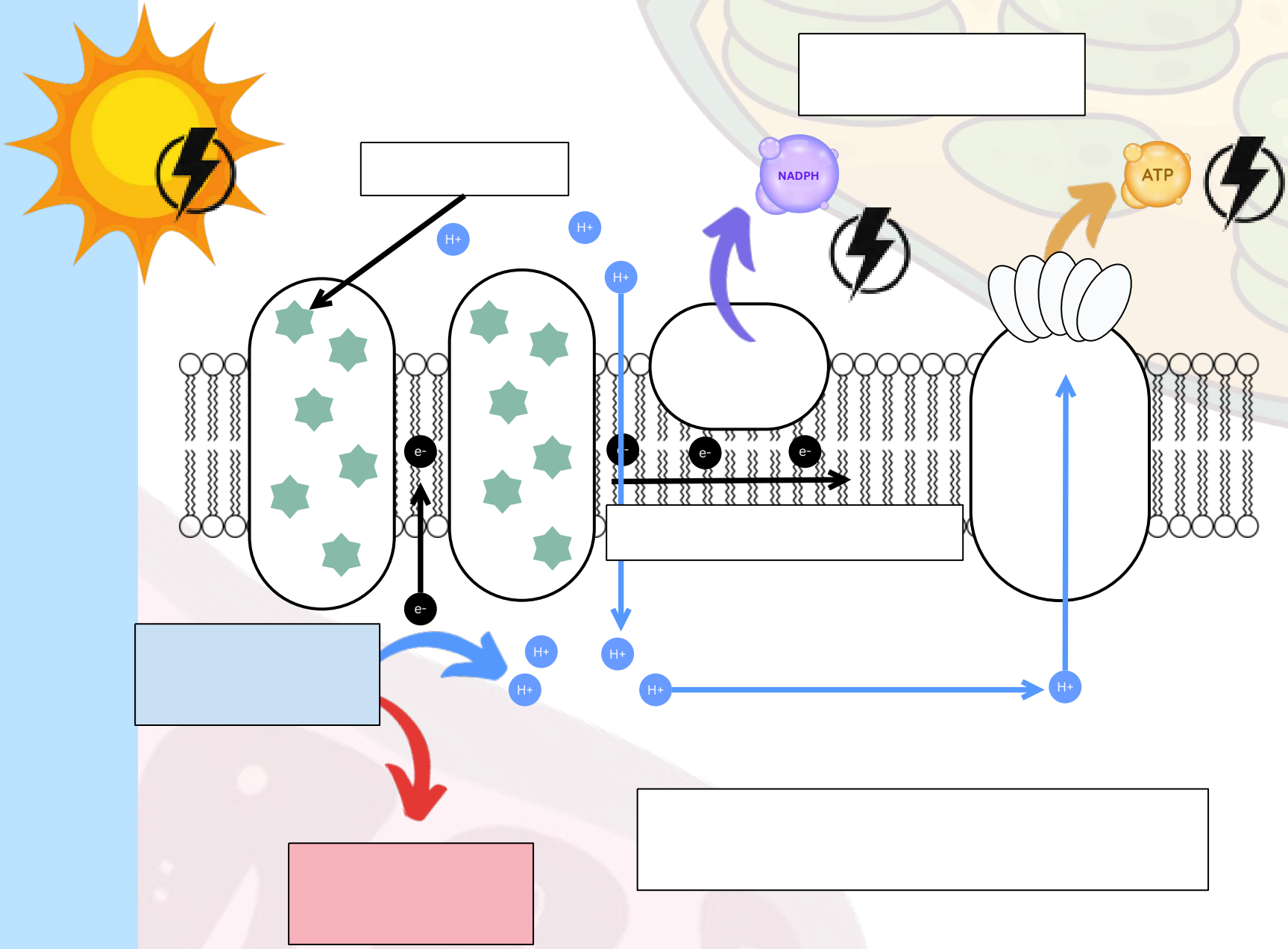
1. What do chloroplasts and mitochondria do in a cell? How do these jobs help the cell get energy?
2. How do chloroplasts and mitochondria look different, and why does it matter? What are thylakoid membranes in chloroplasts and the inner membrane in mitochondria for?
3. How are photosynthesis and cellular respiration opposites but also work together? How do the products of photosynthesis become the reactants for cellular respiration and the other way around?
4. Why do plant cells need both chloroplasts and mitochondria, but animal cells only need mitochondria? What benefits do plant cells get from doing both photosynthesis and cellular respiration?
5. How is the energy made in chloroplasts during photosynthesis connected to the energy made in mitochondria during cellular respiration? How does this connection affect the way energy moves in a cell and between plants and animals?

Steps of Photosynthesis

Steps of Photosynthesis

- **Light-Dependent Reactions**
  - **Location: Thylakoid membranes** of **chloroplasts.**
  - **Process:**
    - Use **sunlight** to **produce energy-rich** molecules **(ATP** and **NADPH).**
    - Split **water** to release **oxygen** as a byproduct.

Steps of Photosynthesis

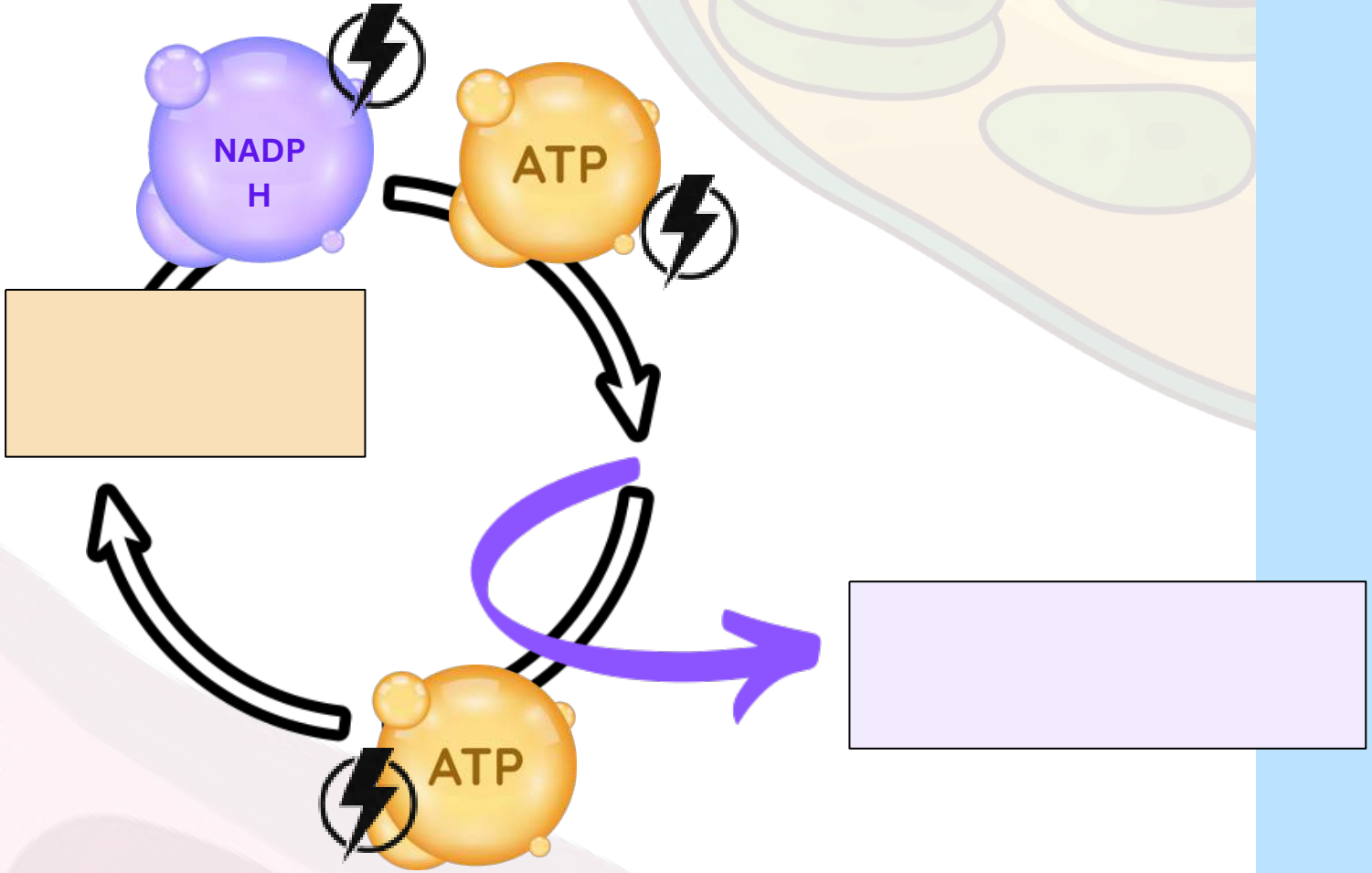


Steps of Photosynthesis

Calvin Cycle / Light Independent Reactions

- **Location: Stroma** of chloroplasts.
- **Process:**
  - Uses **ATP** and **NADPH** from **the light-dependent** reactions to convert **carbon dioxide** into **glucose.**
  - Stores **energy** in the form of **glucose** for later use by the plant.

Steps of Photosynthesis



1. What are the main steps in the light-dependent reactions of photosynthesis? How does sunlight help these reactions?
2. What happens during the Calvin Cycle, and why is it important? How does the Calvin Cycle use the energy made in the light-dependent reactions?
3. How do the light-dependent reactions and the Calvin Cycle work together to produce glucose? Why is glucose important for plants?
4. Why are chloroplasts essential for photosynthesis, and what are their key parts? How do the thylakoid membranes and the stroma help in photosynthesis?
5. How does the process of photosynthesis show the connection between light energy and chemical energy? How do plants use the chemical energy stored in glucose?

STEPS OF CELLULAR RESPIRATION

Steps of **Cellular Respiration**

- **Glycolysis**
  - **Location: Cytoplasm** of the cell**. Anaerobic –** no oxygen needed
  - **Process:**
    - Breaks down **glucose** into two molecules of **pyruvate.**
    - Produces a small amount of **ATP** and **NADH.**
- **Krebs Cycle**
  - **Location:** Mitochondrial **matrix.**
  - **Process:**
    - Breaks down **pyruvate** into **carbon dioxide.**
    - Produces **energy** carriers **(NADH** and **FADH2)** and a small amount of **ATP.**
- **Electron Transport Chain**
  - **Location: Inner mitochondrial membrane.**
  - **Process:**
    - Uses **electrons** from **NADH** and **FADH2 t**o produce a large amount **(~ 18)** of **ATP.**
    - **Oxygen** is the final electron acceptor**,** forming **water** as a byproduct.


$C_6H_{12}O_6$

1. What happens during glycolysis, and why is it important? What is the main product of glycolysis?
2. What is the preparatory reaction, and what does it prepare for? How does this stage help the citric acid cycle?
3. What occurs in the citric acid cycle (Krebs Cycle), and what is its main purpose? What important molecules are produced in this cycle?
4. How does the electron transport chain work, and why is it crucial for cellular respiration? What role does oxygen play in the electron transport chain?
5. How is ATP produced during cellular respiration, and why is it important for cells? How do the different stages of cellular respiration contribute to the overall production of ATP?

Comparing and Contrasting Aerobic and Anaerobic Respiration

- **Aerobic** Respiration
  - **Definition**: Producing **energy** with **oxygen**.
  - Process:
    - Involves **glycolysis** - **anaerobic** but has to happen first, **Krebs Cycle**, and **electron transport chain**.
  - Produces a large amount of **ATP:** 36-38 ATP's.
  - Examples in Nature:
    - Occurs in most **animals** and **plants**.

- Used for sustained energy during activities like running or swimming.

- **Anaerobic Respiration**
  - **Definition**: Producing **energy without oxygen**.

  - **Types of Fermentation**:
    - **Alcohol Fermentation**: Produces **alcohol**, **carbon dioxide**, and a **small** amount of **ATP**. Occurs in **yeast** and some **bacteria**.

    - **Lactic Acid Fermentation**: Produces **lactic acid** and a **small** amount of **ATP**. Occurs in **muscle** cells during strenuous **exercise**. How bacteria make yogurt.

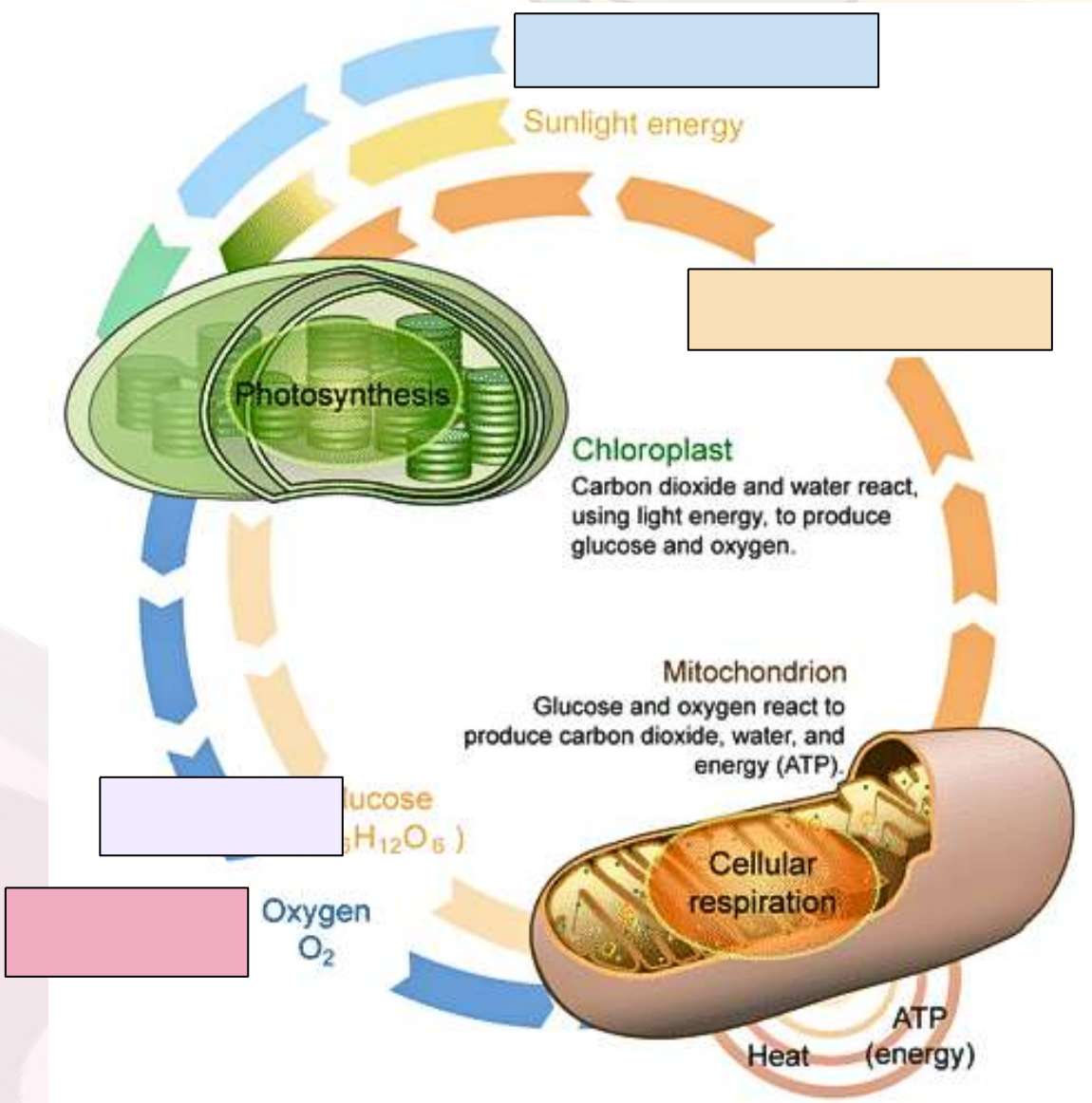
TRANSPORT IN ENERGETICS

Passive and Active Transport

- **Passive** Transport
  - **Definition**: Movement of **substances** across a cell membrane **without** using **energy**.
  - **Examples**:
    - **Diffusion**: Movement of molecules from high to low concentration.
    - **Photosynthesis** - Oxygen leaving the Thylakoid after water splits
    - **Osmosis**: Movement of water molecules through a semipermeable/selectively permeable membrane from high to low concentration.
      - **Photosynthesis** - Water being pulled in through the roots
- **Active Transport**
- **Definition**: Movement of substances across a cell membrane that requires energy (ATP).
- **Examples**:
  - **Protein Pumps**: Transport ions against a concentration gradient using ATP.
  - **Photosynthesis** - Hydrogen ions are pumped into the thylakoid from the stroma.

RELATIONSHIP BETWEEN - PHOTOSYNTHESIS AND RESPIRATION

The _____ of one are the _____ of the other!



Categories	Photosynthesis	Cellular Respiration
Type of Organism		
Purpose		
Organelles		
Reactants		
Products		

1. Why are photosynthesis and cellular respiration important for plants and animals? How do these processes help living things get and use energy?
2. How are the things plants and animals need for photosynthesis and cellular respiration different? Why do plants need carbon dioxide and produce oxygen, while animals need oxygen and produce carbon dioxide?
3. What are the main parts of a plant cell that are involved in photosynthesis and cellular respiration, and how do they work? How do these parts help plants and animals stay alive?
4. How is the way energy moves during photosynthesis different from cellular respiration? Why do plants and animals need both of these processes to survive?
5. What are some ways that photosynthesis and cellular respiration are similar, and how are they different? How do these processes affect the air we breathe and the environment around us?

Summary

1. What is the purpose of photosynthesis, and what organelle carries it out?
    - "The purpose of photosynthesis is to _____."
    - "It happens in the _____, which are found in _____ cells."
    - "This process helps the plant by making _____ and releasing _____."
2. What are the two main stages of photosynthesis, and what happens during each?
    - "The first stage is the light-dependent reactions, which happen in the _____."
    - "During this stage, the plant uses sunlight to make _____ and releases _____."
    - "The second stage is the Calvin Cycle, which happens in the _____ and uses energy to make _____."
3. What are the three main steps of cellular respiration, and what is the goal of this process?
    - "The goal of cellular respiration is to break down _____ and make _____."
    - "Step one is glycolysis, which happens in the _____ and produces _____."

- "Step two is the Krebs Cycle in the _____, which makes _____ and releases _____."
- "Step three is the electron transport chain in the _____, where most of the _____ is made."

4. What is the difference between aerobic and anaerobic respiration?
   - "Aerobic respiration needs _____ and makes a _____ amount of ATP."
   - "Anaerobic respiration does not need _____ and makes _____ ATP."
   - "One example of anaerobic respiration is _____, which happens in _____."
5. . How do autotrophs and heterotrophs get and use energy differently?
   - "Autotrophs make their own food using _____ during _____."
   - "Heterotrophs must eat other organisms to get _____, which they use in _____."
   - "Even though they get food differently, both types of organisms make _____ using _____."
6. Why is ATP important, and how do plant and animal cells use it differently?
   - "ATP is important because it gives cells energy to do things like _____ and _____."
   - "Plant cells use ATP for _____ and also to help with _____."
   - "Animal cells use ATP mostly for _____ and _____."

RESOURCES

Bozeman Science. (2012b, April 4). Photosynthesis [Video]. YouTube. https://www.youtube.com/watch?v=g78utcLQrJ4

Amoeba Sisters. (2021, July 14). Photosynthesis (UPDATED) [Video]. YouTube. https://www.youtube.com/watch?v=CMiPYHNNg28

Science ABC. (2021, December 3). Cellular respiration: How do cells get energy? [Video]. YouTube. https://www.youtube.com/watch?v=JagPP3MX5ks

MooMooMath and Science. (2020, April 2). Relationship between Photosynthesis and Cellular Respiration [Video]. YouTube. https://www.youtube.com/watch?v=rXzN89I4_Yk

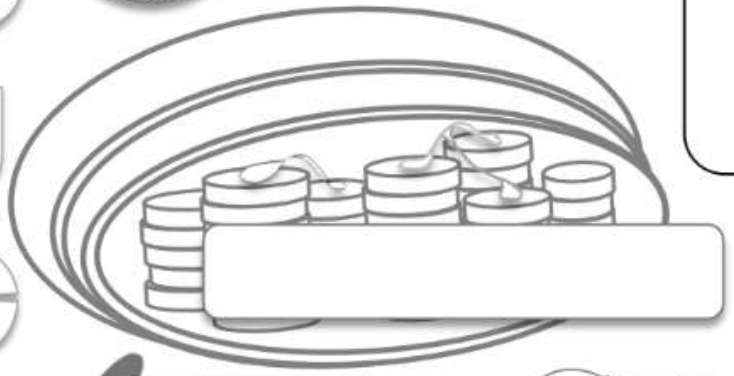
Photosynthesis

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

PLANT

autotroph

PRODUCER

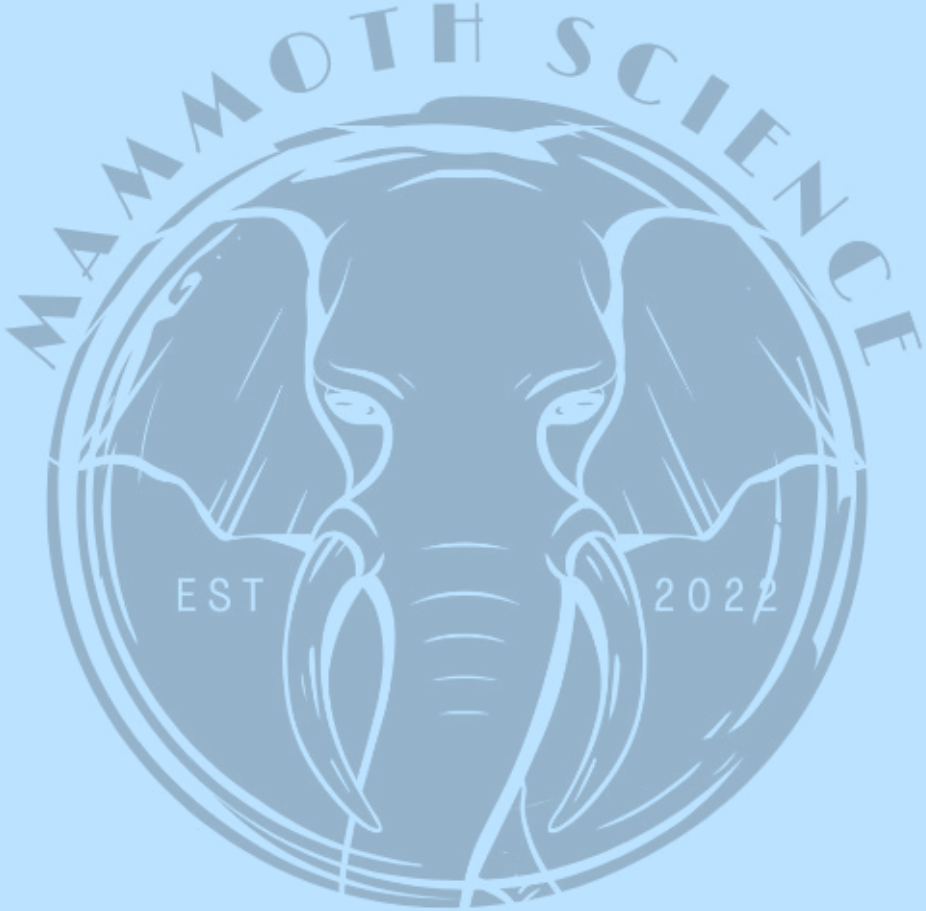


O_2

Autotroph
& heterotroph

Cellular Respiration

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$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