MAMMOTH SCIENCE PUBLISHING
EST 2022

Cellular Respiration

Unraveling the Secrets of Cellular Respiration: A Journey into Energy Production

Biology Narratives: Oliver

Oliver, the rainforest orchid, relies on photosynthesis to convert sunlight into chemical energy, producing glucose and releasing oxygen. In addition, Oliver engages in cellular respiration, converting glucose and oxygen into ATP, which serves as an energy currency for his cellular functions. Oliver's response to the presence or absence of oxygen involves fermentation, enabling him to generate energy anaerobically. Different biomolecules such as carbohydrates, lipids, proteins, and nucleic acids contribute to Oliver's structure and function within the cell. ATP plays a central role in energy coupling and transfer, supporting Oliver's various cellular activities. Overall, Oliver's photosynthesis, cellular respiration, response to oxygen, and utilization of biomolecules and ATP are essential for his survival and growth as a rainforest orchid.

Table of Contents

Background

Oliver - Cellular Respiration

Once upon a time, in the heart of a lush rainforest, there lived a radiant orchid named Oliver. Oliver stood tall and proud, his delicate petals adorned with shades of vibrant purple and white. Like all plants, Oliver possessed a remarkable ability to carry out both photosynthesis and cellular respiration.

As the morning sun bathed the rainforest, Oliver eagerly extended his leaves, soaking in the sunlight. Sunbeams danced upon his velvety petals, and chlorophyll molecules within his cells eagerly absorbed the light. Oliver's leaves, acting as tiny solar panels, converted this radiant energy into chemical energy through photosynthesis. The process allowed him to transform carbon dioxide and water into glucose and oxygen, using the energy from the sun.

Oliver, however, wasn't solely dependent on photosynthesis for his energy needs. Within his cells, even while basking in the sunlight, his mitochondria tirelessly carried out cellular respiration. The glucose produced during photosynthesis was broken down within the mitochondria, releasing stored energy in the form of ATP. This energy fueled Oliver's growth, maintenance, and vibrant beauty.

In the same rainforest, a vibrant poison dart frog named Penelope hopped nearby. Penelope, a beautiful creature adorned with bright colors and intricate patterns, relied solely on cellular respiration for her energy production. As a heterotroph, she couldn't carry out photosynthesis and had to obtain her nourishment by consuming other organisms.

While Oliver and Penelope went about their daily routines, another group of tiny organisms played a vital role in the rainforest energy cycle. Bacteria, dwelling in the soil and other environments, carried out anaerobic respiration or fermentation when oxygen was limited. In this process, glucose was broken down without the presence of oxygen, resulting in the production of lactic acid or ethanol, along with a small amount of ATP.

This anaerobic respiration or fermentation performed by bacteria helped break down organic matter, cycling nutrients back into the ecosystem. Although Oliver and Penelope couldn't directly engage in anaerobic respiration or fermentation, they benefited indirectly from the activities of these bacteria, as they played a crucial role in maintaining the health and balance of the rainforest.

And so, within the vibrant rainforest, Oliver thrived through the dual processes of photosynthesis and cellular respiration. His ability to generate energy from sunlight, coupled with the mitochondria's work, allowed him to flourish. Penelope, on the other hand, depended solely on cellular respiration, skillfully utilizing the energy derived from the food she consumed.

Oliver - Cellular Respiration

As Oliver and Penelope carried out their distinct energy-acquiring processes, they unknowingly supported each other. Oliver's photosynthesis produced oxygen, which was released into the air, providing Penelope with the vital element she needed for her own cellular respiration. In turn, Penelope's carbon dioxide, a waste product of respiration, would be absorbed by Oliver during photosynthesis, completing the cycle.

Together, Oliver, Penelope, and the bacteria created a harmonious dance of energy flow within the rainforest. They embodied the interconnectedness of life, each playing a unique role in sustaining the delicate balance of their shared ecosystem. And as the sun set over the rainforest, Oliver and Penelope continued their vital energy processes, their existence intertwined in the ever-enchanted tapestry of nature.

Student Expectations

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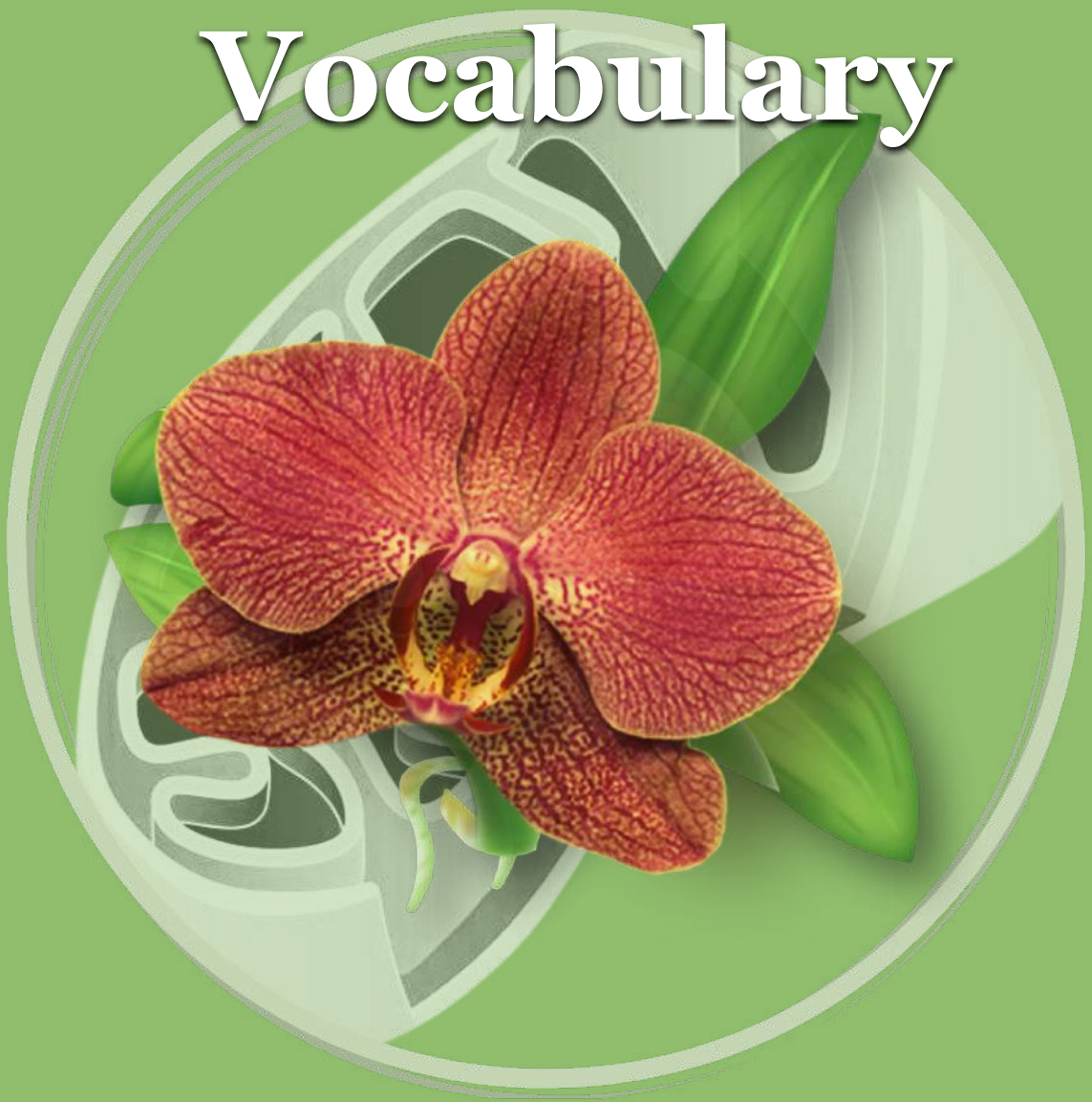
- **Explain** the balanced equation of cellular respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O +$ energy.
- **Identify** the reactants of cellular respiration as glucose ($C_6H_{12}O_6$) and oxygen (O_2), and the products as carbon dioxide (CO_2), water (H_2O), and energy.
- **Summarize** the processes involved in cellular respiration, including glycolysis, the Krebs cycle, and the electron transport chain.
- **Analyze** the relationship between photosynthesis and cellular respiration.
- **Compare** and **contrast** the reactants and products of photosynthesis ($6CO_2 + 6H_2O +$ energy $\rightarrow C_6H_{12}O_6 + 6O_2$) with those of cellular respiration ($C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O +$ energy).
- **Evaluate** the interdependence of photosynthesis and cellular respiration by explaining how the products of one process serve as the reactants of the other.
- **Synthesize** the knowledge of cellular respiration and photosynthesis to explain the cyclical nature of energy flow in ecosystems.
- **Develop** and **support** an argument for the importance of maintaining a balance between photosynthesis and cellular respiration for the sustainability of life on Earth.

Guiding Questions

Guiding Questions

- How does cellular respiration convert glucose and oxygen into carbon dioxide, water, and energy?
- What are the main steps involved in cellular respiration, and how do they contribute to the production of ATP?
- How are photosynthesis and cellular respiration interconnected in terms of reactants and products?
- Why is energy essential in both photosynthesis and cellular respiration? How is energy transferred and transformed between these two processes?
- How do photosynthesis and cellular respiration contribute to the sustainability of life on Earth?

Vocabulary



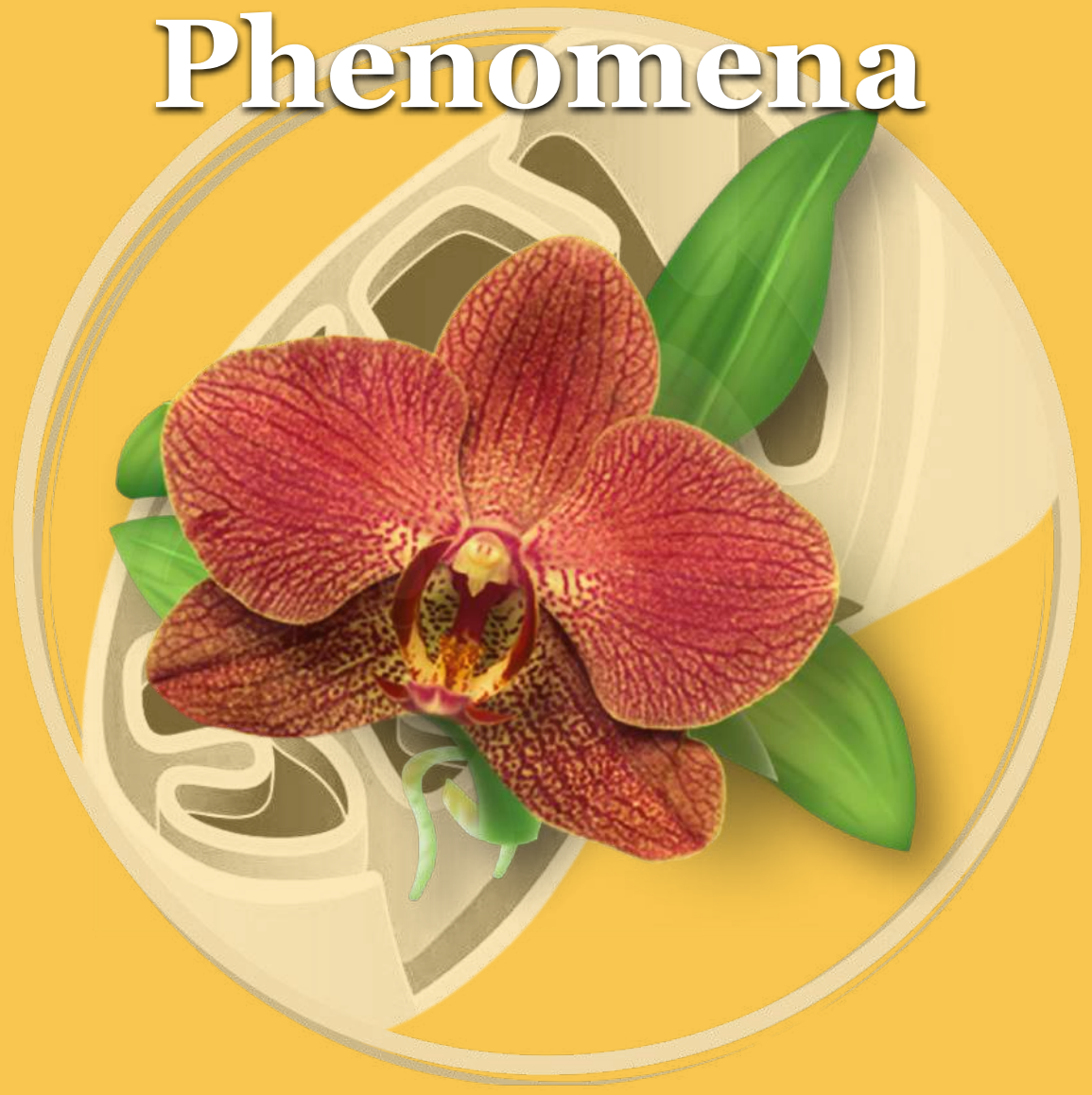
Vocabulary - Page 1

Aerobic Respiration	The type of cellular respiration that occurs in the presence of oxygen, involving the complete breakdown of glucose to produce ATP, carbon dioxide, and water.
Alcohol Fermentation	A type of anaerobic fermentation where pyruvate is converted into ethanol, regenerating NAD+ in the process.
ATP (Adenosine Triphosphate)	The primary energy currency of cells, produced during cellular respiration, which releases energy when its high-energy phosphate bonds are broken.
Anaerobic Respiration	The type of cellular respiration that occurs in the absence of oxygen, typically involving the partial breakdown of glucose to produce ATP and by-products other than carbon dioxide and water.
Citric Acid Cycle (Krebs Cycle)	A series of chemical reactions that occurs in the mitochondria, involving the oxidation of acetyl-CoA derived from pyruvate to produce ATP, carbon dioxide, and electron carriers (NADH and FADH2).
Cristae	The highly folded inner membrane of mitochondria that increases the surface area available for the electron transport chain and oxidative phosphorylation.
Electron Transport Chain (ETC)	A series of proteins located in the inner mitochondrial membrane that facilitates the transfer of electrons from electron carriers (NADH and FADH2) to generate a large amount of ATP through oxidative phosphorylation.
Fermentation	An anaerobic process that follows glycolysis when oxygen is absent, allowing the regeneration of NAD+ by transferring electrons from NADH to organic molecules, producing either alcohol (ethanol) or lactic acid.
FADH2	Flavin adenine dinucleotide, an electron carrier molecule that is reduced during the citric acid cycle, and then oxidized in the electron transport chain.
Glycolysis	The initial stage of both aerobic and anaerobic respiration, where glucose is broken down into two molecules of pyruvate, generating a small amount of ATP.
Lactic Acid Fermentation	A type of anaerobic fermentation where pyruvate is converted into lactic acid, regenerating NAD+ in the process.
Mitochondria	The organelles found in eukaryotic cells where aerobic respiration takes place, including the citric acid cycle, the electron transport chain, and oxidative phosphorylation.

Vocabulary - Page 2

Mitochondrial Matrix	The fluid-filled space inside the inner membrane of mitochondria where the citric acid cycle occurs and contains enzymes, mitochondrial DNA, ribosomes, and other components required for mitochondrial function.
NADH	Nicotinamide adenine dinucleotide, an electron carrier molecule that is reduced during glycolysis and the citric acid cycle, and then oxidized in the electron transport chain.
Oxidative Phosphorylation	The process in which ATP is synthesized using energy from the electron transport chain, combining ADP (adenosine diphosphate) and inorganic phosphate.
Pyruvate	A three-carbon compound produced during glycolysis that serves as the starting molecule for both aerobic and anaerobic respiration.

Phenomena



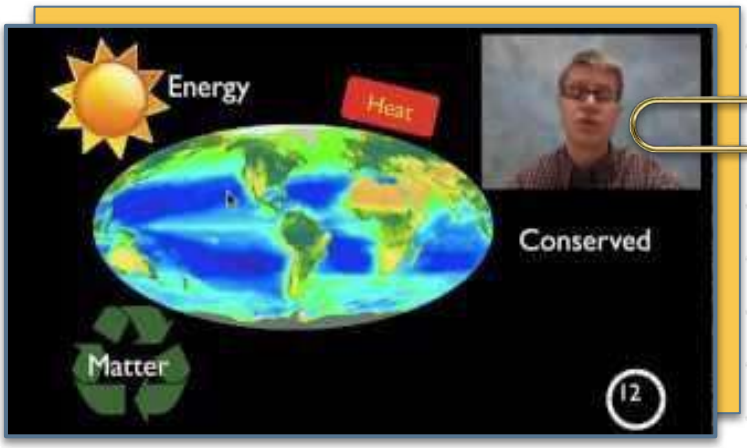
List of Phenomena - P1

Main Phenomena

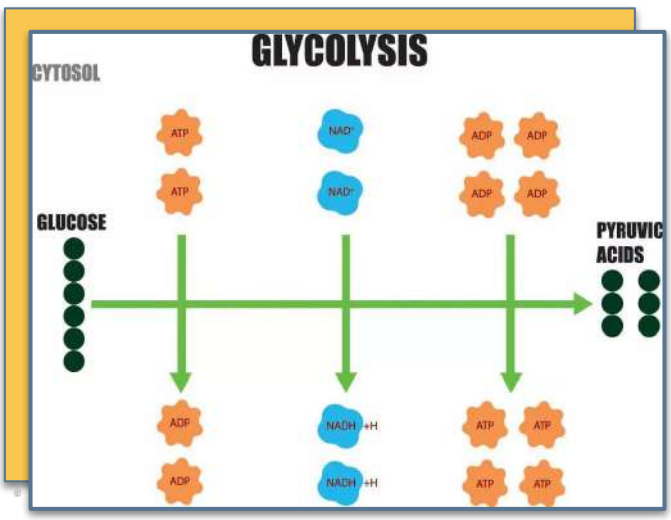
(2020). *Watch Dwayne 'The Rock' Johnson Show Off His 'World-Famous' Pancakes Before He 'Destroys' Them* [Photograph]. People Magazine. https://people.com/thmb/TFL2WRMj7LyUD1aGOacTDiVvLoO=/1500x0/filters:no_upscale():max_bytes(150000):strip_icc():focal(299x0:301x2)/the-rock-pancakes-505a746c1cf94b9d8823b69a777b1949.jpg

How does the process of cellular respiration enable organisms, like Dwayne 'The Rock' Johnson, to convert the energy stored in pancakes (carbohydrates) into a usable form for muscle contraction and other cellular activities?

Bozeman Science (2013, January 4). *LS1C - Matter and Energy Flow in Organisms*. Youtube. https://youtu.be/q52qtdrvah8



How does the flow of matter and energy through different organizational levels of living systems, from cells to ecosystems, contribute to the sustainability of life by enabling the capture, transformation, transport, release, and elimination of matter and energy?

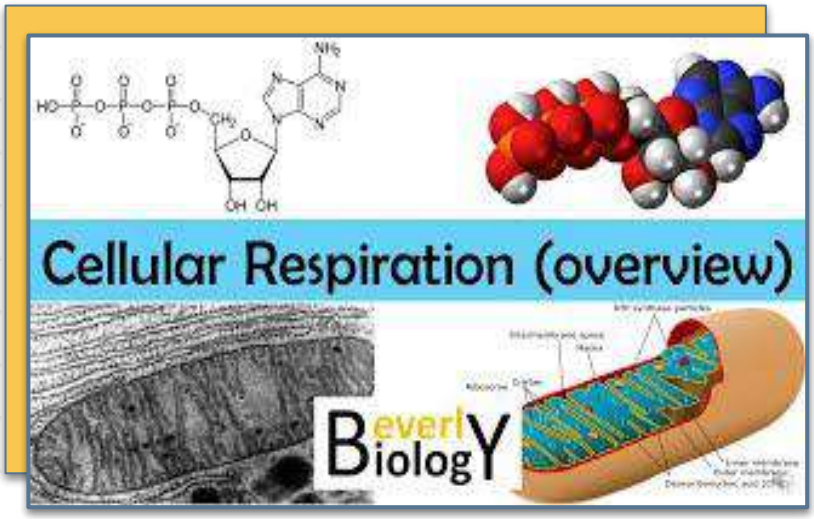


U. (2021). *Glycolysis* [Photograph]. Biology Dictionary. https://cdn-acgla.nitrocdn.com/bvlhcJyiWKFqlMsfAAXRLitDZjWdRlLX/assets/static/optimized/rev-5131b73/wp-content/uploads/2021/03/glycolysis.jpg

How does the visual representation of glycolysis in the provided image help you understand the sequential steps and key molecules involved in this metabolic pathway? Based on your observations, what conclusions can you draw about the role of glycolysis in generating ATP and supplying energy to cells?

Cellular Respiration

List of Phenomena - P2

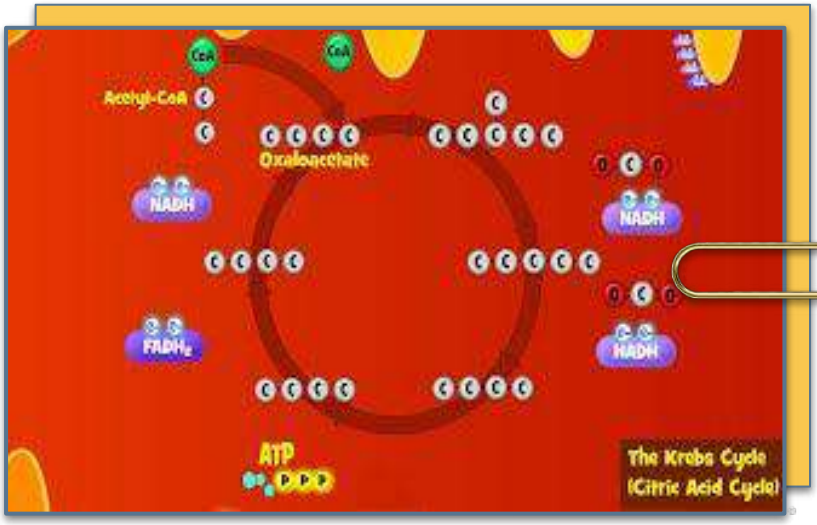


Beverly Biology (2022, December 1). *Cellular Respiration (Overview) - updated.* Youtube. https://youtu.be/khqtT2OxK28

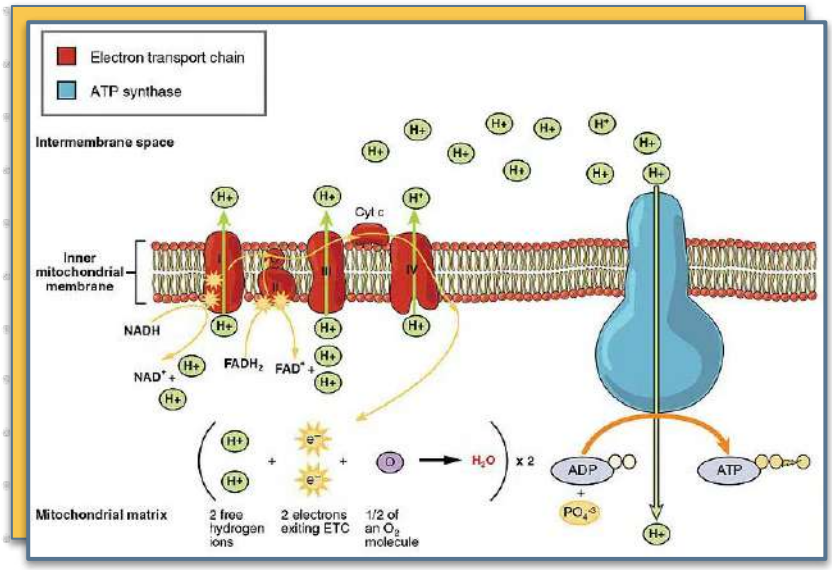
What are the key components, processes, and significance of cellular respiration in living organisms?

Bioman Biology (2021, May 20). *The Krebs Cycle Explained (Aerobic Respiration).* Youtube. Retrieved May 24, 2023, from https://youtu.be/UZImm-yzWrQ

What are the key molecules that participate in the Krebs cycle, and how do they interact with each other? How is the Krebs cycle connected to other metabolic pathways, such as glycolysis?



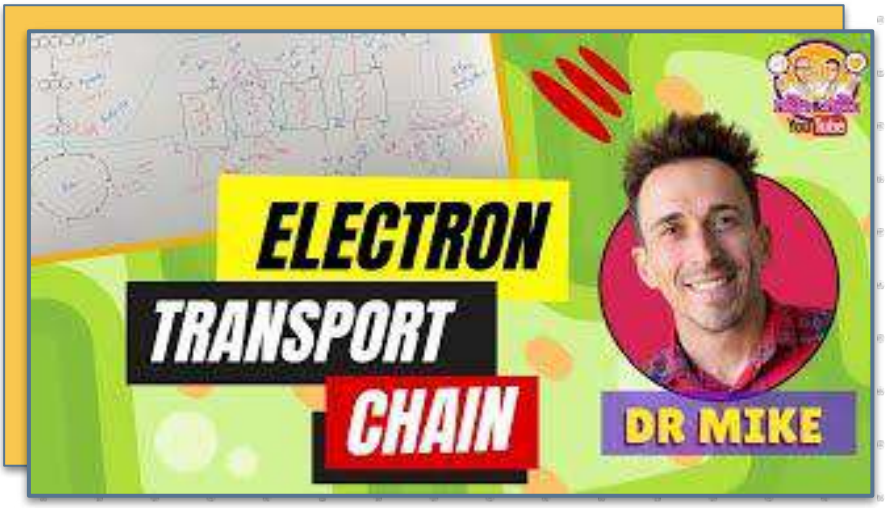
U. (2023). *Electron Transport chain* [Photograph]. Teach Me Physiology. https://teachmephysiology.com/wp-content/uploads/2017/03/etc.jpg.webp



What are the main steps and molecules involved in the Krebs cycle and the electron transport chain, and how do they contribute to ATP production in cellular respiration? How are the Krebs cycle and the electron transport chain interconnected, and what is their combined role in the efficient utilization of high-energy electrons and the generation of ATP?

List of Phenomena - P3

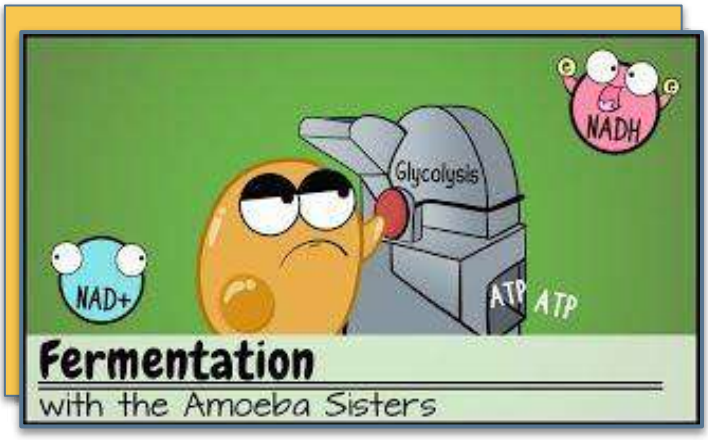
Dr. Matt & Dr. Mike (2023, April 15). *Electron Transport Chain | Made Easy.* Youtube. https://youtu.be/ClBDozXUIWc



How do high-energy electrons from NADH and $FADH_2$ contribute to the generation of ATP through the electron transport chain, as illustrated in the video?

U. (2023). *Alcoholic and Lactic Acid Fermentation in Food – A Primer* [Photograph]. Fermentation - Savory Kitchen. https://savoryandsour.com/wp-content/uploads/2017/08/Woodford_Reserve_Distillery-27527-1.jpg

What are the key steps and metabolic transformations involved in alcohol fermentation, and how does this process differ from other forms of cellular respiration?

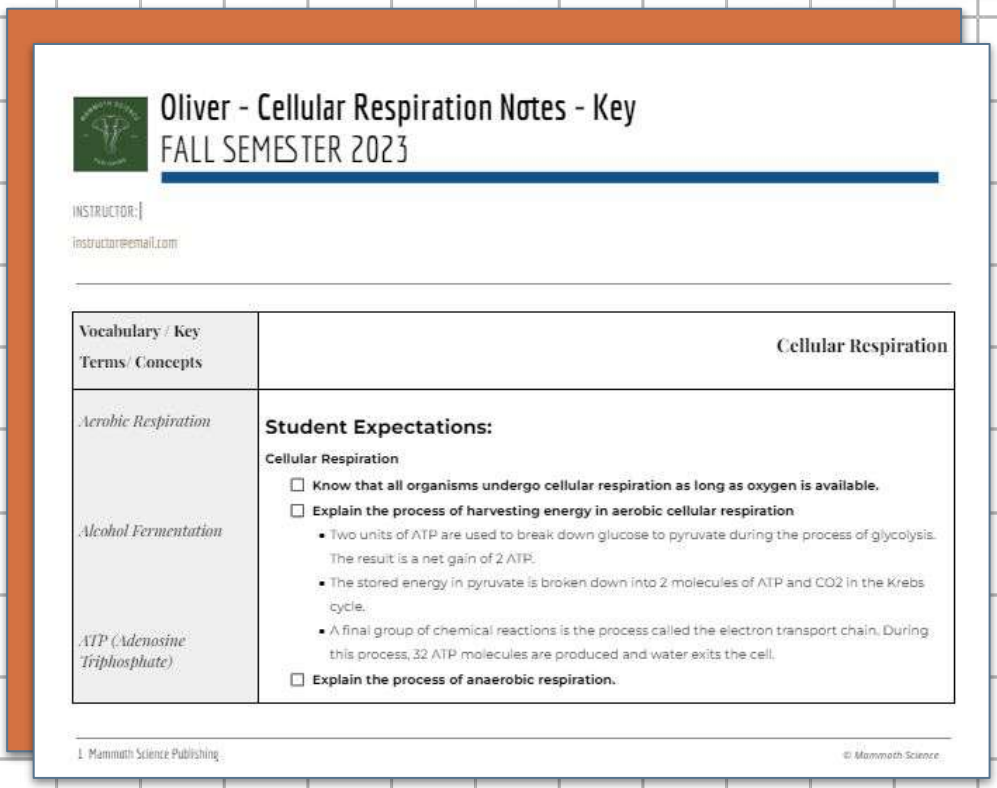


Amoeba Sisters (2018, April 15). *Fermentation*. Youtube. https://youtu.be/YbdkbCU20_M

What happens when you can't do aerobic cellular respiration because oxygen isn't available?

Lecture

Slides and Notes



Oliver - Cellular Respiration Notes - Key
FALL SEMESTER 2023

INSTRUCTOR:
instructor@email.com

Vocabulary / Key Terms / Concepts	Cellular Respiration
Aerobic Respiration *Alcohol Fermentation* *ATP (Adenosine Triphosphate)*	**Student Expectations:** **Cellular Respiration** ☐ **Know that all organisms undergo cellular respiration as long as oxygen is available.** ☐ **Explain the process of harvesting energy in aerobic cellular respiration** ▪ Two units of ATP are used to break down glucose to pyruvate during the process of glycolysis. The result is a net gain of 2 ATP. ▪ The stored energy in pyruvate is broken down into 2 molecules of ATP and CO2 in the Krebs cycle. ▪ A final group of chemical reactions is the process called the electron transport chain. During this process, 32 ATP molecules are produced and water exits the cell. ☐ **Explain the process of anaerobic respiration.**

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Teacher

Student

Instructional Materials

Instructional Materials - P1


Cellular Respiration - C.E.R.

INSTRUCTOR:

A distant cousin of jellyfish may survive without working mitochondria

Summary:

Scientists have discovered a distant relative of jellyfish that can survive without working mitochondria. Mitochondria are the part of cells that produce energy and are considered essential for animal life. The ancestor of all eukaryotes, a large group of organisms with complex cells, engulfed a bacterium about 2 billion years ago. This bacterium evolved into mitochondria, which convert food and oxygen into energy through a process called aerobic respiration. Mitochondria have their own genome, separate from an organism's DNA housed in a cell's nucleus.

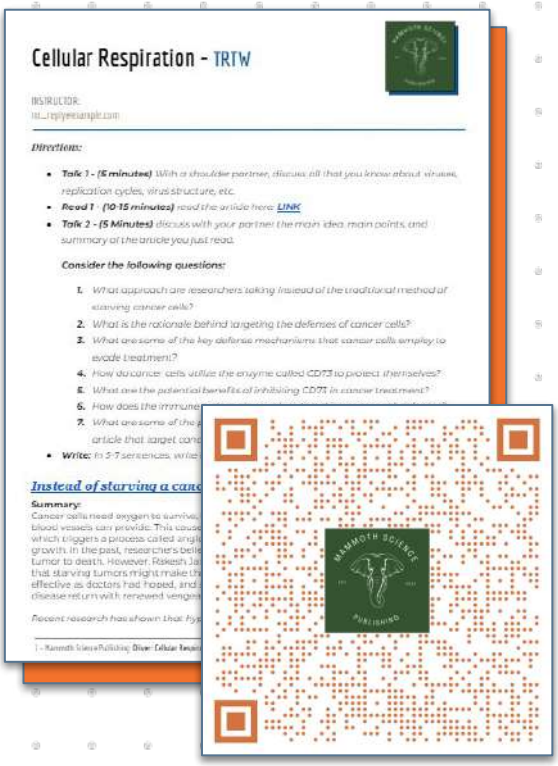
While some single-celled eukaryotes have adapted to live oxygen environments by getting rid of their mitochondrial genomes, scien… without them. However, a parasitic… coral polyps, can survive without mi… a group of microscopic, parasitic an… cnidarian, called Henneguya zamir… relying on its hosts' fish and annelid… Shedding unnecessary DNA throug… giving it an advantage over its mito…

Although biologists believe that mit… this study challenges that assumpti…

Writing Prompt: How does the dis… understanding of what is essential f…

Directions: Read the background … prompts to practice constructing …

- **Prompt 1: Claim**


Cellular Respiration - TRTW

INSTRUCTOR:

Directions:

- **Talk 1 - (5 minutes)** With a shoulder partner, discuss all that you know about viruses, replication cycles, virus structure, etc.
- **Read 1 - (10-15 minutes)** read the article here: LINK
- **Talk 2 - (5 Minutes)** discuss with your partner the main idea, main points, and summary of the article you just read.

Consider the following questions:

1. What approach are researchers taking instead of the traditional method of starving cancer cells?
2. What is the rationale behind targeting the defenses of cancer cells?
3. What are some of the key defense mechanisms that cancer cells employ to evade treatment?
4. How do cancer cells utilize the enzyme called CD73 to protect themselves?
5. What are the potential benefits of inhibiting CD73 in cancer treatment?
6. How does the immune…
7. What are some of the … article that target canc…

- **Write:** In 5-7 sentences, write …

Instead of starving a canc…

Summary:

Cancer cells need oxygen to survive, … blood vessels can provide. This cause… which triggers a process called angi… growth. In the past, researchers belie… tumor to death. However, Rakesh Ja… that starving tumors might make th… effective as doctors had hoped, and … disease return with renewed vengea…

Recent research has shown that hyp…


Cellular Respiration - Respiration in Yeasts
Lab Investigation

INSTRUCTOR:

INTRODUCTION

The conversion of pyruvate to ethanol is carried out by yeast. It takes place naturally in grapes left to ferment on vines, as well as fermentation vats containing crushed grapes. When the ethanol concentration reaches about 12%, its toxic effects kill yeast. Yeasts produce alcohol only when there is little or no oxygen present. When there is enough oxygen present, yeasts break sugar down completely to release water and carbon dioxide.

When a vat of wine is fermenting rapidly, it produces carbon dioxide fast enough to drive off the air over the wine, thus preventing oxygen from dissolving in the wine. When fermentation slows down, wine must be sealed up immediately, before … enters. … fermentation continues, vinegar is formed.

Yeasts are also used in baking. When bread is … carbon dioxide released from the metabolic process of respiration causes the dough to rise. An unleavened bread is merely dough that has not risen. Regardless of the respiration … anaerobic, yeasts release carbon dioxide as metabolic waste.

While there are an infinite number of variables that could be tested using the procedure described below, this lab will focus on temperature as the independent variable.

MATERIALS

- small vials that will remain upright under water (respirometers)
- one-hole rubber stoppers to fit respirometers
- five large (1000 ml) beakers large enough to submerge respirometers
- sugar (50 grams)
- thermometers

LAB INVESTIGATION


Cellular Respiration - Muscle Fatigue
Lab Investigation

INSTRUCTOR:

INTRODUCTION

Your fingers are able to move due to the interaction of the nervous system, muscular system, skeletal system, and circulatory system. You are going to examine the interaction of these systems in terms of the rate (how fast) you are able to continue a task for a limited time.

AIMS

- Provide a body of knowledge, methods and techniques that characterize science and technology
- Enable students to apply and use a body of knowledge, methods … techniques that characterize science and technology
- Develop an ability to analyze, evaluate, synthesize … information

OBJECTIVE

Analyze the effects of changing biological … (increasing heart rate, decreasing blood flow, changing O_2 concentration) on … muscle tissue performance in the lower arm and hand.

SAFETY

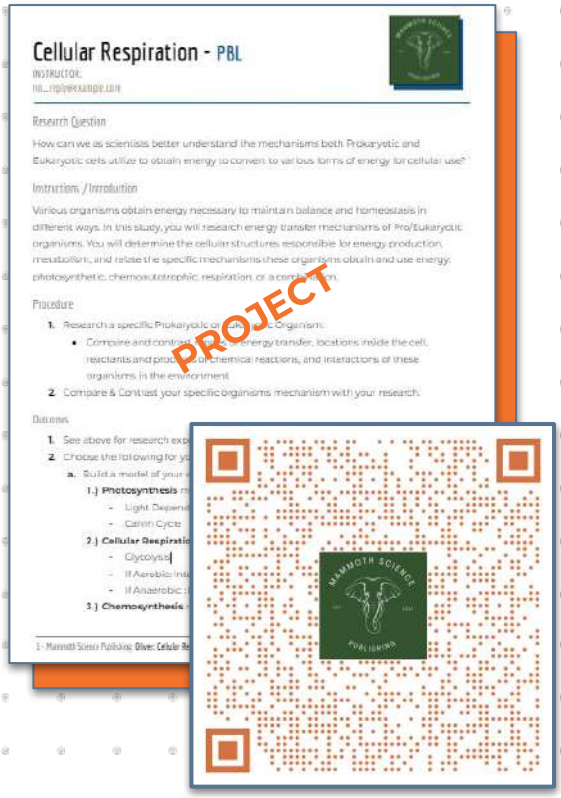
Safety is important during any laboratory activity. All … chemicals or hazardous … are used in this investig… Another concern is health. If you ha… for in this activity, tell your teache… successfully complete the investig… reasons, for example, or if you have … laboratory activity.

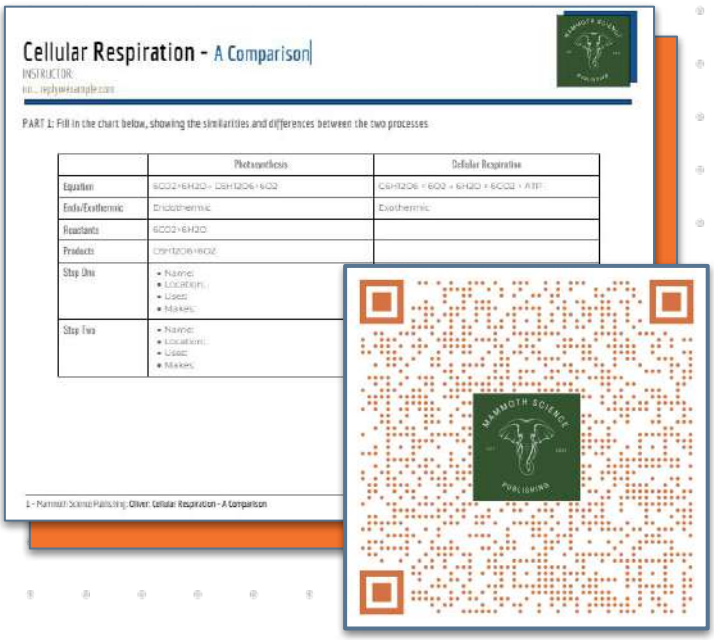
MATERIALS

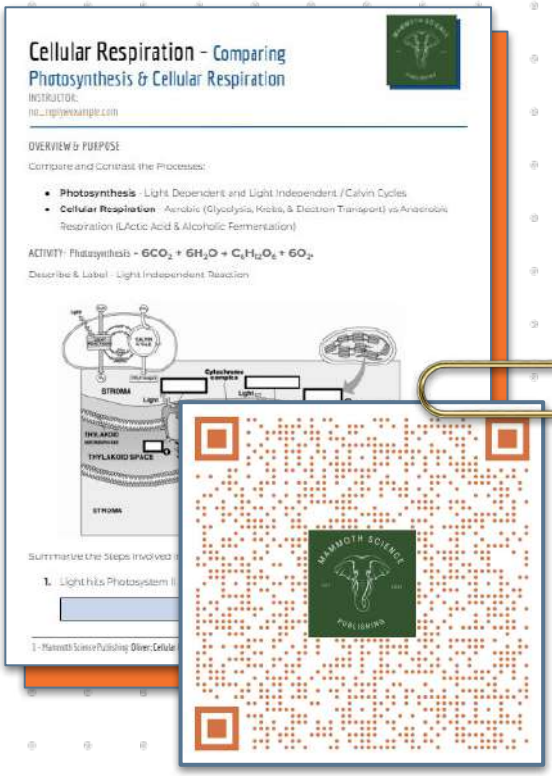
- 1 or more clocks, stopwatches, … second and 1 - minute interva…
- 1 spring clothespin per student
- 1 small, brown paper bag

LAB INVESTIGATION

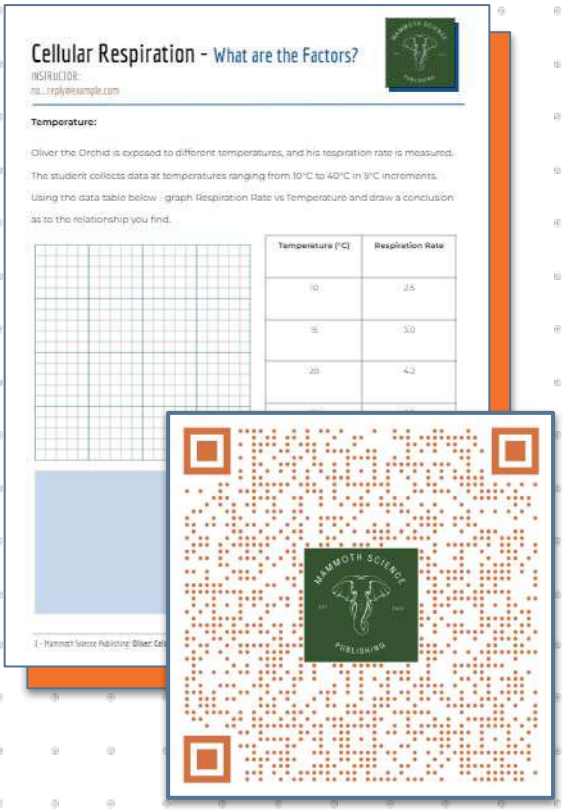
Instructional Materials - P2

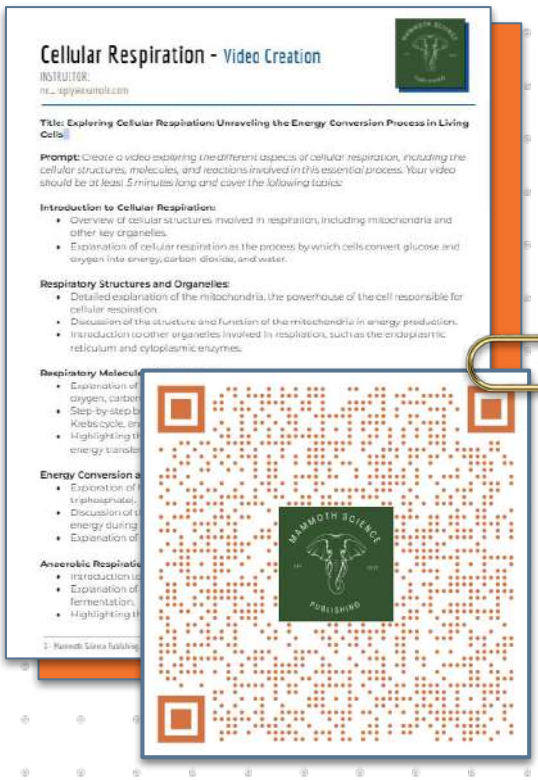




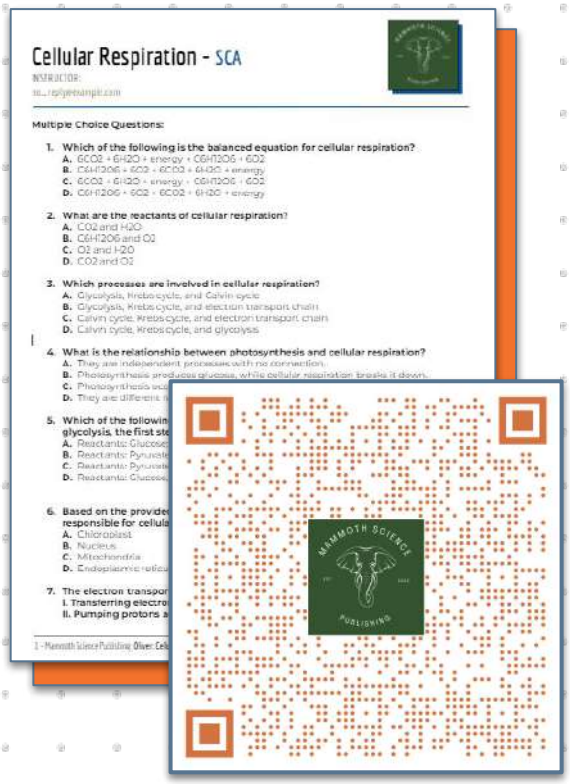


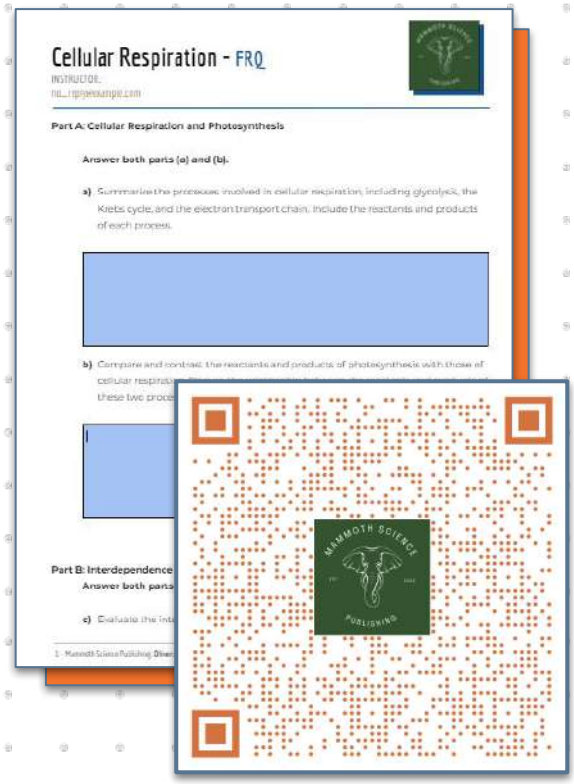
Instructional Materials - P3

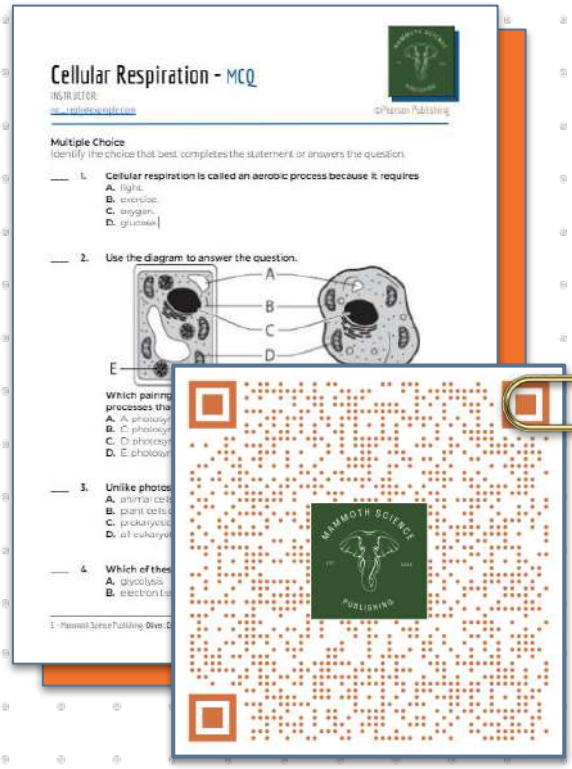




Assessment Materials

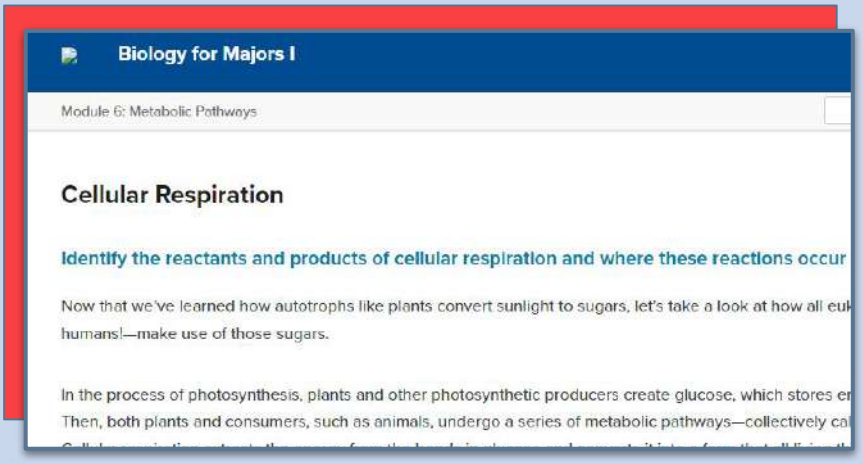






Resources

Websites



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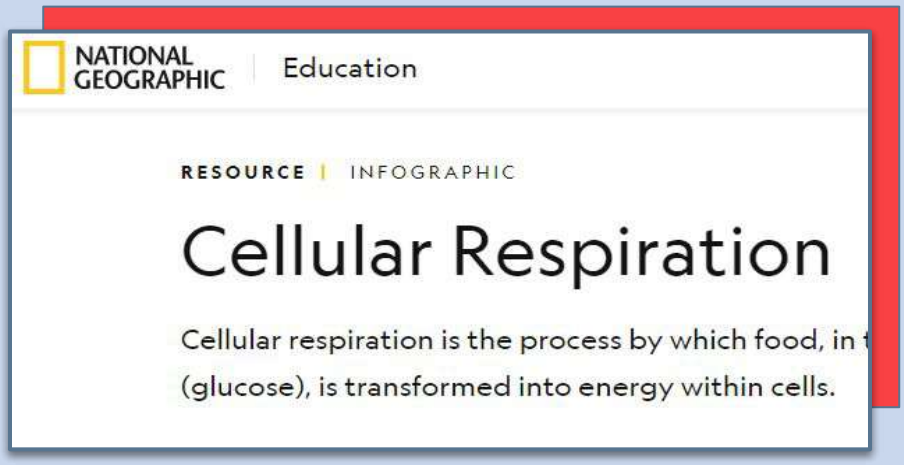
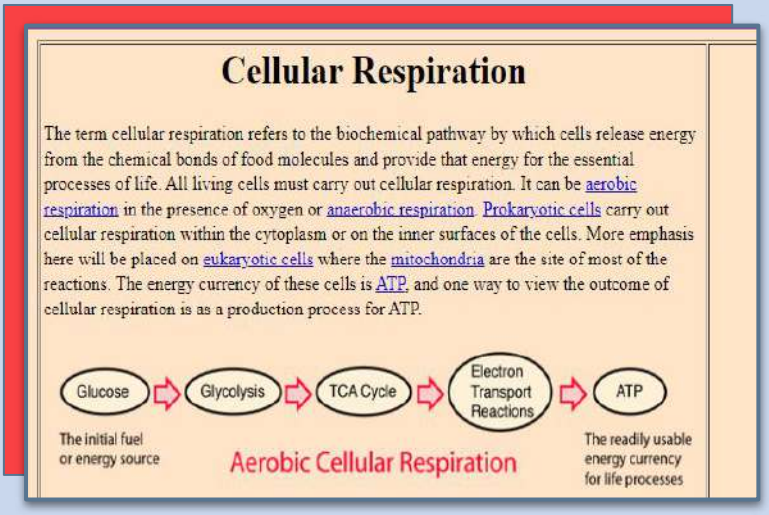


(2023, May 15). *Cellular Respiration*. National Geographic. https://education.nationalgeographic.org/resource/cellular-respiration-infographic/



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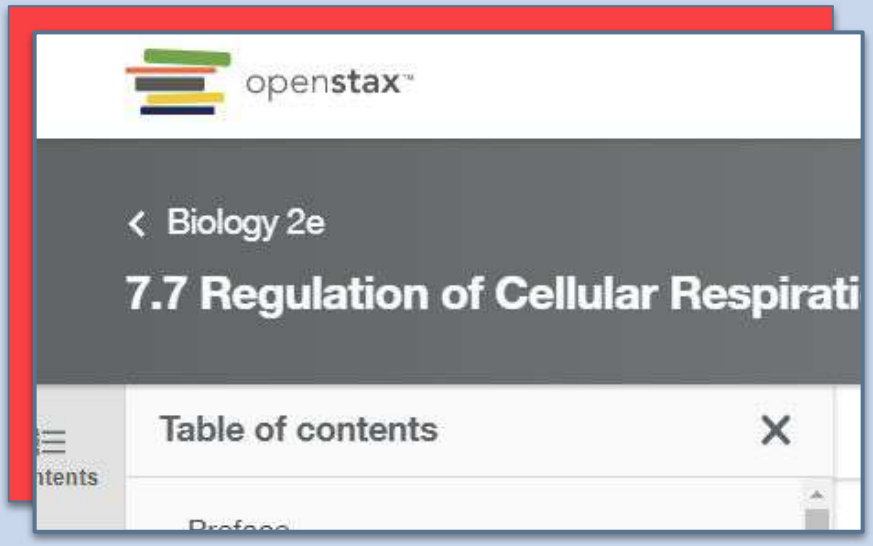
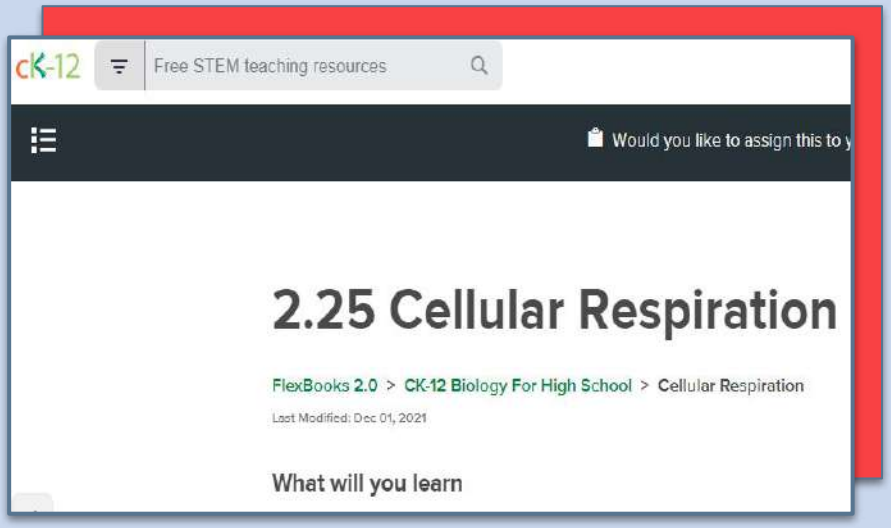
Websites



(2018, March 28). *Cellular Respiration*. Openstax Biology 2E. Retrieved May 25, 2023, from https://openstax.org/books/biology-2e/pages/7-7-regulation-of-cellular-respiration



(2012, June 6). *Cellular Respiration*. CK12. Retrieved May 25, 2023, from https://flexbooks.ck12.org/cbook/ck-12-biology-flexbook-2.0/section/2.25/primary/lesson/cellular-respiration-bio/

(2018, December 6). *Cellular Respiration*. Libretexts. Retrieved May 25, 2023, from https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Biology_(Kimball)/04%3A_Cell_Metabolism/4.05%3A_Cellular_Respiration

Video

- What is ATP?
- Metabolism and ATP
- ATP & Respiration: Crash Course Biology #7
- ATP: Adenosine Triphosphate
- Cellular Respiration Part 1: Glycolysis
- Glycolysis Made Easy!
- Steps of glycolysis | Cellular respiration | Biology | Khan Academy
- Glycolysis | HHMI BioInteractive Video
- Glycolysis Pathway Made Simple !! Biochemistry Lecture on Glycolysis
- Introduction to cellular respiration | Cellular respiration | Biology | Khan Academy
- Cellular Respiration (UPDATED)
- Stages of cellular respiration
- Cellular respiration steps
- Cellular Respiration (in detail)
- Krebs Cycle | Made Easy!
- Krebs / citric acid cycle | Cellular respiration | Biology | Khan Academy
- Cellular Respiration
- Electron Transport Chain | Made Easy
- The Electron Transport Chain Explained (Aerobic Respiration)
- Anaerobic Respiration Fermentation
- Anaerobic Respiration and Fermentation
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