SUCCESS
ACADEMY
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Life Science:
Unit 6
Cellular Energetics: Lessons

Lesson 1: All Systems Go

Lesson Objective: Scholars understand that all living things require energy for survival and that there is a correlation between the availability of energy and survival of a biological system (such as a cell, organism, or population). Materials Needed

- For each group: chart paper, markers

Prep

- Intellectual Prep:
  - Read **Systems Thinking** by Environment and Ecology.

What are scholars doing in this lesson?

- Scholars are introduced to the term biological system and brainstorm as many biological systems as they can. They consider the indicators of health for each system as well as the symptoms and causes of system failure. This opens up a conversation about the needs of living things, which leads to the reveal of this unit's Essential Question: How does the acquisition of energy relate to the health of a biological system?

Do Now

- Follow the **Do Now plan**.

Launch

- Read **The Double Smack of Fishery Collapse** by Harvard Magazine as a class. In pairs, have scholars discuss:
    - Would you classify the marine ecosystems that these fish are a part of as healthy or unhealthy? Why?
        - Do you think it would be possible to restore the fish populations that are suffering? Why or why not?
    - Why is an ecosystem called an ecosystem? What is a system?
    - During this discussion, focus on the interconnectedness of the organisms and highlight “systems thinking.” Scholars should identify the ecosystems as unhealthy due to their current lack of balance and should recognize that restoring their health isn’t as easy as it sounds. (The fish are currently being used to feed people, and if that food source suddenly disappeared, people would still need to eatâ€” and perhaps shifting their diet to include other sources of protein instead would just disrupt another ecosystem, creating a new problem.)
- Explain that in this unit, scholars will be focusing on the health of biological systems! Define **system** and explain to scholars that their first task in this unit will be:
    - to brainstorm as many **biological** systems as they can
    - to consider what each system needs to stay healthy
    - to identify the symptoms of system failure
    - to identify potential causes of system failure
- Model this process with scholars using the article they just read:
    - Biological system = ecosystem
    - Needs to stay healthy = air, water, food, shelter
    - Symptoms of system failure = low biodiversity, dramatic changes in individual populations
    - Potential causes of system failure = increased predators/overfishing by humans, disease, water pollution, natural disasters, etc. (Let scholars brainstorm several ideas here.)
- Encourage scholars to think of the largest and smallest biological systems they can and consider all the levels in between!

Activity

- Scholars work in groups to complete the activity, charting their responses.
    - As scholars are working, circulate and press them to think from macro to micro. Coach groups who struggle to understand that systems can contain other, smaller subsystems (or conversely, can be part of larger systems).

Discourse Debrief activity:

- Call on two to three groups to share their charts. After the class has seen several examples of biological systems, ask:
    - What do the systems you identified have in common?
    - What are the needs of all living things?
    - How does a lack of access to needed things affect the parts of a biological system?

Introduce the Essential Question:

- In this unit, you will focus on one particular need that is common to all living things: **energy**. You will learn how energy is harnessed and used at several levels, ranging from the micro to the macro.
- Introduce the Essential Question: How does the acquisition of energy relate to the health of a biological system?
- Scholars draft initial answers to the question independently in their Lab Notebooks during the last 5 minutes of class.

Accountability (Lab Notebook)

- Write an initial response to the unit's Essential Question: How does the acquisition of energy relate to the health of a biological system?

Energy is important for all living things, so if they're unable to get the energy they need, it could upset the balance of a whole system (like an ecosystem). For example, if plants can't get energy from sunlight, they'll die, and then the animals who eat the plants would die too. This would affect all the organisms in that food web.

Scoring Score scholars on a 1–4 scale (below expectations through exceeding expectations) based on classwork. Do not penalize scholars for initial misconceptions about contentâ€" rate them on effort and writing.

- Look for the following when scoring scholar responses:
    - a clear claim that answers the question
    - specific evidence collected from the activity or their prior knowledge that supports the claim
    - justification/reasoning that ties the evidence to the claim
    - high effort shown in writing, with complete sentences and proper grammar/ punctuation seen throughout the response

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Lesson 2: Chem: It's What's for Dinner

Lesson Objective: Scholars understand that potential energy stored in the atoms of food is extracted by an organism through a series of chemical reactions called metabolism. These chemical reactions make and break the bonds between atoms and are required for the synthesis of ATP, our body's "energy currency." Materials Needed

- For each group: soda can (empty), stirring rod, ring stand and ring, thermometer, 100 mL graduated cylinder, large paper clip, 2 twist ties, 3 food samples with nutrition labels (2–3 g each of samples such as nuts, marshmallows, or soft chips (e.g., cheese puffs), water, matches, small piece of aluminum foil, balance scale
- For each scholar: printed copy of the **introductory information and procedure**, goggles, apron

Prep

- Intellectual Prep:
    - Review **Calorimetry** by OpenStax.
    - Materials Prep:
        - Collect soda/seltzer cans in advance of this lesson.
        - Select and purchase food samples for this lesson. Ensure that scholars are not exposed to allergens. Make copies of the nutrition labels as needed so all scholars will be able to reference them during the lesson.
        - Make any needed modifications and print copies of the introductory information and procedure from the Carolina Biological Supply website.

What are scholars doing in this lesson?

- Scholars complete a calorimetry experiment to learn more about the "fuel" in our food. This experiment drives discussion that unveils the chemistry behind the things we consume every day.

Do Now

- Follow the **Do Now plan**.

Launch

- Explain to scholars:
    - Based on yesterday's lesson, you know there are connections between energy and the health of biological systems. But before we can dive more deeply into learning about them, we must first start by talking more about where our energy comes from. How do we actually acquire it?
    - Scholars should know that humans, like many other organisms, eat food to gain energy. But what is food, exactly? What makes some substances better food sources than others? If our normal food supply began to run out, could we substitute other materials and still reap the benefits (e.g., can humans just switch to eating rocks or

soil)? And what does the human body do with the food we consume anyway, at the "micro" scale?

- Allow scholars to share their ideas. They will likely reference the relevant organ systems they studied during Unit 1 and may recall cellular respiration at a surface level. However, they will be unable to explain precisely how our body breaks down and uses/disposes of the material we consume or exactly where the energy in food comes from.

    - Press scholars hereâ€" they may think they know the answers already, so ask: In what form is the energy our bodies store and use? How is that energy acquired? And how do our cells transform that energy without us consciously directing them to do so? Scholars will quickly realize that there is still much to learn!

- Show scholars a picture of the experimental setup they will be using in class and explain:

Image Credit: **Carolina Biological Supply Company**

- Calorimetry is the measurement of the heat released or absorbed during a chemical reaction. We can use this technique to measure the amount of calories in our food!
- Today, we will measure the calorie content of two to three common snacks. As you are working, you will discuss with your group: What exactly are we measuring? What is the connection between energy, calories, and heat? What "gives" a substance its calories, and why do some foods have more than others?

Experiment

- Scholars perform the **Food Calorimetry: How to Measure Calories in Food** experiment by Carolina Biological Supply Company and discuss the following questions:

    - What are calories a measure of?

    - What is the connection between energy, calories, and heat?
    - What "gives" a substance its calories, and why do some foods have more than others?
    - When we consume food, what happens to it?

- As scholars are working, circulate and press them to defend their statements with evidence. If they seem stuck, direct them to look at the nutrition labels on the snacks for clues. (There, they will see that foods have varying calorie content; can find phrases such as "calories from fat"; and may notice connections between the ingredients or amount of carbohydrates, fat, and/or protein and the total calorie content of the food.)

[**Tip:** If you are short on time, assign one food to each group and perform a "jigsaw" to share results.]

Discourse Debrief activity:

- Scholars share and discuss their data. Ask:

    - What is a calorie? Where do the calories in our food come from?

        - Directly address misconceptions and define **calorie** and **potential energy**. Explain to scholars that while we normally only hear people talk about the calories in food, since calories are just a unit of energy, you can measure the calorie content of many things (e.g., you could measure the calorie content of the gasoline in the tank of a car).
        - Differentiate between the scientific and colloquial use of the term Calorie/calorie. (Scholars are not expected to remember this, so be briefâ€" just give enough information to ensure scholars can discuss the term accurately.)
        - Review the **law of conservation of energy**. Clear up misconceptions about the "creation" or "use" of energy within the human body.

Make broader connections:

- Ask: Why do we need food?

    - Scholars should know that we synthesize energy from some of the material in our food. Specifically, they may recall the three **macronutrients** included on every food label: fats, protein, and carbohydrates!
    - Explain that this transformation of energy is a repeating process in all of our cells. We need to take in food to access its potential energy, use some of our own stored energy to break it down, and transform it into a usable type of energy for our body. (In other words, when you take a bite of cheese, for example, tiny cheese particles don't just break off, rush into your cells, and start powering it!) Define **activation energy** and explain that chemical reactions must occur first to make the potential energy stored in food <u>usable</u> for your body. Our body relies on a complex molecule known as **ATP**, which is able to store and transport chemical energy within cells!

- Ask: What is the connection between eating and metabolism? Where have you heard this term before?
    - Show the **What Is Metabolism in Biology? Video** by MooMooMath & Science (2 minutes, 30 seconds).
        - Pause the video to define **metabolism**, **enzyme**, **catabolic**, and **anabolic** as they come up. Once all terms are defined, play the video again without stopping to allow scholars to apply their new understanding.
        - Explain that since catabolic pathways result in a net release of energy, and anabolic pathways require more energy, cells often use the energy released from catabolic pathways to “fuel” the reactions of anabolic pathways.

Make connections to the Essential Question:

- Ask: What biological systems exist within our bodies?
    - Press scholars to identify several levels of organization within their bodies (e.g., cell, organ, organ system, organism) and explain how each can be thought of as a system.
- How would the systems at each “level” in our bodies be affected if we didn’t get enough calories? Why?

Accountability (Exit Ticket)

1. The synthesis of large proteins from amino acid building blocks is an example of a(n): [1]
    1. metabolic failure
    2. catabolic pathway
    3. anabolic pathway
    4. source of ATP
2. <u>Metabolism</u> can be defined as the sum of the chemical reactions that take place within a living organism’s cells. [1]
3. Proteins, fats, and carbohydrates are three __________ found in our food. [1]
    1. enzymes
    2. macronutrients
    3. calories
    4. systems
4. Which of the following is the most accurate description of energy? [1]
    1. a force exerted upon an object or organism that helps it do work
    2. microscopic particles that come in many forms and help organisms do work
    3. a fluid that flows freely through organisms to help them do work
    4. a quantitative property that must be transferred in order to perform work
5. Evaluate the scientific accuracy of the following statement. Include evidence and reasoning. [3]

“Humans need food to survive because it helps our body to create energy!”

This statement is inaccurate. Energy cannot be created or destroyed. There is already energy stored within the food we eat, so we need food to be able to access and transform that energy.

Scoring Award points as follows:

1. Questions 1–4: Award one point for each correct response.
5. Award points as follows:
    - One point for identifying that the statement is inaccurate
    - One point for evidence (correctly identifying the inaccurate part of the statement)
    - One point for reasoning that further explains the flaw in the original statement, tying the evidence to the claim

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Lesson 3: Subatomic Particles and Elements and Charges, Oh My!

Lesson Objective: Scholars understand that metabolic processes are made possible by atomic structure and the electrical forces within and between atoms. Materials Needed

- For each scholar: computer, a copy of **Bonding with the Periodic Table**

Prep

- Intellectual Prep:
    - Review **Chemical Bonds and Reactions** by Khan Academy.
    - Review **Electronegativity** by Khan Academy.
- Materials Prep:
    - Print color copies of **Bonding with the Periodic Table**.

What are scholars doing in this lesson?

- Scholars complete an activity packet that includes reading and discussion/analysis questions to learn more about how and why atoms make and break their bonds. This helps scholars develop a deeper understanding of how and why our body processes food.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask scholars to "recap" what they learned during the previous lesson.
    - They should identify that our cells need usable energy in the form of ATP, and that synthesis of ATP (and other materials that our body needs!) is dependent on metabolic pathways, or chemical reactions that are taking place in our cells all the time.

    - They should also be able to state that we eat to get some of the materials we need to synthesize ATP. The macronutrients in food contain potential energy, but not in a form that is usable for our cells. So, we put in a little bit of energy to break the bonds between the atoms that make up the compounds in our foods. In return, we “free up” stored energy. (Let scholars know that some of it is also converted into heat.)

- Explain that today, scholars will complete an activity and conduct research to take a deeper dive into the world of chemistry. This will help them to answer a very puzzling question: How do our bodies do all of this without us ever having to direct them to? (In other words, since atoms don’t have the capacity to make decisions, and we certainly aren’t consciously instructing them to follow these metabolic pathways, how do they do it on their own?) It will also ensure they have a solid foundation to understand the more complex material in upcoming lessons.

Activity

- Scholars study the provided resources and complete the activities within their Lab Notebook, which teach them about the following concepts:
    - Subatomic particles and their charges (review from a previous chemistry unit)
    - Valence electrons (review from a previous chemistry unit)
    - Covalent and ionic bonding (review from a previous chemistry unit)
    - Electronegativity

Discourse Debrief experiment/activity:

- Have a scholar come up and draw an atom on the board, labeling its subatomic particles and their charges. (It is recommended that you encourage the use of Bohr models throughout this unit, for simplicity. Check scholar responses to Question 2 in Lab Notebooksâ€” based on performance, you may need to quickly reteach how to create them.)
    - Define **atom**, **subatomic particle**, **proton**, **neutron**, **electron**, and **valence electron**.
- Ask scholars to compare and contrast **covalent** and **ionic bonds**.
    - Note: It’s likely that many scholars misunderstand what an ionic bond is. The actual electron transfer that happens between the two atoms/molecules is <u>not</u> the ionic bond. The ionic bond occurs <u>after</u> the electron donation has occurred, and may or may not be between the same atoms. The donation creates the positive and negative charges that lead to the bonding.
- Ask: What is **electronegativity**, and how does it influence the way atoms and subatomic particles interact?
    - By the end of this discussion, ensure scholars understand the following:
        - Electronegativity is a measure of <u>how strongly</u> an atom pulls bonding electrons toward itself. It varies based on the substance that the atom is made of.
        - When atoms of different elements bond, the differences in their electronegativity determine where the electrons tend to be found. Electrons

are always moving! Thus, at any given instant, they may by chance accumulate in one part of a molecule. That said, we can compare the electronegativity of particles to determine where they are more likely to be found.

    - In a covalent bond, shared electrons tend to be pulled more toward the more electronegative element. (Oxygen is famous for this!) This results in a partial negative charge in one or more areas and a partial positive charge in one or more others.
    - Sometimes, differences in electronegativity are so intense that the more electronegative atom strips away an electron completely from its partner. The two resulting, oppositely charged atoms (or molecules) are known as **ions**. Oppositely charged ions attract one another, forming ... ionic bonds!

Make broader connections:

- Ask: How does what you learned today better help you understand how our body processes the food we eat?

Accountability (Exit Ticket) The diagram below depicts a water molecule.

1. Which of the following can be inferred based on information in the diagram? [1]
    1. Hydrogen has greater electronegativity than oxygen.
    2. Oxygen has greater electronegativity than hydrogen.
    3. Hydrogen and oxygen are equally electronegative.
    4. None of the aboveâ€" it is impossible to make any inference about the relative electronegativity of hydrogen and oxygen based on the provided information.
2. The diagram below depicts a(n) __________. [1]

1. enzyme
2. hydrogen bond
3. ionic bond
4. covalent bond

Scoring

1. Award one point for a correct response.
2. Award one point for a correct response.

Lesson 4: Cellular Respiration (Two Days)

Lesson Objective: By the end of day one, scholars will recall that cellular respiration takes place primarily in mitochondria, which is responsible for synthesizing glucose ($C_6H_{12}O_6$) and oxygen (O_2) into carbon dioxide (CO_2), water (H_2O), and ATP. By the end of Day 2, scholars will understand that glycolysis, the Krebs cycle, and electron

transport are the three main steps in cellular respiration, and will know the inputs and outputs of each.

Materials Needed

- Day One:
    - For each group: 2–3 graduated cylinders, tap water, bromothymol blue (in dropper bottle), plastic wrap
    - For each scholar: gloves, goggles, apron, 2 small beakers or clear cups, 1 stopwatch, 2 straws
- Day Two:
    - For each scholar: color copy of **Diving Deep into Cellular Respiration** by Khan Academy

Prep

- Intellectual Prep:
    - Review **Cellular Respiration** by Wyzant Resource.
    - Review **Steps of Cellular Respiration** by Khan Academy.
- Materials Prep:
    - Day One:
        - Ensure there is space next to each table/group of tables where scholars will be able to perform athletic activities (such as jumping jacks or running in place) during the lab. (Note that scholars should be in groups of no more than four for this experiment.)
    - Day Two:
        - Review, modify as needed, and print copies of the **Exercise and Cellular Respiration Lab Procedure** found in the Extra Resources Folder.
        - Print a color copy of **Diving Deep into Cellular Respiration** for each scholar.

What are scholars doing in this lesson?

- On day one, scholars complete a lab in which they measure the differences in their heart and breathing rates before and immediately after exercising. On day two, scholars take a closer look at cellular respiration and its three major parts: glycolysis, the Krebs cycle, and electron transport.

Day One

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: We now know why our bodies need to synthesize ATP. But how, and where, does it actually happen?
    - Scholars have been exposed to cellular respiration before and may be familiar with the term. Today, they will complete an experiment to experience the effects of exercise on cellular respiration! Along the way, they will draw conclusions about the reactants and products of the process.
    - Don't give away too much about cellular respiration or review its inputs and outputs before the lab. Allow scholars to experience the lab and develop their own inferences.

Lab

- Scholars complete the lab by following the **Exercise and Cellular Respiration Lab**.
    - Scholars measure their heart rate and breathing before and after short bursts of exercise.
        - Breathing is measured by exhaling through a straw into a bromothymol blue solution and tracking the time it takes for the solution to change colors (indicating a high concentration of carbon dioxide).
- After completing the lab, scholars answer analysis questions in their Lab Notebooks and draw conclusions about their data.

Discourse Debrief experiment:

- Ask: How were your breathing and your heart rate different before and after exercising?
    - Do you think the rate of cellular respiration increased or decreased in your body during exercise? Why?
    - What do you think the inputs and outputs of **cellular respiration** are? What is your evidence from the experiment?
        - As you review these with scholars, write their chemical formulas and review proper usage of coefficients and subscripts. Scholars should know how to understand and write the names of all reactants and products of cellular respiration (with the exception of ATP, which may not be memorized).

- Take a minute to discuss **glucose**. What is it? Where does it come from? (Allow scholars to share their ideas, but do not give away too much. They will learn more about this in Lesson 5.)
- Ask scholars where in a cell they think cellular respiration occurs. Confirm that it occurs primarily in **mitochondria** and point them out on a couple of different cell diagrams (such as **these** mitochondria and chloroplasts from Khan Academy), so scholars learn to better recognize mitochondria by their structure.
    - Tell scholars that certain parts of cellular respiration also occur in the cytosol (a part of the cytoplasm) and that this is something that will be elaborated on in the next lesson!

Make connections to the Essential Question:

- Ask: What is the connection between cellular respiration and energy?
- Ask: What biological system(s) does cellular respiration support? Explain.

Make broader connections:

- Ask: Why do many athletes eat higher calorie diets than the average person? Why does this generally not result in weight gain?

Accountability (Exit Ticket) Below are five inputs and outputs of cellular respiration.

$C_6H_{12}O_6$	**ATP**	**$6H_2O$**	**$6CO_2$**	**$6O_2$**
(Glucose)	(Energy)	(Water)	(Carbon Dioxide)	(Oxygen)

1. How many atoms of oxygen make up the compound $6O_2$? [1]

12

2. Describe the process by which food is transformed into usable energy. Be sure to include:

â˜ The name of the process [1]

Where this process occurs [1]

How this process occurs [1]

Food is transformed into usable energy through cellular respiration, which takes place primarily in the mitochondria. During this process, glucose is transformed into ATP through a series of chemical reactions.

3. Complete the formula for cellular respiration in the space provided using the molecules in the bank and your knowledge of science. [2]

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

Scoring

1. Award one point for a correct response.

2. Award one point for each of the following:
    - Stating that the process occurs primarily in the mitochondria
    - Correctly describing how this process occurs
    - Note: Scholars do not receive a point for identifying the process as cellular respiration, as the term is used in both the background information and question 3. Should a scholar misidentify the process completely, ensure you round back with them to discuss, as this likely reflects a major misconception.

3. Award two points for correctly identifying all inputs and outputs. Partial credit may be awarded as follows:
    - Allow one point for four out of six correct inputs/outputs.
    - Allow zero points for three or fewer correct inputs/outputs.
        - Note: Order on each side does not matter.

Day Two

Do Now

- Follow the **Do Now plan**.

Launch

- Write the equation for cellular respiration on the board. Ask the following questions to review content that has been covered so far:
    - We know ATP is an energy-carrying molecule. If energy cannot be created or destroyed, where is the energy on the left side of the equation?
    - How do you know that this process includes one or more chemical reactions?
    - Where do the inputs for cellular respiration come from?
- Explain to scholars that today, they will take a deeper dive into cellular respiration and learn about its three main stages!

Activity Adapted from Khan Academy and Wyzant Resources

- Scholars study the provided resource and complete the activities within their Lab Notebook, which teach them about the major processes that comprise cellular respiration:
    - glycolysis
    - the Krebs cycle
    - electron transport

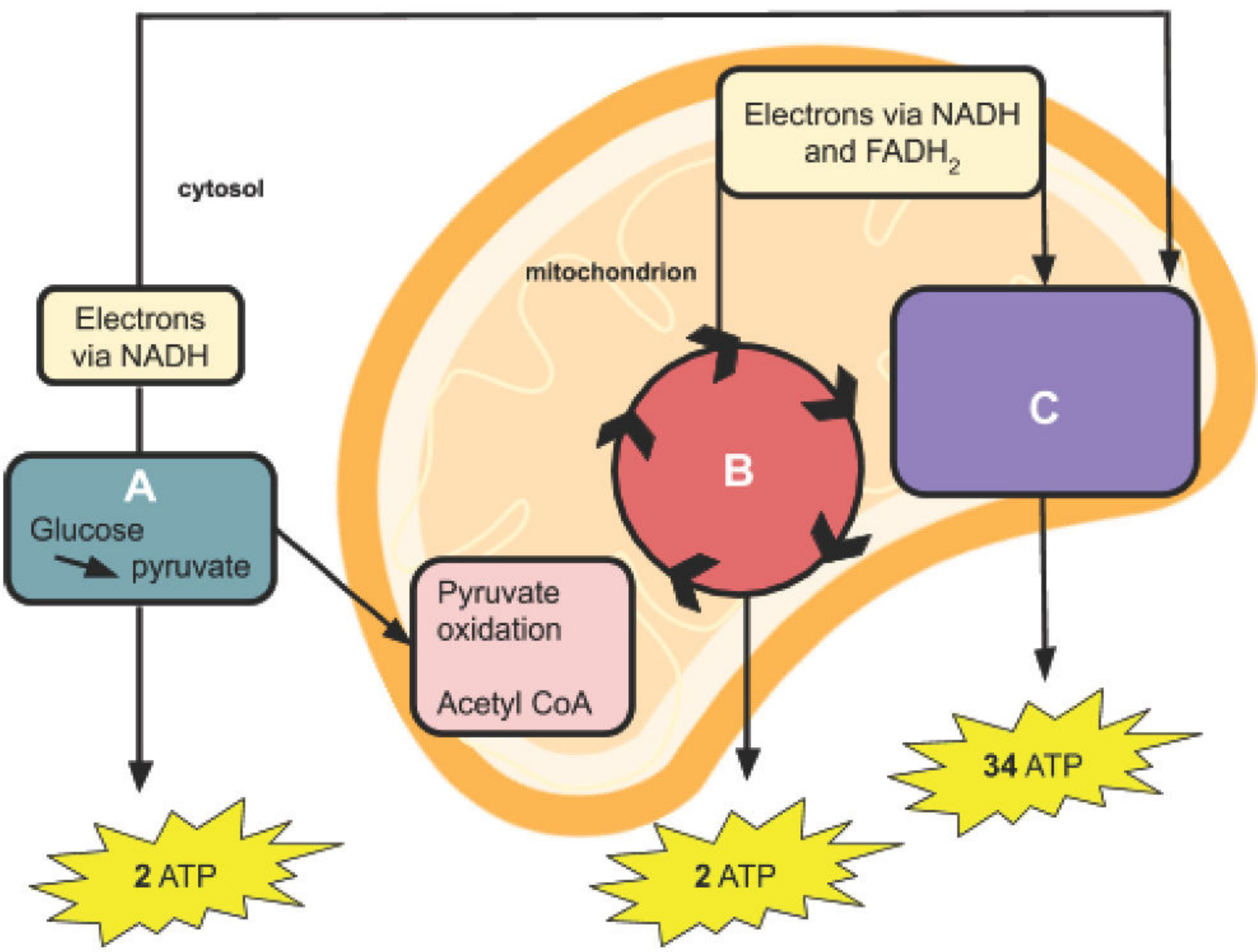
Discourse Debrief the activity:

- Ask: Based on the reading and activities you took part in today, what are the three main stages of cellular respiration? Summarize each stage.
    - Define **glycolysis**, the **Krebs cycle**, and **electron transport** as they come up. Ensure all scholars walk away able to summarize the main purpose of each process and its inputs and outputs. Scholars need not memorize all of the steps in between.
- Ask: How does cellular respiration happen without us making a conscious decision to direct our cells to perform it?

Make connections to the Essential Question:

- Ask: What would happen to a cell if it was unable to perform cellular respiration? Why?
- Ask: Scientists have noticed that oxygen levels in the world's oceans are falling and believe this is related to climate change. What are the implications of this issue for ocean life? Explain.

Accountability (Exit Ticket) The diagram below represents a cell undergoing cellular respiration. The letters A, B, and C represent different processes.



1. Use the diagram above and your knowledge of science to complete the table below. [6

Process	Process Name	Description of Process (including outputs)
A	Glycolysis	Glucose is broken down, resulting in two molecules of pyruvate, two ATP, and NADH.
B	Krebs cycle	Acetyl-CoA made from pyruvate oxidation combines with another molecule and goes through a cycle of reactions to form citric acid. Two ATP, NADH, and $FADH_2$ are produced, and carbon dioxide is released.
C	Electron transport chain (Electron transport is also acceptable)	The $FADH_2$ and NADH deposit their electrons in the electron transport chain. As electrons move down the chain, energy is released. 34 ATP and water are produced.

Scoring

1. Award points as follows:

    - One point for each correctly identified process (must match the correct letter)
    - One point for each accurate description (must define the process scholar named)

Lesson 5: Fabulous Photosynthesis (Two Days)

Lesson Objective: By the end of day one, scholars will recall that photosynthesis is the process by which some organisms use solar energy to transform carbon dioxide (CO_2) and water (H_2O) into glucose ($C_6H_{12}O_6$), oxygen (O_2), and water (H_2O). By the end of day two, scholars will understand that photosynthesis takes place in the chloroplasts, which contain a green substance called chlorophyll that absorbs light energy, and that light-dependent reactions and the Calvin cycle work together to carry out photosynthesis.

Materials Needed

- Day One:
    - For the teacher: model experimental setup
    - For each group: sodium bicarbonate (baking soda), 2 cups of water, liquid dish soap, 2 syringes, 5–7 spinach leaves, 1 hole punch, 2 plastic cups, 1 timer, 2 flashlights
    - For each scholar: **Leaf Disc Assay Procedure**, gloves, goggles, apron
- Day Two:
    - For the teacher: fresh spinach leaves, 95% ethanol, 3 jars, 1 coffee filter, green food coloring, 1 mortar and pestle, 1 funnel, 1 flask, coffee filter

- For each group: extracted chlorophyll solution (labeled "plant extract solution"), alcohol mixed with green food coloring (labeled "solvent dyed green"), 95% ethanol (labeled "solvent"), 1 black light, 3 flasks, 3 funnels, tape, 1 permanent marker
- For each scholar: **Shedding Light on Photosynthesis** by Khan Academy, gloves, goggles, apron

Prep

- Intellectual Prep:
    - Review **The Floating Leaf Disk Assay for Investigating Photosynthesis** by Brad Williamson for Cornell Institute for Biology Teachers.
    - Read **Unit: Photosynthesis** by Khan Academy.
    - Review the **Bloody Chlorophyll Lab** by Carolina Biological Supply Company.
- Materials Prep:
    - Day One:
        - Review, modify as needed, and print copies of the **Leaf Disc Assay Procedure** found in the Extra Resources Folder.
    - Day Two:
        - Print in color: **Shedding Light on Photosynthesis** by Khan Academy.
        - Extract chlorophyll from spinach leaves using the procedure from **Bloody Chlorophyll Lab** by Carolina Biological Supply Company. Make enough for each group to use 10 mL.
        - Add enough green food coloring to a separate container of alcohol labeled "solvent dyed green" to match pigment of extracted chlorophyll as closely as possible and for each group to use 10 mL.
        - In another container labeled "solvent" add enough 95% ethanol for each group to use 10 mL.

What are scholars doing in this lesson?

- On day one, scholars complete a floating disk assay to learn about the raw materials and products of photosynthesis. On day two, scholars observe the fluorescence of chlorophyll and read to take a closer look at photosynthesis and its two major parts: light-dependent reactions and the Calvin cycle.

Day One

Adapted from **The Floating Leaf Disk Assay for Investigating Photosynthesis** by Brad Williamson for Cornell Institute for Biology Teachers

Do Now

- Follow the **Do Now plan**.

Launch

- Explain to scholars that today, they will perform a lab to see how light affects a group of small discs made from plant matter.
    - After observing the results of the experiment, their goal will be to attempt to explain the phenomenon they observed using their knowledge of science.
- Show your model experimental setup under the document camera. Explain to scholars that the small "discs" they see are punched out from spinach leaves and that the experimental group is within a bicarbonate solution.
    - Show scholars a diagram of sodium bicarbonate (such as the one on **Thought Co.** website) so they can see its chemical makeup. Have scholars take note of the elements that make up sodium bicarbonate.

Activity

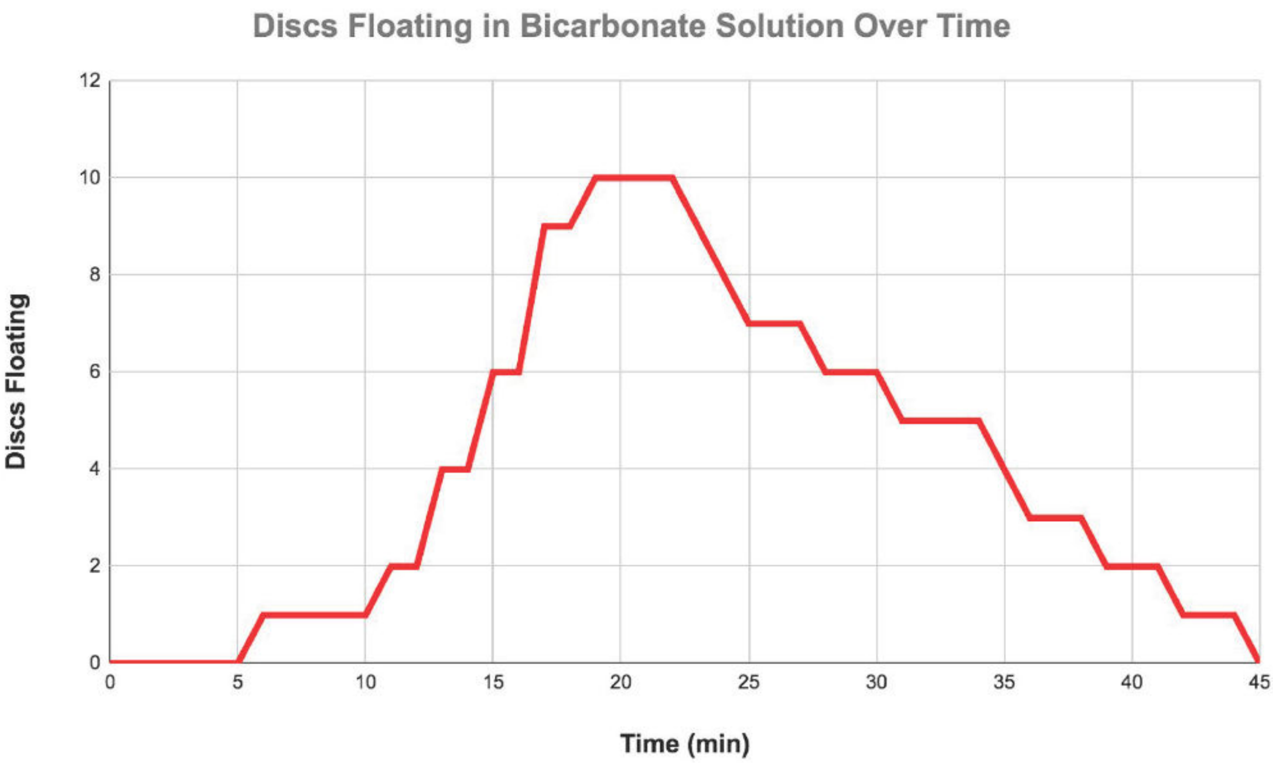
- Scholars follow the **Leaf Disc Assay Procedure**.
- Scholars record their data and answer the analysis questions in their Lab Notebooks:
    - What is the control in your experimental setup?
    - What are the dependent and independent variables of your experimental setup?
    - Make a prediction about the results of your experiment. Explain your reasoning using your knowledge of science.
    - Create a graph of your results in the space provided. Be sure to clearly label your graph with a descriptive title and axis labels.
    - Note: Question 3 must be answered before data collection begins.

Discourse Debrief activity: [**Tip:** Prepare a t-chart to track the inputs and outputs of photosynthesis during the Discourse.]

- Review Question 3 above with scholars:
    - Did your prediction match your results?

- Why do you think this occurred?
    - Press scholars to use their previous knowledge of **photosynthesis** to explain this phenomenon.
        - Scholars should describe that photosynthesis is transforming the carbon dioxide from the soap and sodium bicarbonate reaction into oxygen, making the leaves float.
            - Chart carbon dioxide as a raw material of photosynthesis, and oxygen as a product.

- How might the results be different if this experiment was done in the dark?
    - Tell scholars that when you completed the experiment, you turned off the light source after 20 minutes and continued to log the results. Then, show scholars **this graph**:



- How can you explain the trend in this graph?
    - Scholars should identify light as a raw material of photosynthesis. Add light to your chart. Then, ask scholars to use their prior knowledge to list the remaining inputs and outputs and chart them. (Note: If scholars do not list water as an output, add it yourself before asking the next question.)
        - Once you have the equation listed on the board, ask: Why do you think water is on both sides of this equation?
            - Tell scholars that the water the plant begins with is not the same water that the plant ends with, and this happens because of the bonds being broken and made throughout this process. For the

purposes of simplification, they can expect to see the equation written without the extra $6H_2O$ on each side often.

Make connections to the Essential Question:

- Ask: What is the relationship between photosynthesis and the acquisition of energy by living organisms?
- Ask: What biological systems benefit from the outputs of photosynthesis, both directly and indirectly? Explain.

Accountability (Exit Ticket)

1. Create a diagram of a plant undergoing photosynthesis in the space provided. Be sure to incorporate both the raw materials and end products of this process. You may label your diagram using words or symbols. If you use symbols, create an accompanying key to explain their meaning. [3]

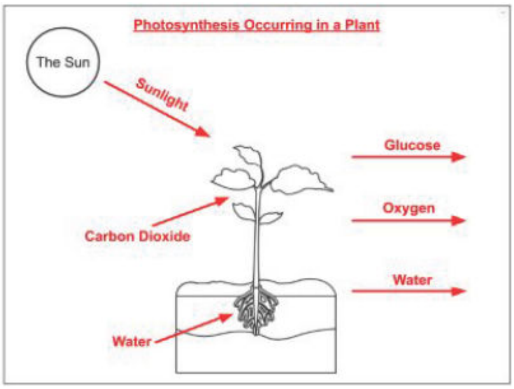


Image Credit: Adapted from **[Vector Stock]**

Scoring

1. Award one point for each of the following:

   - Raw materials are correctly labeled in diagram, including:
     - Water
     - Sunlight
     - Carbon dioxide
   - End products are correctly labeled in diagram, including:
     - Water
     - Glucose
     - Oxygen
   - Diagram is neat and clear.

Day Two

Do Now

- Follow the **Do Now plan**.

Launch

- Show scholars this **video** by Sacred Elements (29 seconds).
    - Define **phototropism**.
        - Ask: Why is plants' ability to move crucial to their survival?
- Write the equation for photosynthesis on the board. Ask the following questions to review content that has been covered so far:
    - Where do the inputs for photosynthesis come from?
    - If energy cannot be created or destroyed, where is the energy on the right side of the equation?
    - How do you know that this process includes one or more chemical reactions?
- Explain to scholars that today, they will perform a lab and study information that will shed light on photosynthesis and its two main stages!

Activity Adapted from Bloody Chlorophyll by Carolina Biological Supply Company. Copyright Carolina Biological Supply Company. Used by permission only.

- Scholars follow the procedure in their Lab Notebooks to observe chlorophyll fluorescence and record their data. (Note that chlorophyll is not named yetâ€" scholars will need to infer after completing the second part of the activity that that is what they are seeing).
    - Scholars should observe that even though the substances look very similar in ambient light, the chlorophyll is the only one to fluoresce red under the black light.
- Scholars study the provided resource and complete the activities within their Lab Notebook, which teach them about the major processes that comprise photosynthesis:
    - Light-dependent reactions
    - The Calvin cycle

Discourse Debrief activity:

- Ask: Why did the substances look different under the black light?
    - Scholars should identify the substance as chlorophyll and explain that **chlorophyll** fluoresces red because it absorbs light energy.

- Ask: Where is chlorophyll created?
    - Define **chloroplasts** and show scholars a diagram of their major structures.
- Ask: Based on the reading and activities you took part in today, what are the two main stages of photosynthesis? Summarize each stage.
    - Define **light-dependent reactions** and the **Calvin cycle** as they come up. Ensure all scholars walk away able to summarize the main purpose of each process and its inputs and outputs. Scholars need not memorize all of the steps in between.

Make broader connections:

- Ask: How does photosynthesis occur without plants "directing" it to happen?
- Ask: Is photosynthesis as a whole a catabolic or anabolic process? Explain.

Make connections to the Essential Question:

- Ask: What would happen to a plant if it was unable to perform photosynthesis? Why?
    - Note: Scholars may have the misconception that plants use photosynthesis to synthesize usable energy. This will be clarified in day two of Lesson 6 and should not be addressed at this moment.

Accountability (Exit Ticket) The diagram below shows photosynthesis broken down into two stages, labeled "Process A" and "Process B." Use the information below and your knowledge of science to answer the questions that follow.

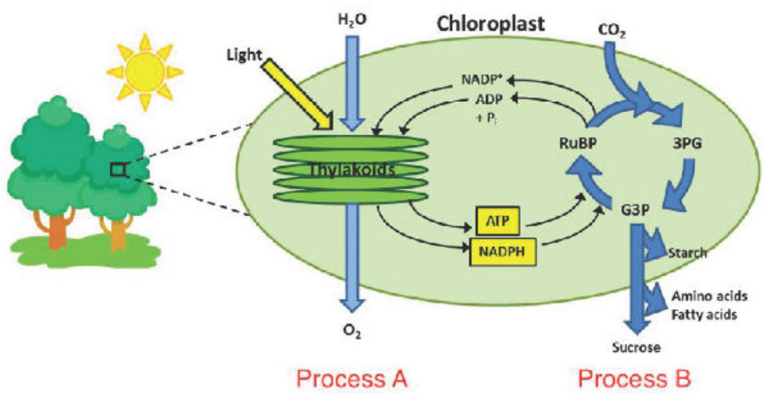


Image Credit: Adapted from Shelley Minteer via ResearchGate

1. Use the diagram above and your knowledge of science to complete the table below. [4]

Process	Process Name	Description of Process
A	Light-Dependent Reactions	Light-dependent reactions convert light energy from the sun into chemical energy in the forms of ATP and NADPH.

B	Calvin Cycle	The Calvin cycle uses energy from the ATP and electrons from the NADPH to convert carbon dioxide into glucose.

2. Would it be possible for Process B to occur before Process A in photosynthesis? Explain your response. [1]

No, this would not be possible because light-dependent reactions (Process A) use energy from the sun to provide the raw materials the Calvin cycle (Process B) needs in order to convert carbon dioxide into glucose.

3. Fill in the blanks to complete the sentences below. [2]

Chlorophyll is a photosynthetic pigment found in many autotrophs, such as plants and algae. This pigment allows plants to absorb light energy from the sun and is found in the *chloroplasts*, the organelles responsible for carrying out photosynthesis.

Accountability

1. Award one point for each of the following:
    - One point for each correctly identified process (must match the correct letter)
    - One point for each accurate description (must define the process scholar named)
2. Award one point for describing that Process A provides the raw materials for Process B (stating that the inputs for Process B are the outputs from Process A).
3. Award one point for each correct response.

Lesson 6: Photosynthesis and Cellular Respiration (Two Days)

Lesson Objective: By the end of day one, scholars recall that heterotrophs obtain food from their environment, whereas autotrophs produce their own food. By the end of day two, scholars understand that regardless of how an organism obtains food, most organisms must use cellular respiration in order to synthesize their "food" into usable energy (ATP). Materials Needed

- Day One:
    - For the teacher: bean seeds, paper towels, water, plastic bags
    - For each group: 2 test tubes (with caps), 20 mL bromothymol blue, 1 pipette, 5 boiled bean seeds, 5 germinating bean seeds, tape and permanent marker for labeling
    - For each scholar: gloves, goggles, apron
- Day Two:
    - For each group: experimental setup from day one
    - For each scholar: gloves, goggles, apron

Prep

- Intellectual Prep:
  - Watch **Cellular Respiration in Plants Video** by nhoxkorocute (3 minutes, 56 seconds).
- Materials Prep:
  - There are two types of beans provided for this lab. Try both in advance in your lab and select one to use for the experiment.
  - Boil half of the beans being distributed to scholars.
  - Germinate half of the beans being distributed to scholars:
    - Soak the bean seeds in water overnight.
    - Dampen a paper towel, ringing out the excess. Fold the paper towel into the plastic bag.
    - Press bean seeds into the dampened paper towel, being sure to place them about an inch apart.
    - Seal the bag and place it by a window. Within three days to a week, your seeds will begin to sprout.

What are scholars doing in this lesson?

- Scholars set up an experiment on day one. While awaiting results, scholars observe a demo that showcases plants producing oxygen in real time. On day two, they revisit their experimental setup to review the results and find that plants release CO_2 in addition to oxygen. Scholars participate in discourse to confirm that plants undergo both photosynthesis and cellular respiration.
  - Note: Many scholars have the existing misconception that plants use photosynthesis to synthesize usable energy from glucose (as opposed to performing both photosynthesis and cellular respiration). Allow scholars to have this misconception through day one but take note of how this misconception manifests. On day two, use the lab and discourse to address this misconception.

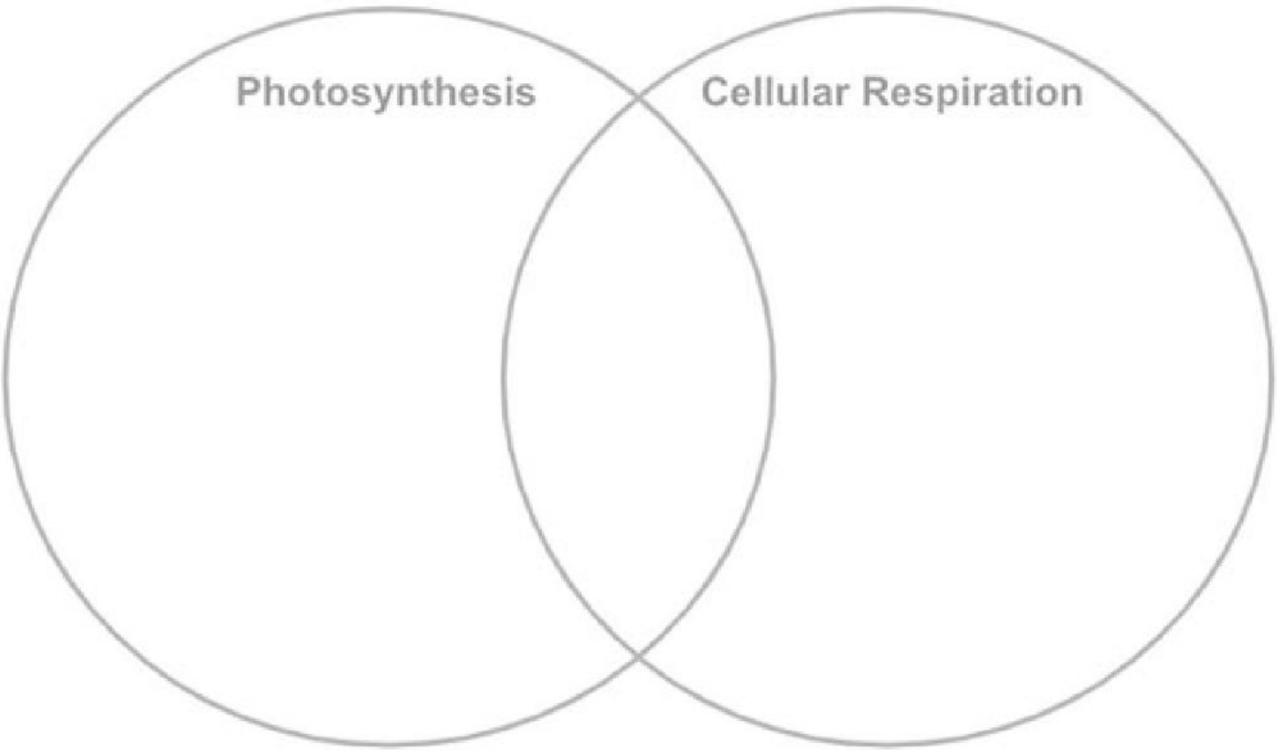
Day One

Do Now

- Follow the **Do Now plan**.

Launch

- Ask: What are the differences and similarities between cellular respiration and photosynthesis?
  - Chart responses to track scholar thinking using a graphic organizer similar to the one below. Be sure not to influence their ideas or correct their misconceptions yet.



- Tell scholars that over the course of the next two days, they will gain a deeper understanding of how these important processes work together within a system by participating in a two-part lab.

Activity Adapted from the **Cellular Respiration in Plants** video by nhoxkorocute on YouTube.

- Scholars follow the procedure in their Lab Notebooks to set up their experiment for data collection on day two.
- Scholars answer the analysis questions in their Lab Notebooks:
    - What are the controls in your experimental setup?
    - What are the dependent and independent variables of your experimental setup?
    - Make a prediction about the results of your experiment. Explain your reasoning using your knowledge of science.

Discourse Demo and debrief:

- Review the third analysis question above with scholars.
    - Scholars share their predictions.
- Show scholars the **Smothered Candle Video** (34 seconds).

[Engagement Tip: As an alternative to showing this video, you can opt to demo this experiment for scholars instead.]

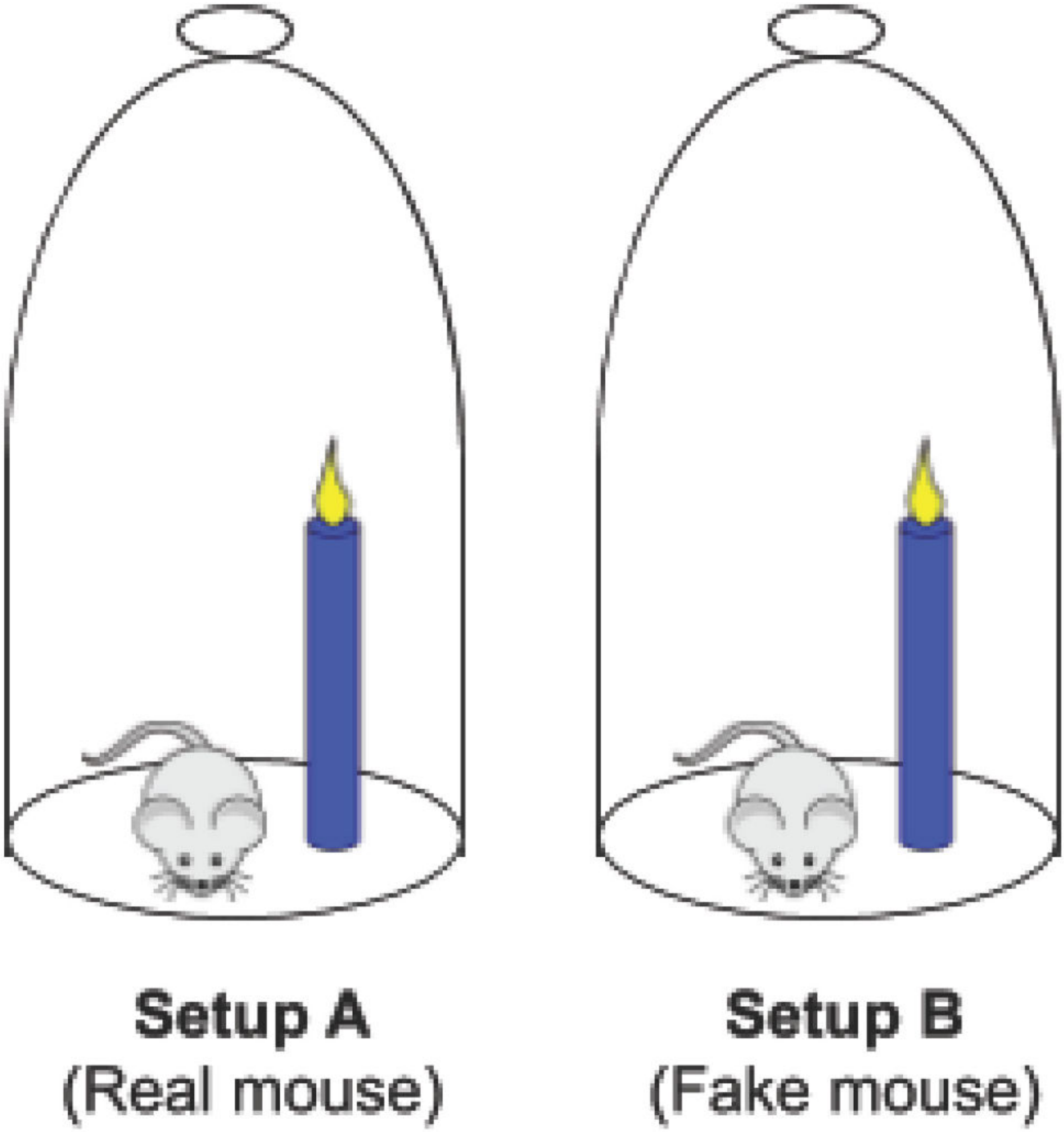
- Scholars discuss their observations and hypothesize as to why the candle went out.

- Show scholars the **Photosynthesis in a Jar Video** (1 minute, 14 seconds).
    - Scholars discuss their observations and hypothesize as to why the candle inside of the cloche with the plant burned longer than the candle inside of the cloche without a plant.
- Scholars have five minutes to answer the question in their Lab Notebooks. This question will serve as the Exit Ticket for day one.

Make connections to the Essential Question:

- After scholars finish their Exit Tickets, come back together as a class and discuss:
    - What would happen to the mouse over time if this experiment continued? Why?
    - If you could add any two things to the experimental setup to help the mouse survive, what would they be and why? (Connect this back to the acquisition of energy and the health of biological systems.)

Accountability (Lab Notebook) A group of scientists performs a similar experiment to the one you observed today in class. However, instead of using plants, they decide to use mice. An image of this experimental setup can be found below.



- Which will burn longer: the candle in Setup A or the candle in Setup B? Explain your reasoning using your knowledge of science. [2]

The candle in Setup B will burn longer because candles need oxygen to burn. The real mouse will breathe in some of the available oxygen and release CO_2, causing the oxygen supply to deplete much faster than the fake mouse, which does not use up any oxygen.

Scoring

- Award one point for each of the following:
  - One point for identifying Setup B

- One point for accurately explaining that the real mouse will use oxygen, causing the candle to burn out more quickly

---

Day Two

Do Now

- Follow the **Do Now plan**.

Launch

- Briefly review the experimental setup from day one. Explain that today, scholars will revisit their experimental setups to draw additional conclusions about the outputs of plants' cellular processes.

Activity Adapted from the **Cellular Respiration in Plants Video** by nhoxkorocute

- Scholars retrieve yesterday's experiment, record observations, and answer the analysis question in their Lab Notebooks based on the results:
    - Was your prediction about the results of this experiment correct? Explain.

Discourse Debrief experiment/activity:

- Ask two to three groups to share their observations. Chart their responses and ask:
    - What trends do you see in this data? What can you infer based on these trends?
        - Why do plants emit both oxygen and CO_2?
            - How does this change your understanding of how plants acquire usable energy?
                - Scholars should be able to conclude that **heterotrophs** aren't the only organisms that perform cellular respirationâ€" plants and other **autotrophs** use photosynthesis to produce food, but they too must convert glucose into ATP in order to transform this food into usable energy.

Make connections to the Essential Question:

- An invasive plant species named Elodea was released into a nearby pond, and experts are using pond dye to eradicate Elodea before it spreads throughout the region.
- Show scholars the photo below and explain that pond dye is either blue or black and prevents sunlight from penetrating the pond water.

Image Credit: **USFWS Mountain-Prairie**, **CC BY 2.0**, via Wikimedia Commons

- Ask: How might the pond dye impact plant life in the pond?
    - Scholars should describe that without sunlight, aquatic plants will no longer be able to undergo photosynthesis and will most likely die.
        - What impact might the eradication of producers have on the pond's broader ecosystem?
            - How can you connect this back to the unit's Essential Question?

Accountability (Exit Ticket) A group of ecologists were studying organisms' acquisition of energy at the Serengeti National Park, in Tanzania. Below is a photograph taken by the group, showing a giraffe feeding on a tree.

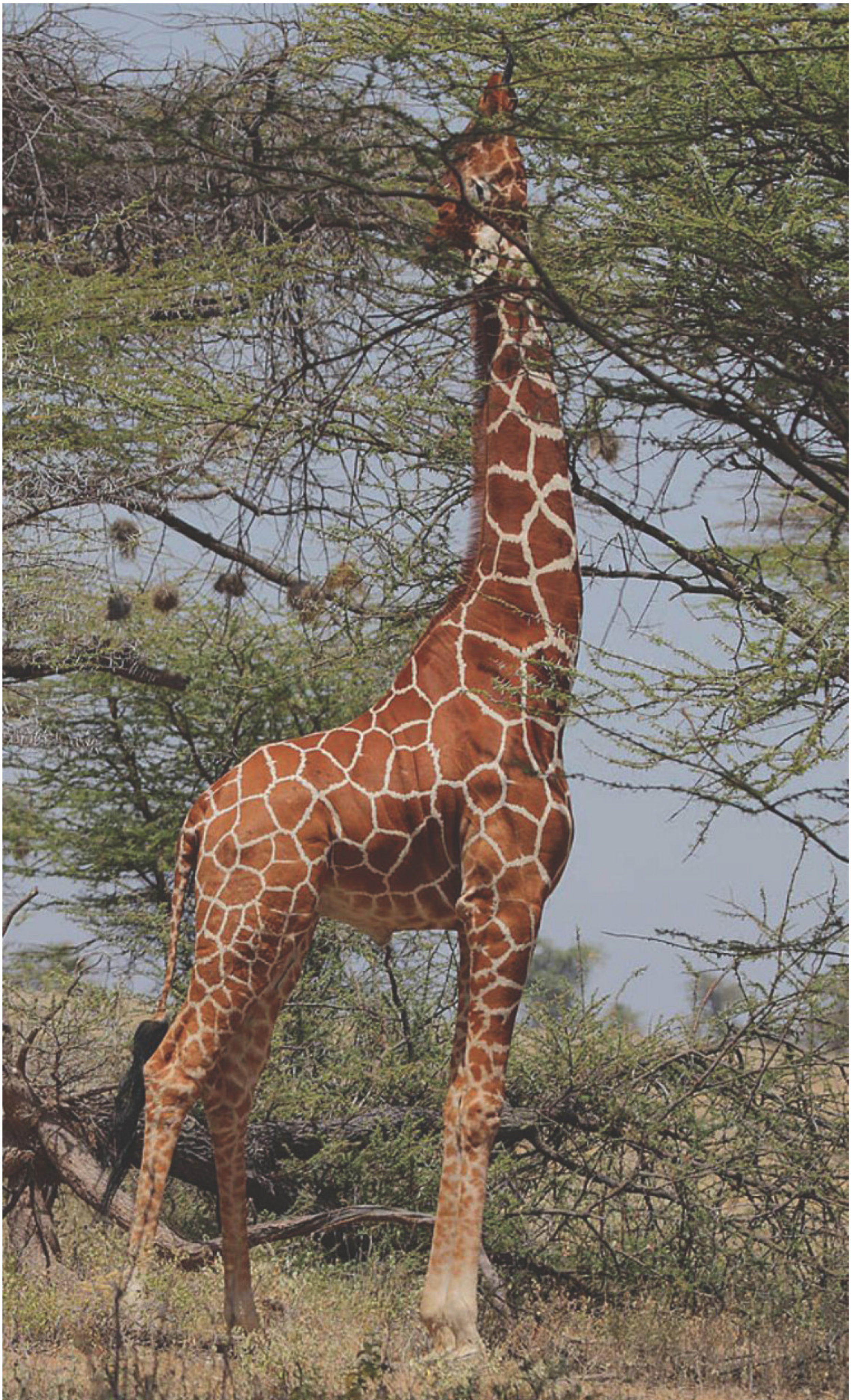


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Image Credit: **Steve Garvie from Dunfermline, Fife, Scotland, CC BY-SA 2.0**, via Wikimedia Commons

1. The ecologists had different ideas about how these organisms acquired their energy:

Dr. Exe: *"The giraffe is a heterotrophic organism, meaning it does not rely on cellular respiration for energy production because it obtains food from its environment."*

Dr. Why: *"The tree uses photosynthesis to convert glucose into energy because it is an autotroph."*

Dr. Zee: *"The tree is an autotrophic organism, which uses cellular respiration in order to convert glucose into energy."*

Which ecologist is most scientifically accurate? Explain your answer using evidence and reasoning. [3]

Possible Exemplars:

I agree most with Dr. Zee because they stated that trees are autotrophic organisms that use cellular respiration to transform food into energy, whereas the other ecologists made incorrect claims about the organisms' energy acquisition. Both the giraffe and the tree require cellular respiration to transform their food into usable energy.

Dr. Zee's statement is the most accurate because cellular respiration is used by the tree to transform glucose into usable energy. This is true of heterotrophs as well, so the assertion made by other ecologists that either autotrophs or heterotrophs do not need cellular respiration to acquire energy is incorrect.

Scoring

1. Award one point for each of the following:

    - A clear claim that identifies Dr. Zee's statement as the most accurate
    - An accurate scientific reason for why they agree with their chosen ecologist that connects to their understanding of cellular energetics
    - Further supporting information for why their ecologist's statement is correct based on information learned in class

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Lesson 7: No Oxygen, No Problem?

Lesson Objective: Scholars learn that fermentation and anaerobic respiration are two other processes that produce a smaller amount of ATP than aerobic respiration. They are also aware that aerobic respiration is not the default process for every organism. Materials Needed

- For each group: 1 timer
- For each scholar: 1 hand grip strengthener, 1 clothespin, 1 stress ball

Prep

- Intellectual Prep:
    - Review **Lactic Acid Fermentation** by Khan Academy.

- Review **Anaerobic Respiration** by Khan Academy.

What are scholars doing in this lesson?

- Scholars participate in a muscle fatigue lab where they complete three timed trials of different physical activities using a hand grip strengthener, a stress ball, and a clothespin to experience lactic acid fermentation firsthand. Scholars then learn about the differences between aerobic and anaerobic processes and study organisms who undergo anaerobic respiration.

Do Now

- Follow the **Do Now plan**.

Launch

- Write the equation for cellular respiration on the board.
    - Ask: How would cellular respiration be impacted in the absence of oxygen?
        - Ask: During what stage(s) of cellular respiration is oxygen used?
- Tell scholars that today, they will be participating in a muscle fatigue lab to better understand what happens to our cells when there is a shortage of oxygen.

Lab

- Scholars complete the muscle fatigue lab by following the directions in their Lab Notebook.

[**Tip:** As an alternative, you can assign different scholars each of the three tasks and they can share their data with one another.]

- Scholars attempt to squeeze a stress ball, a hand strengthener, and a clothespin as many times as possible in one minute.
- Scholars discuss their findings using the questions provided in their Lab Notebooks:
    - How did your performance during each trial change?
    - Why do you believe your performance changed?
    - How do you think cellular processes are related to physical activity?

Discourse Debrief experiment/activity:

- Ask: How did your ability to perform the task change during each trial?

- Based on what you have learned about cellular processes and energy, why do you think your performance changed during each trial?
    - Tell scholars that the “burn” they felt was caused by lactic acid buildup in their muscles due to lactic acid fermentation.
        - Define **fermentation**. Explain that it is an anaerobic process that occurs in the absence of oxygen.
        - Define **anaerobic** and **aerobic** processes. Explain to scholars that some organisms, called anaerobes, do not perform aerobic respiration. Instead they perform anaerobic respiration. Some not only do not need oxygen, but they are actually harmed by it! Most anaerobes are unicellular organisms such as bacteria.

Make broader connections:

- Show scholars the following information.

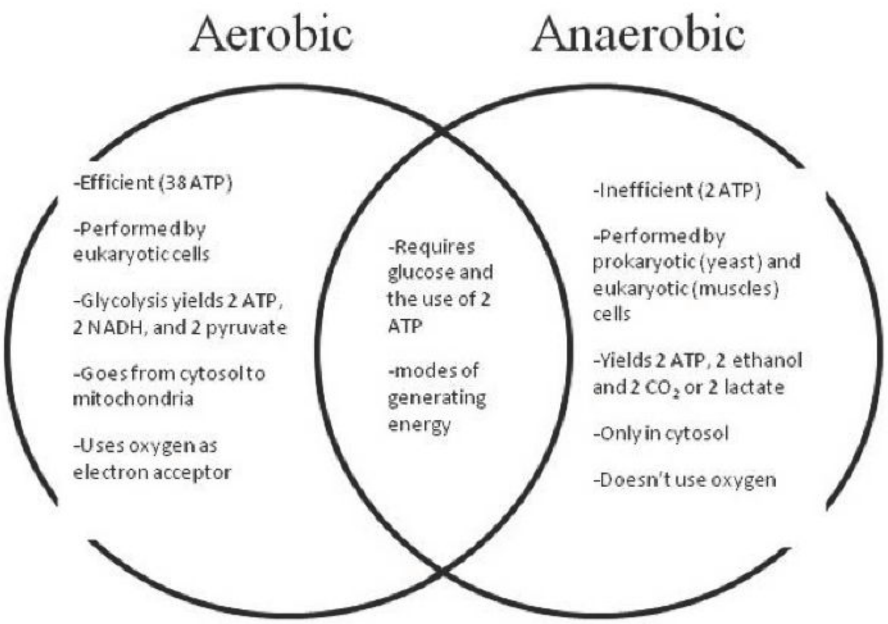


Image Credit: **Difference between Aerobic and Anaerobic Respiration**

- Ask: Why do we primarily use aerobic respiration instead of anaerobic respiration?
    - Scholars should understand that aerobic respiration yields significantly more ATP than anaerobic respiration.
- Tell scholars that while organisms like us need oxygen for our survival, some prokaryotes (like bacteria and archaea) that live in low-oxygen environments rely on anaerobic respiration to break down fuels.

Make connections to the Essential Question:

- Show scholars the **Why Does Your Breath Stink in the Morning? Video** by SciShow (1 minute, 51 seconds).
  - Ask: In this scenario, how can the energy acquisition of bacteria potentially impact the system in which it lives?

Accountability (Exit Ticket) Below are the chemical formulas for three life processes:

I.	$\mathbf{C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2}$ (Glucose) (Ethanol) (Carbon Dioxide)
II.	$\mathbf{C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + ATP + 6CO_2}$ (Glucose) (Oxygen) (Water) (Energy) (Carbon Dioxide)
III.	$\mathbf{C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + 2ATP}$ (Glucose) (Lactic Acid) (Energy)

1. Which of the three processes above are anaerobic? [1]
   1. I only
   2. II only
   3. I and III
   4. I, II, and III
2. Explain your answer to question 1. [1]

Possible Exemplar:

Processes I and III are anaerobic processes because they do not require oxygen in order to take place.

Scoring

1. Award one point for selecting answer C.
2. Award one point for identifying that anaerobic processes do not require oxygen.

Lesson 8: The Carbon Cycle

Lesson Objective: Scholars understand that since matter can be neither created nor destroyed, the same carbon continues to cycle through Earth's spheres. They can explain how human activities impact the carbon cycle, causing carbon to be released into the atmosphere more rapidly and contributing to climate change. Materials Needed

- For each group: 4 ping-pong balls, 1 role play card
  - Note: For this activity, scholars must be separated into exactly 7 groups.

Prep

- Materials Prep:
    - Print **Carbon Cycle Role Play Cards** by California Academy of Science. Make enough of each card so that every scholar has a copy of their individual group's role play card.
    - Post signage designating four areas of the room to represent the lithosphere, the hydrosphere, the biosphere, and the atmosphere.
    - Print color copies of this lesson's Exit Ticket.
- Intellectual Prep:
    - Read **The Carbon Cycle** by NASA Earth Observatory.
    - Read **The Conservation of Mass** by Nature Education.

What are scholars doing in this lesson?

- Scholars physically model the carbon cycle as they participate in a role playing activity. As they track the transfer of carbon throughout the Earth's spheres, scholars gain insight into the law of conservation of matter and consider how human activities impact the carbon cycle.

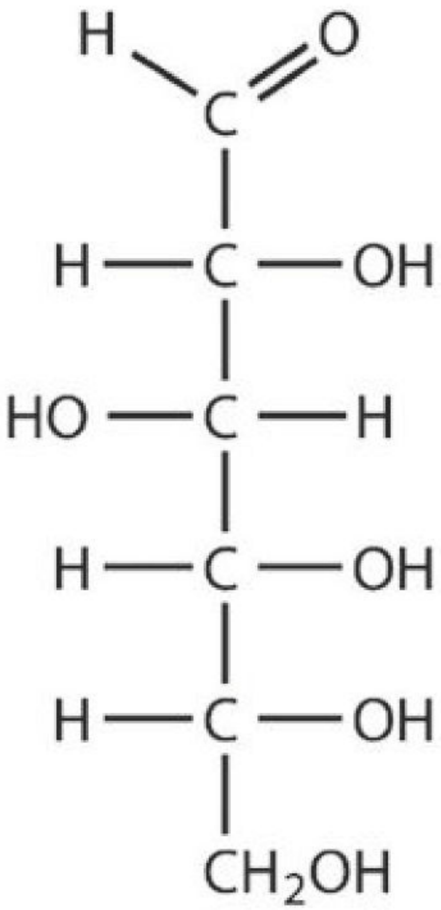
Do Now

- Follow the **Do Now plan**.

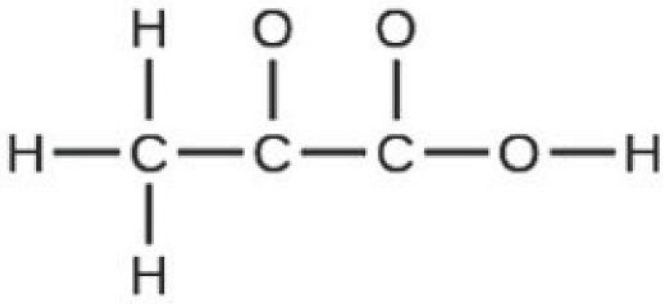
Launch

- Show scholars the chemical makeup of some of the molecules they have studied throughout this unit:

Glucose



Pyruvic Acid



Carbon Dioxide

- Tell scholars that carbon is an important element in cellular processes and that carbon changes forms when bonds are broken or made.
- Tell scholars that carbon's ability to bond with many other elements makes it crucial to almost all organisms. Then, show them the following facts:
    - Carbon is the sixth most abundant element in the universe.
    - Approximately 10 million carbon compounds have been discovered.
    - It is estimated that carbon is the foundation of 95 percent of known compounds.
        - Show scholars these images to give them a better understanding of the relative abundance of carbon in various places:

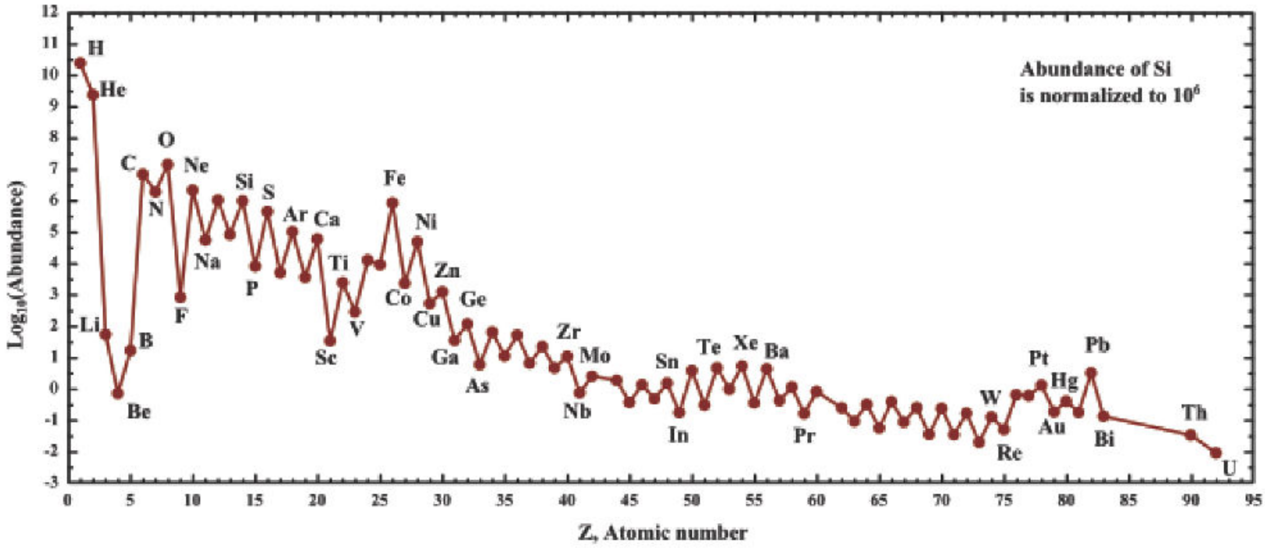


Image Credit: “The abundance of elements in the solar system” from **MHz`as**, **CC BY-SA 3.0**, via Wikimedia Commons

Element	Proportion (by mass)
Oxygen	65%
Carbon	18%
Hydrogen	10%
Nitrogen	3%
Calcium	1.5%
Phosphorus	1.2%
Potassium	0.2%
Sulfur	0.2%
Chlorine	0.2%
Magnesium	0.05%
Iron	<0.05%
Cobalt	<0.05%
Copper	<0.05%
Zinc	<0.05%
Iodine	<0.05%
Selenium	<0.01%

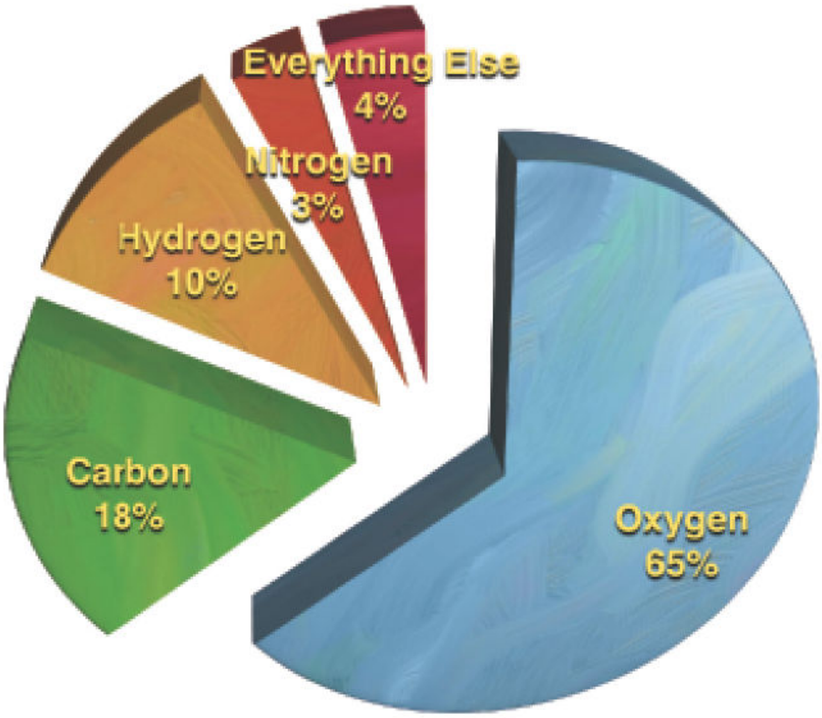


Image Credit: “The abundance of elements in the human body” from **Biology LibreTexts**, **CC BY-NC-SA 3.0 US**

- Tell scholars that today, they will model the carbon cycle to track the transfer of carbon throughout Earth’s spheres.

Activity Adapted from Carbon Cycle Role Play by California Academy of Sciences

- Read the activity directions in Lab Notebook with scholars:
    - You will be split into seven groups, and each group will be given a role: atmosphere, water, sediments and rocks, land plants, land animals, aquatic plants, or aquatic animals.
    - Four areas of the room have been designated to represent the hydrosphere, the lithosphere, and the atmosphere. Depending on your role, you will be in a different area:
        - Lithosphere: sediments and rocks
        - Hydrosphere: water
        - Atmosphere: atmosphere
        - Biosphere: land plants, land animals, aquatic plants, and aquatic animals

    - Your group will be given four ping-pong balls that represent carbon atoms as well as a role play card that defines your group's role and includes a list of options for carbon movement along with an explanation for this movement.
    - Based on your role, your group will decide how you will distribute your carbon to the other groups.
    - As your group transfers carbon to other groups, you must say your script lines to explain the carbon movement that you have chosen.

- Divide scholars into seven groups and lead the activity. Each group is given four ping-pong balls and assigned a **Carbon Cycle Role Play Card**.
- Find strategic moments to pause activity and link the transfer of carbon to the cellular processes scholars have studied throughout this unit.

Discourse Debrief experiment/activity:

- Ask: How does carbon flow throughout the Earth's spheres? Give examples.
    - Create a model of the carbon cycle on chart paper as scholars share the pathways of carbon.
- Ask: Did the amount of carbon change in this system change? Why or why not?
    - Define the **law of conservation of mass**.

Make connections to the Essential Question:

- Ask: How is the carbon cycle related to our acquisition of energy?
- Ask: How have human activities in recent years affected the "balance" of the carbon cycle?
    - How do large concentrations of carbon in our atmosphere affect biological systems?
        - Scholars should recall that carbon dioxide is a greenhouse gas, and many of them will link carbon to **climate change**. Once scholars share their ideas, show them the **How Do Greenhouse Gases Actually Work? Video** by MinuteEarth (3 minutes, 8 seconds) to clear up any misconceptions they might have about climate change and greenhouse gases.

Accountability (Exit Ticket) The Industrial Revolution marked the beginning of new manufacturing processes throughout Europe and the United States. It took place from approximately 1750 until 1840 but had a lasting impact on the mass production of goods. From then on, machinery and chemical manufacturing took the place of hand production methods on a broad scale. These practices have continued to be further developed and used to this day. Use the information about carbon emissions and the Industrial Revolution below and your knowledge of science to answer the questions that follow.

Carbon Emissions and the Industrial Revolution

From **Climate.gov**

"The amount of carbon dioxide in the atmosphere (pink line) has increased along with human emissions (blue line) since the start of the Industrial Revolution in 1750. Emissions rose slowly to about 5 billion tons a year in the mid-20th century before skyrocketing to more than 35 billion tons per year by the end of the century."

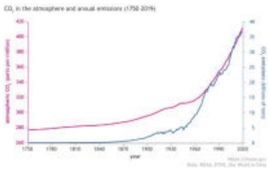


Image Source: NOAA

"Carbon dioxide concentrations are rising because of the fossil fuels that people are burning for energy. Fossil fuels like coal and oil contain carbon that plants pulled out of the atmosphere through photosynthesis over the span of many millions of years; we are returning that carbon to the atmosphere in just a few hundred years."

1. Describe the impact human activities have had on climate change over the last 200 years. [3]

Possible Exemplars:

Human activities over the last 200 years have directly caused climate change. Since the Industrial Revolution, atmospheric carbon has increased drastically due to the heavy use of machinery and chemical manufacturing used when producing goods. Carbon is a greenhouse gas that traps heat in the Earth's atmosphere, so high atmospheric carbon has caused global average temperatures to rise.

The reliance on machine-based production has caused global average temperatures to rise. This is because this method of production and those similar to it have released a greenhouse gas called carbon into the atmosphere at an alarming rate. Greenhouse gases trap heat on the Earth's surface, which is the cause of climate change.

Human activities since the Industrial Revolution led to an increase in the amount of atmospheric carbon. Since carbon is a greenhouse gas, it traps heat in the atmosphere and causes climate change.

2. Saraya says, "I'm not worried about climate change because I know that matter cannot be created or destroyed. That means that the amount of carbon and oxygen atoms on our planet (the components of carbon dioxide) actually aren't changing at all, and we've got nothing to worry about!" Evaluate this statement. [3]

Possible Exemplars:

I disagree with Saraya. While matter cannot be created or destroyed, it *can* change forms. When CO_2 is released during the burning of fossil fuels or other human activities, we are releasing that CO_2 in the form of a harmful greenhouse gas. Greenhouse gases trap heat in the atmosphere, causing climate change.

While Saraya makes some accurate claims, I disagree with the idea that climate change is not a troubling reality. It is true that matter cannot be created or destroyed and that the carbon and oxygen released into the air is the same carbon and oxygen that was buried in the ground. However, they are being released into the air at a much faster rate than they would be during natural processes. CO_2 acts as a greenhouse gas and causes climate change because it traps heat in the atmosphere.

Scoring

1. Award one point for each of the following:

    - A clear claim that explains the connection between human activities and climate change

- Inclusion of evidence from the text
- Justification/reasoning as to why the evidence supports their claim using their knowledge of science

2. Award one point for each of the following:

   - A clear claim that effectively evaluates Saraya's statement
   - Inclusion of evidence from the text
   - Justification/reasoning as to why the evidence supports their claim using their knowledge of science

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Lesson 9: Factory Farming: Life-Saving Solution or Ecological Nightmare?

Lesson Objective: Scholars learn that factory farming was created by scientists in response to the growing demand for food. They can articulate that this is an ineffective solution because of its lack of efficiency and damage to the Earth and its potential to more broadly upset biological systems at the macro level. Materials Needed

- For each scholar: computer

Prep

- Materials Prep:
  - Send scholars the following link:
    - **Ending Factory Farming: Environmental Damage** by Compassion in World Farming
- Intellectual Prep:
  - Read **What Is Conservation of Energy?** by Khan Academy.

What are scholars doing in this lesson?

- Scholars research and answer questions about factory farming. As they do this, they study energy transformations and make connections to the law of conservation of energy and then to the unit's Essential Question.

Do Now

- Follow the **Do Now plan**.

Launch

- Ask a scholar to recap what they already know about why food access is so important for heterotrophs.
- Tell scholars that a lack of food access has been a problem for decades and that scientists knew food shortages would only grow as the world's population increased. So in the 1960s, scientists developed a potential solution: factory farming.
    - Define **factory farming**.
- Today, scholars will research factory farming to study the impacts of this solution on our environment and the health of Earth's biological systems, 60 years after its conception.

Activity

- Scholars work in groups to learn about factory farming and answer the questions in their Lab Notebooks:
    - How does factory farming contribute to climate change?
    - Approximately what portion of the world's crops are used for animal feed?
    - How is factory farming different from conventional farming methods?
    - Would you describe factory farming as an efficient use of resources? Explain.
    - Describe the impact of factory farming on a biological system of your choice.

Discourse Debrief experiment/activity:

- Ask: Now that we understand the threat of climate change, is factory farming still a good solution?
- To help scholars draw connections between this lesson and their prior knowledge from the unit, ask the following:
    - Is factory farming an efficient use of energy?
        - If energy is conserved anyway, why does it matter to us how or when it is transformed or "used"?
    - How does factory farming impact the carbon cycle?
        - How will the increased carbon in the atmosphere as a result of factory farming impact the Earth's ecosystems? Why?
    - What might happen if the other animals were cut out of the equation completely and humans just ate a plant-based (vegetarian or vegan) diet? (Make connections to energy pyramids/trophic levels here!)
    - What are some other concerns about factory farming? Explain.
- Allow scholars five minutes to answer the question in their Lab Notebooks. This question will serve as the Exit Ticket.

Make connections to the Essential Question:

- Show scholars **The Hidden Cost of Hamburgers Video** by Reveal (7 minutes, 51 seconds) and ask:
    - In this context, how does energy acquisition impact biological systems?

Accountability (Lab Notebook)

- Should other countries implement the United States' factory farming model? Use evidence from today's activity and explain your reasoning.

Sample responses:

Other countries should not use factory farming because of the negative long-term impacts on the environment. Factory farming releases a lot of carbon, methane, and other greenhouse gases into the atmosphere and is a huge contributor to global warming. Over time, the changing climate will disrupt the balance of many ecosystems, leading to a decline in the health of biological systems on a broader scale.

No, countries should simply adopt plant-based diets instead. Approximately one-third of the world's crops are used as animal feed on factory farms. This is an inefficient use of energy resources because a high amount of calories in plant feed yields significantly fewer calories in meat. Those plants could just go directly to humans, who could transform the stored energy within them.

Scoring

- Award one point for each of the following:
    - A clear claim that states that other countries should not adopt factory farming practices
    - Inclusion of at least one piece of relevant, accurate evidence from the text
    - Justification/reasoning as to why the evidence supports their claim using their knowledge of science

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Lesson 10: Spread the Word! (One to Two Days)

Lesson Objective: Scholars can clearly explain how the acquisition of energy affects biological systems (at multiple levels) and provide relevant evidence from the unit. Materials Needed

- For each group: plain white copy paper or chart paper, colored pencils, markers, computer (Note: Exact materials will depend on chosen format for final project.)
- For each scholar: a copy of the **Final Project Rubric**

Prep

- Materials Prep:
    - Determine whether scholars will create a final brochure, poster, or digital presentation. Assemble the necessary materials for the final project accordingly.

What are scholars doing in this lesson?

- Scholars create informational materials to teach others how the acquisition of energy affects the health of biological systems, highlighting multiple systems that vary in size and complexity. They include supporting evidence from several lessons to strengthen their arguments.

[**Tip:** If two days are available, you may choose to allow one for project creation and one for presentations and peer/self-evaluations. If you are short on time, you could instead have each scholar create a project individually and allow them to complete the remainder at home.]

Do Now

- Follow the **Do Now plan**.

Launch

- Explain to scholars that this is their opportunity to educate others about the relationship between the acquisition of energy and the health of biological systems. In this lesson, they will create informational materials to share with others in the school community.
- Outline the project format and share the rubric and available materials with scholars.
    - Review each section of the rubric together and ensure scholars understand the assignment.

Activity

- Using the project rubric as a guide, scholars begin creating informational materials to answer the unit's Essential Question!
- As scholars are working, circulate and ask them how they are incorporating evidence from the unit into their materials. Study scholar work and identify any lingering misconceptions, pausing to coach scholars and help them update their notes as needed. (At this point in the unit, these should be rareâ€" if you identify a misconception, make a plan to round back with the scholar(s) before the final exam to allow them extra opportunities for practice.)

Presentations

- Groups present their work to the class.
    - Scholars evaluate each presentation and offer positive and constructive feedback.
        - If time allows, scholars can use copies of the rubric to perform peer and/or self-evaluations.

Accountability (Projects)

Grade scholar projects. Look for evidence of writing with best effort and give feedback on explaining claims with strong support from scientific knowledge learned throughout the unit.

- Directions: Construct a resource that answers the Essential Question and teaches others about the connection between the acquisition of energy and the health of biological systems. Support your argument by including information about the scientific concepts you learned throughout the unit and explaining their connection to the Essential Question.

Scoring Score scholars out of eight points using the provided **rubric**.

Unit Vocabulary

Vocabulary List

- **system**
- **biological**
- **energy**
- **calorie**
- **potential energy**
- **law of conservation of energy**
- **macronutrient**
- **activation energy**
- **ATP**
- **metabolism**
- **enzyme**
- **catabolism**
- **anabolism**
- **atom**
- **subatomic particle**
- **proton**
- **neutron**
- **electron**
- **valence electron**
- **covalent bond**
- **ionic bond**
- **electronegativity**
- **ion**
- **cellular respiration**
- **glucose**
- **mitochondria**

- **glycolysis**
- **Krebs cycle**
- **electron transport**
- **photosynthesis**
- **phototropism**
- **chlorophyll**
- **chloroplast**
- **light-dependent reactions**
- **Calvin cycle**
- **heterotroph**
- **autotroph**
- **fermentation**
- **anaerobic**
- **aerobic**
- **carbon**
- **carbon cycle**
- **law of conservation of mass**
- **climate change**
- **factory farming**