SUCCESS ACADEMY EDUCATION INSTITUTE

Life Science:
Unit 6

Cellular Energetics: Introduction

Purpose: The Why, What, and How of This Unit

Essential Question: How does the acquisition of energy relate to the health of a biological system?

Unit Storyline Synopsis: Scholars engage with the Essential Question by considering what they already know about how organisms acquire and transform energy. They also learn to better understand a term they hear often: *system*. What exactly is a system, and how does systems thinking support scientists in their work every day?

Before scholars are able to answer the Essential Question, they will first stop to consider what food and energy *are*. They explore the idea that energy is stored in food and discover that organisms must transform the energy in food in order for it to become usable. They come to realize that this is possible due to the chemical makeup of food.

Scholars continue to learn about energy acquisition in various organisms as they revisit two processes they are already familiar with: cellular respiration and photosynthesis. They gain a much deeper conceptual understanding of these processes and their stages, and they learn that many systems and their components must work together for organisms to undergo these remarkable processes.

In the Elaborate lessons, scholars apply their understanding of energy acquisition and biological systems in new contexts as they learn about the carbon cycle and how human activities such as factory farming impact the most important biological system of all: our planet. Then, they conclude the unit by sharing their newfound knowledge.

Why This Unit? In this unit, scholars make authentic connections between the disciplines of life, earth, and physical sciences, reinforcing their understanding that these branches of science are deeply interconnected. They build on their prior knowledge of photosynthesis and cellular respiration to deepen their understanding of how critical these processes are to life on Earth, and they are introduced to the idea that these processes are influenced by the chemical properties of their materials. The discoveries

made and connections drawn in this unit will benefit scholars greatly as they prepare for high school– and college-level science.

This unit also features an Essential Question that supports scholars in applying the content they study to real-world problems facing us today, including climate change and global food access. This reinforces their understanding of biological systems at the “macro” level.

What Is the Bottom Line?

Big Idea: Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter.

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

Big Idea: As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- Systems of specialized cells within organisms help them perform the essential functions of life.
- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. New water is also synthesized during this process.
- Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles.
- Photosynthesis and cellular respiration cycle carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Big Idea: Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- The availability of energy limits what can occur in any system.
- Although energy cannot be destroyed, it can be converted to less useful formsâ€” for example, to thermal energy in the surrounding environment.

How do Next Generation Science Standards practices and crosscutting concepts support mastery of the Big Ideas? Science and Engineering Practices highlighted in this unit:

- **Developing and Using Models**
    - Develop and/or use a model to predict and/or describe phenomena.

- **Constructing Explanations and Designing Solutions** (the Constructing Explanations portion)
    - Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
    - Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.

Crosscutting Concepts highlighted in this unit:

- **Energy and Matter**
    - Matter is conserved because atoms are conserved in physical and chemical processes.
    - Energy cannot be created or destroyedâ€” it only moves between one place and another place, between objects and/or fields, or between systems.
    - Energy drives the cycling of matter within and between systems.
- **Systems and System Models**
    - Systems may interact with other systems; they may have subsystems and be a part of larger complex systems.
    - Models can be used to represent systems and their interactionsâ€” such as inputs, processes, and outputsâ€” and energy, matter, and information flow within systems.

Safety

Plan carefully for safety in all lessons. The top safety risks in this unit include:

- In Lesson 2, scholars will conduct an experiment that requires an open flame. Ensure that scholars are aware of the risks associated with using the flame and understand how to conduct the experiment safely. Work with your manager to develop clear directions and ensure that scholars are aware of all necessary safety precautions that must be taken.
- In Lesson 2, scholars use matches. Ensure scholars are aware of how to work with these materials safely to avoid accidentally burning themselves, as well as what to do should they burn themselves. Ensure that scholars do not wear loose clothing or long jewelry, and long hair is tied back. Ensure that scholars wear proper personal protective equipment (PPE) as indicated in this lesson.
- In Lesson 2, scholars use different food products. Be conscious of the allergies your scholars have whenever using food products in the classroom. If scholars have severe allergies to the food needed for Lesson 2, you will need to find an alternative. Ensure that scholars wear proper PPE as indicated in this lesson.
- Lessons 4 and 7 require scholars to exert themselves physically (e.g., perform jumping jacks, repeatedly squeeze hand grip strengtheners). Ensure that you are aware of scholars' physical limitations and plan for accommodations as needed.
- Lessons 4 and 6 use bromothymol blue, a pH indicator solution. Review all safety information and the Safety Data Sheet for **bromothymol blue** and ensure that proper precautions are

taken before conducting this lesson. Ensure that scholars wear proper PPE as indicated in this lesson.

- Lesson 5 uses ethyl alcohol. Review all safety information and the Safety Data Sheet for **ethyl alcohol** to ensure that proper safety precautions are taken before conducting this lesson. Ensure that scholars wear proper PPE as indicated in this lesson.
- Lesson 5 uses baking soda. Review all safety information and the Safety Data Sheet for **baking soda** to ensure that proper safety precautions are taken before conducting this lesson. Ensure that scholars wear proper PPE as indicated in this lesson.

Important Note: These lesson plans highlight some of the safety risks you should be aware of while teaching these lessons. These safety suggestions are not meant to take the place of a formal science safety training. Please be sure to follow all safety rules from your district, as well as all local, state, and federal science safety guidelines.

Unit Storyline

Engage: What is the connection between energy, chemistry, and our food? Scholars begin to experience the real-world synthesis of multiple branches of science as they are introduced to this unit's Essential Question: How does the acquisition of energy relate to the health of a biological system?

- **Lesson 1: All Systems Go.** Scholars investigate how real-world problems facing aquaculture today may impact the natural world. As they draw connections between what organisms need to survive and the ecosystems in which they live, they begin to consider what a system is and how biological systems are affected by the ways in which humans and other living things acquire energy.

Explore: Scholars begin to lay a foundation for answering the Essential Question by digging deeper into the concept of "food" as well as the means through which organisms harness and transform energy. They also learn to identify biological systems at both the macro and micro levels.

- **Lesson 2: Chem: It's What's for Dinner.** Before scholars can even think about answering the Essential Question, they need to better understand it. They know we need food to survive and extract energy from the things we eat. But what is food, and what exactly is its relationship to energy? Scholars perform a calorimetry experiment to learn more. At the end of the lesson, they are introduced to the energy-carrying molecule used by their own cells: ATP.
- **Lesson 4: Cellular Respiration, Day One.** Scholars see an example of cellular respiration in action and draw on their prior knowledge to construct explanations for the phenomenon they are observing. They learn to view the cell as a biological system and consider how access to the materials needed for cellular respiration affects its health.
- **Lesson 5: Fabulous Photosynthesis, Day One.** Scholars complete a lab to observe the effects of photosynthesis. Recalling what they have learned in previous years, they define photosynthesis and identify its inputs and outputs. Then, they consider how the process is critical to cellular health.
- **A Note on Unit Structure:** Lessons 4 and 5 each consist of one "Explore" lesson and one "Explain" lesson. The recommended order for teaching these lessons is to complete two mini "Explore-Explain" cycles, teaching in the following order:
    - Lesson 4, Day 1 (Explore)

- Lesson 4, Day 2 (Explain)
- Lesson 5, Day 1 (Explore)
- Lesson 5, Day 2 (Explain)

Explain: Scholars learn about the interactions of charged particles, solving the mystery of what goes on in our bodies at the atomic level. Then, they get an in-depth look at both photosynthesis and cellular respiration. Building on their surface-level understanding from previous years, scholars learn that these two processes aren't just "opposites" (though their chemical equations might make it seem that way). By the end of the Explain, scholars will understand the importance of these processes and why biological systems at the cellular level depend on them.

- **Lesson 3: Subatomic Particles and Elements and Charges, Oh My!** Scholars now know that the synthesis of ATP is necessary for survival, but a huge question remains: How are the necessary reactions that result in the production of ATP actually able to take place in our bodies? Scholars study atomic structure, bonding, and electronegativity to fill in critical gaps and answer these questions!
- **Lesson 4: Cellular Respiration, Day Two.** Scholars conduct research using provided resources to learn more about cellular respiration and the major processes that comprise it. They come to realize how essential it is for organismal survival and tie this information to the Essential Question.
- **Lesson 5: Fabulous Photosynthesis, Day Two.** Scholars conduct research using provided resources to learn more about photosynthesis and the major processes that comprise it. By the end of this lesson, they emerge with a deepened understanding of how all of Earth's organisms rely on producers for survival.
- **Lesson 6: Photosynthesis and Cellular Respiration.** Scholars synthesize their discoveries from Lessons 4 and 5 by completing a lab that demonstrates the interdependence of photosynthesis and cellular respiration. By the end of this lesson, scholars will understand the unique role of each processâ€" and this knowledge will be crucial to answering the Essential Question.

Elaborate: These lessons are designed to help scholars draw connections between the acquisition of energy and the health of biological systems at the macro level. Scholars first extend and broaden their understanding, learning how organisms are able to produce energy in the absence of oxygen. Then, they take a deeper dive into the carbon cycle, drawing connections between climate change and agriculture and applying it to a real-life example: factory farming.

- **Lesson 7: No Oxygen, No Problem?** Scholars know what their bodies need and where it comes from. Now, they need to understand how their bodies actually do work and what happens if the materials for aerobic respiration are in short supply.
- **Lesson 8: The Carbon Cycle.** Scholars explore the connections between our use of energy and the delicate balance of the carbon cycle. By the end of this lesson, scholars will understand how high concentrations of carbon dioxide in the atmosphere affect biological systems on a broader scale and how humans have contributed heavily to this current issue.
- **Lesson 9: Factory Farming: Life-Saving Solution or Ecological Nightmare?** Access to food, our source of energy, is necessary for our survival. However, a lack of access to food has been a problem for decades, and it is only worsening globally. In the 1960s, scientists developed a potential solution that is still used today: factory farming. In this lesson, scholars apply their knowledge from throughout the unit to analyze factory farming and weigh its benefits against some unintended consequences.

Evaluate: Scholars use what they have learned throughout the unit to develop compelling responses to the Essential Question. They present their work to their peers, educating not only their classmates but also the broader school community.

- **Lesson 10: Spread the Word! (1–2 Days)** In small groups, scholars synthesize their newfound knowledge and create informational posters, brochures, or digital presentations to teach others about the connection between the acquisition of energy and the health of biological systems.

Extra Resources

In addition to the resources linked throughout the guide, use the following materials to help you prepare to launch this unit with scholars:

- **Printable Exit Tickets**
- **Printable Lab Notebook**