ScienceNews
EDUCATOR GUIDE

RANDALL DAVIS (IMAGE OBTAINED UNDER USFWS MARINE MAMMAL PERMIT NO. MA-043219 TO R. DAVIS)

August 14, 2021

How Muscle Cells Keep Otters Warm

SOCIETY FOR SCIENCE

SN EDUCATOR GUIDE

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About this Guide

In this Guide, based on the online *Science News* article "Sea otters stay warm thanks to leaky mitochondria in their muscles," students will learn about how mitochondria help the ocean's smallest mammal generate body heat. Then, students will discuss cell structure and energy production, diagram how mitochondria function and brainstorm a research question.

This Guide includes:

Article-based Comprehension Q&A — Students will answer questions about the online *Science News* article "Sea otters stay warm thanks to leaky mitochondria in their muscles," which explores scientists' efforts to figure out how the ocean's smallest mammal maintains an extreme metabolism. A version of the story, "How muscles keep otters warm," appears in the August 14, 2021 issue of *Science News*. Related standards include NGSS-DCI: HS-LS1; HS-PS1.

> **Student Comprehension Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Students will answer basic questions about cell structure and energy production, draw diagrams to visualize how mitochondria in sea otters may function differently than in other marine mammals and brainstorm a research question for further investigation. Related standards include NGSS-DCI: HS-LS1; HS-PS1.

> **Student Discussion Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

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Article-based Comprehension, Q&A

Directions for teachers: Ask students to read the online *Science News* "Sea otters stay warm thanks to leaky mitochondria in their muscles," which explores scientists' efforts to figure out how the ocean's smallest mammal maintains an extreme metabolism. A version of the story, "How muscles keep otters warm," appears in the August 14, 2021 issue of *Science News*.

1. What are sea otters? Describe the animals.

Sea otters are the ocean's smallest marine mammal. They are lean, meaning they have little body fat, and muscular.

2. What is metabolism? What surprised scientists about sea otters' metabolism while at rest?

Metabolism describes how food gets converted into cellular energy. While at rest, sea otters' metabolism is three times as fast as predicted for a mammal their size.

3. How do sea otters keep their metabolism at such high levels?

Sea otters eat a quarter of their body mass in food every day.

4. What is sea otters' average body temperature? How does metabolism relate to body temperature?

The rate at which food gets converted into energy in cells generates enough heat for sea otters to maintain an average body temperature of 37° Celsius.

5. What are mitochondria? How do mitochondria help sea otters' muscle cells generate heat?

Mitochondria are organelles in cells that generate energy. These structures pump protons across the organelle's inner membrane to store energy that can be used to power cells. Some of that energy can be lost as heat if protons leak back over the membrane before they can be used for work.

6. How do leaky mitochondria contribute to sea otters' extreme metabolism?

Sea otters need to eat more food to make up for the energy that was lost as heat, which revs up the animals' metabolism.

7. Is this heating method the main way that sea otters stay warm? When is the method probably used?

No, sea otters' cells probably use this method when the animals need more heat than usual to maintain their body temperature.

8. Why does ecophysiologist Terrie Williams say the finding could be a "game changer" for scientists' understanding of marine mammal evolution?

The finding is one of the clearest pieces of evidence yet for how some marine mammals regulate their body temperature.

9. What implications does the finding have for scientists' understanding of sea otter evolution?

In the future, the finding could help improve scientists' understanding of how sea otter ancestors evolved to live and thrive in the seas.

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Student Comprehension Worksheet

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Cross-curricular Discussion, Q&A

Directions for teachers:
This discussion requires that students have basic knowledge of cell structure and function. The first set of questions can be discussed as a class, or you could ask students to answer the questions with a partner. Then have students read the online *Science News* article "Sea otters stay warm thanks to leaky mitochondria in their muscles" and answer the second set of questions on their own. Ask students to answer the third set of questions with a partner, and then discuss the third set of questions as a class. A version of the story, "How muscles keep otters warm," appears in the August 14, 2021 issue of *Science News*.

Want to make it a virtual lesson? Post the online *Science News* article to your virtual classroom. Discuss the article and questions with your class on your virtual platform.

Defining a cell's powerhouse

1. List some of the main components, or organelles, found in many animal cells.

Nucleus, mitochondria, smooth endoplasmic reticulum, rough endoplasmic reticulum, golgi apparatus, peroxisome, lysosome.

2. Which organelle is in charge of energy production? Describe it.

Student answers will vary depending on each student's depth of knowledge. Students may say that mitochondria are double membrane-bound organelles that produce most of a cell's energy. Cells have differing numbers of mitochondria based on how much energy the cells need to function. Mitochondria have their own set of DNA.

3. How does that organelle produce energy? What type of energy is produced and how is that energy used?

Student answers will vary depending on each student's depth of knowledge. Generally, mitochondria use a process called cellular respiration to pump protons across their inner membrane to produce chemical energy in the form of a molecule called adenosine triphosphate, or ATP. During cellular respiration, energy from food is used to bond a phosphate group to adenosine diphosphate, or ADP, creating ATP. When the cell needs energy to power other biochemical reactions, the newly formed bond can be broken, releasing energy stored within the bond.

How sea otters do energy differently

1. Explain how mitochondria in the sea otters that scientists studied help keep the animals warm.

In animal cells, mitochondria pump protons across their inner membrane to create and store energy in the form of ATP. In the sea otters studied, instead of making ATP, some of the protons went back across the inner membrane, which released some of that energy as heat. This heat energy helps keep sea otters warm.

2. Draw a simple diagram of a sea otter's mitochondrion to visualize how the organelle generates heat as described by the *Science News* article. Then, draw a second diagram of a mitochondrion that belongs to a different species of marine mammal. This mitochondrion should not leak protons across its inner membrane. Use arrows to show the movement of heat energy in each diagram.

Student diagrams will vary, but the diagrams should show protons leaking back across the otter mitochondrion's inner membrane and heat being released from the mitochondrion. Diagrams of another animal's mitochondrion should show no protons leaking and no heat being released. Each mitochondrion diagram could show the production of ATP within the organelle.

3. Building on the diagrams you created, draw the body of a sea otter and the body of a larger marine mammal, such as a seal or a whale, around the appropriate mitochondrion. (Note: this drawing will not be to scale.) For the sea otter, draw and label at least one additional adaptation that the animal relies on to stay warm in cold ocean environments. For the other animal of your choice, draw and label an adaptation that the animal may use to keep warm, assuming that this animal does not have leaky mitochondria like sea otters do. Use arrows to represent the flow of heat energy from the animal to the ocean water. Explain your diagrams in the space below.

Student diagrams will vary. All sea otter mitochondrion diagrams should already show heat coming from the mitochondrion. Once students draw an otter around the mitochondrion, those arrows will show heat moving from the mitochondrion to the otter's body. Students should add another set of arrows to the updated diagram that shows heat going from the sea otter's body to the ocean water. An additional adaptation that sea otters use to stay warm is a thick fur coat.

If students choose to draw a seal or a whale, there should be no heat arrow going from the mitochondrion to the mammal's body. There could be a layer of blubber drawn on the outside of the animal with an arrow indicating that the blubber layer keeps some heat inside the body. Since sea otters lose heat faster than seals and whales do, because the otters' bodies are smaller and have less surface area, arrows in the sea otter diagram should be larger than the arrows in the seal or whale diagram.

4. Name an alternative adaptation that might have helped sea otters stay warm in cold water. Had the adaptation occurred, how might it have affected sea otters' bodies and behavior?

Otters could have packed on more body fat to minimize the amount of heat their bodies lose to cold water. If that alternative adaptation had occurred, sea otters might be larger and/or slower swimmers.

What comes next?

1. What are some questions the scientists in the article have about the outcomes of the study?

Scientists don't know what triggers sea otters' mitochondria to leak protons, and they don't know whether the trait is genetic or whether it develops from environmental exposure over time.

2. What is a question you have about the study and/or its implications?

Student answers will vary but could mention the methods of the study, possible explanations of the results and whether or not other species also have leaky mitochondria.

3. Brainstorm a research question that would help answer your questions or those of the scientists.

Student answers will vary.

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Student Discussion Worksheet

Directions: Answer the first set of questions as directed by your teacher, then read the online *Science News* article "Sea otters stay warm thanks to leaky mitochondria in their muscles." Answer the second set of questions on your own and then work with a partner to answer the third set of questions. A version of the story, "How muscles keep otters warm," appears in the August 14, 2021 issue of *Science News*.

Defining a cell's powerhouse

1. List some of the main components, or organelles, found in many animal cells.

2. Which organelle is in charge of energy production? Describe it.

3. How does that organelle produce energy? What type of energy is produced and how is that energy used?

How sea otters do energy differently

1. Explain how mitochondria in the sea otters that scientists studied help keep the animals warm.

2. Draw a simple diagram of a sea otter's mitochondrion to visualize how the organelle generates heat as described by the *Science News* article. Then, draw a second diagram of a mitochondrion that belongs to a different species of marine mammal. This mitochondrion should not leak protons across its inner membrane. Use arrows to show the movement of heat energy in each diagram.

3. Building on the diagrams you created, draw the body of a sea otter and the body of a larger marine mammal, such as a seal or a whale, around the appropriate mitochondrion. (Note: this drawing will not be to scale.) For the sea otter, draw and label at least one additional adaptation that the animal relies on to stay warm in cold ocean environments. For the other animal of your choice, draw and label an adaptation that the animal may use to keep warm, assuming that this animal does not have leaky mitochondria like sea otters do. Use arrows to represent the flow of heat energy from the animal to the ocean water. Explain your diagrams in the space below.

4. Name an alternative adaptation that might have helped sea otters stay warm in cold water. Had the adaptation occurred, how might it have affected sea otters' bodies and behavior?

What comes next?

1. What are some questions the scientists in the article have about the outcomes of the study?

2. What is a question you have about the study and/or its implications?

3. Brainstorm a research question that would help answer your questions or those of the scientists.