

ASPECT

Assessing Students' Progress on the Energy Concept

Hibernating Bear: AP31-6

Middle school – Energy and Chemical Reactions

TASK OVERVIEW

Students are presented with a scenario in which bears are going into hibernation. They are asked to create a model that represents the chemical reaction happening inside the bear that is involved in releasing energy to the bear. Students are tasked with using their model to explain why bears lose weight during hibernation.

TARGETED DCIs, SEPs, AND CCCs

Disciplinary core ideas

- PS3.D-M.2: Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.

Science & engineering practices

- SEP2-M.6: Develop a model to describe unobservable mechanisms.
- SEP6-M.2: Construct an explanation using models or representations.

Crosscutting concepts

- CC5-E.2: Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the

substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems.

- CC4-M.2: Models can be used to represent systems and their interactions-such as inputs, processes, and outputs-and energy, matter, and information flows within systems.

Related Performance Expectations

- MS-LS1-7: Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. [*Clarification Statement:* Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [*Assessment Boundary:* Assessment does not include details of the chemical reactions for photosynthesis or respiration.]

TASK PERFORMANCE EXPECTATION

Create a model that describes how the unobservable process of cellular respiration results in the bear's obtaining energy during hibernation. Use a model to explain how matter flows into and out of a bear during hibernation results in the bear's losing mass.

LINK TO ONLINE VERSION

<http://assess.bsos.org/i/test/602> (Along with AP42-6 & AP59-4)

Task

Prior to winter, black bears eat large quantities of food and gain up to 30 pounds of additional body weight. The food that the bears eat is made up of carbon-containing molecules such as glucose, carbohydrates, fats, and proteins. When winter begins, the bears go into dens or caves to hibernate. After several months of hibernation, they wake up and leave their dens. Scientists who study hibernating bears have found that bears lose a quarter of their body weight during hibernation.



Black bear den, NPS Photo / Harlan Kredit

Observations of hibernating bears show that they breathe in and out during hibernation, but they do not eat, drink, or "go to the bathroom."

How is it possible for bears to stay alive during hibernation if they don't eat anything?

Let's start with the observation that the bear is still breathing in and out during hibernation, which means that there is matter flowing into and out of the bear during hibernation.

-
1. Which of the following molecules are being breathed in by the bear during hibernation? Choose all that apply.
 - A. Molecules of oxygen
 - B. Molecules of carbon dioxide
 - C. Molecules from the food the bear ate before hibernating
 - D. Molecules of water
-
2. Which of the following molecules are being breathed out by the bear during hibernation? Choose all that apply.
 - A. Molecules of oxygen
 - B. Molecules of carbon dioxide
 - C. Molecules from the food the bear ate before hibernating
 - D. Molecules of water
-

We also know that during hibernation bears are getting the energy they need to stay warm and survive the winter. This energy comes from a chemical process called cellular respiration that goes on inside the bears' bodies.

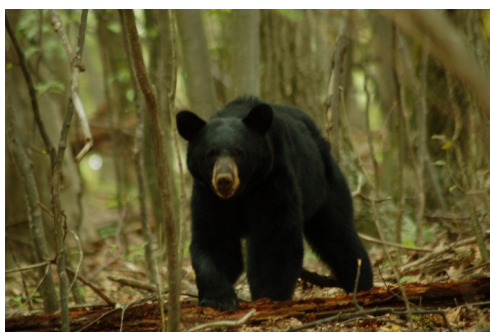
-
3. How is breathing related to cellular respiration? To help show your thinking on this question, create a diagram in the space below. The diagram should clearly show what molecules are reacting and what molecules are being produced during cellular respiration.

In your diagram, consider the bear to be a system with inputs and outputs. Your diagram should include:

- A boundary separating what is inside and outside the bear
- The matter that enters and leaves the bear as the bear breathes in and out during hibernation



-
4. Explain how breathing is related to cellular respiration. Be sure to link the molecules that the bear breathes in and out to the cellular respiration process.



A. Drauglis / flickr

-
5. Now think about the fact that the bear loses weight during hibernation. Use your diagram to write an explanation for what caused a bear to decrease in mass during hibernation. Think about the difference in masses of the molecules the bear breathes in and out during hibernation. Be sure to refer to your diagram in your explanation.
-

Alignment to Targeted DCIs, SEPs, and CCCs and Scoring Rubrics

QUESTION 1

Which of the following molecules is the bear breathing in during hibernation? Choose all that apply.

- A. Molecules of oxygen
- B. Molecules of carbon dioxide
- C. Molecules from the food the bear ate before hibernating
- D. Molecules of water

LEARNING GOAL

Learning Performance

- Consider the relevant inputs to the bear system

Targeted DCIs, SEP, and CCC

- CC4-M.2: Models can be used to represent systems and their interactions-such as inputs, processes, and outputs-and energy, matter, and information flows within systems.

SCORING RUBRIC

Elements of a Correct Response

Categories	Elements
Student selects the correct multiple-choice answer	A. Molecules of oxygen

This item is used for scaffolding and is not scored

QUESTION 2

Which of the following molecules is the bear breathing out during hibernation?
Choose all that apply.

- A. Molecules of oxygen
- B. Molecules of carbon dioxide
- C. Molecules from the food the bear ate before hibernating
- D. Molecules of water

LEARNING GOAL

Learning Performance

- Consider the relevant outputs from the bear system

Targeted DCIs, SEP, and CCC

- CC4-M.2: Models can be used to represent systems and their interactions-such as inputs, processes, and outputs-and energy, matter, and information flows within systems.

SCORING RUBRIC

Elements of a Correct Response

Categories	Elements
Student selects the correct multiple-choice answer	B. Molecules of carbon dioxide D. Molecules of water

This item is used for scaffolding and is not scored.

QUESTION 3

How is breathing related to cellular respiration? To help show your thinking on this question, create a diagram in the space below. The diagram should clearly show what molecules are reacting and what molecules are being produced during cellular respiration.

In your diagram, consider the bear to be a system with inputs and outputs. Your diagram should include:

- A boundary separating what is inside and outside the bear
- The matter that enters and leaves the bear as the bear breaths in and out during hibernation



LEARNING GOAL

Learning Performance

- Create a diagram that illustrates relationships between the inputs and outputs to the bear and the process by which the bear gets energy.

Targeted DCIs, SEP, and CCC

- PS3.D-M.2: Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.
- SEP2-M.6: Develop a model to describe unobservable mechanisms.
- CC4-M.2: Models can be used to represent systems and their interactions-such as inputs, processes, and outputs-and energy, matter, and information flows within systems.

SCORING RUBRIC


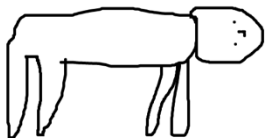

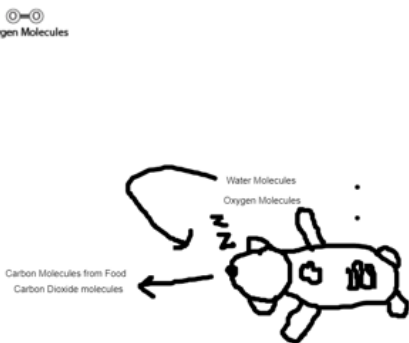
Ideal Response

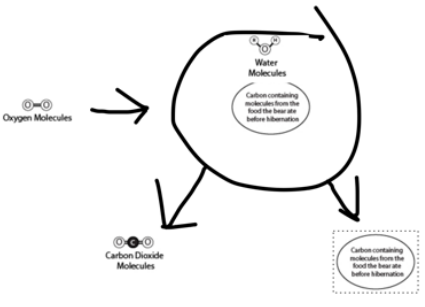

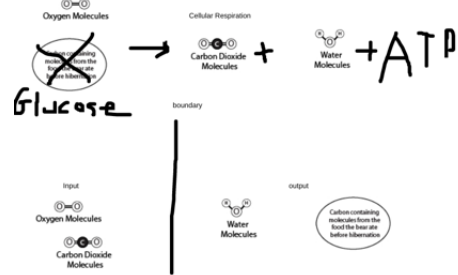
Students draw a boundary (such as a circle) that represents the bear system and include oxygen flowing into the system (representing the bear's breathing in) and carbon dioxide leaving the system (representing the carbon dioxide the bear breaths out). Their model also indicates that inside the bear oxygen molecules react with molecules of food to form carbon dioxide and water molecules and this reaction releases energy.

Elements of a Correct Response

Categories	Elements
Student's model includes boundaries between systems	<ul style="list-style-type: none">Model includes a boundary separating the inside of the bear from the surroundings
Student's model includes the essential components including inputs and outputs	<ul style="list-style-type: none">Model includes glucose/carbon containing molecules as a component of the bear system.Model includes oxygen as an input into the bear system.Model includes carbon dioxide as an output from the bear system.Model includes water as an output from the bear system. <p><u>Note:</u> The DCI does not explicitly mention that water is a product. So, it is up to the user to decide if water being a product is an essential element of a correct response.</p>
Student's model shows the interactions between components	<ul style="list-style-type: none">The model shows atoms in molecules rearranging to form different molecules by showing that the reactant molecules are different than the product molecules, typically by using an arrow that points from the reactants to the products.

Sample Student Responses

Student response	Scoring description
	<p>Score = 0</p> <p>The model does not include any of the elements of the rubric.</p>
	<p>Score = 1</p> <p>The model includes boundaries for the bear system but does not include any components or interactions.</p>
	<p>Score = 2</p> <p>The model includes boundaries for the bear system and oxygen as an input into the system.</p>
	<p>Score = 3</p> <p>The model includes boundaries for the bear system, oxygen as an input, and carbon dioxide as an output.</p>

	<p>Score = 4</p> <p>The model includes boundaries for the bear system, glucose as a component of the system, oxygen as an input, and carbon dioxide as an output. The model does not show atom rearrangement during the chemical process.</p>
	<p>Score = 5</p> <p>The model includes the essential components and interactions but does not clearly define the boundaries of the system.</p>
	<p>Score = 6</p> <p>The model includes all the elements in the rubric.</p>

QUESTION 4

Explain how breathing is related to cellular respiration. Be sure to link the molecules that the bear breathes in and out to the cellular respiration process.

LEARNING GOAL

Learning Performance

- Explain how a bear breathing in oxygen and breathing out carbon dioxide is related to the chemical process happening inside the bear that gives it energy.

Targeted DCIs, SEP, and CCC

- PS3.D-M.2: Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.
- SEP6-M.2: Construct an explanation using models or representations.
- CC4-M.2: Models can be used to represent systems and their interactions-such as inputs, processes, and outputs-and energy, matter, and information flows within systems.

SCORING RUBRIC

Ideal Response

Some of the matter that the bear breathes in is oxygen molecules that are used as a reactant in the reaction that provides the bear energy. Some of the matter that the bear breathes out is carbon dioxide and water molecules that are the products of the reaction that provides the bear energy.

Elements of a Correct Response

Categories	Elements
Student states or uses a general science idea	<ul style="list-style-type: none">• Oxygen molecules that are breathed in are reactants of cellular respiration.• Carbon dioxide molecules that are breathed out are products of cellular respiration.• Water molecules that are breathed out are products of cellular respiration. <p><u>Note:</u> The DCI does not explicitly mention that water is a product. So, it is up to the user to decide if water being a product is an essential element of a correct response.</p>

Sample Student Responses

Student response	Scoring description
"Breating is related because you take in oxygen and breathe out carbon diaxide."	Score = 0 The response does not explain how breathing is related to cellular respiration.
"breathing helps us get oxygen to perform cellular respiration"	Score = 1 The response describes how the oxygen breathed in is a reactant in cellular respiration.
"When you breathe in, you take the oxygen needed for cellular respiration. When you breathe out, you get rid of carbon dioxide produced by the cellular respiration."	Score = 2 The response describes that the oxygen breathed in is used as a reactant and the carbon dioxide breathed out is a product, but it does not include the role water plays.
"We need oxygen and glucose to perform cellular respiration so we intake oxygen through breathing. When cellular respiration is complete, the products are ATP, water, and CO ₂ . Since CO ₂ is bad for humans, our exhale is what gets the CO ₂ out our bodies."	Score = 3 The response includes all the elements of the rubric.

QUESTION 5

Now think about the fact that the bear loses weight during hibernation. Use your diagram to write an explanation for what caused a bear to decrease in mass during hibernation. Think about the difference in masses of the molecules the bear breathes in and out during hibernation. Be sure to refer to your diagram in your explanation.

LEARNING GOAL

Learning Performance

- Use a model to construct (or identify) an explanation for how the bear lost weight during hibernation by considering the difference in mass between the inputs and outputs of the bear.

Targeted DCIs, SEP, and CCC

- PS3.D-M.2: Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials.
- SEP6-M.2: Construct an explanation using models or representations.
- CC5-E.2: Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems.
- CC4-M.2: Models can be used to represent systems and their interactions-such as inputs, processes, and outputs-and energy, matter, and information flows within systems.

SCORING RUBRIC

Ideal Response

During hibernation bears breathe in oxygen and breath out carbon dioxide. Carbon dioxide (CO_2) has more mass than oxygen (O_2) since it contains a carbon atom in addition to two oxygen atoms. The breathing in of oxygen and out of carbon dioxide results in a net loss of mass for the bear as carbon atoms leave the bear. Over time this results in the bear's losing weight.

OR

During hibernation the bear breathes in oxygen which reacts with carbon-containing molecules that were already part of the bear system. Carbon atoms from these carbon-containing molecules are used to form carbon dioxide which leaves the bear system when the bear breathes out. During this process, atoms that were once a part of the bear leave the bear's body which means it loses mass.

Elements of a Correct Response

Categories	Elements
Student makes a claim that answers the question	<ul style="list-style-type: none"> The bear decreased in mass/lost weight because <ul style="list-style-type: none"> Matter/atoms that was/were once part of the bear's body left/is no longer part of the bear's body. the bear exhaled more mass than it took in. <p><u>Note:</u> Students who explicitly state that matter is destroyed or not conserved should not receive the claim point.</p>
Student uses the crosscutting concept about the flow of matter into and out of a system to provide evidence.	<ul style="list-style-type: none"> The bear breathes in oxygen molecules. The bear breathes out carbon dioxide molecules. The bear breathes out water molecules. (optional)
Student states or uses science ideas	<ul style="list-style-type: none"> Carbon dioxide has more mass than oxygen. Carbon-based food molecules already inside the bear are involved in a reaction (that produces carbon dioxide).
Student uses reasoning to link crosscutting concepts to the claim	<ul style="list-style-type: none"> There is a net loss of mass (weight, atoms, or matter) from the bear during hibernation because oxygen is entering the bear and carbon dioxide is leaving the bear, and carbon dioxide is heavier than oxygen. <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> The carbon atoms that leave the body as part of carbon dioxide came from carbon-based molecules that were part of the bear's body, therefore, there is a net loss of mass (weight or atoms are also acceptable) from the bear during hibernation.

Sample Student Responses

Student response	Scoring description
"I would say that during hibernation the bear would lose weight because the bear is not eating and drink but if the bear just sleeps its not get the energy that it need to survie the winter"	Score = 0 The response does not use ideas about cellular respiration; instead it describes that the weight loss is caused by not eating or drinking.
"The bear will breathe out more molecules over time by breathing in oxygen and carbon dioxide, but also by breathing out that same carbon dioxide."	Score = 1 The response only includes the crosscutting concept about the flow of matter into and out of the bear system.
"The bear doesn't eat causing it to lose weight, along with the oxygen combining with the food molecules to come out of the bear causing it to lose weight"	Score = 2 The response includes a claim and the idea that oxygen reacts with food molecules and that the product of those reactions leave the bear.
"The bear isn't consuming any fuel during hibernation. Therefore, while it takes in oxygen, the fuel from the food was already in the bear's system. When oxygen and fuel react to produce water and carbon dioxide, the bear is outputting the matter from both the oxygen it took in and the fuel supply."	Score = 3 The response includes crosscutting concepts of inputs and outputs, science ideas about cellular respiration and reasoning, but it does not include an explicit claim that links the output of matter to mass loss.
"As shown within my diagram, molecules from the food the bear ate and carbon dioxide molecules leave the bear as it breathes in hibernation. The molecules from the food the bear ate will have a larger mass than the oxygen and water the bear is breathing in, therefore there is more mass leaving the bear than there is entering the bear, and therefore the bear loses weight."	Score = 4 The response includes all the elements in the rubric.

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A180512 to BSCS Science Learning. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

