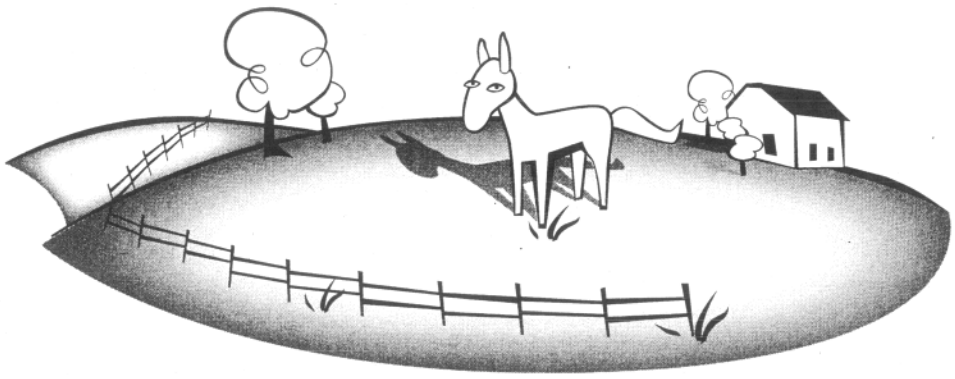
Respiration



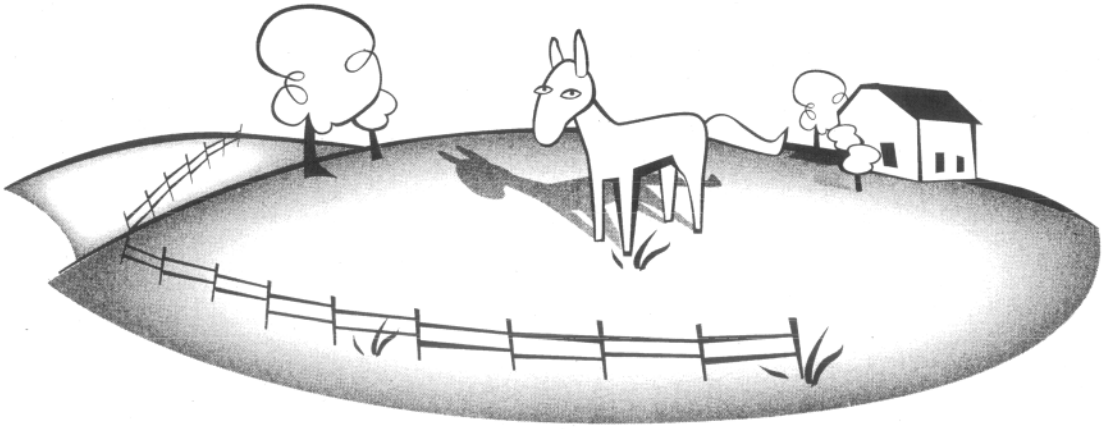
Put an X next to the organisms on the list that use the process of respiration.

____ human	____ grass	____ duck
____ frog eggs	____ mushroom	____ tomato plant
____ fish	____ chick inside an egg	____ human body cell
____ germinating seed	____ horse	____ apple tree
____ worm	____ single-celled pond organism	____ honeybee
____ bacteria		
____ butterfly larvae inside a chrysalis		

Explain your thinking. How did you decide whether an organism uses the process of respiration?

Respiration

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about respiration. The probe is designed to find out whether students recognize respiration as a process that all living things use in order to obtain energy or whether they have a restricted macroscopic meaning of respiration.

Related Concepts

cellular respiration, respiratory system

Explanation

Everything on the list uses the process of respiration. Respiration is an essential life process carried out by all living organisms—from single-celled to multicelled—to provide the energy that organisms need to function. Aerobic respiration happens at two levels. At the organism level, it generally involves taking in the air that contains the oxygen needed by cells and eliminating carbon dioxide from the body. At the cellular level, the oxygen is used to break down molecules of food in order to release the energy needed by cells to function. Carbon dioxide is released by the cell as a waste product.

Most people, including students, commonly understand that animals with some form of a respiratory system breathe in oxygen from the air through their respiratory systems and breathe out carbon dioxide. They usually equate the gas exchange during aerobic respiration with breathing rather than a cellular process. All animals respire, but they are not the only organisms to do so. Because every living organism is composed of at least one cell, and all cells need energy to function, then every

organism must carry out some form of cellular respiration regardless of whether it has a respiratory system that includes organs such as lungs or gills.

While different types of organisms may perform respiration in different ways, all organisms use respiration to release energy through the breakdown of molecules within a cell. Aerobic respiration involves an interchange of gases between an organism and its environment. Sometimes this interchange involves multicelled structures (e.g., organs) in an organism that take in oxygen and make it available to the cells. For example, plants take in oxygen through their leaves and animals take in oxygen through their lungs or gills where it is sent to and used within their cells to break down sugars (food) to release energy. Single-celled organisms can absorb oxygen into a cell directly from the environment. Respiration can also occur in the absence of oxygen. This type of anaerobic respiration occurs with some types of bacteria and fungi as well as in the muscle cells of animals when there is a lack of oxygen.

Organisms in an immature stage of development, such as the butterfly larvae in a chrysalis, frog eggs, and a chick developing inside an egg, also respire by taking oxygen, making it available to their cells, and releasing energy from food molecules. They are all living things that need energy to develop. Under the right conditions of temperature and moisture, seeds respire by taking in oxygen, although they can be dormant for long periods of time before germination. Plants utilize oxygen in the process of respiration. They also take in carbon dioxide and release oxygen in the process of photosynthesis. However, these two processes are not opposites nor are they mutually exclusive. Respiration in plants also happens during photosynthesis.

Curricular and Instructional Considerations

Elementary Students

At the elementary school level, students distinguish between living and nonliving things and learn that most living things need air. Respiration at this level is usually equated with breathing and focuses on familiar structures of animals and plants that take in oxygen, such as lungs, gills, and leaves. As students investigate single-celled organisms, they learn that these simple organisms also need air.

Middle School Students

In middle school, students continue to learn about various structures that take in oxygen and make it available to cells, including the structures of insects and aquatic organisms. At this level, they begin to connect the taking in of oxygen to the needs of cells, developing a basic understanding of cellular respiration without going into the details of cell structure and biochemical processes. Students connect the need of cells for oxygen to their growing understanding of oxidation as a process that releases energy from food within cells. At this stage, students should begin to develop the generalization that all organisms respire, since energy is needed by all living things.

High School Students

In high school biology class, students build on their basic middle school understanding of cellular respiration to examine the process at the cellular and molecular level, including the eukaryotic structures involved, such as mitochondria as well as prokaryotic cellular respiration. They learn about and distinguish between the processes of aerobic respiration and anaerobic respiration. However, at this level, as students learn about the process of photosynthesis in more detail, some may believe that only animals respire and that photosynthesis is the opposite process in plants.

Administering the Probe

Eliminate items from the list that students may not be familiar with, or explain each one, showing pictures if they are unsure as to what the organism is. For elementary school students who are not expected to know about cellular respiration, consider adapting this probe by using familiar language, such as, "Does it use air?" and reducing the number of choices. For high school students, consider adding other nonanimal choices, such as "algae" and "virus," and replace "human body cell" with specific types of cells.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 The Characteristics of Organisms

★ Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light.

5–8 Structure and Function in Living Systems

★ Cells carry out the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or organism needs.

9–12 The Cell

- Cells have particular structures that underlie their functions. Inside the cell is a concentrated mixture of thousands of different molecules that form a variety of different structures that carry out such cell functions as energy production.

9–12 Matter, Energy, and Organization in Living Systems

- Living systems require a continuous input of energy to maintain their chemical and physical organizations.
- The chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken down and new compounds with lower energy bonds are formed.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993)

K–2 The Cell

★ Most living things need water, food, and air.

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

3–5 The Cell

★ Some living things consist of a single cell. Like familiar organisms, they need food, water, and air; a way to dispose of waste; and an environment they can live in.

3–5 The Human Organism

- By breathing, people take in the oxygen they need to live.

6–8 The Cell

- Within cells, many of the basic functions of organisms, such as extracting energy from food and getting rid of waste, are carried out. The way in which cells function is similar in all living organisms.

6–8 Flow of Matter and Energy

★ Animals get energy from oxidizing their food, releasing some of its energy as heat.

6–8 The Human Organism

★ To burn food for the release of energy stored in it, oxygen must be supplied to cells and carbon dioxide must be removed. Lungs take in oxygen for the combustion of food and they eliminate the carbon dioxide produced.

9–12 The Cell

- Within every cell are specialized parts for the transport of materials, energy transfer, protein building, waste disposal, information feedback, and even movement.

Related Research

- Although students have ideas about gas exchange and usually equate it with breathing, few students at any age have a complete understanding of respiration (Driver et al. 1994).
- In a study by Haslam and Treagust (1987), most students thought respiration and breathing were synonymous.
- Studies have found that although young children recognize air as being necessary for life, they have limited understanding of what happens to air once it is inhaled. Many think only organisms with lungs use air. Few students, all the way through high school, connect food with the use of oxygen (Driver et al. 1994).
- Some students think oxygen is the gas needed by animals and carbon dioxide is the gas needed by plants. Some students think photosynthesis is the plant version of energy release or that respiration only happens in animals (Driver et al. 1994).
- Some students think plants only use oxygen (respire) in the dark (Driver et al. 1994).

Suggestions for Instruction and Assessment

- When teaching students the idea that organisms need air (or oxygen), explicitly address the variety of ways that organisms take in air (or oxygen) so that students do not equate exchange of gases only with animals that have lungs. Furthermore, when students learn about various structures that allow multicellular organisms to take

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

in oxygen, be sure to address how single-celled organisms also take in oxygen.

- Photosynthesis is not the opposite of respiration. The intake and release of gases in the two processes is opposite, but the processes themselves are not opposites. Teaching this idea of opposites may perpetuate the notion that animals use oxygen (and thus respire) and plants do not and that gas flow in plants always happens in opposite directions.
- For students in middle school, explicitly connect the idea of cells taking in oxygen to the need to release energy from food.
- Be careful when using a burning analogy to describe how energy is released from food. Oxidation reactions involving food are not combustion reactions.
- The idea that seeds, frog's eggs, and the chrysalis of a butterfly do not respire or use air may be connected to students' ideas about living or nonliving. In order to accept the idea that these stages in an organism's life respire or need air, they need to accept that they are living stages. It may be useful to combine this probe with the probe from Volume 1 of this series, "Is It Living?" (Keeley, Eberle, and Farrin 2005).

Related NSTA Science Store Publications and Journal Articles

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London and New York: RoutledgeFalmer.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

Littlejohn, P. 2007. Building leaves and an understanding of photosynthesis. *Science Scope* 8 (30): 22–25.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

Related Curriculum Topic Study Guide

(Keeley 2005)
"Photosynthesis and Respiration"

References

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

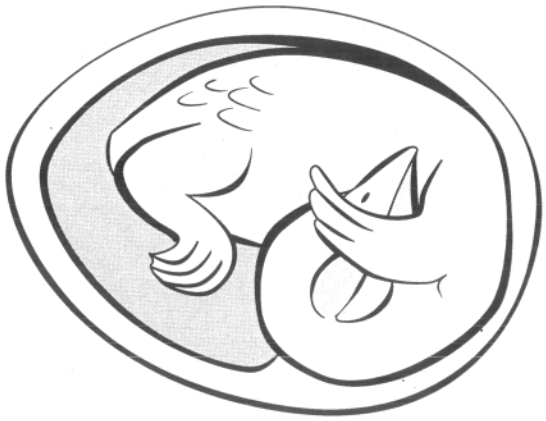
Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London and New York: RoutledgeFalmer.

Haslam, F., and D. Treagust. 1987. Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education* 21 (3): 203–211.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

Keeley, P., F. Eberle, and L. Farrin. 2005. *Uncovering student ideas in science: 25 formative assessment*

Chicken Eggs



The students in Mrs. Bartoli's class were studying how chickens develop from an egg. The students put a dozen freshly laid, fertilized chicken eggs in an incubator. They wondered what would happen to the mass of an egg as the chick inside developed. This is what the students thought:

Group A: "We think an egg will gain mass. An egg's mass is more just before hatching than when the egg was laid."

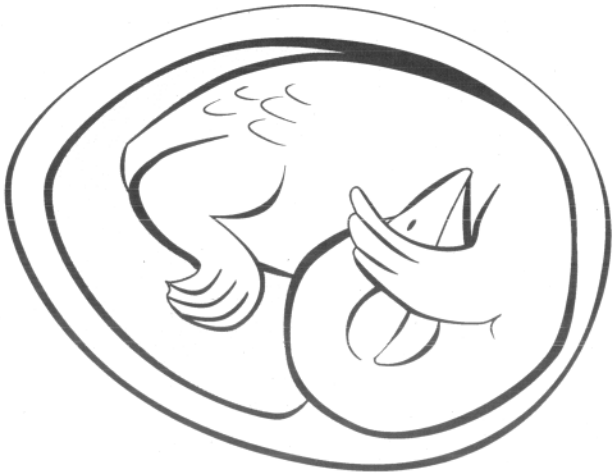
Group B: "We think an egg will lose mass. An egg's mass is less just before hatching than when the egg was laid."

Group C: "We think the mass of an egg stays the same as the chick develops inside."

Which group do you most agree with? Explain your thinking.

Chicken Eggs

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about food, transformation of matter, growth and development, conservation of mass, and systems. The concepts underlying this probe are complex. It is not important that students know exactly what happens to the mass of an egg and why. Rather, this probe is used as an interesting context to draw out their ideas about several interrelated concepts in science.

Related Concepts

conservation of matter, embryo development, food, system, transformation of matter

Explanation

The best answer is Group B's: "We think an egg will lose mass. An egg's mass is less just before hatching than when the egg was laid." During normal incubation, chicken eggs lose approximately 16%–18% of their original mass (Snyder and Birchard 2005). On an average, bird eggs from small hummingbirds to large ostriches lose 15% of their original weight. This weight loss is primarily the result of water vapor passing through the permeable eggshell. Water vapor is a waste product of metabolism.

The egg yolk serves as food for the developing embryo inside. This food is used for the energy the embryo needs to carry out life processes, such as respiration. During respiration, carbon dioxide and water vapor are released as waste products. Molecules from the food are converted into the building material the embryo needs for growth and development.

Intuitively it would seem that the egg would weigh more after the chick has devel-

oped inside. The liquid matter (yolk and "white part") inside the freshly laid egg is transformed into the body tissues of the embryo, which continues to grow and develop as cells divide. The yolk provides the energy and source of building material the chick needs for its development. Although oxygen does diffuse through the porous cell and is used during respiration, most of the material the embryo needs for development is packaged inside the cell at the time it is laid. Because the eggshell is permeable to gases, oxygen enters into the egg through the shell and some water vapor diffuses through the eggshell to the outside environment. If the eggshell were a perfect closed system, there would be no change in mass.

It is not important that students know that an egg can lose a significant percentage of its original mass. What is significant is that they recognize that matter is conserved during the transformation of the egg material and development of the chick but that some of this matter may escape through the egg because it is not a closed system.

Curricular and Instructional Considerations

Elementary Students

In the elementary grades, students study the life cycles of different organisms. Incubating chicken eggs is a common activity in some classrooms. Students at this level can examine eggs, learning that developing embryos, like all animals, need food and that the yolk is the source of the embryo's food. However, the more complex notion of food being transformed into the body material of the embryo should wait until middle school.

Middle School Students

In the middle grades, students develop a scientific conception of what food is and how it provides energy as well as building material for organisms. At this level, students can begin to understand the transformation of the yolk into the body material of the developing chick as a result of chemical reactions and cell division. They also develop the idea of open versus closed systems and can use this idea to consider whether some materials can diffuse in and out of living and nonliving membranes or other porous materials.

High School Students

At this level, students investigate more complex ideas about embryology, chemical processes of metabolism, and passage of materials in and out of an open system. They should know about the breakdown and recombination of molecules during biochemical changes and how matter is conserved in each of these changes. They should recognize the semipermeable nature of membranes and porosity of other seemingly impermeable materials and explain how and why materials pass from an internal to external environment or vice versa.

Administering the Probe

This probe can be accompanied by a visual representation that shows the changes inside a chicken egg at different stages of development.

However, be aware that the representation may reinforce the misconception that the egg would weigh more because it looks like there is more "stuff" inside the egg with the late stage embryo compared with the freshly laid egg that contains mostly liquid-like matter. When used as a discussion prompt, this probe can lead to a very lively discussion and argument among students that elicits ideas about food, conservation of matter, transformations, role of gases, and open and closed systems.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 The Characteristics of Organisms

- Organisms have basic needs—for example, animals need air, water, and food.

K–4 Life Cycles of Organisms

- Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying.

5–8 Structure and Function in Living Systems

- Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells.

5–8 Properties and Changes of Properties in Matter

- In chemical reactions, the total mass is conserved.

5–8 Regulation and Behavior

- All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing environment.

9–12 Cells

- Every cell is surrounded by a membrane that separates it from the outside world.
- ★ Most cell functions involve chemical reactions. Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules.
- In the development of multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues, and organs that make up the final organism.

9–12 Matter, Energy, and Organization in Living Systems

- ★ As matter and energy flow through different levels of organization of living systems—cells, organs, organisms, and communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993 and 2008)

K–2 Flow of Matter and Energy

- Plants and animals both need to take in water, and animals need to take in food.

3–5 Flow of Matter and Energy

- Some source of "energy" is needed for all organisms to stay alive and grow.

6–8 Structure of Matter

★ No matter how substances within a closed system interact with one another or how they combine or break apart, the total mass of the system remains the same. The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how the same atoms are rearranged, then their total mass stays the same.

6–8 Cells

- Cells repeatedly divide to make more cells for growth and repair.
- About two-thirds of the weight of cells is accounted for by water, which gives cells many of their properties.

6–8 Flow of Matter and Energy

★ Food provides molecules that serve as fuel and building material for all organisms.

9–12 Cells

- Every cell is covered by a membrane that controls what can enter and leave the cell.

Related Research

- Field tests of this probe with middle and high school students reveal that most students think the mass will be greater because the chick inside the egg is getting bigger. Some students use conservation reasoning to say the mass stays the same. Although their ideas about conservation of mass during the transformation of matter are correct, they fail to consider whether the egg is a closed system.
- Some students use an intuitive rule of "more A, more B" (Stavy and Tirosh 2000). They reason that if the chick gets bigger inside the egg, then the mass or weight of the egg increases.
- Children often do not recognize that food is the material basis for growth—that is, that the food becomes transformed and incorporated into the body, thus making the body bigger (Driver et al. 1994).
- In a study conducted by Russell and Watt (1989), elementary children assumed that the growth inside an egg is associated with an increase in mass within what they assumed was a closed system. They described the process of growth as creating new material rather than transforming material (yolk) that was in the egg. Only a very small minority considered some type of transformation of the contents inside the egg into a complete chick.
- Some ideas about embryonic development contribute to students' notions about what is happening inside the egg. Some children believe that the chick had always been there

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

inside the egg waiting until it was time to hatch. Others thought all the parts of the chick were there when the egg was laid and that they came together in the egg (Driver et al. 1994).

Suggestions for Instruction and Assessment

- This probe can be used as a P-E-O probe (Predict, Explain, Observe) with activities that involve egg incubation. Have students predict what would happen to the mass of the eggs as the eggs develop over the course of their incubation. Have students explain the reasons for their predictions. Then have students test their ideas and observe the decrease in mass. Encourage students to come up with alternative explanations to account for the discrepancy between their predictions and their observations.
- Probe further to find out students' conceptions of an open versus closed system in relation to the egg. One way to show that water can pass through an egg shell is to place a raw egg in corn syrup. The mass of the egg in corn syrup will decrease because water from inside the egg flows through the membrane and shell into the syrup. It moves from a higher concentration inside the egg to a lower concentration in the corn syrup. The corn syrup molecules are too large to pass into the egg. You can also try this with molasses. Careful observations will reveal a thin layer of water resting on top of the molasses.
- Find the mass of a raw egg and leave it in a warm, dry area for two to three weeks. Find the mass of the egg again, noticing a decrease in mass. Encourage students to propose ideas about where the loss in mass came from. Did anything leave the egg?
- *Safety caution:* Always have students wash their hands after handling eggs.
- Use a graphic of a chick embryological development such as the one at *http://msucares.com/poultry/reproductions/poultry_chicks_embryo.html* (Mississippi State University Extension Service 2004). Have students propose ideas about (a) where the material is coming from that leads to the growth of the chick inside the egg and (b) the chemical life processes that are occurring.

Related NSTA Science Store Publications, NSTA Journal Articles, NSTA SciGuides, NSTA SciPacks, and NSTA Science Objects

American Association for the Advancement of Science (AAAS). 2001. *Atlas of science literacy.* Vol. 1. (See "Flow of Matter in Ecosystems" map, pp. 76–78.) Washington, DC: AAAS.