# Formative Queries for the High School Biology Classroom

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This booklet contains a set of formative assessment probes. They are intended to be used as planned formative assessments administered prior to the beginning of a unit or lesson. Each probe is related to a specific concept taught in a typical high school Biology classroom.

**3/29/2012**

# Table of Contents



I would to acknowledge my course team at Lincoln-Way East High School
Scott Fletcher, Jeff Kastel, Lance Lokanc, Julie Widinski, & Ross Widinski
for their assistance in piloting these probes and providing valuable feedback on the teacher pages for each probe.
GO EAST! GO GRIFFINS! GO BLUE!

# A Formative Assessment Probe "Walk-Through"

***Purpose:*** The purpose describes the specific concept the probe was designed to target.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:*** This section lists specific concepts and ideas addressed by the probe. The concepts and ideas are for grades 9-12 and labeled with the section in *Chapter 5: The Living Environment* from *The Benchmarks for Science Literacy*.

***Specific Ideas and Concepts from National Science Education Standards:*** The section lists specific concepts and ideas addressed by the probe. The concepts and ideas are for grades 9-12 and labeled with the subsection of *Content Standard C for Life Sciences* from the *National Science Education Standards*.

***Related Misconceptions Research:*** This section contains commonly held ideas, misconceptions, naïve ideas, misunderstandings, and incomplete ideas which are typical of high school students' thinking as reported in the research and related to the probe. Two sources were used to compile the ideas in this section: *The Research Base* chapter in the *Benchmarks for Science Literacy* and related chapters in *Making Sense of Secondary Science: Research Into Children's Ideas.*

***Background:*** This section describes facts and terminology related to the concept addressed by the probe. It also contains instructional implications for grades 9-12 identified in the *Benchmarks for Science Literacy* and the *National Science Education Standards.*

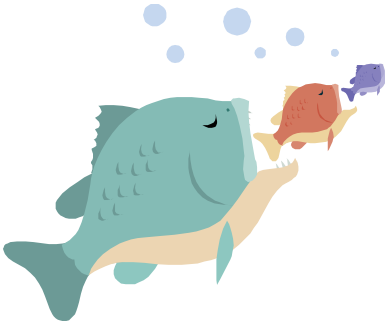
***Administering the Probe:*** The first paragraph of this section briefly describes the type of probe being used, and how to administer the probe as a paper and pencil assessment to students. The second paragraph of this section briefly describes an alternative method for administering the probe that couples individual thinking about the probe with social interaction about one's thinking.

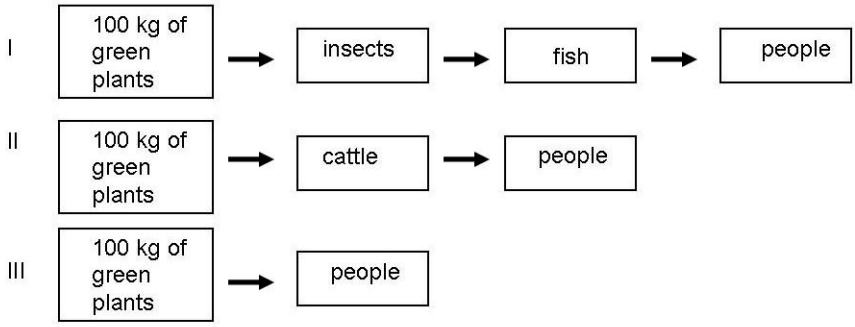
***Vocabulary:*** Any words that require students have prior knowledge to complete the probe.

***The Probe:*** This is the only section shared with the students. The probe itself consists of a question prompt, choices for students to select as a response, direction to the student for selecting a response, and a request to the student to elaborate the thinking or reasoning they used in making their answer choice(s).

# Life on Top

Consider the three diagrams below. They represent three situations in which 100 kg of green plants serve as the original source of food for each of the food chains. In situation II, for example, cattle eat 100 kg of green plants and then people eat the beef that is produced by the cattle as a result of having eaten the plants.






In which of the three situations is the most energy available to people?

A) I

B) II

C) III

D) Situations I and II will roughly tie for the most energy.

E) The same amount of energy will be available to people in all three situations.

Please indicate and explain your answer choice.

***Key:*** The "correct" answer to the probe is revealed here for the teacher, along with some explanation of what the various choices might reveal about student thinking related to the concept.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student. The last column allows the teacher to tally the number of coded responses given by the students.

| Level | Code | Descriptor | % Response |
|---|---|---|---|
| Competent Reasoning | 3 | | |
| Developing Reasoning | 2 | | |
| Beginning Reasoning | 1 | | |
| Reasoning is unclear | 0A | | |
| Reasoning is Missing | 0B | | |

***Suggestions for Instruction:*** Possible ideas to address misconceptions, specific ideas, and concepts targeted by the probe are briefly described here.

***References:*** Included in this section are sources used to develop the probes and ideas described in the "suggestions for instruction" section.

# Is That Thing Alive or What? - Characteristics of Living Things

***Purpose:*** Elicit students' knowledge of the characteristics of living things.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:***

- *5B Cells, Grades 9-12*: Every cell is covered by a membrane that controls what can enter and leave the cell to maintain homeostasis. Cells capture and release energy during metabolic reactions. Genetic information encoded in DNA within cells is virtually the same for all life forms. Complex interactions among chemicals within cells cause distinct cycles of growth, development, and reproduction. Cells can respond to stimuli produced in local or distant parts of an organism or even by another organism.

***Specific Ideas and Concepts from National Science Education Standards:***

- *Standard C - The Cell, Grades 9-12:* Cell functions involve chemical reactions involved in metabolism. Cells store and use information to guide their functions using DNA the universal genetic code. Cells respond to their environment to maintain homeostasis and control growth and cell reproduction. Cells require energy. Development of a multicellular organism occurs as a single cell multiplies and differentiates to form many specialized cells.

***Related Misconceptions Research:***

- The four most common attributes used to identify living things are eating/drinking, moving/walking, breathing, and growing.

- Only 5 out of 32 students had a concept of living similar to a biologist and most overextended the concept to nonliving things as well as a result of using only one or a few attributes. High school students mainly use obvious criteria to distinguish between living and nonliving and rarely mention structural criteria or biochemical characteristics.

***Background:***

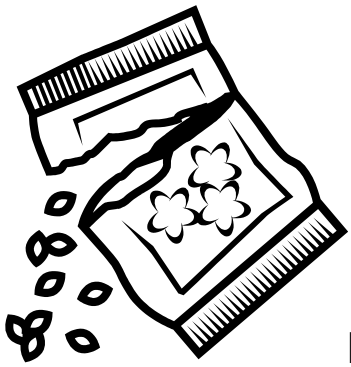
Some signs of life are not easily recognized. Sometimes, dormant, or slow-growing organisms appear to be non-living unless observed under the right conditions or over long periods of time. There is no firm scientific definition of life. There is no single test to establish the presence or absence of life. However, there is a list of characteristics that are shared by almost all living things. They are made of at least one cell; they require energy to maintain organization, homeostasis, and metabolism; they exchange matter and energy with environment; they grow and develop and reproduce.

***Administering the Probe:***

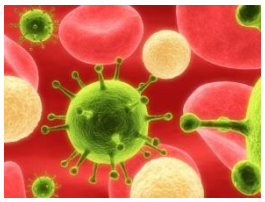
This is a "friendly talk probe" where two or more persons are talking about their ideas. Their ideas are related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. Students should be directed to select the person they most agree with and justify their selection. Make sure students are familiar with the vocabulary terms listed below and the objects used in the probe.

This probe could also be used as an "Agreement Circles" probe. Students stand in a circle as the teacher reads a statement about which objects are alive. When a student agrees with a statement he or she steps to the center of the circle, other students will join him or her if they agree also. Students engage in small group discussion to defend their thinking. Students who still agree with their small group step the center of their circle, anyone disagreeing stays on the circumference. As the teacher listens to small group discussion, information about students' thinking is revealed. The teacher can then plan to provide lessons that will help students explore their ideas further and enhance conceptual understanding.

***Vocabulary:*** none



# Is That Thing Alive or What?



Four biology students were discussing whether some objects set out by their teacher were alive or not. The objects included a sunflower seed, a lizard, some bread mold, a houseplant, and a microscope with a slide of bacteria from some yogurt. Here are their thoughts about which items were alive:

Susie: "Only the lizard and the houseplant are alive."

Sam: "I agree with Susie – the lizard and houseplant are alive – and I also think the sunflower seed is alive too."

Carl: "I disagree with both Susie and Sam. I think all five objects are alive."

Natasha: "I think that all of them are alive except the bacteria – there can't be living bacteria in yogurt that we eat. That would be gross!"

Which biology student do you most agree with?

What rule or rules do think the student you chose is using to classify something as alive?

***Key***

Correct choice: Carl) "I disagree with both Susie and Sam. I think all five objects are alive."

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Response |
|---|---|---|---|
| Competent Reasoning | 3 | The objects are made of cells, contain genetic material to be able to reproduce, maintain homeostasis, have a metabolism | |
| Developing Reasoning | 2 | The object grows and reproduces<br>The object needs energy (food)<br>The objects can be classified into kingdoms of life<br>Student chooses "Carl" | |
| Beginning Reasoning | 1 | The object moves<br>The objects have similar physical characteristics<br>Bacteria are not alive<br>Student chooses "Natasha," "Carl" | |
| Reasoning is unclear | 0A | Cannot describe rule without using the word "living" | |
| Reasoning is Missing | 0B | | |

***Suggestions for Instruction Following Analysis of the Probe:***

Have students research "characteristics of life" using the Internet. Have them note similarities and differences among definitions. Provide a series of videos of organisms and have students note visible characteristics of life common to all the organisms. Explicitly discuss characteristics of life that are not visible. Explicitly teach that defining life is a difficult task and not all biologists agree on a common list. Discuss how many characteristics are not limited to just living things. Discuss as a class how life will be defined as you study living things together throughout the year. Have students construct a concept map of the characteristics of living things.

***References:***

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

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

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# Life At the Top: The Flow of Energy Through Ecosystems

***Purpose:*** Elicit students' knowledge of the nature of energy conversion within organisms and energy transfer from one trophic level to the next.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:***

- *5E Flow of Matter and Energy, Grades 9-12*: At each link in a food web some energy is stored in newly made structures but much is dissipated into the environment. Continual input of energy from sunlight keeps the process going.

***Specific Ideas and Concepts from National Science Education Standards:***

- *Standard C – The Interdependence of Organisms, Grades 9-12:* Energy flows through ecosystems in one direction, from producers to herbivores to carnivores, to decomposers.

- *Standard C – Matter, Energy, and Organization in Living Systems, Grades 9-12:* Energy can change forms and is conserved as it flows through different levels of organization in living systems. Plants capture energy by absorbing light and using the energy to form strong covalent bonds between carbon containing molecules (matter) which can be used as sources of energy for life processes.

***Related Misconceptions Research:***

- Half of a sample of undergraduate biology students explained the phrase "life depends on green plants" in terms of food chains and even fewer mentioned harnessing solar energy as the reason why green plants are crucial in the food chain.

- Students consider the flow of energy in living systems in terms of energy being formed and used rather than in terms of energy conversion.

- Students tend to confuse energy with food and temperature and may not appreciate the unique importance of energy conversions in photosynthesis and cell respiration. Stronger organisms are considered to have more energy which they use in order to feed on weaker organisms with less energy. Some students also see energy as adding up through an ecosystem so that the top predator would have all the energy from the previous levels.

***Background:***

Organisms are linked to one another and to their physical setting by the transfer and transformation of energy. Healthy ecosystems ensure a healthy biosphere by regulating the flow of energy and matter. Energy passes from organism to organism in food webs. Food webs identify the relationships among producers, consumers, and decomposers in an ecosystem. A visual model that is shaped like a pyramid can show how the energy flows through a food chain, how the amount of energy is decreasing and becoming less available for organisms as it enters each trophic level, and how much of the energy in the ecosystem is lost to the atmosphere as heat.

Most high school students understand the concept of population but few students understand and apply the idea of interdependence and energy flow when considering population interactions. Energy transfer through molecular configurations in living systems is less obvious than the observable energy transfers in physical systems. Energy in living systems can be accounted for by thinking of it as being stored in molecular configurations created during photosynthesis and released during cellular respiration. The latter can be observed as heat generated by organisms.

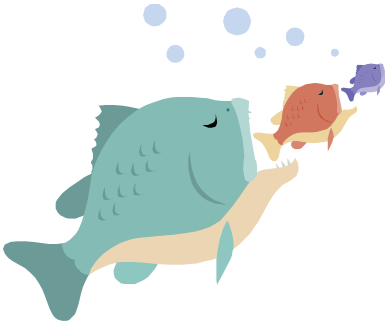
***Administering the Probe:***

This is a "prediction probe" where the student is asked to choose one option they think best represents the outcome of the situation and justify their choice. The probe is directly related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. This probe could lead to an inquiry where the students test their predictions through observation and analysis of researched energy pyramid data; the students would then make modifications to their explanation if needed. Make sure students are familiar with the vocabulary terms listed below and the organisms used in the probe.

This probe could also be used as a "Commit and Toss" to provide a non-threatening way to publicly acknowledge the variety of ideas with which students enter the classroom. Students anonymously commit to a response and describe their thinking on paper; then, they crumple up the paper into a ball. The teacher signals students to toss the paper balls around the room until told to stop. When given the stop signal each student picks up a paper ball and reads the author's response and thinking. Students are asked to stand in a designated area of the room for the response on the paper. This would allow the teacher to get a quick read on student thinking. Students in each of the areas can be asked to briefly summarize and share the thinking described on their papers. The teacher can then publicly record the ideas and lead a class discussion about which lines of thinking the class believes are most plausible. These ideas can be revisited during the explanation phase of the learning cycle.

***Vocabulary:*** food, food chain

# Life on Top



Consider the three diagrams below. They represent three situations in which 100 kg of green plants serve as the original source of food for each of the food chains. In situation II, for example, cattle eat 100 kg of green plants and then people eat the beef that is produced by the cattle as a result of having eaten the plants.

I 100 kg of green plants → insects → fish → people

II 100 kg of green plants → cattle → people

III 100 kg of green plants → people

In which of the three situations is the most energy available to people?

A) I

F) II

G) III

H) Situations I and II will roughly tie for the most energy.

I) The same amount of energy will be available to people in all three situations.

Please explain your answer choice.

***Key***

Correct choice: C) III

This question requires students to know that energy is expended as matter is transferred from one trophic level to the next. Students who choose I or II are likely relying on their personal experiences that do not include scientific reasoning.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Response |
|---|---|---|---|
| Competent Reasoning | 3 | Energy is used at each step<br>Some energy lost to environment at each step<br>Student marks choice C | |
| Developing Reasoning | 2 | Energy is not destroyed but transferred evenly<br>All food contains energy<br>Student marks choice C, E | |
| Beginning Reasoning | 1 | More calories, less consumed at higher levels<br>Energy in fish, insects combined equals cattle<br>Energy increases with each level.<br>Higher quality (protein) food.<br>More food choices available at higher levels.<br>Uses energy / nutrients (food) interchangeably<br>Student marks choice A, B, C, D | |
| Reasoning is unclear | 0A | | |
| Reasoning is Missing | 0B | | |

***Suggestions for Instruction:***

Using a local ecosystem as a reference point, help students establish a knowledge base through reading text materials, viewing videos, and visiting websites about the ecosystem. Ask students to create, through observation and inference, reasonable food chains that might exist within the ecosystem. Demonstrate for students how food chains connect into food webs and have them create their own food webs with the food chains previously hypothesized. Emphasize to students the importance of interdependence and energy flow within the food chains and webs. Sharing and discussing a story like *Wolf Island* by Celia Godkin can be an effective way to consider how change impacts the ecological communities formed by food chains and webs.

Explicitly teach about trophic levels and energy pyramids. Demonstrate how trophic levels fit the pyramid model using actual numbers of organisms. Incorporate the sun as an energy source in the pyramid. Using arrows and the 10% rule, show how its energy flows up through, and out of, the pyramid from one trophic level to the next. Incorporate abiotic factors (water, carbon dioxide) as sources of matter in the pyramid and show how matter flows up through the pyramid and back to the base through decomposers. This will visually emphasize the difference between the flow of energy and matter within an ecosystem.

***References:***

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

Center for Environmental Education and Natural History at Miami University (Oxford). (2011). *Wetlands Are Wonderlands.* Retrieved from http://www.cas.muohio.edu/scienceforohio/Wetlands/L.html

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Moldy Bread - Cycling of Matter in Ecosystems

***Purpose:*** Elicit students' knowledge of matter transformations within and between living things.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:***

- *5E Flow of Matter and Energy, Grades 9-12*: The flow of matter is initiated with the transformation of sunlight energy into food matter which is transformed to create growth. Chemical elements that make up living things pass through food chains and food webs to combine and recombine in different ways.

***Specific Ideas and Concepts from National Science Education Standards:***

- *Standard C – The Interdependence of Organisms, Grades 9-12:* Atoms and molecules on the earth cycle among living and nonliving components of the biosphere.

- *Standard C – Matter, Energy, and Organization in Living Systems, Grades 9-12:* Plants capture energy by absorbing light and using the energy to form strong covalent bonds between carbon containing molecules (matter) which can be used to assemble larger molecules (matter) capable of life sustaining activity. Matter can change forms and is conserved as it flows through the different levels of organization in living systems.

***Related Misconceptions Research:***

- Only half of a sample of undergraduate biology students explained the phrase "life depends on green plants" in terms of food chains. Only 10% of a sample of students mentioned the importance of the oxygen cycle between plants and animals in the context of the sun as the energy source that drives the cycle.

- Students did not consider food chains within the context of matter cycling and interdependence with other organisms.

- Few students view matter as being conserved through photosynthesis, assimilation of food, decay, and respiration. Some students think of food as a requirement to be used up growth rather than food being transformed and made part of a growing organism's body. Students tend to regard food which is eaten as a source of energy belonging to a food chain, while food incorporated in the body of the eater is not recognized as the material which is the food for the next level.

***Background:***

Ecology, the study of relationships between living things and their environment, in part involves the study of biogeochemical cycles – a pathway by which a chemical element or molecule moves through living and nonliving parts of an ecosystem. As matter flows through different levels of organization – cells, organs, organisms, communities – and between living systems and the physical environment, chemical elements are recombined in different ways. The matter is essentially recycled, although in some cycles there may be places where the element is accumulated or held for a long time. High school is an appropriate time to consider what the flow of matter through living systems suggests for human beings.

Although students may indicate an understanding that living systems are composed of cells, they may have difficulty associating living systems with the molecular level. Most high school students understand the concept of population but few students understand and apply the idea that organisms in populations are linked to one another and to their environment by the transfer and transformation of matter. Students have a general understanding of the cycling of matter in ecosystems through small localized cyclical processes. They often express the misconception that matter is created and destroyed at each step of a cycle rather than continuously transformed. Instruction that traces matter through an ecosystem may help correct students' misconceptions and difficulties with the concept of processes transforming matter within an ecosystem.

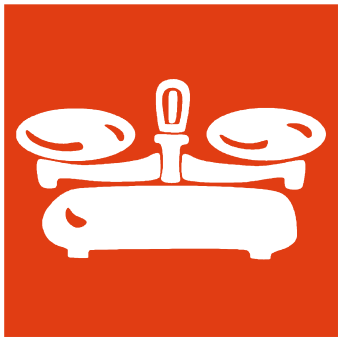
***Administering the Probe:***

This is a "prediction probe" where the student is asked to choose one option they think best represents the outcome of the situation and justify their choice. The probe is directly related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. This probe could lead into an inquiry where students test their predictions. Having the students create the set up described in the probe and record their observations of the results may help them understand that as the mold decomposes the bread, materials are returned to the biosphere. Make sure students are familiar with the vocabulary terms listed below and the organisms used in the probe.

This probe could also be used as a "Sticky Bars" probe to help students recognize the range of ideas existing in class. Each student anonymously writes their answer on a Post-It note and passes it to the teacher. The teacher then arranges the notes on a large board to form a bar graph of the students' responses by placing each similar response atop each other. Students should be given time to work in pairs or small groups to discuss the pattern revealed by the data and what steps should be taken next, to bring the class to a common understanding.

***Vocabulary:*** biomass, growing, mass

# Moldy Bread



A loaf of bread was left uncovered for two weeks on a balance measuring its mass. Three different kinds of mold grew on it, decomposing the bread. Assuming that the bread did not dry out, which of the following is a reasonable prediction of the mass of the bread and mold together?

A) The mass has increased, because the mold has grown.

B) The mass remains the same as the mold converts bread into biomass.

C) The mass decreases as the growing mold converts bread into energy.

D) The mass decreases as the mold converts bread into biomass and gases.

Please indicate and explain your answer.

***Key***

Correct choice: D) The mass decreases as the mold converts bread into biomass and gases.

When mold grows on bread, the mold is actually decomposing the bread. Some of the carbon in the organic molecules is converted to carbon dioxide during cellular respiration by the mold and some is incorporated into the biomass of the mold.

Students who choose (A) likely do not realize mold is heterotrophic cannot photosynthesize. Students who choose (B) likely do not realize that the mold is respiring. Students who choose (C) likely do not distinguish between matter and energy.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Response |
|---|---|---|---|
| Competent Reasoning | 3 | Mold grows and gives off waste gasses which will decrease the mass of the bread and mold | |
| Developing Reasoning | 2 | Bread is decomposing, but mold is growing<br>Bread is losing mass because mold is decomposing it<br>Student marks choice B, C | |
| Beginning Reasoning | 1 | The mold uses the bread<br>The bread is shrinking because it is being decomposed<br>Mold is lighter than bread<br>Mold grows on top of bread making it heavier<br>Mold grew because the bread was left out<br>Mold converting bread mass into energy<br>Student marks choice A, C, D | |
| Reasoning is unclear | 0A | | |
| Reasoning is Missing | 0B | | |

***Suggestions for Instruction:***

Providing an analogy to human recycling of glass, paper, plastics, and metal may provide a more tangible example on which they can hang new ideas about biogeochemical cycles.

Allowing the students to create an ecosystem in a jar is an effective way to help students visualize the physical components of an ecosystem. It is imperative to have the students explicitly reflect on the purpose for everything they place in the jar. Typically, the larger the jar the better; ecosystems can be sustained for a year or more if designed properly. Whether an ecosystem fails, or works, it will be necessary to conduct explicit reflective discussion regarding observations of changes over time, the reasons for the outcome, and how they connect to the processes occurring in each cycle.

The students could work in jigsaw groups to research the cycles (carbon / oxygen, nitrogen, water). Each expert would research one cycle and create a product that effectively communicates the key processes of their cycle. Students should be required to refer to their ecosystem jars within their product.

***References:***


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

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

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Lusk, T. (1999, April 23). *What goes around comes around!* Retrieved from http://www.uen.org/Lessonplan/preview.cgi?LPid=1797

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National Research Council. 1996. *National science education standards.* Washington D.C.: National Academy Press.

# The Mighty Oak - Photosynthesis

***Purpose:*** Elicit students' knowledge about plant assimilation of carbon dioxide from the air to synthesize organic compounds for growth.

***Specific Ideas and Concepts from <u>Benchmarks for Science Literacy</u>:***

- *5C Cells, Grades 9-12*: A living cell is composed of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. A cell uses these elements to assemble many different types of molecules that carry out the work of the cell.

***Specific Ideas and Concepts from <u>National Science Education Standards</u>:***

- *Standard C - The Cell, Grades 9-12:* Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment. This process of photosynthesis provides the vital connection between the sun and energy needs of living organisms.

- *Standard C – Matter, Energy, and Organization in Living Systems, Grades 9-12:* The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong chemical bonds between the atoms of carbon containing molecules. These molecules can be used to assemble larger molecules with biological activity. The energy stored in bonds between atoms can be used as sources of energy for life processes.

***Related Misconceptions Research:***

- Only 11% of students identified food as having both the potential to provide energy and building material for living things. Defining food as organic compounds which organisms can use as a source of energy for metabolic processes rarely occurs in science classrooms.

- Less than half of students failed to mention that carbon dioxide is the source of increasing weight of growing seedlings although many knew carbon dioxide was absorbed.

- Many students believe that plants get their food from the soil and that plants feed in similar ways to animals. Students saw plant uptake of carbon dioxide and water akin to the processes of breathing and drinking and that the plants remained unchanged during these processes.

***Background:***

Living systems require a constant input of energy to maintain their chemical and physical organization. The process of photosynthesis provides a vital connection between the sun and the energy needs of living systems. Light can initiate many chemical reactions such as photosynthesis. Plants are multicellular organisms that perform photosynthesis in order to make food. Plants contain chloroplasts, the site of photosynthesis.

Energy transformation is a function of nearly all cells. The molecular aspect of these transformations should wait until students have had a chance to observe energy transformations in physical systems. Energy should be thought of as being stored in molecules constituted during photosynthesis and released during oxidation. Nonetheless, this a difficult concept for students to grasp even with the use of molecular models.

Although students may indicate that they know living things are made of cells, they are less likely to associate living things being made of molecules. Additionally, many high school students express the misconception that matter is created and destroyed during each step of a process rather than undergoing continuous transformation.

***Administering the Probe:***

This is a "familiar phenomenon probe" where students are asked to select and justify a response that matches their thinking. The question and items in the list are related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. Make sure students are familiar with the vocabulary terms listed below.

This probe could also be used as a "Human Scatterplot." Make one classroom wall the "Y - axis" with the answer choices, and another wall the "X – axis" with a range from low to high confidence. The students are given time to think and formulate their answer. Then the students are required to get up and move to an area of the room that matches their answer choice and confidence level in the answer. This allows the teacher and students to gain a visual read on the variety of thinking among members of the class. It also raises the awareness of a need to work together to gain a common understanding. Students in an answer choice area with low confidence levels can be paired with students of high confidence level in the same area to share ideas and possibly raise confidence levels. Students standing in different answer choice areas can be paired to engage in scientific argument.

***Vocabulary:*** leaves, mineral, roots

# The Mighty Oak

An acorn, the seed of an oak tree, has a dry mass of only a few grams. Under favorable conditions the acorn will sprout into a sapling and grow to be a mature oak tree with a dry mass 1 ton or more. Which of the following contributes most directly to this huge increase in mass?

A. The roots absorb minerals from the soil.

B. The leaves absorb $CO_2$ gas from the atmosphere.

C. The roots absorb water from the soil.

D. Light from the sun is absorbed into the leaves.

Please indicate the letter of the choice you think contributes most directly to the increase in mass as the acorn grows into a tree.

Explain your reasoning for selecting the choice you did and not selecting the other choices.

***Key***

Correct choice: B) The leaves absorb $CO_2$ gas from the atmosphere.

The majority of plant mass is obtained from the carbon and oxygen atoms within carbon dioxide molecules. These atoms are incorporated into sugars during photosynthesis. Although minerals and water are taken up by the roots and are needed for plant metabolism, they do not substantially contribute to the plant's mass. Sunlight is a form of energy which cannot be converted to mass.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Response |
|---|---|---|---|
| Competent Reasoning | 3 | Photosynthesis in the leaves converts carbon dioxide to glucose stored in the tree<br>Student marks choice C | |
| Developing Reasoning | 2 | Carbon dioxide provides nutrients for the tree<br>Student marks choice C | |
| Beginning Reasoning | 1 | Mineral substances help promote growth<br>Water promotes growth<br>Roots are intake for the tree<br>Light is needed for photosynthesis<br>Absorbing any substance will make it weigh more<br>Light from the sun helps the tree gain mass<br>Student marks choice A, B, C, D | |
| Reasoning is unclear | 0A | | |
| Reasoning is Missing | 0B | | |

***Suggestions for Instruction Following Analysis of the Probe:***

Explicitly and reflectively discuss the need for light in creating glucose (food) for the plant and the importance of glucose as energy and building material for creating growth. Providing a description of van Helmont's experiment and sample data for students to analyze may help them understand the idea that plant biomass is derived from intake of carbon, not substances in the soil.

Explicitly discuss the role of light and pigments in the process of photosynthesis. Explain that pigments are molecules that can "capture" different wavelengths of light. Demonstrate that white light is composed of several wavelengths using a prism. Conduct a paper chromatography lab to illustrate the different types of pigments present in different types of leaves like spinach and red cabbage. Set up plants growing under different colors of light and white light over time to illustrate the relationship between wavelength of light, pigments, and plant growth.

Explicitly teach that in nature carbon dioxide is present in air and dissolved in water, and can enter a plant's cells via diffusion. The carbon is then used to synthesize other carbon containing structures – cellulose for structure, starch for food storage – or oxidized through cell respiration resulting in the formation of ATP. Water also diffuses into plant cells, where in the presence of light it dissociates to release oxygen which diffuses out of the plant cells. Explain to students that these biochemical processes can be measure by detecting the appearance of products (which is easier than attempting to detect the disappearance of reactants). Oxygen, a product of photosynthesis, is not very soluble in water and as a result appears as bubbles in water. Students can observe oxygen production by place sprigs of Elodea in test tubes under a lamp and counting the number of bubbles produced over time. The effect of carbon dioxide on oxygen production can be observed by placing one Elodea sprig in tap water, one in tap water with baking soda (carbon dioxide source) added, and one in boiled (to drive off carbon dioxide)and cooled water. Starch, another product of photosynthesis, can be detected using an iodine indicator that stains blue-black when starch is present. First microwave the leaves in a few milliliters of 95% ethanol for about 10 seconds (long enough for the ethanol to turn green). Using forceps remove the leaves from the ethanol and place them in a dish with iodine. Rinse the iodine from the leaves, if starch is present the leaves will appear blue-black.

Involve the students in a kinesthetic model to demonstrate the roles of photons, electrons, electron carriers, water, and protons during the light reactions. Review the products of light reactions and explicitly teach the Calvin cycle including the terms NADPH, RuBP, PGAL, ATP, Glucose, and Carbon Dioxide. Students could use manipulatives to create a model of the Calvin cycle that incorporates the products of the light reactions and traces the pathway of carbon from carbon dioxide through the cycle into glucose and then into storage organelles within cell.

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# A "Grape" Question: Respiration

***Purpose:*** Elicit students' knowledge about food and energy transformations in organisms.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:***

- *5C Cells, Grades 9-12*: A living cell is composed of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. A cell uses these elements to assemble many different types of molecules that carry out the work of the cell.

***Specific Ideas and Concepts from National Science Education Standards:***

- *Standard C - The Cell, Grades 9-12:* Most cell functions involve chemical reactions where food taken into the cells reacts to provide the chemical pieces needed to synthesize other molecules. The breakdown of some food molecules enables the cell to store energy in specific chemicals that are used to carry out many cell functions.

- *Standard C – Matter, Energy, and Organization in Living Systems, Grades 9-12:* The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong chemical bonds between the atoms of carbon containing molecules. These molecules can be used to assemble larger molecules with biological activity. The energy stored in bonds between atoms can be used as sources of energy for life processes. The chemical bonds of food molecules contain energy that is released when the bonds are broken. This energy is temporarily stored as ATP.

***Related Misconceptions Research:***

- Only 11% of students identified food as having both the potential to provide energy and building material for living things. Defining food as organic compounds which organisms can use as a source of energy for metabolic processes rarely occurs in science classrooms. Students do not understand the meaning of the word food as a material that serves as a substrate for respiration.

- Respiration is synonymous with breathing. Students do not frequently associate with the idea that oxygen is used for cellular respiration. Air is simply breathed into lungs and then exhaled – it does not involve energy conversion. Many students think that respiration actually forms energy used in energy conversions.

***Background:***

Living systems require a constant input of energy to maintain their chemical and physical organization. The process of photosynthesis provides a vital connection between the sun and the energy needs of living systems. Light can initiate many chemical reactions such as photosynthesis. Plants are multicellular organisms that perform photosynthesis in order to make food. Plants contain chloroplasts, the site of photosynthesis.

Energy transformation is a function of nearly all cells. The molecular aspect of these transformations should wait until students have had a chance to observe energy transformations in physical systems. Energy should be thought of as being stored in molecules constituted during photosynthesis and released during oxidation. Nonetheless, this a difficult concept for students to grasp even with the use of molecular models.

Although students may indicate that they know living things are made of cells, they are less likely to associate living things being made of molecules. Additionally, many high school students express the misconception that matter is created and destroyed during each step of a process rather than undergoing continuous transformation.

***Administering the Probe:***

This is a "friendly talk probe" where two or more people are talking about their ideas in a context familiar to students. Students are asked to select the person they most agree with and explain their reasoning. The question and items in the list are related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. Make sure students are familiar with the vocabulary terms listed below and the items used in the probe.

This probe could also be used as "Agree & Disagree Statements." The teacher shares the prompt. Each of the friend's responses can be placed in a "Statement" column with the choices "agree," "disagree," "it depends on," and "not sure." Students check the choice that best matches their thinking about the statement and provides a brief justification for their thinking. There is also a second column titled "How can you find out?" where students think about and record ways to test their thinking or sources they could consult to find out if their thinking is accurate. Once students have had time to complete the "Agree & Disagree" organizer on their own, they get together in small groups to share and discuss each statement and their thinking. The teacher carefully listens to the thinking shared within the groups and can group students with similar ideas together to further investigate their ideas.

***Vocabulary:*** glucose

# A "Grape" Question

Six friends were sharing a bowl of grapes. Eric asked, "How could glucose from a grape provide energy to your muscle cells to move your fingers to pick up more grapes?" The following are answers Eric's friends gave in response to his question:

Billy: "The glucose is digested into simpler molecules having more energy."

Shannon: "The glucose reacts to become other molecules."

Tyler: "The glucose is turned into energy."

Hannah: "The energy of the glucose is transferred to other molecules."

Jessica: "The energy of the glucose is transferred to carbon dioxide and water."

Which of Eric's friends do you agree with most? Explain the reasoning for your choice.

***Key***

Correct choice: Hannah) "The energy of the glucose is transferred to other molecules."

This question elicit student understanding of how chemical potential energy is stored and released through transforming carbon containing molecules. Students who choose "Billy" demonstrate lack of understanding of the conservation of energy. Similarly, students who choose "Tyler" lack understanding of conservation of matter. Students who choose "Jessica" may know something about cell respiration but are confused about the process. Students who choose "Shannon" are not properly tracing matter.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Response |
|---|---|---|---|
| Competent Reasoning | 3 | Energy in chemical bonds can be transferred from one molecule to another<br>Students chooses "Hannah" | |
| Developing Reasoning | 2 | Cell respiration breaks down glucose to release carbon dioxide and water<br>Student chooses "Jessica" | |
| Beginning Reasoning | 1 | Glucose makes energy<br>Glucose is sugar which turns into energy<br>Glucose turns into ATP which has energy<br>Student chooses "Billy," "Shannon," "Tyler" | |
| Reasoning is unclear | 0A | Cannot describe rule without using the word "living" | |
| Reasoning is Missing | 0B | | |

***Suggestions for Instruction Following Analysis of the Probe:***

Introduce the link between gas exchange involving the processes of photosynthesis and cellular respiration, as well as the connection between food consumption and gas production by having students set up a few inquiry labs.

One lab requires that a carbon dioxide indicator (brom thymol blue, cabbage juice) is added to three test tubes. One tube contains *Elodea*, one tube contains human breath (added via a straw), and one tube is left with just the indicator. Cover the tubes and allow to sit overnight. Discuss the results in terms of carbon dioxide production.

A second inquiry lab can be set up using germinating seeds in a respirometer. The respirometer tube contains a small drop of detergent or dye and the chamber with the seeds contains a cotton ball soaked in limewater to absorb carbon dioxide produced by the seeds. As the seeds respire, the detergent or dye drop will be drawn through the respirometer tube. Measuring the distance over which the drop moved can be used to gauge how much oxygen is consumed over time. Discuss results in terms of oxygen consumption.

A third inquiry lab can be set up using varying liquids as food sources and active dry yeast. Have students observe the yeast in solution under a microscope to observe their living characteristics. Liquids to be used could include water, soda (flat), juice, milk, chicken broth, vegetable oil, egg white. Add equal amounts of each liquid to a separate plastic bottle (like a clean dry water bottle), and then add a teaspoon of dried yeast to each bottle. Cap each bottle tightly and shake the contents vigorously to mix. Place a balloon over the top of each bottle and place the bottles in a warm location out of direct light. Measure the circumference of the balloon. Discuss results in terms of percentage of carbohydrate, lipid, protein found on the food label for each liquid.

Explicitly teach the chemical reaction for cellular respiration, the steps in cellular respiration, and key vocabulary terms (ATP, glycolysis, Krebs cycle, electron carrier, electron transport). Have students use manipulative to trace the electrons and carbon atoms in glucose through the cell respiration process to the production of ATP, carbon dioxide, and water using the manipulatives.

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# Eureka It's Alive! - Cells

***Purpose:*** Elicit students' knowledge of cell structure at the molecular, cellular, and systems level.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:***

- *5C Cells, Grades 9-12*: Every cell is covered by a membrane that controls what enters and leaves the cell. A living cell is composed of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. A cell uses these elements to assemble many different types of molecules that carry out the work of the cell. Cells contain specialized parts for transport of materials, energy capture and release, protein building, waste disposal, passing information, and movement. Multicellular organisms have cells that perform specialized function for organisms.

***Specific Ideas and Concepts from National Science Education Standards:***

- *Standard C - The Cell, Grades 9-12:* Every cell is surrounded by a membrane. Inside the cell is a concentrated mixture of thousands, of different molecules which form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material. Most cell functions involve chemical reactions where food taken into the cell reacts to provide the chemical pieces needed to synthesize other molecules. Breakdown and synthesis are made possible by a large set of protein molecules called enzymes.

***Related Misconceptions Research:***

- Proteins, carbohydrates, and water are thought to be made of cells. Most students do not indicate that living things are made of molecules.

- Students think molecules are larger than cells and that single celled organisms contain organs like intestines and lungs.

***Background:***

All organisms are composed of cells – the fundamental units of life whose details usually are only visible through a microscope. Different body tissues and organs are made up of different kinds of cells. Cells carry out the many functions needed to sustain life. This requires that cells 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. Food (carbon based) molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules. Carbon occurs in all organisms as complex molecules that control the chemistry of life - proteins, carbohydrates, lipids, nucleic acids.

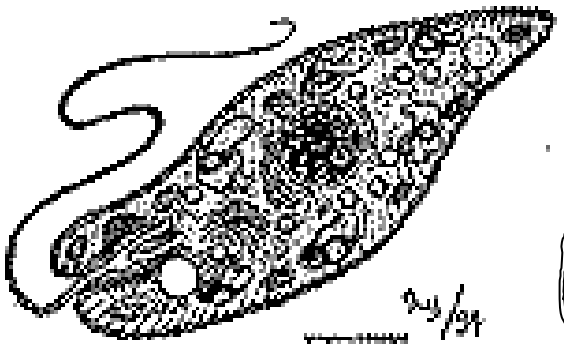
Students might indicate that they know about cells and that living things are made of cells, but they do not often associate living things with being made up of molecules. An ideal way to approach functioning microscopic units is to first address the needs of macroscopic organisms. Information transfer and energy transformation, functions of nearly all cells, can be discussed from a molecular viewpoint after students have had a chance to observe such phenomena in living systems.

***Administering the Probe:***

This is a "Justified List" probe where the students are required to check off items in a list that accurately match the question and then justify their choices. The question and items in the list are related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. Make sure students are familiar with the vocabulary terms listed below and the items used in the probe.

This probe could also be used as a think-pair-share to allow students to share and modify their ideas as a result of peer interaction. The students first take time to complete the probe individually. The each student shares their response with a partner and the two discuss, clarify, and possibly challenge each others' thinking. The pairs could then form small groups for similar sharing, discussing, and clarifying. The teacher is circulating among the pairs and groups during the sharing time to make note of misconceptions that will need to be targeted during instruction. A whole class discussion can be used at this point to allow for additional teacher and peer feedback as to student ideas.

***Vocabulary:*** function, organism, structure



# Eureka! It's Alive!

A scientist discovers a new unicellular organism. Which items listed below might the scientist be able to study within the new organism to better understand the organism's structure and function?

| | | |
|---|---|---|
| ____ heart | ____atoms | _____chloroplast |
| ____carbohydrates | ____nucleus | _____enzymes |
| ____mitochondria | ____lipids | _____DNA |
| ____lung cells | ____ribosomes | _____molecules |
| ____muscle tissue | ____protein | _____chromosome |
| ____intestines | ____vacuole | _____brain tissue |

Explain your reasoning for excluding certain items on the list and including others.

***Key***

Students should have checked carbohydrates, mitochondria, atoms, nucleus, lipids, ribosomes, protein, vacuole, chloroplast, enzymes, DNA, molecules, chromosome.

This probe requires that students know unicellular organisms, like multicellular organisms are made of molecules and contain specialized structures to carry out specific cellular functions. However, unlike multicellular organisms, unicellular organisms do not contain specialized cells organized into tissue or organs. Students who checked heart, lung cells, muscle tissue, intestines, or brain tissue are likely relying on personal experience rather than scientific reasoning.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Responses |
|---|---|---|---|
| Competent Reasoning | 3 | Checked all items like atoms, molecules, organelles because they are smaller than cells<br>Excluded all items like tissues and organs because they are larger than a cell | |
| Developing Reasoning | 2 | Checked some but not all items like atoms, molecules, organelles because they are smaller than cells<br>Excluded all items like tissues and organs because they are larger than a cell | |
| Beginning Reasoning | 1 | Checked some but not all items like atoms, molecules, and organelles because they are found in all living organisms<br>Checked items that are organs or tissues as well as atoms, molecules, organelles because you can't live without those parts or they are human parts | |
| Reasoning is unclear | 0A | | |
| Reasoning is missing | 0B | | |

***Suggestions for Instruction Following Analysis of the Probe:***

Introduce students to the link between atoms / molecules and the relationship to body systems through a directed case study involving the impact of a nutrient deficiency, or overabundance, on a body system. Students could also conduct nutrition label analyses of their favorite foods to identify the kinds of nutrients (elements and molecules) that are present in the food they consume. Traditional high school lab organic chemical analysis of food products provides another effective way to link the concept of cellular nutrients to food consumption.

Having students create illustrated nanoscale posters that include a powers of ten number line and objects that nest inside each other from the smallest to the largest end of the scale, can help them visually understand the relationship between organization and size in the physical and biological worlds. It may also be helpful to allow students to observe molecular models of the macromolecules found within cells to help students visualize the atomic and molecular organization of cell structure and function.

Explicit and reflective discussion with regard to the connection between nutrition (food consumed), cell structure, cell function, and systems function must take place. An effective way to develop student understanding is to have them create a storyboard in which they follow a particular nutrient from a food product they consume, to a cell where it would be digested and transformed, to its final destination within their body.

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# Antibiotic Resistance: Mutation and Protein Synthesis

***Purpose:*** Elicit students' knowledge of the appearance of new characteristics in a population.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:***

- *5B Cells, Grades 9-12*: The majority of molecules assembled within a cell are protein, which are long folded chains made from 20 different amino acid molecules. The function of each protein depends on its specific sequence of amino acids and it shape that is the result of the attraction between its amino acid parts. The genetic information encoded in DNA molecules provides instructions for assembling proteins.

- *5B Heredity, Grades 9-12*: Genes are segments of DNA molecules. Inserting, deleting, or substituting segments of DNA molecules can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting feature may help, harm, or have little or no effect on the offspring's success in its environment.

- *5F Evolution of Life, Grades 9-12:* New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells of an organism cannot be passed on to the next generation.

***Specific Ideas and Concepts from National Science Education Standards:***

- *Standard C - The Cell, Grades 9-12:* DNA is used to direct the synthesis of protein molecules.

- *Standard C - The Molecular Basis of Heredity, Grades 9-12:* Changes in DNA occur spontaneously as low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes on organism's offspring.

- *Standard C – Biological Evolution, Grades 9-12:* Species evolve over time. Evolution is the consequence of the interactions of the potential for a species to increase its numbers, the genetic variability of offspring due to mutation and genetic recombination, a finite supply of resources required for life, and the ensuing selection by the environment of those offspring better able to survive and leave offspring.

***Related Misconceptions Research:***

- High school students have some understanding that characteristics are determined by a particular genetic entity which carries information translatable by the cell. Students

of all ages believe that some environmentally produced characteristics can be inherited, especially over several generations.

- Most students regard adaptation in terms of individuals changing in major ways in response to their environment in order to survive, satisfy the organism's need, or desire to fulfill some future requirement.

- Students believe that a mutation modifies an individual's own form over its lifetime rather than only its germ cells and offspring. Explanations about insects or germs *becoming more* resistant rather than *more* insects or germs *becoming* resistant may reinforce these understandings.

***Background:***

Proteins, found in all cells, are complex macromolecules composed of amino acids. Protein synthesis is the mechanism that transfers an organism's genotype to its phenotype. Protein synthesis occurs in two steps – transcription and translation. The idea that protein molecules assembled by cells conduct the work that goes on inside and outside the cells in an organism can be learned without going into biochemical details. It is sufficient for students to know that the molecules involved are different configurations of relatively few kinds of amino acids, and that the different shapes of the molecules influence what they do.

DNA provides for both the continuity of traits from one generation to the next and the variation that in time can lead to differences within a species and to entirely new species. Mutations are sudden structural changes within a gene of an organism which may result in the creation of a new phenotype or trait not found in the parental type. Students should understand that mutation generally occur at random and are selected for against based on their ability to help an organism better survive in its environment.

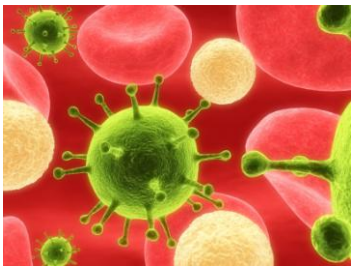
Students should acquire a general picture of the functions of the cell and know that the cell has specialized parts for these functions. Although students may indicate that they know living things are made of cells, they may not associate living things being made of molecules like DNA or protein.

***Administering the Probe:***

This is a "familiar phenomenon" probe where the students are asked to select and justify a response that matches their thinking. The distracters are related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. Make sure students are familiar with the vocabulary terms listed above and the organisms used in the probe.

This probe could also be used as an "I Think..We Think" probe. Students are given a two column sheet of paper with one column labeled "I Think" and the other column labeled "We Think." Students write their answer and justification in the "I Think" column. The teachers provides time for the students to share and discuss their "I Think" columns in small groups. Students should record ideas of the group in the "We Think" column of the paper. The teacher then leads a whole group discussion and records group ideas on a "The Class Thinks" chart. Students can then be asked to individually reflect on their original "I Think" responses and make modifications if necessary.

***Vocabulary:*** antibiotic, bacteria



# Antibiotic Resistance

*Staphylococcus aureus* is a species of bacteria commonly found on the skin or in the noses of healthy people. The bacteria are typically harmeless, although occasionally they can get into the body through breaks in the skin and cause an infection. The infection may result in pimples or boils and in serious cases can also affect the blood, bones, or joints. Methicillin - resistant *Staphylococcus aureus* or MRSA is a strain of bacteria that resists treatment with the oral antibiotic methicillin and other penicillin related drugs. Which statement best describes why the bacteria are resistant to treatment with the antibiotic drugs?

A. The bacteria secrete a protective coating that shields them from the effects of the drug.

B. Bacteria become immune to antibiotics.

C. Some people do not take the full antibiotic treatment prescribed to them.

D. Antibiotic-resistant bacteria are stronger bacteria.

Indicate which choice best describes your thinking and provide an explanation for your choice.

***Key***

Correct choice: C) Some people do not take the full antibiotic treatment prescribed to them. This can lead to bacteria carrying the potential for resistance to be "left behind" to survive and prosper.

Students who choose letters A or B hold the misconception that living things can adapt at will to suit their own needs in a changing environment. Students who choose D may think that the bacteria have undergone mutation that confers resistance but lack the understanding that it allows those bacteria to survive and reproduce.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Response |
|---|---|---|---|
| Competent Reasoning | 3 | Bacteria carrying resistance gene are left behind to reproduce<br>Student marks choice C | |
| Developing Reasoning | 2 | Bacteria have undergone a mutation<br>Student marks choice D | |
| Beginning Reasoning | 1 | Bacteria mutate to fight off the antibiotic<br>Bacteria will learn to fight off the antibiotic<br>Student marks choice A, B | |
| Reasoning is unclear | 0A | | |
| Reasoning is Missing | 0B | | |

***Suggestions for Instruction Following Analysis of the Probe:***

Introduce the concept of mutation using sets of sentences composed of three letter words. Each sentence should be printed on each of five cards as follows: the first card contains the original sentence, the second contains the sentence with one letter missing and the letters shifted (deletion – frameshift mutation), the third contains the sentence with one extra letter and the letters shifted (insertion – frameshift mutation), the fourth contains the sentence with one letter substituted but the sentence still makes sense (substitution – missense mutation), and the fifth contains a sentence with one letter substituted but the sentence no longer makes sense (substitution – nonsense mutation). Have the students observe a few sets of the 5 sentences and discuss the patterns they observe.

Explicitly teach about the types of gene mutations, and the relationship between mutagens, gene mutations, DNA, and protein synthesis. Use role play or a graphic organizer to have students model the process of protein synthesis using a normal and mutated gene. Explicitly and reflectively discuss the differences in the protein product produced and how this relates to a bacterium's ability to resist action of an antibiotic drug. Explicitly teach about the ways bacteria can incur mutations, the processes of transformation and conjugation as ways that antibiotic resistant genes can spread to other bacteria, and the concept of binary fission as it relates the propagation of a resistance mutation in later bacteria generations. Explicitly and reflectively discuss the effects of not completing a course of antibiotics or not thoroughly washing one's hands as ways for bacteria to be left behind.

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# Where Have All the Prize Bucks Gone?: Evolution by Natural Selection

***Purpose:*** Elicit students' knowledge of natural selection and adaptation.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:***

- *5B Heredity, Grades 9-12*: Genes are segments of DNA molecules. Inserting, deleting, or substituting segments of DNA molecules can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting feature may help, harm, or have little or no effect on the offspring's success in its environment.

- *5F Evolution of Life, Grades 9-12:* New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells of an organism cannot be passed on to the next generation. Natural selection provides for the following mechanism of evolution: some variation in inherited characteristics exists within every species, some of these characteristics give some individuals and advantage over other in surviving and reproducing, and the advantaged offspring in turn are more likely to survive and reproduce. As a result the proportion of individuals that have advantageous characteristics will increase.

- *10H Explaining the Diversity of Life, Grades 9-12:* Darwin argued that certain biologically inherited characteristics give an organism an advantage in surviving and reproducing compared to other organisms of the same species. The offspring would also inherit and pass on those advantages, and over generations the accumulation of the inherited disadvantages would lead to new species.

***Specific Ideas and Concepts from National Science Education Standards:***

- *Standard C – Biological Evolution, Grades 9-12:* Species evolve over time. Evolution is the consequence of the interactions of the potential for a species to increase its numbers, the genetic variability of offspring due to mutation and genetic recombination, a finite supply of resources required for life, and the ensuing selection by the environment of those offspring better able to survive and leave offspring.

***Related Misconceptions Research:***

- Most students regard adaptation in terms of individuals changing in major ways in response to their environment in order to survive, the organism's needs, or a desire to fulfill some future requirement.

- Students show confusion between an individual's adaptations over its lifetime and inherited changes in a population over time. They tend to believe Lamarckian theories of inheritance of acquired characteristics. A major hindrance appears to be student's ability to integrate the occurrence of new traits in a population and their effects on long term survival. Students also have difficulty understanding that changing a population results from the survival of a few individuals that preferentially reproduce, not from gradual changes of all individuals in the population.

***Background:***

Biological adaptations include changes in structures, behaviors, or physiology that enhance the survival and reproductive success in a particular environment. Mutations in DNA occur spontaneously at low rates. Only mutations in germ cells can create the variation that changes and organism's offspring. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations within a population. Evolution is the consequence of the interactions of the genetic variability of offspring due to its mutation and recombination of genes. Species evolve over time.

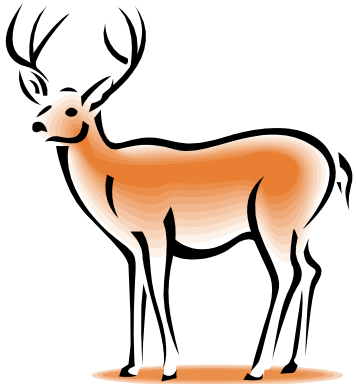
***Administering the Probe:***

This is a "familiar phenomenon" probe where the students are asked to select and justify a response that matches their thinking. The distracters are related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. Make sure students are familiar with the vocabulary terms listed below and the organism used in the probe.

This probe could also be used as an "I Think..We Think" probe. Students are given a two column sheet of paper with one column labeled "I Think" and the other column labeled "We Think." Students write their answer and justification in the "I Think" column. The teachers provides time for the students to share and discuss their "I Think" columns in small groups. Students should record ideas of the group in the "We Think" column of the paper. The teacher then leads a whole group discussion and records group ideas on a "The Class Thinks" chart. Students can then be asked to individually reflect on their original "I Think" responses and make modifications if necessary.

***Vocabulary:*** growth rate, mutation, population

# Where Have All the Prize Bucks Gone?



A recent issue of *Hunting & Fishing* magazine reported that populations of male deer (bucks) reaching sexual maturity have smaller antlers than they did in the past. Which statement best explains the decreased antler size of the buck population?

A. The bucks grow their antlers slowly and reproduce as quickly as they can.

B. More mutations occur to help the deer population.

C. Bucks that reproduce with smaller antlers are less desirable to hunters.

Indicate which choice best describes your thinking and provide an explanation for your choice.

***Key***

Correct choice: C) Bucks that reproduce with smaller antlers are more likely to survive, reproduce, and pass on the slower antler growth rate because they are less desirable to hunters.

This question requires students to know that energy is expended as matter is transferred from one trophic level to the next. Students who choose I or II are likely relying on their personal experiences that do not include scientific reasoning.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Response |
|---|---|---|---|
| Competent Reasoning | 3 | The deer survive, reproduce, and pass on the gene for "slow antler growth"<br>Student marks choice B, C | |
| Developing Reasoning | 2 | The bucks with small antlers survive because they are selected for survival<br>Student marks choice C | |
| Beginning Reasoning | 1 | Hunters selected long antler bucks, so bucks evolved smaller antlers<br>Mother nature takes over to help deer survive<br>Mutations are made to help animals survive<br>The deer are changing so they can survive and reproduce<br>Student marks choice B, C | |
| Reasoning is unclear | 0A | | |
| Reasoning is Missing | 0B | | |

***Suggestions for Instruction Following Analysis of the Probe:***

Explicitly teach Darwin's theory of evolution by natural selection. Afterward, it should be emphasized that natural selection is neither a random process nor does it happen within a single generation time frame. This can be modeled using a deck of cards and dividing students into two teams, working in pairs, to reach a goal of producing a full suit of 13 cards. The suit of cards is shuffled after each round, and then the cards are checked again. Team A students must look for the full sequence every time until the goal is accomplished. Team B students build the sequence by pulling the ace when it first appears as the top card, then adding to the suit stack whenever the next card for the sequence is shuffled to the top. Explicit and reflective discussion after the activity should center on how the Team B method mimics Darwin's idea of natural selection.

Helping students transfer the concept of natural selection to a population of organism's can be accomplished by having them participate in a natural selection simulation which requires data collection and analysis of gene frequencies over time. This should be followed by explicit and reflective discussion of how selection for or against particular gene alleles may cause the gene frequencies and therefore phenotypes in a population to change over generations of time. This can also lead into a discussion of Darwin's idea of descent with modification.

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# Birds of a Feather: Cladisitcs and Biological Classification

***Purpose:*** Elicit students' knowledge of how biologists classify organisms.

***Specific Ideas and Concepts from Benchmarks for Science Literacy:***

- *5A Diversity of Life, Grades 9-12*: A classification system is a framework created by scientists for describing the vast diversity of organisms, indicating the degree of relatedness between organisms, and framing research questions. Similar patterns of development and internal anatomy suggest relatedness among organisms. The degree of relatedness among organisms or species can be estimated from the similarity of their DNA sequences, which often closely match their classification based on anatomical similarities.

***Specific Ideas and Concepts from National Science Education Standards:***

- *Standard C – Biological Evolution, Grades 9-12:* Species evolve over time. The millions of different species of plants, animals, and microorganisms that live on Earth today are related by descent from common ancestors. Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on their similarities which reflect their evolutionary relationships.

***Related Misconceptions Research:***

- Few students classify pictures of animals as a biologist would. Only about half would categorize fish, boy, frog, snail, snake, and whale as animals. Reasons for identifying something as an animal included four legs, large size, land habitat, fur, and noise production. Also, about half used characteristics common to all living things as critical attributes of animals.

- Few students refer to genetics or show understanding of the genetic basis of the concept "species."

***Background:***

Taxonomy is the branch of biology that identifies, classifies, and names different types of organisms. Classification is the arrangement of organisms into orderly groups based on their similarities.

***Administering the Probe:***

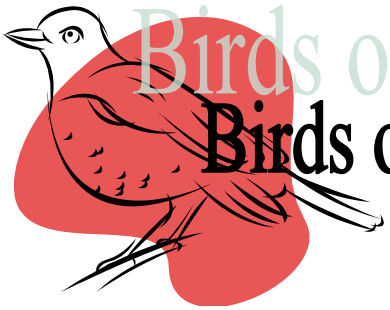
This is a "justified list" probe where the students are asked a question and provided a list of items to check off that match the question. Students are then required to explain their reasoning for checking off the items that they did. The question posed is related to specific concepts from *Benchmarks for Science Literacy*, the *National Science Education Standards,* and the research on student learning. Make sure students are familiar with the vocabulary terms listed below and the organisms used in the probe.

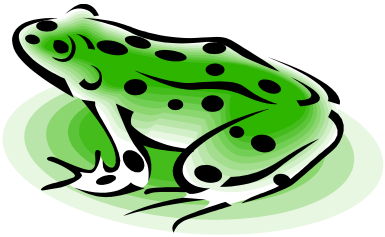
This probe could also be used as a "Card Sort." The question can be posed by the teacher, and names and pictures of the organisms can be printed on sets of cards for the students. Sample categories that could be used to sort the cards are "Related to Birds," "Not Related to Birds," "Not Sure." Students work in pairs or small groups to discuss each of the cards and develop common agreement about under which category a card should be placed. The teacher can circulate among the pairs and groups to listen to reasoning being used by students to place the cards. The teacher can lead a whole group discussion and create a class card sort organizer that can be referred back to and modified throughout instruction.

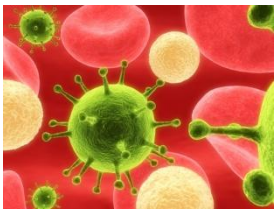
***Vocabulary:*** ancestor, family tree

Birds of a Feather Flock Together

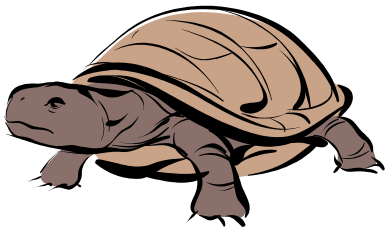
# Birds of a Feather Flock Together







Our best current knowledge suggests that all organisms that are alive today or that have lived on this planet in the past are part of one large connected group, much like an ancestral family tree. Each branch on the tree contains a group of closely related organisms. Which organisms alive today are most closely related to birds? Put an "X" next to the organisms you think are on the same branch as birds in the family tree of life.



| | | | |
|---|---|---|---|
| ___ jellyfish | ___bumblebee | ___turtle | ___dandelion |
| ___bacteria | ___horse | ___salamander | ___paramecium |
| ___hermit crab | ___frog | ___earthworm | ___bread mold |
| ___crocodile | ___pine tree | ___coral | ___platypus |

Please explain the reasoning or rule behind the choices you marked with an "X."

***Key***

Students should have checked crocodile and may have also checked turtle, salamander, frog, and platypus, as well as horse.

This probe requires that students know that classification of organisms relies on similarities between the organisms that go beyond their outward physical features, behaviors, and habitats. Students who check bumblebee likely do so because they fly and have wings. Some students may check platypus because of its duck like bill. Some students may check earthworm and pine tree because they are found in a bird's habitat.

***Sample Rubric for Coding Responses***

The responses have been grouped into four general levels, coded 1 through 3, that encompass the range of reasoning demonstrated among high school students Beginning (informal thinking), Developing (a mix of informal and scientific thinking), and Competent (scientific thinking). The descriptor column illustrates the general types of responses that could be associated with each level of reasoning. You will find that the rubric does not list every possible response that you might see. In these cases, you should be as objective as possible; if a response seems to bridge two categories consider assigning a 1.5 or 2.5 to that student.

| Level | Code | Descriptor | % Responses |
|---|---|---|---|
| Competent Reasoning | 3 | Organisms share similar DNA.<br>Organisms have shared derived characters like lay eggs or have a backbone. | |
| Developing Reasoning | 2 | Organisms have shared derived characters like lay eggs or have a backbone. | |
| Beginning Reasoning | 1 | Organisms have similar behaviors i.e. "both fly"<br>Organisms have similar habitat i.e. "live near trees" | |
| Reasoning is unclear | 0A | | |
| Reasoning is missing | 0B | | |

***Suggestions for Instruction Following Analysis of the Probe:***

Explicitly teach the Linnaen system of classification. Introduce students to the concept of cladistics and some of the issues in the science of Systematics by reading and discussing the essay "What If Anything Is a Zebra?" by Stephen Jay Gould. This will also get the students thinking about the relationship between biological classification and evolution.

Explicitly teach students about phylogenetic trees (cladograms) and shared derived characters. Engage the students in an interactive class demo that shows the hierarchical grouping of organisms based on their shared derived characters. Organism names and pictures are placed on index cards that fit inside Ziploc baggies. The Ziploc baggies are of various sizes so as to nest inside one another. Each baggie is labeled with a letter and a list of shared derived characters. The largest baggie has the most comprehensive list of shared derived characters and the smallest baggie the least number. Organism cards that best fit the lists of shared derived characters on the baggies are placed inside of their respective baggies until all organisms are appropriately placed.

Explicitly teach the concept of speciation and how it involves genetic differentiation, ecological differentiation (niche separation), and reproductive isolation. Engage students in an inquiry using real data to develop likely phylogenies for related organisms living in an area. The data should be from different sources such as geography, geology, morphology, and molecular genetics in order to emphasize the importance of multiple independent lines of evidence. Explicitly and reflectively discuss how scientists use a variety of criteria to compare explanations and select the better ones.

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