Understanding and Teaching Biology

Chapter 7

Biologists Then and Now: Ernst Haeckel and Steven Jay Gould

Ernst Haeckel (1834–1919)

Ernst Haeckel was a German biologist who studied comparative anatomy and evolution. He is probably most well known for the statement that confuses many first-year biology students, “ontogeny recapitulates phylogeny,” also known as the law of recapitulation. Haeckel also coined a number of terms that are commonly used in biology today, including **phylum** and **ecology**. Haeckel was trained as a medical doctor and was also a student of art, but in 1859, after he read Darwin’s *Origin of Species*, he gave up his medical practice and began to study evolutionary biology. He was particularly interested in using evolutionary theory to challenge religious views of Earth history that he felt were contrary to the scientific evidence. He spent a number of years studying invertebrate groups, including radiolarians and sponges, and he created a series of scientific drawings for which he became well known (see Image 2.13 in Chapter 2 for a stunning image of Haeckel’s radiolarians).

He named nearly 150 new species of radiolarians during a trip to the Mediterranean, and his study of these invertebrates led to his later experimental work on development, leading to his “law of recapitulation.” The law of recapitulation was the idea that ontogeny, or the growth (size change) and development (shape change) of an individual organism during its embryonic stages demonstrated its phylogeny, or the evolutionary history of its species. In other words, during their development, embryos of advanced species pass through stages representing more primitive species in their evolutionary history. This theory was an attempt to bring together the evolutionary ideas of Lamarck (that individual organisms evolved during their lifetime to better survive in their environment) and Darwin’s ideas of evolution through natural selection. The law of recapitulation has since been shown to be untrue, but it helped push forward scientific thinking about the complexities of evolutionary biology. Haeckel’s work is an example of how scientific inquiry is best seen as an ongoing process of hypothesis building, experimentation, and evolving explanations rather than simply as a collection of facts (see Image 7.1).

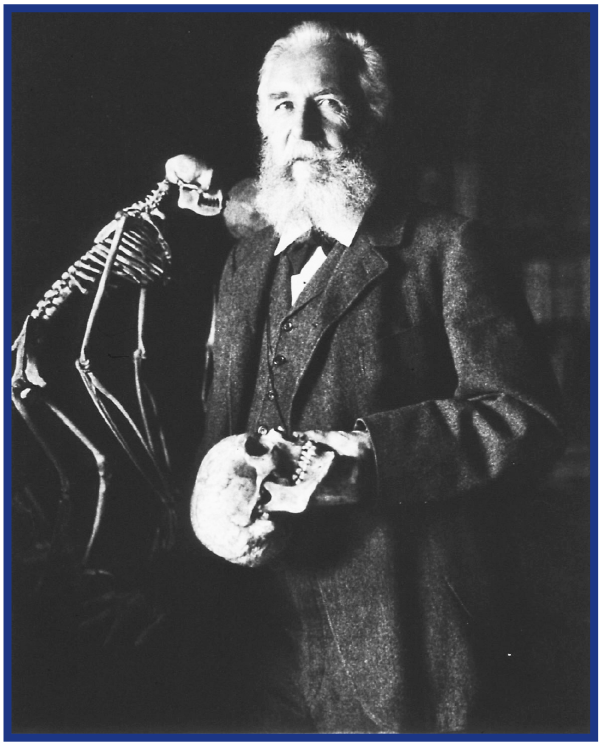
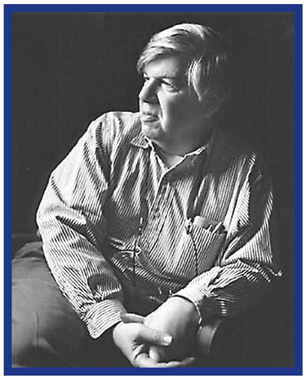


Image 7.1 Ernst Haeckel with a monkey skeleton and human skull.

Stephen Jay Gould (1941–2002)

Stephen Jay Gould was an American paleontologist, historian of science, and evolutionary biologist. He was one of the best-known scientists of his generation and was hugely influential both in the scientific community and in popular science. Gould spent most of his career teaching biology and evolution at Harvard University. Gould is probably best known for his series of popular science essays that appeared as a regular column in the journal, *Natural History*. Many of these essays were later reprinted in books, among them *Ever Science Darwin* and *The Panda's Thumb*. Other widely read popular science books by Gould include *Wonderful Life* and *The Mismeasure of Man*. These essays and books have educated a generation of readers about the mysteries, the beauty, and the complexities of evolutionary biology and the diversity of life on Earth.

Gould also made significant contributions to the science of evolution. Most significant was his development, along with biologist Niles Eldredge, of the theory of punctuated equilibrium. This theory proposes that most evolution is marked by long periods of evolutionary stability, which are then punctuated by rare instances of branching evolution. This idea is in contrast to the long-held belief that evolutionary change happens in a smooth and continuous way; the theory of phyletic gradualism. The idea of steady evolutionary change was central to Darwinian theory and had been the dominant view in evolutionary biology for over a hundred years. Through their study of land snails, Gould and Eldredge presented evidence that a better model of evolutionary change is that it tends to occur relatively rapidly and in bursts, followed by longer periods of relative evolutionary stability.



SOURCE: Lara Shirvinski, Science Research Laboratory (http://commons.wikimedia.org/wiki/File:Stephen_Jay_Gould_(by_Kathy_Chapman).jpgArt)

Image 7.2 Photo of Stephen Jay Gould by Kathy Chapman

In his later years, much of Gould's efforts were dedicated to arguing against sociobiology, evolutionary psychology, and creationism. He argued that science and religion are two distinct ways of human understanding whose authority and range of explanation do not and should not be allowed to overlap (see Image 7.2).

The Place of Biology in Science Education

Biology is the study of life in all its myriad forms. Understanding the foundations of biological life in both plants and animals means addressing fundamental questions concerning the meaning of life and the act of creation. How is it possible that biological forms have come into being in what is essentially a harsh and inhospitable physical universe? The photograph of Earth taken from the Moon by *Apollo 11* in July 1969 caused human beings to see the world in a new way, as a tiny speck of teeming life in a vast and cold solar system, galaxy, and universe (see Image 7.3).

The study of the biological sciences carries with it not only the need to understand issues about the nature of creation, but also questions concerning the appropriate use of life forms. Thus, the study of biology is a profoundly ethics-bound field. Should we experiment with the cloning of animals, for example? Should we use animals to test new drugs, or less important things like cosmetics? Should we manipulate plants to make better crops with which to feed people? Are we creating unforeseen dangers when we manipulate animals and plants for the advantage of human beings? What potential benefits to humankind might arise from embryonic stem cell research? At what cost?

SOURCE: Courtesy of NASA.

Image 7.3 Photograph of the Earth Taken by *Apollo 11* Astronauts From the Moon

The biological sciences bring to our attention the myriad complexity of living forms. Even the simplest of life forms are, in many ways, more complex than the most intricate inventions that humans have created. No one who studies animals or plants can help but wonder at both their complexity and their diversity. Biology suggests to us that life is diverse and coexistent, while at the same time competitive and often surprising.

Biology, perhaps more than any other branch of science, forces us to confront the finite nature of human endeavors and the extent to which we are but passing and ephemeral moments in an ongoing parade of living organisms that have come and gone throughout the history of our planet. Gaining a basic understanding of core concepts in the biological sciences should help students better appreciate the beauty and diversity of life on Earth.

Measurement in Biology

As in other science disciplines, measurement is an important aspect of biological research. Not only does biological science require us to measure life forms, but also to determine issues of time related to the biological systems, such as how long it takes a plant to grow, how tall it grows, or, in the case of an animal, what its life span is or the number of times its heart beats in a minute or during the duration of its life.

Measuring Peak Flow Rate of Breathing

We use many different means to monitor biological systems. In the case of human beings, medical devices provide an excellent example of the methods used to measure biological phenomena. Diabetics, for example, will use a glucometer, which is a device for measuring the glucose or sugar level of their blood. Another example is the measurement of heartbeats using an electro-cardiogram, or EKG, which is a device that measures the regularity of a heartbeat to determine whether or not there are erratic patterns that could indicate a life-threatening condition. A third example of a biological measuring device is a peak flow meter that is used by people with asthma to monitor the flow of their breathing. Peak flow is a measure of the ability to expel air from the lungs. It is measured as a flow rate in liters per minute (LPM). (See Experiment 28.)

To see a demonstration of this experiment, go to www.sagepub.com/buxton2e.

Experiment 28 Measuring Peak Flow Rate

In the following activity, you will compare the peak flow rates of the members of your class when they breathe.

Materials You Will Need for This Activity

- Peak flow meter (can be purchased at most pharmacies or drug stores for under $10)
- Alcohol wipe
- Graph paper

SOURCE: Photo by Jean-Marie Buxton

Image 7.4 Photograph of a Child Using a Peak Flow Meter

What You Will Do

1. Each student in the class will measure his or her peak flow while breathing. To do this, you wipe the mouthpiece of the flow meter with the alcohol wipe to sterilize it, take a deep breath, and blow as hard and fast as you can into the meter.
2. Read the flow off the meter dial. Repeat two more times for a total of three trials.
3. Record your highest reading with your name in a table on the board in your class.
4. When everyone has recorded his or her peak flow of air, look for patterns in the data.
5. Brainstorm as many ways to graph the data as you can.

6. Make a bar graph of peak flow differentiated by gender. Is there a pattern?
7. Make a line graph of peak flow vs. height. Is there a pattern?
8. What other graphs and patterns can you look for?

What you will learn: People's peak flow rates vary widely, but males, tall people, non-asthmatics, nonsmokers, and those who are more physically active tend to have a higher peak flow rate.

Core concept demonstrated: Variation in a biological phenomenon across a population

Thinking like a scientist: Who uses peak flow meters and how is this activity related to the concept of environmental health? There have been a number of professional athletes with asthma. What do you think their peak flow rates would be?

Correlation With National Standards:

NSES Science: A.1; C.4; F.1; F.8

NCTM Math: A1; B1; B4; D1; D2; E1; E2

NCTE Language Arts: 7; 8

NCSS Social Studies: 7; 8

Estimating Lengths of Very Small Objects

During the Renaissance, a remarkable number of inventions were introduced that were responsible for the transformation of science. In the case of astronomy, the invention of the Galilean or optical telescope and the Newtonian reflecting telescope literally made planets and stellar systems visible that had previously been invisible to human stargazers. Along with the invention of astronomical devices came devices that allowed people to view things at a microscopic level. The most important of these was the microscope, which was initially a simple tube with a plate for the object at one end and at the other end a magnifying lens that would increase the size of an object by up to 10 times. The first truly modern microscope was developed by Anton van Leeuwenhoek (1632–1723), who experimented with developing very small but very powerful lenses with precise curvatures to give them very large magnifications—up to 270 times the size of the object. Leeuwenhoek's microscope was followed, in turn, by designs by Robert Hook, who significantly improved on Leeuwenhoek's creations. This constant improvement of microscopes is a process that has continued into our own era and includes the invention of computer-based electron microscopes. (See Experiment 29.)

Experiment 29 Estimating Lengths of Very Small Objects

In the following activity, you will learn how to estimate the lengths of very small objects.

Materials You Will Need for This Activity

- A magnifying glass
- A box of small straight pins
- A metric ruler
- A strand of your hair

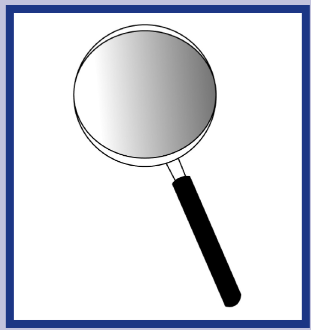


Image 7.5 Magnifying Glass

What You Will Do

1. Place the ruler on a flat surface.
2. Line up pins side by side to determine how many pin widths make one centimeter and how many make one millimeter.
3. Place a strand of your hair on a white piece of paper.
4. Look at the hair under the magnifying glass.
5. Place a pin next to the hair and compare the widths of the two.
6. Using your knowledge of the width of the pin, estimate the width of the hair strand.

What you will learn: You can make accurate estimates of very small objects by comparing the object under magnification to a known standard.

Core concept demonstrated: Measuring very small objects

Thinking like a scientist: Could you use a similar procedure for even smaller objects, using a microscope? Describe what you would do.

Correlation With National Standards:

NSES Science: A.1; C.1; F.10; G.4

NCTM Math: A3; D2; E1

NCTE Language Arts: 7

NCSS Social Studies: 2

Measuring Population Change

In biological systems, it is extremely important to understand at what rate different species reproduce. This is true of animals as well as people. With human beings, for example, this will determine population needs for schools, retirement homes, and pensions. Insurance companies create actuarial tables that take into account the factors that influence the survival rate of various populations, so that they can set life insurance costs that allow people to be insured without the insurance companies going out of business. (See Experiment 30.)

Experiment 30 Measuring Population Change

In the following activity, you will learn about population growth by exploring a classic model of rabbits reproducing.

Materials You Will Need for This Activity

- Paper and pencil

What You Will Do

1. Imagine that a newly born rabbit can reproduce when it is one month old. Suppose that the rabbit never dies and that it continues reproducing a new rabbit every month. This rabbit will then reproduce when it is one month old, two months old, and so on. Assuming that none of the rabbits die and that each rabbit reproduces every month, how many months will it take to have at least one million (1,000,000) rabbits?
2. Make a data table to help you keep track of the growing number of rabbits.

What you will learn: The number of rabbits doubles every month. This model of rabbit reproduction is based on an exponential numerical sequence. It is also based on what is known as a Fibonaccian sequence, in which the first two numbers in a sequence equal the third number in the same sequence and which is the basis for many other patterns found in nature. For example, as we discussed in Chapter 1, a chambered nautilus expands based on a Fibonaccian sequence, as does a spiral galaxy.

Core concept demonstrated: Exponential functions and population growth

Thinking like a scientist: Is this model of population growth likely to actually occur in the natural world? Why or why not? What might a more reasonable model of population growth for rabbits look like? Do some animal or plant populations sometimes grow out of control? Why might this happen?

Correlation With National Standards:

NSES Science: C.5; C.7; F.2

NCTM Math: A2; B1; B4

Classification

Understanding the complex forms of life found on Earth requires us to organize and classify them. In doing so, we see the relationship between different species, what seemingly different life forms have in common as well as what makes seemingly similar life forms different from one another. Biologists have estimated that there are somewhere between 10 and 40 million different species or organisms currently inhabiting the Earth. Of all these, only about 1.5 million have been classified scientifically.

The basis of biological classification is the species. A species is a group of interbreeding organisms that do not ordinarily breed with members of other groups. Thus, despite their wide variety of appearances, domesticated dogs all belong to the same species because they can interbreed. Two nearly identical looking black birds, however, may belong to different species and not interbreed.

Classifying Using All of Your Senses

We use many different means to observe and understand the world and then to classify what we observe. Our five senses provide different means to sense and decode what is around us. We see with our eyes, we hear with our ears, we taste with our tongue, we feel with our hands, and we smell with our nose. When used together, the five senses give us powerful observational tools. The senses provide an interface through which we understand the world around us and serve as the basis for how we classify things. (See Experiment 31.)

Experiment 31 Observation in the Bag

In the following activity, you will use all of your senses (except sight) to observe and classify objects hidden inside bags.

Materials You Will Need for This Activity

- Brown paper bags
- Small food samples such as raisins, chocolate chips, lemon, lime, grape, potato chip, apple, potato, orange, hard candy, cold cereal, and the like

Image 7.6 Blindfolded Eating

What You Will Do

1. Number the bags from 1 to 5 and place a different food sample in each.
2. Make a data table listing the different senses in the columns and the bag numbers in the rows.

3. Use your sense of hearing when you shake each bag, and write a description of the sound made.
4. Use your sense of touch to reach in each bag (without looking!), and describe the feel of each sample.
5. Use your sense of smell and sniff the contents of each bag, and describe the smell.
6. Close your eyes and taste a sample of each food; describe each taste.
7. Based on your data collection, draw a conclusion about what is in each bag.
8. Finally, look in the bag to check the accuracy of your conclusions.
9. How can you classify the items that were in the bags? How are they similar and different from each other?

What you will learn: The contents of the bags can be determined with reasonable accuracy using senses other than the sense of sight.

Core concept demonstrated: "Observation" in science often involves the use of more than just the sense of sight. Using multiple senses results in more robust observations and can aid in classification.

Thinking like a scientist: Which of the senses (besides sight) gave you the best clues to determine what the samples were? Why do you think that was? Which of the senses (besides sight) gave you the least information to determine what the samples were? Why do you think that was? Are there ways that you can classify the items based on your use of all your senses that you could not do based only on sight? Explain.

Correlation With National Standards:

NSES Science: A.1; A.2; C.4; G.1

NCTM Math: B4; C4

NCTE Language Arts: 4; 11

Classification Systems

The Swedish scientist Carolus Linnaeus (1707–1778) developed an important system of classifying things found in nature. In doing so, he made it possible to define the key differences between various plants and animals. It was Linnaeus who introduced the use of the term "species" to represent the most refined unit in the organization. Linnaeus also suggested that each organism should be classified using a distinct binomial (two-part) name. In this classification system, the first term represents the organism's generic name (called the genus) while the second term represents the organism's species. The current classification systems used by modern biologists have been built directly upon the Linnaean system of classification (see Image 7.7). (See Experiment 32 on page 209.)

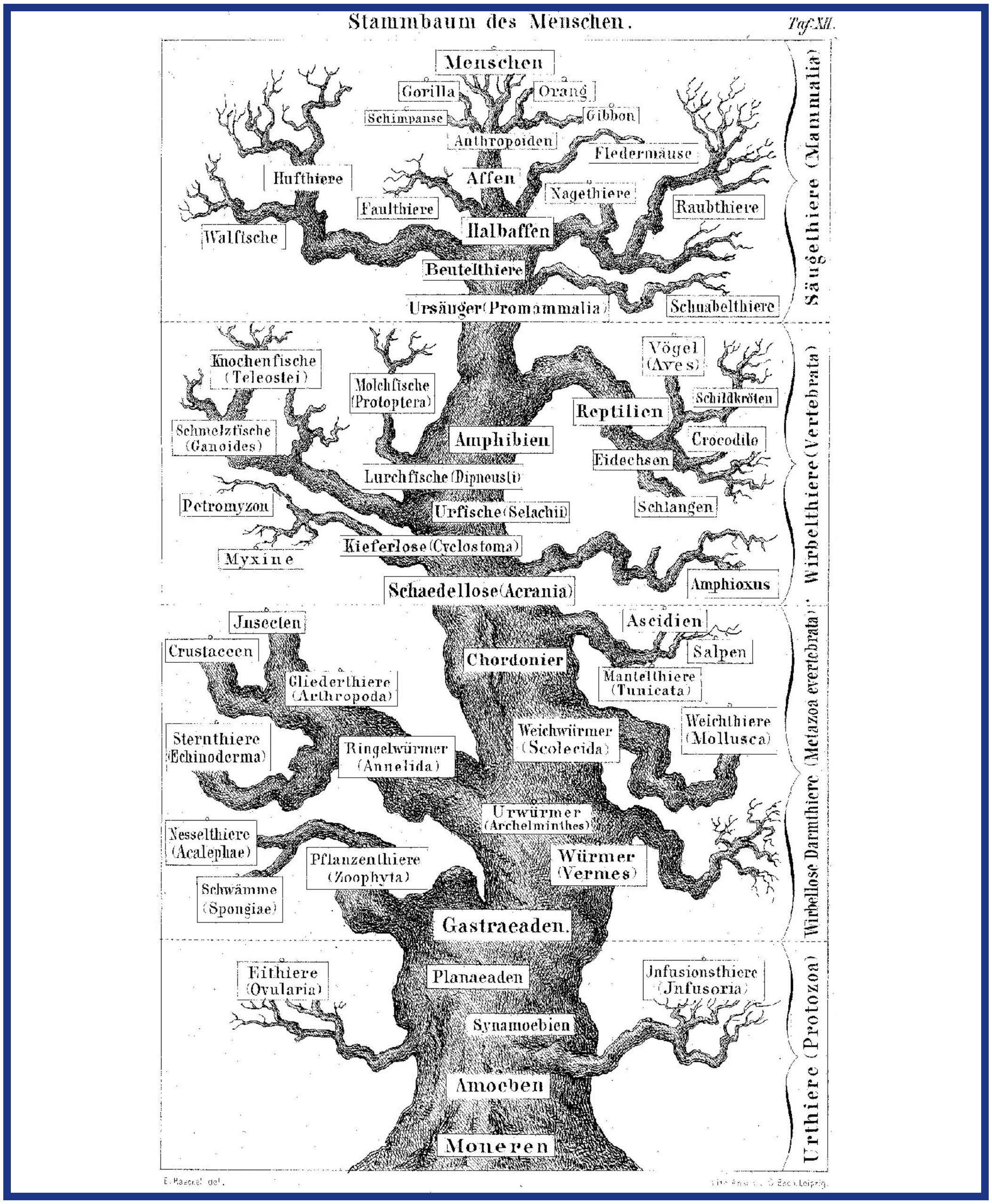


Image 7.5 Pedigree of Man, 1874 Classification systems are illustrated in this "Pedigree of Man," created by the German biologist Ernst Haeckel (1834–1919).

SOURCE: Ernst Haeckel (Wikimedia Commons, http://commons.wikimedia.org/wiki/Image:Pedigree_of_man_(Haeckel_1874).jpg).

Experiment 32 Developing a System of Classification

In the following activity, you will experiment with creating systems of classification.

Materials You Will Need for This Activity

- Photographs of members of your immediate and extended family
- Chart paper
- Paper and pencil

What You Will Do

1. Look at the pictures of your family members. Consider how you can break them down into different classifications based on gender (male/female), age (young/old), responsibility, hair color, etc.
2. On the chart paper, draw boxes and place the pictures of family members showing how different individuals fall within different classifications. Rearrange the pictures several times to classify them in different ways.
3. Go outside on your school grounds and find an area with plants and animals.
4. List the living as well as nonliving things you find and classify them according to their various physical properties.
5. Try to list at least 20 different organisms sorted or classified into groups.
6. Look at each of your groups and see whether you can classify the group into subgroups.

What you will learn: All organisms have distinctly different characteristics that can be used for classification.

Core concept demonstrated: Humans divide the natural world into categories based on distinct properties or characteristics.

Thinking like a scientist: Think about how classification is an important part of not only our natural, but also our social lives. How do we classify nations? Think about features such as geographical setting, climate, politics, and religion. How do we classify people based on their race or ethnicity? How do we classify people based on their intelligence or ability?

Correlation With National Standards:

NSES Science: A.2; C.1

NCTE Language Arts: 4; 5

NCSS Social Studies: 9

The Linnaean System of Classification

The full system of classification for living things developed by Swedish scientist Carolus Linnaeus involves eight different categories (kingdom, phylum, class, order, family, genus, species, and variety). You can more easily remember this system and its order by using the following mnemonic or memory device or another one that you make up yourself: "King Phillip Came Over For Good Spaghetti and Vegetables."

King = Kingdom

Phillip = Phylum

Came = Class

Over = Order

For = Family

Good = Genus

Spaghetti = Species

Vegetables = Variety

A Collie dog, for example, is of the kingdom Animalia, the phylum Cordata, the class Mammalia, the order Carnivora, the family Canidae (group with dog-like characteristics), the genus Canis (coyote, wolf, and dog), species Canis familiaris (domestic dog), and the variety Collie. (See Experiment 33.)

Experiment 33 Classifying Different Animals

In the following activity, you will begin to classify different animals using the Linnaean categories.

Materials You Will Need for This Experiment

- Paper and pencil
- Animal pictures from books or magazines
- Internet access

Image 7.7a Cat

What You Will Do

1. Try to classify as many of the taxonomic properties that you can for the following animals:
   - A Siamese cat
   - A goldfish
   - A grasshopper

2. Consult the Internet for help on classifying these animals. Use search terms such as "Linnaean classification" and "animal classification."

3. The Linnaean classification system is useful to scientists because it allows scientists from around the world to share a common understanding of which organism is being talked about. There are many other ways to classify animals, however. Look at the pictures of animals in a book or magazine about animals and discuss how else they could be classified.

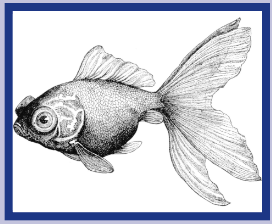


Image 7.7b Goldfish

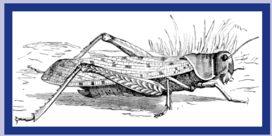


Image 7.7c Grasshopper

What you will learn: The Linnaean classification system helps to highlight the differences and similarities between various animals based on their natural characteristics.

Core concept demonstrated: How taxonomic classification systems break down the characteristics of living things

Thinking like a scientist: Think about the advantages and limitations of using various taxonomic systems. How can such systems potentially distort what things are like in the world? How can such systems help us understand what things have in common?

Correlation With National Standards:

NSES Science: C.1; G.4

NCTE Language Arts: 4

Plants

Plants are some of the most varied life forms on Earth and play essential roles in supporting the planet's numerous ecosystems. Plants serve as producers and are at the bottom of many food chains, feeding the majority of animals. Plants are the only organisms that are able to convert light energy from the sun into food through the process of photosynthesis. Plants also play an important role in producing the oxygen that we, and all the other animals, breathe. Plants produce oxygen as a part of the process of photosynthesis. The oxygen that plants produce is then used by people and other animals when we breathe. In fact, all of the oxygen in our atmosphere originally comes from plants.

Another important ecological role that plants play is to provide a habitat for other organisms. A wide variety of animals of all shapes and sizes live in, on, and under plants. Plants provide shelter, safety, and food for these animals. Additionally, plants play a role in influencing the climate. For example, plants provide shade, which helps to moderate the temperature and serves as a buffer against wind and rain. In large enough numbers, such as in the rainforests, plants can modify entire weather patterns over large areas of the Earth. Plants also play an important role in creating and maintaining soil. The roots of trees and other plants help to hold the soil together, thus reducing erosion. One of the short-term consequences of deforestation is that it causes an increase in soil erosion because the soil no longer has the tree roots to help keep it in place. Plants help to create new soil as well. Soil is composed of broken-down rocks combined with the decomposed remains of plants and animals. Without this plant matter, soil would be mostly sand and clay, lacking many of the nutrients that new plants need to grow.

Many of us give little thought to plants, but it should be clear that plants play a significant role in our lives. Without plants, there could be no animal life on Earth.

Seed Germination

Seeds are incredible biological devices. They contain the genetic information to grow an entire plant. In addition, they can lie dormant for long periods of time before the growth of a plant takes place. This is an important biological feature that makes possible much of life on Earth. A seed is grown, drops into the soil, and becomes active or germinates when the conditions of weather and moisture make it possible for the cycle of life to continue. (See Experiment 34.)

Experiment 34 Seed Germination

In the following activity, you will explore and observe the germination of seeds.

Materials You Will Need for This Activity

- Paper towels
- Baby food jars
- Radish seeds
- Water
- Light source

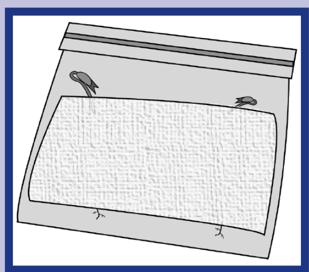


Image 7.9 Seed Germination

What You Will Do

1. Crumple a piece of paper towel, and place it in the bottom of your jar.
2. Add enough water so that the paper towel is wet and there is a shallow layer of water on the bottom.
3. Place 5 radish seeds on the paper towel, keeping them out of the water.
4. Put your jar in the same place as the jars of your classmates.
5. Observe your jar each day for 10 days, and draw a picture of your seeds each day.

What you will learn: Seeds germinate and grow at different rates. The roots grow down regardless of how the seed is originally positioned.

Core concept demonstrated: Germination of seeds

Thinking like a scientist: Which grew first when your seeds sprouted, the root or the stem? What factors were present that may have helped your seeds germinate and grow? Did the seeds need sunlight to grow? Why or why not? What sources of energy did the seeds in this experiment use? Is energy gained or lost as the plant grows?

Correlation With National Standards:

NSES Science: A.1; C.2

NCTE Language Arts: 7

Plant Cells

Like all organisms, plants are composed of **cells**. Cells are the basic unit of life and the building blocks for all organisms, whether plants or animals. There are some differences, however, between plant cells and animal cells. Below is a brief overview of the parts of a plant cell and their functions. Every plant consists of millions of tiny plant cells. Every cell is made up of different parts that help it work. These cell parts are called *organelles*. All of the organelles in a cell work together to keep the cell alive. Each organelle in a plant cell has a unique set of functions. The analogy of a factory is sometimes used to describe the role of each organelle in the cell.

Cell wall—All plant cells have a rigid cell wall around them. The cell wall is like the brick wall of a factory; the cell wall helps to support the plant cell, just like the walls of a factory keep the building standing up.

Cell membrane—The cell membrane allows certain things to go in and out of the cell. It is like a guarded door in a factory; it allows some things to go in and out, but not others.

Cytoplasm—The cytoplasm is the liquid in the cell in which all the other organelles float around. It is like the floor of a factory; it provides a surface where all the work gets done.

Ribosomes—The ribosomes make proteins. They put together the different pieces of proteins that the cell makes. Ribosomes are like the assembly line in the factory; they use certain materials to put together a product.

Endoplasmic reticulum (ER)—The ER is a transportation network that moves materials. The ER is like a supply truck; it distributes materials around the cell.

Lysosome—The lysosome digests wastes in the cell. It is like the cleaning crew of a factory; it gets rid of materials in the cell that the cell does not need.

Nucleus—The nucleus controls what the cell does and contains its DNA. The nucleus is like the control room of the factory; it gives directions to all the other parts of the cell.

Chloroplast—The chloroplast helps the plant make its own food. It is like a power supply; it provides the cell with the materials to make food. (See Experiment 35.)

Experiment 35 Making a Plant Cell Model

In the following activity, you will make a model of a plant cell.

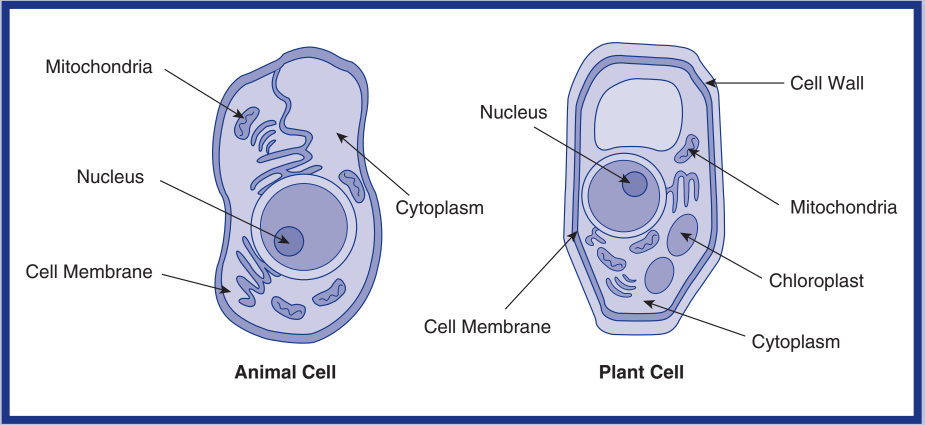


Image 7.10 Plant and Animal Cells

Materials You Will Need for This Activity

- Cytoplasm—yellow clay or play dough
- Endoplasmic reticulum—yarn or cooked spaghetti
- Ribosomes—cake sprinkles
- Vacuole—plastic-bubble packing material
- Lysosome—red clay or play dough
- Chloroplasts—green clay or play dough
- Cell wall—aluminum foil
- Cell membrane—plastic wrap
- Nucleus—blue clay or play dough
- Nuclear membrane—plastic wrap
- Chromosomes—pencil shavings
- Microscope
- Onion skin

What You Will Do:

1. Make the cell membrane by placing a large piece of plastic wrap on the table.
2. Make the cytoplasm by forming a ball of yellow clay or play dough, laying it on the plastic wrap, and pressing it into a "pancake" about 6 inches in diameter.
3. Using the materials listed above, find the supplies to represent each cell structure, and gently press each item into the cytoplasm, with the exception of the cell wall.
4. Wrap the cytoplasm pancake carefully around the cell parts and seal the edges together, forming a ball.
5. Wrap the cell membrane (plastic wrap) around the cytoplasm and then wrap the cell wall (aluminum foil) around the cell membrane.
6. Shape the cell into a rectangular form and then carefully cut the cell in half with a large knife to expose a cross section of the cell.
7. Now that you have made a model plant cell, you will look at a real plant cell. Take a small piece of onion skin and place it on a microscope slide.
8. Look at the onion skin under the microscope. Can you observe individual cells? Individual organelles? How do they appear similar to or different from your cell model?

What you will learn: Plant cells are composed of multiple components that are tightly packed into a cell structure.

Core concept demonstrated: Basic form and components of a plant cell

Thinking like a scientist: Why do you think a cell has so many component parts? Plant cells have cell walls but animal cells do not. Why do you think this is? What would happen if plant cells didn't have these cell walls? What would happen if animal cells did?

Correlation With National Standards:

NSES Science: C.4; C.9

NCTE Language Arts: 1; 4

Variables in Plant Growth

Plants are extraordinary biological engines. They move and grow and process nutrients as animals do; however, the process by which they do this is different. Instead of processes such as eating, digestion, and muscular movement, plants employ the process of photosynthesis to grow. In the following experiment, we will explore variables that influence photosynthesis in plants. (See Experiment 36.)

Experiment 36 The Effect of Acid Rain on Plant Growth

In the following activity, you will simulate the effect of acid rain on the growth of radish plants.

Materials You Will Need for This Activity

- 3 Styrofoam cups
- Masking tape
- Marker
- Potting soil
- Radish seeds (note that if you already germinated radish seeds in Experiment 34 you can use these sprouts rather than sprouting new seeds)
- Ruler
- pH strips or pH soil test kit

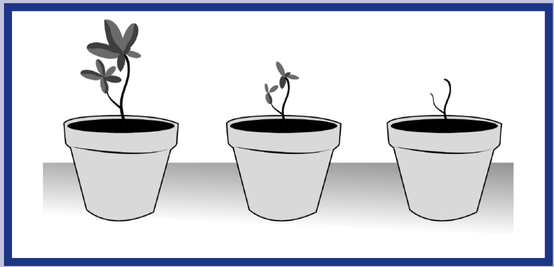


Image 7.11 Acid Rain

What You Will Do:

1. Label three Styrofoam cups A, B, and C with masking tape and marker.
2. Fill each cup with potting soil.
3. With your finger, make a hole about three to five cm deep in the soil.
4. Place five radish seeds in each hole (or plant radish sprouts from Experiment 34).
5. Cover the seeds with soil.
6. Water the seeds in cups A and B with 50 ml of water.
7. Water the seeds in cup C with 50 ml of vinegar.
8. Place the cups in a windowsill with sunlight.
9. Predict what you think will happen to the seeds in each cup.
10. Check your plants each day.
11. Using a ruler, measure their growth in centimeters every three days. Record this information in a data table.
12. Every other day, add 20 ml of water to cups A and B. Add 20 ml of vinegar to cup C.
13. After one week, continue to water only cup A every other day with 20 ml of water. Water pots B and C with 20 ml of vinegar.
14. Make new predictions about what you think will happen to the seeds in each cup.
15. Continue measuring and recording plant growth every three days.
16. After 21 days, take the last measurements of plant height and then measure the pH of the soil in each of the cups.
17. Using the data table you have made, construct a bar graph to display your results.

What you will learn: The lower pH caused by the vinegar will negatively impact plant growth. The more dramatic the pH change, the more pronounced the effect on plant growth.

Core concept demonstrated: Chemical changes in the water or soil can affect plant growth

Thinking like a scientist: How did your results compare with the results of other groups? How can you explain any differences? How did your results compare with your predictions that you made at the beginning of the experiment? What changes could you make in this experiment, based on the information you now have, to extend your understanding of this topic? How could what you have discovered be used to make you a better gardener or farmer?

Correlation With National Standards:

NSES Science: A.1; A.2; C.3

NCTM Math: B4; D2; E1

NCTE Language Arts: 4; 7

Animals

Many people think of the study of animals when they think of biology. Animals come in all shapes and sizes, from microscopic protozoa to mammoth whales, from the ancient jellyfish to the relatively modern *Homo sapiens*. The cellular and anatomical structure of animals, and how they differ from other forms of life such as plants, is one essential component of animal biology. At the ecological level, the ways animals interact with each other and with other elements in the environment is another primary component. For young scientists, the careful observation of animal behaviors provides insights into both the nature of animal life forms and the ways in which animals interact with their natural environment.

Dissecting Owl Pellets

Animal droppings or poop may be pretty gross stuff, but the elimination of fecal matter is an essential part of animal biology. All animals, whether they are reptiles, mammals, birds, fish, or insects, must eliminate biological waste. Nutrients are absorbed by the body when animals eat, and the waste materials need to be expelled. Some creatures have developed unique ways to deal with this biological necessity. Owls, which eat small creatures whole, must expel sharp objects such as bones and hard-to-digest fur. Rather than expelling this material through fecal matter, owls regurgitate it as furry boney lumps called owl pellets. In the materials that are expelled, there is a great deal of interesting residue that provides information about the owl and its diet. Thus, owl pellets provide clues for biologists about what the owls have recently eaten. It is actually possible to take a pellet apart and reconstruct the skeleton of an owl's small prey, such as voles or field mice. (See Experiment 37.)

Experiment 37 Owl Pellet Dissection

In the following activity, you will explore the contents of an owl pellet and attempt to reconstruct the skeleton and identify the last creature eaten by the owl.

Materials You Will Need for This Activity

- Owl pellet
- Paper plates
- Pair of tweezers
- Toothpicks
- Latex gloves
- Glue
- Skeletal chart of mouse or vole (usually included with owl pellets if purchased from a science supply company)

*Safety Note—The owl pellets, which come from a biological supply house, have been sterilized to kill germs, but it is still recommended to wear latex gloves when handling the pellets.

Image 7.12 Owl

What You Will Do

1. Measure the pellet (length, width, and mass).
2. Carefully pull the pellet apart.
3. Separate the bones from the fur with the tweezers or toothpicks.
4. Set the bones on one plate and fur on another.
5. Organize and classify the bones into piles.
6. Count the number of each type of bone found in your owl pellet.
7. Record your bone count results on a bar graph.
8. Try to reconstruct the skeleton of the creature by laying out the bones on a flat surface.
9. Glue your skeleton to a piece of paper.

What you will learn: Owl pellets contain the skeletal remains of small prey that can be sorted and at least partially reconstructed.

Core concept demonstrated: Examination of reconstruction of an animal skeleton

Thinking like a scientist: What additional materials would help you to more accurately construct the skeleton of the owl's prey? How was your task similar to that of a paleontologist attempting to reconstruct a dinosaur skeleton? What makes the paleontologist's task even more difficult?

Correlation With National Standards:

NSES Science: A.1; C.4

NCTM Math: C4

NCTE Language Arts: 1; 4; 7

Animal Cells

Different life forms have different cellular structures. The basic structures of animal cells are different from those of plant cells. Animal cells don't have a cell wall. This makes them more flexible than plants which have rigid cells. Animal cells do not have chloroplasts because they do not make food through photosynthesis. Instead, animal cells have Golgi bodies and vacuoles that help distribute nutrients that provide energy for cell functions. (See Experiment 38.)

Experiment 38 Making an Animal Cell Model

To see a demonstration of this experiment, go to www.sagepub.com/buxton2e.

In the following activity, you will make an edible model of an animal cell.

Look at Image 7.8 for a picture of an animal cell compared to a plant cell.

Materials You Will Need for This Activity

- 1 package of Jell-O (light color)
- 1 package of Knox gelatin mixture (to make Jell-O stiffer)
- 1 paper plate
- 1 small plastic cup
- 1 plastic knife
- 1 plastic spoon
- Toothpicks
- 2 blue or green pieces of Fruit Roll-up (Golgi bodies)
- 2 red or yellow pieces of Fruit Roll-up (endoplasmic reticulum)
- 1 teaspoon of round cake sprinkles (ribosomes)
- 4 Hot Tamales (or similarly shaped candy) (mitochondria)
- 4 chocolate-covered raisins (vacuoles)

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- 1 gum ball (nucleus)
- Microscope
- Microscope slide

What You Will Do

1. Mix the Jell-O gelatin according to the directions. Add some unflavored Knox gelatin to the Jell-O to make it stiffer.
2. Pour the Jell-O mixture into individual plastic cups until they are about two-thirds full. Put them in the refrigerator to set.
3. Remove the Jell-O from the plastic cup by turning it over and placing it on a paper plate.
4. Cut the Jell-O in half to form two cylinders.
5. Use a spoon to carefully scoop out a hole in the bottom (larger) half of the Jell-O.
6. Place the gumball in the hole to represent the nucleus of the cell.
7. Continue in this way, using the spoon to make spaces to put the other cell parts into the cell as directed in the materials list above.
8. Parts can be put into both the top and bottom half of the Jell-O cell.
9. When all the parts are in place, carefully take the top part of the cell and place it back on the bottom half.
10. Now that you have made a model animal cell, you will look at a real cell. Use a clean toothpick to scrape the inside of your cheek.
11. Place the cheek cells on the microscope slide and look at them under the microscope. Can you observe individual cells? Individual organelles? How do they appear similar to or different from your cell model?

What you will learn: Animal cells contain many components that are tightly packed into every cell.

Core concept demonstrated: The components and basic structure of an animal cell

Thinking like a scientist: How does this model of an animal cell differ from the plant cell model you constructed earlier (Experiment 35)? How is it similar? How did your observations of the cheek cell differ from your observations of the onion skin cells in Experiment 35? How are they similar?

Correlation With National Standards:

NSES Science: C.4; C.9

NCTE Language Arts: 1; 4

Bird Census and Journal on Animal Behavior

Every 10 years the U.S. **Census** counts all of the people in the United States. In 2000, for example, it was determined that the population of the country was 282,421,906 (http://www.census.gov/). The unofficial U.S. population in early 2010 was 308,702,901. Census takers want to know more than just the number of people living here, however. They are interested, for example, in the number of men and women, children and adults, the types of jobs people have, where they live, and so on. This information is enormously important to better understand future trends in our country. For example, it allows sociologists to predict future demands on schools or the number of people who are going to be retiring.

Similarly, conducting censuses of animals is a very important source of information for biologists. An animal census can provide information about the stability or health of a population, as well as provide insight into the behaviors of particular species. Unlike people, however, animals cannot simply be asked to respond to a census, so biologists need to develop other methods. (See Experiment 39.)

Experiment 39 Conducting a Bird Census

In the following activity, you will conduct a bird census by observing birds in your schoolyard and keeping track of their behavior over time.

Materials You Will Need for This Activity

- Bird guide (preferably specific to your state or region. Guides that are relevant to your geographic region can readily be found from online booksellers. Many of these books should also be available in your local library. In addition, your local Audubon Society may have information, including websites, for learning more about birds in your part of the country.)
- Binoculars (optional)
- Notebook and pencil

What You Will Do

1. Make a census table in your notebook with 3 columns: kind of bird, where the bird was spotted, what the bird was doing.
2. Go outside in the schoolyard and look for birds.
3. For every bird you see, make an entry in your census journal, recording where the bird was spotted, what the bird was doing, and, if you are able to, identifying the species or more general type of bird.
4. Make your observations for about 10 to 15 minutes.

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5. Repeat your observations either every day for a week or once a week for at least a month, but preferably for the entire school year. It is best if you go to the same spot to observe each time.
6. Once you have collected all your data in your table, discuss how you could express and share your data using graphs or other representations.

What you will learn: Within a given ecosystem, there are a wide variety of bird species with a wide variety of behaviors, both of which change over the course of the year.

Core concept demonstrated: Variation of species and behaviors in a given ecosystem

Thinking like a scientist: What kinds of birds were the most common in your schoolyard? Was this consistent over the year or did it change with the seasons? Were the bird behaviors consistent over the year or did they change? What might explain any changes you recorded over the year? How might a scientist make use of bird census data of this kind? Check out the Citizen Science Project for projects that connect amateur bird watchers with bird biologists: http://www.birds.cornell.edu/ NetCommunity/citsci/

Correlation With National Standards:

NSES Science: A.2; C.3; C.7; G.1

NCTM Math: A3; B1; E1

NCTE Language Arts: 1; 3; 7

NCSS Social Studies: 3

Neither Plant nor Animal: Protista, Monera, Viruses, Bacteria, Fungi

When Linnaeus first developed his system of classifying living organisms, he considered only plants and animals. We now know, however, that plants and animals are not the only forms of life on Earth. A later organization divided living organisms into two main groups: the monera, including bacteria and blue-green algae (organisms whose cells lack a nucleus); and the eucaryotes, including protozoa, algae, plants, fungi, and animals (organisms whose cells contain a nucleus). More recently, this arrangement has been replaced by the six-kingdom classification that divides the living organisms into the following kingdoms: Plants, Animals, Fungi, Protists, Archaebacteria, and Eubacteria. We have discussed plants and animals. Fungi used to be confused with plants, but they have no chloroplasts and do not make their own food. They include mushrooms, molds, and yeasts. Protists are single-celled organisms but with complex cell structures, unlike bacteria. Protists include algae, protozoa, and some types of molds.

Archaebacteria are single-celled organisms that live in environments with little or no oxygen and high acidity, such as hot springs and deep ocean vents. Thus, they are quite rare and were the last of the kingdoms to be included in the current classification system. Eubacteria account for the rest of the bacteria that are not archaebacteria and thus we are more familiar with this kind. They are the bacteria in our yogurt and also the bacteria that can make us sick. Some of these groups of organisms are easy to overlook, but they all play important roles in the Earth's ecosystems.

Microscope Studies of Pond Water

One amazing thing about biology is the growing awareness of the variety of life that exists at all scales, even at the microscopic level. If you look at a pond, it usually appears to be mostly empty water with plants growing around the edges and probably some algae growing on the surface. On careful examination, however, you will typically find a complex ecosystem with a wide variety of plant and animal life. Some of these plants and animals are visible to the naked eye, but even more can be seen with the aid of a microscope. (See Experiment 40.)

Experiment 40 Exploring Pond Water

In the following activity, you will take a sample of pond water and catalog the microscopic forms that can be observed.

Materials You Will Need for This Activity

- Pond water sample
- Petri dish or watch glass
- Magnifying glass
- Medicine dropper
- Microscope
- Microscope slides and cover slip
- Field guide of pond organisms

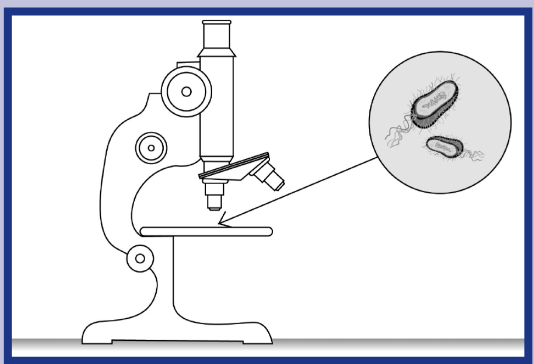

Image 7.13 Pond Water Under a Microscope

What You Will Do

1. Collect water samples from nearby ponds, streams, or canals and bring the samples back to the classroom.
2. Use the medicine dropper to place several drops of pond water into a small dish. Record and draw anything you observe in your sample with the naked eye.
3. Next, observe the sample using a magnifying glass. Record and draw anything you observe.

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4. Get a microscope slide and a cover slip. Use the medicine dropper to put one or two drops of pond water on the middle of the slide, and put the cover slip on top of the pond water.

5. Look at the slide you made using the microscope. Record and draw anything you observe under the microscope.

*Safety Note—Pond water may contain harmful bacteria or other substances. Never drink the water and try to keep it out of cuts or other injuries where it can cause infections.

What you will learn: There are a number of living organisms in pond water, some of which can be seen with the naked eye and some of which require magnification.

Core concept demonstrated: Protista are among the microscopic organisms found in pond water.

Thinking like a scientist: How can you tell whether the pond organisms you observed were animals, plants, or protista? What strategies can you use to differentiate the three? Which were the most common in your pond sample? Why might this be? Do you think this would hold true in samples from other ponds? Why or why not?

Correlation With National Standards:

NSES Science: A.1; C.3; C.7

NCTM Math: D2

NCTE Language Arts: 4; 7

NCSS Social Studies: 3; 8

The Action of Yeast in Dough

Organic material can be altered as a result of biological and biochemical processes. For example, the fermentation process that results in wine occurs when grapes are crushed and the sugars undergo a biochemical process. A similar process occurs in the making of bread. Bread "rises" because of the addition of yeast that produces a gas. Yeast feeds on the sugars in flour and gives off carbon dioxide in the process.

Yeast is a fungus. It is so small that just one gram contains over 20 billion yeast cells. These cells will produce carbon dioxide, as long as there is enough simple sugar present for the yeast to use as food. (See Experiment 41.)

Experiment 41 The Power of Yeast

To see a demonstration of this experiment, go to www.sagepub.com/buxton2e.

In the following activity, you will look for evidence of the biochemical reaction that takes place when yeast feeds on sugar.

Materials You Will Need for This Activity

- 1 packet of active dry yeast
- 2 tablespoons sugar
- 1 cup very warm (but not hot) water (about 110°F)
- A large balloon
- An empty 16- or 20-ounce water bottle

Image 7.14 Bread Dough

What You Will Do

1. Stretch out the balloon by blowing it up several times.
2. Add the yeast and the sugar to the cup of warm water and stir.
3. When the yeast and sugar are dissolved, pour the mixture into the empty water bottle.
4. Attach the balloon over the mouth of the water bottle.
5. Observe the balloon every few minutes over the next 30 minutes.
6. Sketch what happens to the balloon.

What you will learn: Yeast feeds on sugar and produces the gas carbon dioxide. This is what happens in the balloon and it is also what happens when bread rises. The carbon dioxide gas gets trapped in many little balloon-like bubbles in the bread dough, and once it is baked, this gives the bread its texture.

Core concept demonstrated: Fungi such as yeast produce biochemical reactions.

Thinking like a scientist: What do you think would happen if you used twice as much yeast in this experiment? Half as much yeast? Twice as much sugar? Half as much sugar? Hotter water? Colder water? You might want to try some of these variations to compare them with your initial results.

Correlation With National Science Standards:

NSES Science: A.1; A.2; C.1; C.2

NCTM Math: D1; D2

NCTE Language Arts: 1; 7

Looking for Helpful Bacteria in Our Food

Have you ever cut yourself and put an ointment on the cut so it doesn't get infected? The reason you do this is to kill bacteria, which can easily enter an open wound and spread. You have probably also used an antibacterial soap or gel to clean your hands. You probably think that bacteria are always harmful and will make you sick. This is true for some bacteria, but it is not always the case. Bacteria in food can be both good and bad. You don't want to eat a spoiled piece of meat that has begun to rot and is growing bacteria. However, certain kinds of bacteria are necessary to make some of our favorite foods, including cheese, buttermilk, and yogurt. (See Experiment 42.)

Experiment 42 Making Yogurt

In the following activity, you will use a bacterial culture to make yogurt.

Materials You Will Need for This Activity

- 1 gallon of 2% milk
- Box of instant nonfat dry milk
- Container of plain (no fruit added) yogurt (be sure the label indicates that the product contains a live culture)
- Kitchen thermometer
- Measuring cup
- Large saucepan
- Stove or hot plate
- Styrofoam cups or used and cleaned yogurt cups
- Sugar (optional)
- Fruit preserves (optional)

Image 7.15 Yogurt Container

What You Will Do

1. Mix one gallon of 2% milk and 2-3/4 cups of nonfat dry milk in a large saucepan.
2. Sugar may be added to the milk before boiling, if desired. Try 1 cup the first time, and then adjust to taste in subsequent batches.
3. Heat the milk in the saucepan to boiling and then let the milk cool to 110°F. (Be careful not to let the milk boil over! Boiling the milk kills unwanted bacteria.)
4. Remove any "skin" that may have formed on the milk as it cooled.
5. Warm 1 cup of starter culture (plain yogurt bought at the store or dry starter culture can be purchased online) to 110°F in a warm water bath and then add the starter to the milk once the milk has also cooled to 110°F.

6. Mix well, but gently, so as not to stir in too much air.
7. Sanitize your yogurt containers (Styrofoam cups or used yogurt cups) by rinsing them in boiling water or running them through a dishwasher on "sanitize" mode.
8. If fruit is to be added to the yogurt, first warm the fruit in a warm water bath so that its temperature is 110°F. Put the fruit in the bottom of the cups before adding the milk.
9. Pour the milk into the clean containers and cover them with a lid (plastic wrap can be used or the tops of used yogurt cups sterilized with boiling water).
10. The cups of yogurt must now be incubated, maintaining their temperature at 110°F until the milk coagulates with a firm custard-like consistency (this generally takes from 3 to 6 hrs). Do not stir the yogurt during this period.
11. There are several ways to control the temperature during incubation: Yogurt containers can be kept warm in an oven or a Styrofoam cooler box with a lightbulb placed inside to generate heat; yogurt containers can be placed into pans of 110°F water in an oven or an electric frying pan that can be turned on to warm from time to time to maintain water temperature; electric heating pads or solar energy may also be used.
12. After a few hours at 110°F, check for coagulation by gently tilting the cups in which you have been making your yogurt.
13. Once the yogurt is firm, place it in the refrigerator. Eat when cold.

*Safety Note—Close adult supervision is required during the boiling process. As with all food preparation, all containers and materials should be thoroughly cleaned both before and after use.

What you will learn: Bacteria combined with milk during an incubation process results in the transformation of milk into yogurt.

Core concept demonstrated: Some bacteria are beneficial to humans and are part of what we eat.

Thinking like a scientist: Imagine that the batch of yogurt you made didn't turn out right—either it never coagulated or perhaps it tasted bad. What are some of the possible things that could have gone wrong? How could you test your ideas about what had gone wrong to see whether your explanation was correct or not? What are some of the hypotheses that you could generate?

Correlation With National Standards:

NSES Science: A.1; A.2; C.4; E.4; G.1

NCTM Math: D1; D2

NCTE Language Arts: 1; 7; 8

NCSS Social Studies: 8

Ladder of Life: The Building Blocks of Organisms

Cellular construction, photosynthetic processes, and the role of surface areas represent some of the basic structural principles underlying the development of various life forms. Understanding these principles provides us with a growing awareness of how different life forms respond developmentally to the range of forces that act upon them in the world.

Cell Packing

Biological forms consistently make use of the most efficient structures possible. This is almost certainly a matter of survival. In the case of cellular forms, cells generally arrange themselves in ways that allow the maximum number of cells to be put into a minimal space. This makes it possible for the organism to be structurally stronger and to maximize the biological functions contained within it. The British scientist Darcy Wentworth Thompson (1860–1948) concluded in the 1930s that many biological forms, like cells, consistently have the same geometry and that this is primarily a result of efficient packing. In many cases, this results in hexagonal patterns that are highly efficient packing configurations. You can see this in the shape of a turtle shell, as well as in the shape of many plant cells. (See Experiment 43.)

To see a demonstration of this experiment, go to www.sagepub.com/buxton2e.

Experiment 43 Cell Packing

In the following activity, you will observe how materials are packed in ways that make them more efficient to stack.

Materials You Will Need for This Activity

- A 12-ounce can of Pringles© potato chips
- A 12-ounce bag of regular or loose potato chips
- A balance

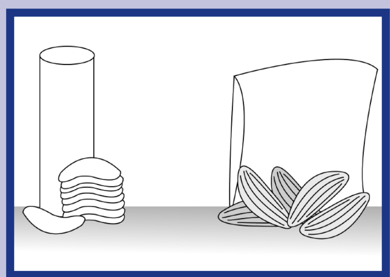

Image 7.16 Chip Packing

What You Will Do

1. Empty the potato chips into two separate piles. You can open the bag of loose chips and simply dump it. Slide the Pringles© out of their can so that they remain stacked on top of one another.
2. Take the loose chips and drop them into the empty Pringles can. Be careful not to crush them. When the can is as full as possible without having crushed the chips, weigh the can on the balance. Record this weight.
3. Empty the can. Now slide the stack(s) of Pringles© back into the can until it is full. Weigh the can. Record this weight and compare it with the weight of the loose chips.

What you will learn: How tightly objects can be packed together will depend on how they are shaped and how they are aligned.

Core concept demonstrated: Efficiency in design and packing

Thinking like a scientist: How can efficiency of the type demonstrated above be useful for people who must transport expensive goods great distances? If you were to design a space station, how might the characteristics of Pringles© inform the type of structure that you built and launched into space? Where can you see design principles of this type in living organisms?

Correlation With National Standards:

NSES Science: A.2; C.4; E.4; G.3

NCTM Math: C1; C4

NCTE Language Arts: 7

NCSS Social Studies: 8

Photosynthesis–Transpiration Interactions

In addition to all the other functions a plant cell carries out (see Experiment 35), the chloroplasts in plant cells must produce the sugars that serve as food for the plant. This is done through the process of photosynthesis. The English chemist Joseph Priestly (1733–1804) discovered that when he captured air under an inverted jar and burned a candle in it, the candle burned out very quickly. He also discovered that placing a mouse in the jar with the candle would cause the candle to burn even faster. He then showed that when he placed a plant in the jar, the candle would burn longer. In 1778, Jan Ingenhousz repeated Priestly's experiments. He discovered that the candle kept burning because sun and light on the plant caused it to produce oxygen. (See Experiment 44.)

Experiment 44 Photosynthesis and Transpiration

In the following activity, you will look for evidence that plant cells engage in photosynthesis and transpiration and the production of oxygen.

Materials You Will Need for This Activity

- 2 or more small pots
- A spray bottle or mister
- A packet of pea seeds

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- A large cardboard box
- A bag of potting soil
- A glass bottle or jar

What You Will Do

1. Germinate the pea seeds by placing them on a damp paper towel in a tray and covering them with warm tap water. A root should spout in two to three days. After the roots appear, the seeds are ready to be planted in the pots.
2. Fill the pots with the potting soil mixture up to 2-1/2 inches from the top.
3. Place the seeds carefully on top of mixture, and cover them with 1/4 to 1/2 inch of soil.
4. Spray water over the top of the soil until the soil is well saturated.
5. Place half of the pots in a well-lit place and the other half of the pots in the closed cardboard box.
6. Spray all the plants lightly with water every two to three days, but otherwise be sure the plants in the box remain in the dark.
7. At the end of one week to 10 days, remove the pots from the closed box and compare them with the pots of seedlings that were grown in the light. What do you see?
8. Remove one seedling from each pot and compare the root structure of the seedlings grown in the dark with the seedlings grown in the light.
9. Leave the pots that were in the dark in the light for a few days, and compare the results.
10. Now place a glass bottle over one of the seedlings, and put it in the sunlight.
11. The next day, observe the inside of the bottle. The condensation you see is the result of water vapor being given off by the plant when it exchanges oxygen for carbon dioxide in the transpiration process.

What you will learn: Comparing a plant left for a week in the dark with one exposed to sunlight allows you to see the key role of photosynthesis in plant cells. Covering a plant with a bottle allows you to see the condensation that is the result of transpiration and the production of oxygen.

Core concept demonstrated: Plant photosynthesis

Thinking like a scientist: Several of the largest mass extinctions of plants and animals in the history of the Earth seem to have been caused by asteroid or meteor impacts that filled the atmosphere with dust and debris for months or possibly even years. How does what you know about photosynthesis explain how such an event could cause this type of extinction? When the Indonesian volcano Krakatoa erupted in 1883, huge amounts of dust were expelled into the stratosphere. Weather was changed across the entire surface of the Earth, and the next year was referred to as "the year without a summer." How do you think this eruption affected plant growth?

Correlation With National Standards:

NSES Science: A.1; A.2; C.4; G.4

NCTM Math: D2; E1

NCTE Language Arts: 7

Cells as Natural Forms

In the opening of this chapter we discussed Ernst Haeckel's extraordinarily detailed and beautiful drawings of radiolarians (see Image 2.13 in Chapter 2). One of the remarkable discoveries of this work was that as complex as these radiolarians appear to be, they take on shapes and forms that are highly predictable. These shapes also correspond to the shapes taken by soap bubbles when suspended in differently shaped metal frames. This process is based on minimal surfaces; as part of an evolutionary process, the radiolarians take on the most structurally and energy efficient forms possible. The forces that shape radiolarians and soap bubbles can be seen at work in other contexts as well. For example, if you suspend vegetable oil in alcohol and water, it will take the form of a sphere, which is the most efficient and minimal form possible. (See Experiment 45.)

Experiment 45 Minimal Surfaces in Natural and Biological Forms

To see a demonstration of this experiment, go to www.sagepub.com/buxton2e.

In the following activity, you will see how spheres are formed as vegetable oil takes on the most efficient form and shape possible.

Materials You Will Need for This Activity

- A flat-sided bottle
- Rubbing alcohol
- An eyedropper
- Vegetable oil
- Water

What You Will Do

1. Fill a flat-sided bottle (a round bottle will distort what you see) 2/3 full with rubbing alcohol.
2. Using a eyedropper, place a few drops of vegetable oil on the surface of the alcohol.

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3. Slowly add water to the bottle until the drops of oil float between the water and the alcohol.
4. No matter how many drops you add, the oil will always form into spheres.

What you will learn: Nature is essentially parsimonious and likes to save energy. Natural forms will tend to take on the simplest and most efficient shape possible. The shape that can hold the greatest volume within the least area is a sphere. This is why soap bubbles become round. What happens with the oil in this experiment is what happens when a soap bubble is formed. The surface area of the suspended soap bubble or oil causes it to take the shape of a sphere because this is the most economical way it can function—it saves energy and space. Similarly, whenever a drop of water falls through the sky as a raindrop, it will always tend to form a sphere.

Core concept demonstrated: Minimal surfaces and volume

Thinking like a scientist: Why are raindrops not perfectly shaped spheres? What other factors influence their shape? What shape would a drop of water take in outer space?

Correlation With National Standards:

NSES Science: C.1; C.8; G.4

NCTM Math: C1; C4; D2

NCTE Language Arts: 7; 8

Code of Life: All Life Is Based on the Same Genetic Code

Biological systems have extraordinary means by which to communicate complex information and data. DNA represents a means by which biological systems can store and transfer this information using a genetic code. A genetic code is a set of rules that serve to map DNA sequences onto proteins in a cell. Almost all living things use the same genetic code. This code determines the characteristics and appearance of the organism as well as which characteristics will be modified or changed through the process of evolution.

Modeling the DNA Double Helix

The DNA double helix holds the genetic code for all life on Earth, and as such, its discovery is seen as one of humankind's greatest scientific breakthroughs. The two names most closely associated with DNA are James Watson (1928–) and Francis Crick (1916–2004), who are widely credited with identifying its structure in the late 1950s. While Watson and Crick undoubtedly deserve credit, there exists a significant controversy around this key scientific discovery. Watson and Crick shared a 1962 Nobel Prize for this work with Maurice Wilkins, who had worked on DNA research independently of Watson and Crick. Wilkins worked in a lab at King's College, London with a chemist named Rosalind Franklin. Between 1951 and 1953, Franklin did most of the foundational work and came very close to solving the puzzle of DNA structure completely on her own. Tensions between Wilkins and Franklin, at least in part due to Franklin being a successful woman in a field very much dominated by men at that time, led Wilkins to show critical parts of Franklin's work to Watson and Crick without Franklin's knowledge or permission. Watson and Crick were able to use this new information of Franklin's to quickly solve the puzzle of DNA's structure and publish their conclusions without giving credit to Franklin.

As a sad end to the story, Franklin developed cancer a few years later and died in 1958. The Nobel Prize guidelines prohibit posthumous awards; thus, Franklin was ineligible to even be considered when the prize was awarded to Watson, Crick, and Wilkins in 1962. Thus, despite her significant contributions, it seems unlikely that Rosalind Franklin will ever be anything but a footnote in the story of DNA's scientific discovery and description. (See Experiment 46.)

Experiment 46 Making a Model of the DNA Double Helix

In the following activity, you will create a model of the DNA double helix structure.

SOURCE: Created by Michael Ströck (Wikipedia, http:// en. wikipedia .org/wiki/Image:DNA_Overview.png).

Image 7.17 Double Helix

Materials You Will Need for This Activity

- Styrofoam balls (about 120)
- Double-end toothpicks (about 100)
- Wooden or metal ring stand to serve as a support
- Paint brushes for painting the Styrofoam balls
- Paints (5 colors)
- Tape or other adhesive

What You Will Do

1. Decide what colors you want to use for each of the five small molecules that make up a larger DNA molecule. These are the four base molecules (Adenine, Thymine, Guanine, Cytosine) as well as Phosphate molecules that hold the base molecules in place.
2. Paint 20 balls each of the four colors you chose for the base molecules and 40 balls the color you chose for Phosphate. Let the balls dry.
3. Start from the base of your stand, and connect the molecules to each other using toothpicks. The large DNA molecule must wrap around the stand's column.

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4. The base molecules of DNA are almost always found as base pairs. Adenine (A) pairs with Thymine (T) and Guanine (G) pairs with Cytosine (C). The prime features of the structure are two strands of DNA wrapped around each other, creating a right-handed helix.
5. Make a pair of C–G (Cytosine–Guanine) by connecting the proper color of balls with a toothpick. Then add a phosphate molecule to each end of the C–G pair. Attach this chain of 4 molecules to the backbone (stand) with tape or other adhesive.
6. Assemble the second row, which can be C–G again or A–T. Attach phosphates to both ends and then attach to the stand just above the first row, but rotated a small amount clockwise relative to the first row.
7. Continue the ladder in this fashion until you run out of balls. Remember that each row must rotate a small amount clockwise relative to the prior row, to create the spiral.

What you will learn: A DNA molecule appears quite complex but, in fact, is made primarily of only two set pairs of molecules with a surrounding support structure.

Core concept demonstrated: Structure of DNA

Thinking like a scientist: Why do you think the DNA molecule has formed in the shape that it has? How can a repeating structure of only four basic molecules possess all the genetic code to grow a new organism as complicated as a human being? Think about minimal surfaces and some of the ideas developed in this book.

Correlation With National Standards:

NSES Science: C.4; C.5; E.5; G.1; G.4

NCTM Math: A1; B1; C4

NCTE Language Arts: 1; 8

NCSS Social Studies: 8

DNA "Fingerprints" for Solving Mysteries

Have you ever watched a detective show on TV in which the suspect was caught because of fingerprints he left behind? Fingerprints are unique to every individual, and fingerprint evidence has been used by police since the eighteenth century. Genetic information, in the form of DNA, is as unique to each of us as our fingerprints; we have a unique genetic code that identifies us. Thus, if a criminal leaves a hair at the scene of a crime, it can be used to identify that individual. When DNA is tested, a process called polymerase chain reaction (PCR) is used to amplify small well-defined strands of a DNA sample, which can then be compared to a known standard (such as for detecting genetic diseases) or to another sample (such as in the case of matching a suspect's DNA with that found at a crime scene). A similar process can be done using chromatography to see the "fingerprints" of colored DNA markers. (See Experiment 47.)

Experiment 47 Black Marker "Fingerprints"

To see a demonstration of this experiment, go to www.sagepub.com/buxton2e.

In the following activity, you will use chromatography to identify a "mystery marker."

Materials You Will Need for This Activity

- Five different brands of black markers
- Coffee filters
- Scissors
- Large bowl with about one inch of water in the bottom
- Ruler
- Tape

Image 7.18 Fingerprint

What You Will Do

1. Cut coffee filters into rectangular strips about one inch wide and six inches long.
2. Draw a horizontal line across each strip of coffee filter about one inch from the bottom, using a different black marker for each strip.
3. Label each strip, so you know which marker was used on it.
4. Place the ruler across the top of the bowl of water.
5. Tape the strips to the ruler so that the strips hang down with the water touching the bottom of the coffee filter, but not touching the ink.
6. The water should creep up the coffee filter strips and separate each ink line into a unique pattern.
7. Now have a person not in your group write a short note on a coffee filter using one of the markers, without telling anyone which marker was used. How can you solve the mystery to find out which marker was used to write the note?
8. Use the same procedure you used to test the five markers originally to find the "color fingerprint" of the mystery marker.
9. Compare the pattern from the mystery marker to the five standards you have created to see which one it matches. Check your answer with the person who wrote the note.

What you will learn: Even though the inks from different markers appear the same, they are actually made of many different dyes. Chromatography can be used to separate the dyes in the different inks to make different patterns. A different type of separation technique is used in much the same way to identify DNA samples.

Core concept demonstrated: Separation techniques can be used to identify individual subjects.

Thinking like a scientist: What do you think would happen if you used colored markers instead of black markers? Would they separate into different components, or are the colors based on one dye? How else might chromatography be used in the study of proteins, in industrial chemistry, and so on?

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Correlation With National Standards:

NSES Science: A.1; A.2; C.5; C.8; F.10

NCTM Math: E1; E3

NCTE Language Arts: 4; 7

NCSS Social Studies: 8

Genetic Defects

The chromosomes found within living cells represent extremely complex mechanisms for turning on and off different functions in cellular systems. The analogy can be made that chromosomes are like the keys that open the locks on a door and, in turn, allow certain cellular functions to take place. They can also be thought of as catalysts for setting these functions in motion. Genetic defects are generally a result of one or more abnormalities on one or more chromosomes. Many genetic defects can now be detected prenatally (before a baby is born), and other tests for genetic defects are routinely done with newborns while they are still in the hospital. One such test is a hearing test to check the baby for evidence of hearing loss or deafness. (See Experiment 48.)

Experiment 48 Hearing Loss Simulation

In the following activity, you will experience what life is like for people with a hearing loss.

Materials You Will Need for This Activity

- Earplugs (with the greatest amount of noise blockage or attenuation you can find)
- Earmuffs, scarves, or wool hats

Image 7.19 Hearing Loss

What You Will Do

1. Divide the class into two groups: one that will simulate moderate hearing loss and one that will simulate minor hearing loss.
2. Group A (moderate hearing loss) will use earplugs to filter out most of the sound.
3. Group B (minor hearing loss) will use earmuffs, scarves, or wool hats to filter out some of the sound (but less than those wearing the earplugs).

4. Students will spend the entire day with the simulated hearing loss.
5. All students will use a journal to record the following:
   a. Which group they are in
   b. How they were treated by other students and people they encountered
   c. How they responded to the way others treated them
   d. How they felt during the simulation
   e. How the simulation changed or did not change their view of hearing loss

*Safety Note—The teacher should send a memo to other teachers in the school and to the students' homes prior to the day of the activity to advise them of the purpose of the activity. Instruct students to be careful not to do anything that might be dangerous because of their blocked hearing, such as crossing the street alone.

What you will learn: Hearing loss, which is often genetically based, affects many aspects of a person's life and requires the person to change and adapt many behaviors.

Core concept demonstrated: The effect of hearing loss on social behavior

Thinking like a scientist: In what ways did you have to adapt to your simulated hearing loss? What were the differences between the ways the group with moderate hearing loss and the group with minor hearing loss adapted? How might the adaptations in this activity be different from those that would be used in a simulation of vision loss?

Correlation With National Standards:

NSES Science: A.2; C.4; C.5

NCTE Language Arts: 4; 7; 12

NCSS Social Studies: 3; 8

Evolution: Natural Selection and Evidence for Species Evolution

Evolution can be defined as a change in the gene pool of a population over time. A gene is a hereditary unit that is passed on from generation to generation. The gene pool is the collection of all the genes in a given population. One of the most commonly cited examples of observed evolution is the case of the English moth. This moth comes in two colors, a light moth and a dark moth. In the mid-1800s, dark moths only accounted for about 2% of the English moth population. By 1900, however, approximately 95% of the English moths around the English city of Manchester were of the dark variety. In rural areas, however, light moths still made up the majority of the population.

The moths' color was determined by a single gene. Therefore, the increase in dark-colored moths represented a change in the gene pool, or evolution. The increase in number of dark moths was a result of natural selection. During England's industrial revolution, pollution from the factories darkened the bark of the trees that the moths frequently rest on. Against this dirty background, birds could more easily see the light-colored moths and ate more of them. As more of the light-colored moths were eaten, more dark moths survived to reproduce. The greater number of dark-colored offspring survived to continue this pattern. This is an example of natural selection.

It is important to understand that in evolution, individuals do not evolve. In the example of the English moths, no light-colored moths changed to a dark color to avoid being eaten. Instead, individuals that were dark color were more likely to survive and reproduce, and over time the moth population evolved to include more dark moths.

Bird Beak Models

Have you ever gone to the zoo or watched a nature program and seen different types of birds? Have you noticed the variations in birds' beaks, depending on where they live and the types of food they eat? This is part of an evolutionary adaptation that has led to extraordinarily different types of bird beaks. A bird like a stork or egret that primarily hunts small fish has a beak that allows it to spear its prey. By contrast, a parrot, which feeds largely on nuts that must be cracked, has a conical beak that is very strong (Never put your finger in a parrot's beak! Ouch!). (See Experiment 49.)

To see a demonstration of this experiment, go to www.sagepub.com/buxton2e.

Experiment 49 Bird Beak Models

In the following activity, you will explore models of bird beaks and examine what type of beak is best suited for eating various types of food.

Materials You Will Need for This Activity

- Tweezers
- Birdseed
- Nutcrackers
- Goldfish crackers
- Nut picks
- Apples
- Slotted spoons
- Peanuts
- Tongs
- Gummy worms
- Bird guidebooks or other accurate pictures of birds

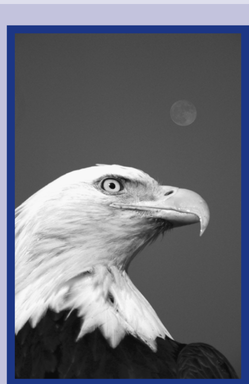


Image 7.20 Bird Beak

What You Will Do

1. Arrange the five representations of different types of bird foods and the five tools that represent different types of bird beaks in a tray.
2. Using the food and "beaks" in front of you, try to determine the foods that a bird with that type of beak would be best suited to eat and why. Fill in the table below.

Tool/Bill	Type of Food	Best Fit? Why?
Tweezers		
Nut Picks		
Slotted Spoon		
Tongs		
Nutcracker		

3. Using a bird book or a website of bird photos or drawings select six different bird pictures. Make predictions about the type of food each bird might eat based on the shape of its beak and what you learned from collecting food with the different model beaks.

What you will learn: Different species of birds have evolved over time to have different beak forms in order to compete effectively for specific kinds of foods.

Core concept demonstrated: Evolutionary adaptations

Thinking like a scientist: Did everyone agree with the matching between the types of foods and the model beaks? If there was any disagreement, how could you resolve it? Are all types of bird beaks equally common, or are some more common than others? Why might this be? How might geography play a role in bird beak adaptations?

Correlation With National Standards:

NSES Science: A.1; A.2; C.4; C.8; G.1

NCTM Math: E1

NCTE Language Arts: 7; 8

Stereoscopic Vision

Almost all animals have two eyes. This is not an accident, but instead is an evolutionary adaptation. Animals that tend to be hunted as prey (e.g., deer, rabbits, many fish, and mice) usually have their eyes placed on the sides of their heads to allow for the greatest possible field of vision (see Image 7.21). Predators such as bears, foxes, lions, housecats, wolves, and humans have eyes that are located on the front of their heads facing forward and closely spaced to one another (see Image 7.22). This orientation of the eyes for predatory animals makes possible stereoscopic vision and enhanced depth perception, which is a significant advantage for predators when hunting.

This young sheep, a herbivore (plant eater) and a herd animal that is hunted by predators like wolves and mountain lions, has eyes that are set in the side of its head for increased field of vision.

The close forward eye placement on this bear is typical of a predatory or hunting animal.

Stereoscopic vision results when the brain combines the images that are received from each eye into a single image. A slight offset of the two images allows the viewer to have greater depth perception. Depth perception is lost as you bring what is being observed very close to the viewer's eye. (See Experiment 50.)

Image 7.21 Sheep

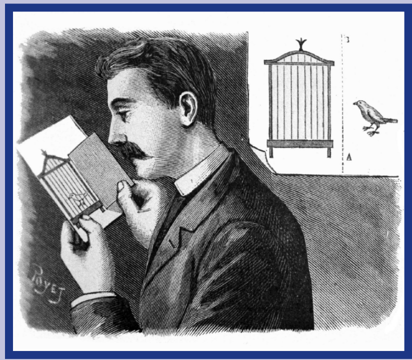
Image 7.22 Bear

Experiment 50 Experimenting With Stereoscopic Vision

In the following activity, you will see how stereoscopic vision works.

Materials You Will Need for This Activity

- Two 3″ × 5″ cards
- Image 7.23
- A pencil or pen



SOURCE: Illustration by Poyet from Good (1893).

Image 7.23 Bird in Cage

What You Will Do

1. Draw the image of the bird and birdcage as illustrated in the upper right hand corner of Image 7.21. Your drawing should be divided in half and take up as much space as possible on the card.
2. Hold the card in front of your face like the man in Image 7.21. Make sure you hold the blank card at a right angle to your drawing (on the dotted line marked B–A). Now, move your nose slowly toward the center of the picture. As you do so, you will see the bird move into the cage.

What you will learn: When your eyes get too close to an image, you lose your depth perception. Your brain can no longer distinguish the two different views of each image it is receiving from your eyes as it usually does. Instead, the two different images come together.

Core concept demonstrated: Binocular or stereoscopic vision as an evolutionary adaptation

Thinking like a scientist: What types of toys or visual devices can be created based on this phenomenon? Why is depth perception important? Why can't a person who is blind in one eye get a driver's license in some states?

Correlation With National Standards:

NSES Science: C.4; C.6; C.8

NCTM Math: C4

NCTE Language Arts: 7

Evolutionary Adaptations to Fill Ecological Niches

Think about what a giraffe, an elephant, and a brachiosaurus dinosaur might have in common. Each is (or was) a plant eater that evolved to eat plant material from tall growing plants. The brachiosaurus had a long neck that allowed it to reach its head high and feed from tall plants; the giraffe uses the same approach today. An elephant achieves the same goal by using its trunk to tear leaves off trees or to pick things up off the ground. Each of these three species evolved to fill an ecological niche, eating plant material out of the high trees, thus allowing them to successfully compete with the various other species living in the same environment. (See Experiment 51.)

Experiment 51 Design-an-Organism

In the following activity, you will design an organism that is well suited for living in a specific environment.

Materials You Will Need for This Activity

- Paper and pencil
- Modeling clay

What You Will Do

1. Discuss the ecosystem around your school. What kinds of plants and animals live in this ecosystem? How have these plants and animals adapted so that they are well suited to survive?
2. You will design a new organism (either plant or animal) to fit into a certain niche, either in your local ecosystem or in another ecosystem of your choosing. Think about the following questions:
   - How big is your organism?
   - What kind of food will it eat? How much food will it need to survive? How will it get this food?
   - What behaviors will your organism possess to aid its survival?
   - How will your organism reproduce? How often?
   - What niche will the organism fit into and what organisms already occupy that niche?
   - What will your organism look like? Make sure to consider both structure and function in your design.
3. Draw a picture of your organism and write a description of how each of its parts and behaviors helps it to survive in this ecosystem.
4. Finally, make a clay model of your organism, highlighting the features that allow it to survive and thrive in its environment.

What you will learn: A habitat is a place where an organism lives. A habitat contains the basic necessities for that organism, such as light, food, air, water, temperature, and sufficient space. A niche is the role and position of an organism within a particular habitat. Each organism in an established ecosystem tends to have a distinct niche. Thus, any newly introduced organism will likely have to engage in competition with an organism that is already occupying that niche.

Core concept demonstrated: Over time, species adapt to fill certain ecological niches in an environment.

Thinking like a scientist: Predict the impact of your new organism on the ecosystem. Will the other organisms currently filling the niche that your new organism is moving into be able to co-exist with the new organism? Why or why not? Is it common for a new organism to appear suddenly in an ecosystem it did not previously inhabit? What might cause this?

Correlation With National Standards:

NSES Science: A.2; C.1; C.3; C.4; C.8

NCTE Language Arts: 4; 5; 8

NCSS Social Studies: 3

Biomes and Ecosystems: Interactions Between Plants, Animals, and the Non-Living World

What Is a Biome?

Biomes and **ecosystems** represent the settings in which plants, animals, and the non-living world interact. A **biome** is generally defined as a large area containing similar flora, fauna, and microorganisms. Examples of biomes include coniferous forests, deserts, tropical rainforests, and Arctic tundra. Each biome contains species that have adapted to survive in that biome's varying conditions. For example, elk and big horn sheep thrive in the high mountains while alligators and wading birds are well suited to surviving in the marshlands.

Ecosystems are similar to biomes, only generally smaller in area. While some ecosystems can be quite large, such as the Amazon rainforest, ecosystems can also be as small as the stream running through your neighborhood. Ecosystems are often defined as the dynamic interactions between plants, animals, microorganisms, and their environment. Within an ecosystem, each organism has its own niche, or role, to play.

Tracing Food Webs

Think for a moment about a farmer in a pioneering region in the United States during the nineteenth century. Such a farmer might have some cows and pigs, a small vegetable garden, and might produce some larger crops such as corn or wheat. Every year the farmer might slaughter a certain number of animals to eat and might find a certain number of other animals, such as deer or wild turkey, he could hunt off the land. He would combine these animal food sources with the crops that he grew, plus other plants he foraged, such as wild nuts and berries. His cows and pigs would need to be fed corn or other grains, and the animal wastes might be composted, with the help of decomposers such as worms, and then used as fertilizer for the vegetable garden.

The ecosystem in which this farmer is the top-level consumer represents a complex web of consumers and producers. All living organisms are part of complex food webs in which some species are producers, others are consumers, and still others are decomposers. (See Experiment 52.)

Experiment 52 Tracing Food Webs

In the following activity, you will role-play a food web as each member of the class takes on the role of one organism in an ecosystem.

Materials You Will Need for This Activity

Index cards with holes punched in two corners and yarn tied through to hang around neck. Label the cards as follows:

- 1 card labeled "Sun"
- 2 cards labeled "frog"
- 6 cards labeled "grass"
- 2 cards labeled "mouse"
- 5 cards labeled "grasshopper"
- 4 cards labeled "snake"
- 2 cards labeled "chicken"
- 2 cards labeled "hawk"

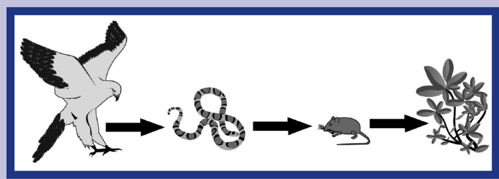


Image 7.24 A Food Chain

What You Will Do

1. Clear a space in the middle of the room and pass out the role cards, one per person.
2. The person representing the Sun stands in the center of the room. Discuss the importance of the Sun to all living things. What uses the Sun to make food?
3. People representing the grass stand in a circle around the Sun. The grass needs the Sun to make food, so each person representing grass should place one hand on a shoulder of the Sun. Discuss the importance of plants in the food chain.
4. Tell everyone else to find an organism that their organism eats. Have them stand behind the organism they eat, placing one hand on that person's shoulder.
5. There should be at least four people (counting one plant and the Sun) in each food chain that makes up the food web.

What you will learn: There is a fundamental interdependence between consumers and producers, predators and prey. These organisms form intricate food webs that can be disrupted when there are too many or not enough of a given organism in an ecosystem.

Core concept demonstrated: Food webs

Thinking like a scientist: Did any of the organisms have a difficult time finding a place in the food web? Who is competing for food? Is it easier for an omnivore, an herbivore, or a carnivore to find food? What is the difference between a food web and a food chain?

Correlation With National Standards:

NSES Science: C.3; C.7; F.2; F.7

NCTM Math: B1

NCTE Language Arts: 4; 7

NCSS Social Studies: 3

Measuring the Greenhouse Effect

As you will recall from the previous chapter, the atmosphere is just one system within a complex collection of interconnected Earth systems. Earth's atmosphere extends to a distance of approximately 600 miles above the planet's surface. Life forms, however, cannot exist more than five or six miles above the Earth's surface. The conditions for life on Earth are profoundly shaped by atmospheric conditions, and changes in these conditions can affect a wide range of life forms. In recent years, the production of greenhouse gases through the burning of fossil fuels has led to changes in the Earth's atmosphere and, thus, changes in weather and global climate. (See Experiment 53.)

Experiment 53 Greenhouse Effect Model

To see a demonstration of this experiment, go to www.sagepub.com/buxton2e.

In the following activity, you will create a model to study the effect of carbon dioxide on temperature changes as a result of trapped gases similar to those that create the greenhouse effect on the Earth's atmosphere.

Materials You Will Need for This Activity

- Two 2-liter plastic soda bottles (with their labels removed)
- Modeling clay
- Vinegar
- Baking soda
- Two thermometers
- Measuring spoons
- Sunlight

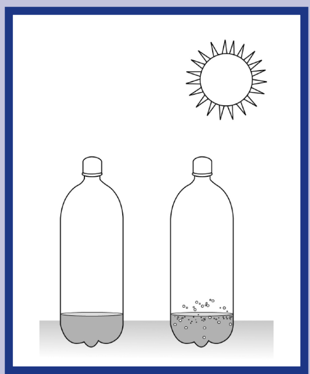


Image 7.25 Greenhouse Model

What You Will Do

1. Label one 2-liter bottle "With Carbon Dioxide" and label the other bottle "Without Carbon Dioxide."
2. Add two teaspoons of baking soda and then two teaspoons of vinegar to the bottle labeled "With Carbon Dioxide." This mixture will produce carbon dioxide gas.
3. Quickly cover the opening of the bottle with modeling clay to stop the carbon dioxide from leaking out.
4. Add two teaspoons of vinegar only to the bottle labeled "Without Carbon Dioxide" and cover the bottle opening with modeling clay.
5. Carefully make a small hole in the modeling clay covering the opening of each bottle and poke the thermometers through the holes.
6. Place both bottles in a sunny place.
7. Make a data table and record the temperature in each bottle every five minutes for a 60-minute period.
8. Make a line graph representing the temperature in each bottle over the 60-minute time period.

What you will learn: The heating effect you observed in this activity is known as the greenhouse effect because carbon dioxide in the Earth's atmosphere acts like the glass in a plant greenhouse. The carbon dioxide allows warm sunlight to enter the bottle but prevents the re-radiated heat from escaping the bottle. The greenhouse effect is a natural phenomenon that is actually very important to life on Earth. Without this effect at work, the average temperature on Earth would be approximately 30°C colder than it currently is. However, the enhanced greenhouse effect, also known as global warming, has the potential to create too much warming, which could result in a destructive global sea level rise, significant shifts in the planet's climate patterns, and other dire consequences for the inhabitants of Earth.

Core concept demonstrated: Greenhouse effect

Thinking like a scientist: There is currently both scientific and political debate about the enhanced greenhouse effect, how significant this effect might be in the future, and what the consequences might be. Why is it difficult to agree on concrete answers to these questions? What might allow for more definitive answers?

Correlation With National Standards:

NSES Science: A.1; C.3; E.3; F.9; F.10; G.1

NCTM Math: B1; D1; D2

NCTE Language Arts: 4; 7; 8

NCSS Social Studies: 3; 8

Unintended Consequences

In science, as in life more generally, taking an action may sometimes lead to unexpected consequences. For example, rabbits were introduced in Australia in 1895. However, they became a major pest because there were no predatory animals, such as foxes and coyotes, to keep the rabbit population under control. If people had realized the way in which rabbits would overrun the Australian countryside, they surely would not have introduced them.

Unintended consequences can occur in other ways as well. Aspirin was introduced as a pain reliever in the late nineteenth century. It was eventually found that a small daily dose of aspirin also reduced the risk of heart disease. While this was beneficial, the introduction of other drugs have had unexpected tragic consequences. For example, in the 1960s, the drug thalidomide was used to help women deal with morning sickness during pregnancy. However, it was soon discovered that thalidomide caused birth defects, including missing limbs. (See Experiment 54.)

Experiment 54 Unintended Consequences

In the following activity, you will explore the law of unintended consequences by analyzing social and geographical structures in a major city.

Materials You Will Need for This Activity

- Historical and modern maps of New York City
- Historical and modern photographs of New York City
- Note—Alternatively, you could use maps and photos of the largest city in your state to make this activity more relevant for your students.

What You Will Do

1. Study the historical and modern maps and photos of New York City. New York City was founded in 1624 by Dutch fur traders and settlers. They chose the site because of the excellent harbor created by the Hudson River and the access the river gave them to the interior of the region.
2. Think about how establishing the city initially on the island of Manhattan influenced its early development. What happened as the city outgrew Manhattan? What technologies had to be implemented to cope with population growth?
3. Create a list of unexpected consequences resulting from the decision to establish a city at the mouth of the Hudson River.

What you will learn: Social systems, like natural systems, develop and evolve in unexpected ways.

Core concept demonstrated: Unintended consequences and their impact on environments

Thinking like a scientist: Why is the country's main theater district in New York and not in Iowa? Think about the other major cities in the U.S., such as Los Angeles, Chicago, or Houston. Why might they have developed where they did? What might be some of the unintended consequences of their development?

(Continued)

(Continued)

Correlation With National Standards:

NSES Science: A.2; C.3; C.7; F.7; F.10; G.1

NCTE Language Arts: 1; 4; 8

NCSS Social Studies: 3; 8

The Human Body and Human Health

In the sciences, we spend more money and time on research into the human body and its functioning than on any other topic. Human beings are complex organisms shaped by many different forces, including the mechanics of our bodies, the foods we eat, and the drugs we take to improve our health.

Tracking Food Choices

Different types of foods are good for us for different reasons. Too much or too little of a food can lead to a nutritional deficiency or other type of health problem. For example, too much sugar causes diabetics to have various blood circulation problems that can lead to blindness or the loss of limbs. Keeping a balanced diet is an extremely important part of people's health. (See Experiment 55.)

Experiment 55 You Are What You Eat

In the following activity, you will track the food choices you make during a three-day period and then evaluate the health benefits of those choices.

Materials You Will Need for This Activity

- Food journal
- Food pyramid

What You Will Do

1. Keep a record of all the food you eat during meals and between meals over a three-day period.
2. For each day, list the foods you eat. When possible, try to write down an estimate of the amount of each food as well (e.g., 2 celery sticks, 4 Oreo cookies).
3. After three days, make a chart based on the categories found in the food pyramid at http://www.mypyramid.gov/pyramid/index.html.
4. Write the foods you ate each day in the proper category of the food pyramid and compare what you actually ate with what is recommended.

What you will learn: The six components of the food pyramid are grains, vegetables, fruits, milk, meat/beans, and physical activity, with vegetables and milk products recommended in higher amounts than the other food groups. Refined sugars (candy, cookies, etc.) are not part of the pyramid at all, meaning that they do not add to your daily nutrition in any substantial way and should be eaten only in very limited amounts.

Core concept demonstrated: The importance of proper nutrition

Thinking like a scientist: In what categories were you eating sufficient quantities of nutritious food? In what categories were you not eating enough? What social features in American society influence the food choices we make? How might these features be similar or different in other countries? Physical activity was added to the newly revised food pyramid—it was not in earlier versions. Why do you think this was done?

Correlation With National Standards:

NSES Science: A.1; C.6; F.1; G.1

NCTM Math: A3; B1

NCTE Language Arts: 1; 5; 7

NCSS Social Studies: 1

Creating a Model of the Human Arm

For as long as we have had consciousness, humans have been interested in the workings of our own bodies. The oldest recorded anatomical records can be found in Egyptian papyruses, dating to more than 3,000 years B.C. Diseases of the eyes, hemorrhoids, rectal prolapse, intestinal parasites, abdominal pain, fractures, and urological conditions are all mentioned in early Egyptian documents.

Medical research came later to Western culture, largely originating in ancient Greece. The Greek scholar Hippocrates (460–377 B.C.) is generally considered the father of Western medicine for proposing the concept that illnesses might have natural (rather than supernatural or spiritual) causes and cures. Hippocrates believed that the study of anatomy must be the foundation of medicine. In the East, the classic Hindu medical manuscript *Susruta Samhita* (A.D. 200) demonstrated an advanced understanding of surgery, describing more than 100 operations and the instruments that should be used. In the modern era, our understanding of human anatomy continues to grow as new technologies allow us to analyze and understand more and more information about the human body and disease.

One of the most interesting aspects of anatomy is its relationship to basic principles found in physics. In fact, the skeletal system of an animal represents a complex system of levers and counter-levers. When connected together by muscles and cartilage, an animal's limbs provide the ability to perform an incredibly varied and complex range of activities. (See Experiment 56.)

Experiment 56 Modeling the Human Arm

In the following activity, you will create a working model of the muscles that move the human arm.

Materials You Will Need for This Activity

- Tape
- Hole punch
- 2 empty toilet paper rolls
- 2 five-inch long balloons
- 1 pipe cleaner cut in half

What You Will Do

1. The two toilet paper roles represent the upper and lower arm. To connect the two arm parts, make two holes 180 degrees apart, 1/2 inch from the end of each cardboard tube.
2. Thread a piece of the pipe cleaner through the holes on each side of the two tubes to connect them together, and bend the ends to form a joint. The pipe cleaner represents the ligaments that function to hold the muscles in place. The tubes represent the major bones in your arm.
3. Bend your model arm at the "elbow" to form an L shape.
4. Inflate one balloon slightly, and tape one end of the balloon to each arm part on the inside of the arm's L shape. This simulates the contracted biceps muscle.
5. Inflate the other balloon slightly and tape it to the arm parts on the outside of the L. This simulates the triceps muscle.
6. Move your model arm's lever up and down. What happens to the balloons?

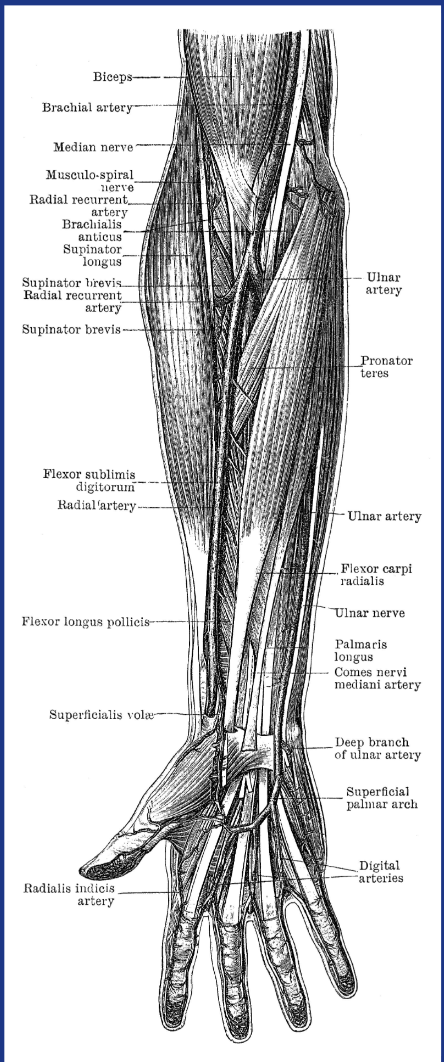


Image 7.26 A Nineteenth-Century Anatomical Drawing of the Human Arm

What you will learn: Every moving bone in the human body has at least two muscles connected to it. These pairs of muscles work together to facilitate movement. When you bend your arm at the elbow, the top muscle (biceps) contracts and shortens.

This causes your forearm bones to pull into a bent position. At the same time, the bottom muscle (triceps) stretches because it is relaxed. When you straighten your arm, the opposite occurs—the biceps relaxes and straightens, and the triceps contracts and shortens. The contraction of the triceps pulls down the bones of your forearm and your arm straightens out.

Core concept demonstrated: Basic physical mechanics of the human arm

Thinking like a scientist: Compare how your model arm moves with what you feel when you bend and straighten your own arm. Now, describe what you think happens in your legs when you walk or run. How does what you have learned influence how you would design prosthetic arms and legs for amputees?

Correlation With National Standards:

NSES Science: A.1; A.2; C.4; C.8; G.1; G.4

NCTM Math: C4; D2

NCTE Language Arts: 5; 12

Spreading Infectious Illnesses

SOURCE: Courtesy of the Library of Congress.

Image 7.27 Demonstration at the Red Cross Emergency Ambulance Station in Washington, DC, During the Influenza Pandemic of 1918

An infectious disease like the flu represents a biological mechanism that has an extraordinary evolutionary capacity to spread itself across hosts. This can be seen in the case of the great flu epidemic of 1918 that killed more people worldwide than were killed during the fighting in World War I (see Image 7.27). In the two years that the pandemic took its course, a fifth of the world's population was infected. An estimated 675,000 people died from the disease. The 1918 flu was airborne and carried from person to person via germs that were carried on their hands, through sneezing, and so on. (See Experiment 57.)

Experiment 57 Spreading Infectious Disease

In the following activity, you will simulate how disease spreads as well as play the role of an epidemiologist trying to figure out who started the spread of the disease.

Materials You Will Need for This Activity

- Small (8-ounce) plastic cups
- pH strips or universal indicator
- Moderately strong acid or base such as dilute HCl or dilute sodium hydroxide (lye) (lemon juice or vinegar can also be used but are much more easily detected because of their odor)

What You Will Do

1. In advance, prepare one cup per student by filling halfway with water.
2. Add 10 drops of dilute HCl or NaOH (or 10 ml of lemon juice or vinegar) to one of the cups without allowing students to know this.
3. Tell the students that this activity simulates how germs (or many infectious diseases) spread. Warn students not to drink the liquid in their cups.
4. Give each student a cup of liquid and have students mingle in the center of the classroom.
5. Have each student share the liquid in his or her cup with another student by pouring the liquid back and forth several times between their cups and then putting half back in each cup.
6. Have students mingle some more and then repeat the sharing process with two other students (for a total of three).
7. Each student needs to remember the three people with whom he or she shared and the order in which this took place.
8. Using the pH test strips or universal indicator, test each student's liquid to see whether the infection spread to him or her or not.
9. Now, ask students to think like an epidemiologist (or a detective) and see whether they can come up with a strategy for determining which student had the original contaminated cup ("patient zero").

*Safety Note—Be sure to warn the students not to drink their samples. While the amount of lye or HCl needed for the pH reaction is minuscule, at higher concentrations, both lye and HCl are very strong and dangerous chemicals.

What you will learn: Disease can spread rapidly through a population, potentially growing exponentially as every infected individual infects several others. Using reasoning and logic, it is sometimes possible to trace the spread of a disease backwards from those currently infected to the originally contaminated individual.

Core concept demonstrated: Spread of disease through a population

Thinking like a scientist: In this simulation, is it possible to figure out who the original patient zero was, or is the best that can be accomplished to figure out who the first two infected individuals were? Why is this so? Think back to Chapter 1, and the discussion of the Broad Street pump and the London cholera epidemic of the nineteenth century. How is solving the mystery in this activity similar to what Dr. John Snow did to solve the mystery in London? How is it different?

Correlation With National Standards:

NSES Science: A.1; A.2; C.2; C.6; F.1; F.5; G.1

NCTM Math: A3; E1

NCTE Language Arts: 7; 11

NCSS Social Studies: 8

Reflecting on Science

1. Biology is sometimes divided into two categories: biology at the cellular or microscopic level (microbiology) and biology at the organismal and environmental level. Make a Venn diagram comparing and contrasting these two domains.
2. Most of the early study of biology focused on human anatomy and medicine, with the study of other life science topics generally coming substantially later. How could you explain this historical trend?
3. There are many exciting, yet ethically challenging, breakthroughs that could, in the next few years, potentially redefine how we understand and make use of certain aspects of biology. These topics include the human genome project, embryonic stem cell research, and cloning. How do you believe the decisions should be made to guide our understanding and application of these emerging topics in biology?

Internet Connections: Biology

The following websites provide information that may prove helpful for teaching biology:

The University of Arizona Biology Project—with information for teachers plus lesson plans
http://www.biology.arizona.edu/

Cells Alive—interactive website about all things cellular
http://www.cellsalive.com/

Dr. Saul's Biology in Motion—animated models on many biology topics
http://www.biologyinmotion.com/

Frank Potter's Science Gems: Life Science—links to numerous high-quality life science resources
http://www.sciencegems.com/life.html

Biosphere 2—a fascinating site on the Biosphere 2 project integrating many biology topics
http://www.b2science.org/

Net Frog—an online virtual frog dissection
http://www.mhhe.com/biosci/genbio/virtual_labs/BL_16/BL_16.html

Student Study Site

The companion website for *Teaching Science in Elementary and Middle School* (2nd edition) can be found at: http://www.sagepub.com/buxton2e.

Visit the web-based student study site to enhance your understanding of the chapter content and to discover additional resources that will take your learning one step further. Study materials include

- Video demonstrations of experiments
- Interactive self-quizzes to test your understanding of chapter material
- Full PDF journal articles related to core content
- Web resources, and more

Reference

Good, A. (1893). *La science amusante* (Vols. 1–3). Paris: Le Librarie Larousse.