Biodiversity and Global Change

Lobster Die-off!

An Event-based Science Unit

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Peabody Fellows

Biodiversity and Global Change Program

The Peabody Fellows Biodiversity and Global Change Program aims to improve science teaching and learning among middle and high school teachers and students in Connecticut around the topic of Biodiversity and Global Change. Global change is among the most scientific and societal issues of the 21st century as humans have an increasing impact on the environment. Understanding how global changes affect biological diversity, and vice versa, requires an integrated knowledge of the earth and life sciences. The curriculum unit, “Lobster Die-off!” developed as part of this project studies one of the local effects of worldwide issues such as ocean warming, pollution and invasive species.

Please note this unit is still in draft form. All comments are welcome.

This program is supported by a Museums for America grant

from the Institute of Museum and Library Services,

and the Bay and Paul Foundations.

Activity 4: Temperature Tracking

Objective

To investigate how water temperature differences can create a current.

Background

The warming effects of the sun directly affect the surface of the ocean. Where the sun's rays are more direct, the temperatures of the water may be warmer. Where the sun's rays are less direct, the ocean temperatures will be colder. As the upper layers of the water are warmed or cooled, the layers may develop different water temperatures than layers of water below. A sharp change in temperature between layers is called a thermocline. The density of the water is affected by temperature. As the density of water at the surfaces increases, it sinks beneath the less dense water below it. Some of the major deep water currents in the world's oceans are generated by changes in density.

CT Science Content Standard

5.1 Sound and light are forms of energy.

- Describe how light is absorbed and/or reflected by different surfaces.

9.1 Energy cannot be created or destroyed; however, energy can be converted from one form to another.

- Energy is transferred by conduction, convection and radiation.

NSES Content Standards

- Properties and changes in matter
- Motions and forces
- Transfer of energy

Part 1

Materials

Clear plastic box

3 Celsius thermometers

Tape

Several ice cubes made with uncolored water

Several ice cubes made with colored water

Watch with a second hand

Procedure

1. Have students read the Discovery Files related to Long Island Sound and Biodiversity: Long Island Sound Habitat Changes, Alien Invaders, Climate, and Wind and Water.
2. Have students conduct an experiment to demonstrate how water temperature differences can create a current. Take a clear plastic box and attach the three thermometers with tape to the inside of the box as shown in Figure 1. The thermometers will be positioned in three different places: at the top, middle and bottom of the box.

[FIG 1 TO COME HERE]

3. Fill the box with warm tap water so that all the bulbs of the thermometer are covered by water. Distribute the Activity 4 handout: Temperature Data Sheet. Set up a data sheet as shown in Figure 2. Record the three thermometer readings in the start row. Use the watch to time the intervals. Call out each interval. Have students record the three thermometer readings for each interval as it occurs.
4. Students add several uncolored ice cubes to the water at the left end of the box. Which thermometer do they predict will become cold first?
5. Students read the thermometers every 15 seconds after the ice cubes are in place. Have them record these readings and stop when the readings on the three thermometers change.
6. Did students' predictions in Step 4 prove to be correct? Students develop a hypothesis to explain the results of the experiment.
7. Students add several colored ice cubes to the water at the left end of the box. Observe the plastic box from the side. Do students' observations support the hypothesis? Where is the thermocline?
8. Students create a graph that shows the movement of the colored water. Have students determine what conclusions may be drawn from their graphs. Guide students in answering such questions as:
   a. What can you conclude about the temperature of water at different layers of the ocean?
   b. How do these different temperature layers seem to move?
   c. What would happen to the movement of water if somehow the temperature layers were reversed?
   d. Could this have an impact on the living things that inhabit the ocean?

Part 2

Materials:

1 Large wide-mouth glass jar,

1 Small, long-shaped jar

Strong string

Warm water

Cold water

Food coloring

FIG 2 TO COME HERE

Procedure:

1. Fill the large jar with cold water.
2. Tie a string around the neck of the smaller jar.
3. Fill the small jar with very warm water and put in a few drops of a vivid food coloring to color this water.

4. Students predict what will happen.
5. Place the small jar into the larger jar and observe the movement of warm water. Students answer the following: How does the warm and cold water move? What would happen if you put warm water in the larger jar and cold water in the smaller jar? Which way would the cold water move?

Scoring Rubric

The observation of students as they conduct the experiment, and then a formal evaluation of the quality of their explanation of the cause of ocean currents, will result in both individual and group assessment of this activity.

- Explanation is neat, well-written and contains logical information supported by a diagram. 2 points
- Explanation fails in one aspect but is otherwise complete. 1 point
- Explanation is incomplete. 0 points

Activity 4 Student Handout

Temperature Data Sheet

Time (sec.)	Top Thermometer reading (C)	Middle Thermometer Reading (C)	Bottom Thermometer Reading (C)
Start			
15			
30			
45			
60			
75			
90			

Discovery File: Long Island Sound Habitat Changes

A habitat is the place where an organism lives. All habitats provide food, oxygen/water, space and shelter. The habitat of a deer is the woods. The habitat of a butterfly is a meadow or area where the nectar plants on which it feeds are found. When an organism's habitat changes, the organism must adapt or die. Lobsters inhabit shallow water along the sea floor. Up until recently, Long Island Sound provided excellent habitat for the American lobster. We often think of habitat destruction as a physical loss such as the cutting down of trees. In the case of an organism that inhabits salt water, habitat loss can mean simply the changing or alteration of the habitat in such a way that it can no longer support a kind of organism. Consider the changes to Long Island Sound described below that are believed to have contributed to the lobster die-off.

I. Oxygen levels and hypoxia

Oxygen is dissolved in sea water. We breathe oxygen when we take in air using our lungs. Lobsters and other sea creatures breathe oxygen when they take in water through their gills. Since the 1970s, the amount of oxygen in the waters of western Long Island Sound has been dropping to a level that is stressful to lobsters. This reduction in oxygen is called hypoxia ("hypo" is Greek for "under" or "beneath" and "oxia" meaning "oxygen.") The reasons for this reduction are an increase in nutrients such as nitrogen flowing into Long Island Sound from sewage and fertilizers. When the Long Island Sound watershed becomes more developed, there is more pavement and more fertilizers used on lawns. More pavement causes more water with fertilizers (nutrients) to flow into Long Island Sound. Sometimes during a big rainstorm, sewage treatment plants will release untreated sewage. Once in the Sound, these extra nutrients cause more algae to grow. When they die, bacteria break them down and use oxygen in the process, causing dissolved oxygen, or oxygen in the water, to go down.

II. Sulfide and Ammonia

When bottom sediments (sea floor soils) do not receive sufficient oxygen, a different type of bacteria (anerobic – literally "without oxygen") takes over and releases increased amounts of sulfide and ammonia compounds. These compounds make lobsters sluggish.

III. Temperature

Lobsters prefer temperatures below 20.5 degrees Celsius. The summer temperature of sea floor waters in Long Island Sound has been rising since the 1970s, creating a condition that is stressful to lobsters. This also causes an increase in thermal stratification, which makes the problem of decreased oxygen even more severe.

IV. *Neoparamoeba paraquedensis*

An increase in this parasite created an additional stress on lobster populations. The parasite is one of forty lobster parasites found naturally in the Sound. Scientists believe that *Neoparamoeba paraquedensis* can become more dangerous to lobsters and also reproduce more quickly when conditions favor it.

Discovery File: Alien Invaders

Long Island Sound is an environment forever vulnerable to change. Over the past decade, more than 100 alien species of plants and animals have been introduced into the Sound environment. The non-native species have taken up residence in nearly every ecological niche and are now comfortably settled in and competing for resources with the local residents.

Animals and plants are introduced from all parts of the globe, tagging along on the outside of ships, in ballast tanks, blown along on stray water currents or even intentionally introduced for reason long since forgotten.

These organisms have a potential to become invasive species. An invasive species is an organism that is "non-native" (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

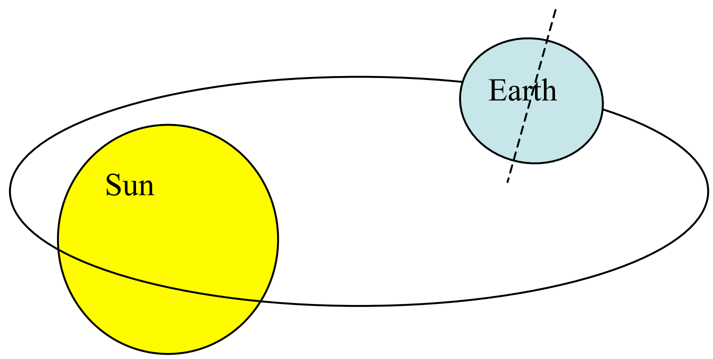
These new organisms cause problems for the existing organisms, compromising all areas of the Sound. All species, including endangered species are compromised by these introduced species. Introduced species may be eating native species, their food, destroying their habitat and or taking their place within the habitat. This process changes the habitat and puts pressures on native species that may not be adapted to compete with the new arrivals.

In the early months of the lobster die-off, it was thought that invasive organisms might be playing a role. But scientists soon discounted that possibility. For more information, see: www.invasivespecies.gov and www.nemw.org/biopollute.htm. Also see *Galapagos Islands: Nature's Delicate Balance at Risk* by Linda Tagliaferro, and published by Lerner Publishing, 2001; and *Food Chains* by Alvin Silverstein, Virginia Silverstein, and Laura Silverstein Nunn, published by Twenty-First Century Books/Millbrook Press, 1998.

Discovery File: Climate

Climate is a description of the temperature and weather found in a particular location. The climate of a particular location is determined by several factors including the sun, local geography and local bodies of water.

The most important factor in climate is the sun, specifically, the way that the sun and the Earth interact. The Earth rotates on its **axis** once every day. This **rotation** is what causes the differences in sunlight between night and day. Even as the Earth is rotating, it is also revolving around the sun. A full **revolution** takes one year to complete. As the Earth is rotating, it is doing so on a slightly tilted axis. The axis is tilted at about 23 degrees off center. This tilt, combined with the revolution, causes the seasons to change. Between the **vernal equinox** in the spring and the **autumnal** equinox in the fall, the northern **hemisphere** is pointing toward the sun. During the other half of the year, the southern hemisphere is pointing toward the sun. When do you think Australia, located in the southern hemisphere, experiences summer? The higher the **latitude**, the more drastic the temperature changes are between the seasons. Here in Connecticut, we are about half way from the **equator** to the North Pole, so we have significant temperature change between summer and winter.



After latitude the next most influential factor in determining climate is the water in the area. Water and land trap and release **heat** at different rates. Water heats and cools much more slowly than land. To prove this you can do a simple experiment. Put a thermometer in a glass of water and another one in a pile of soil. Which thermometer heats up faster? Look at a map, Rome, Italy and New York City, USA are both at about the same latitude. Italy is surrounded on three sides by the Mediterranean Sea; New York City only has water on one side. Which city do you think has the more moderate climate?

Finally, geography plays a part in local climate as well. An area at a higher **altitude** is going to have a cooler climate than one at sea level. For example, there is a glacier at the top of Mt. Kilimanjaro in the middle of Africa, an otherwise very hot place. However, geography plays a bigger role than simply changing altitude; mountains and glaciers can interrupt wind patterns.

Discovery File: Wind and Water

Wind and water **circulate** around the globe carrying heat and **nutrients** from one location to another. As you know, the Earth is rotating. The Earth is rotating faster than the atmosphere around it, which causes the basic prevailing West to East wind patterns. You can think of this wind as being sort of like the wind that hits your face when you go on a roller coaster ride. You are moving, but the atmosphere around you is not. The prevailing winds are not the only type of air movement, though.

There is another type of air movement caused by **thermal expansion**. This air movement causes air to move between the poles and the equator. When the sun shines on the Earth, it always reaches the equator, so the equator is always hot. The sun also reaches other latitudes, but the sunlight at higher latitudes is not as direct as at the equator. That is, because higher latitudes receive less direct sunlight, the air there is not as hot. Because it gets more heat, the air at the equator expands. When the air expands, every molecule takes up more space than it did before. As the hot air expands, it pushes other air out of the way. It cannot push down, the ground is too hard; it has to push up. So hot air will rise. When the extra air moves into the upper atmosphere, it joins other air that was already there, causing the pressure to rise. At the poles, there is less direct sunlight, so the air there does not absorb as much heat as the air at the equator. As a result of the ice at the poles and the smaller amounts of direct sunlight at the poles, the air there does not expand, so it does not cause high pressure in the upper atmosphere. So, at the poles, there is high pressure at the ground level and low pressure in the upper atmosphere. At the equator it is just the opposite; there is low pressure at the ground level and higher pressure in the upper atmosphere. Have you ever seen what happens at a doorway when the door is opened for recess? Lots of kids are all together in the hallway and everybody wants to go outside where there is lots of room. Air is like that, too. In places that have high pressure, like the upper atmosphere over the equator, the air moves to some place with more room, like the upper atmosphere over the poles. What do you think air at ground level does?

All of this air movement causes the climate in a particular place to have hot or cold, wet or dry winds. Cold, wet winds bring rain and snow. Hot dry winds absorb moisture and dry out the land. As an example, look at the Cascade Mountains on the west coast of the United States. The prevailing wind comes off the Pacific Ocean, so it is very wet. When the air hits the mountain, it must go up because it can't turn around. As the air moves up, it cools. Cold air holds less water than hot air, so it rains. By the time the air get over the mountain, it has very little water left in it, so the land on the Eastern side of the Cascade Mountains is much drier than the land on the Western side of the mountains. Where does your rain come from?

Water movement on Earth is very similar to air movement. Water at the equators absorbs more direct sunlight than water at the poles. Furthermore, water at the poles is covered by white ice. Which do you think absorbs more heat, dark water or white ice? Since water, like air, expands when it is heated, the warmer water pushes on the cooler water causing a pattern of currents like the Gulf Stream. Where does the Gulf Stream flow?

Every substance contains energy from the movement of its particles called thermal energy. The higher the temperature of a substance, the greater is its thermal energy. The direction of energy transfer is always from a warmer thing to a neighboring cooler thing. Water tends to move from areas of warm water to areas of cold water.

The oceans and their marine life are affected by annual variations of temperature and solar radiation. Seasonal changes take place first in the upper layers because it is here that solar radiation is absorbed and heat is exchanged with the atmosphere. Deeper waters are affected later.

Activity 5: Temperature and Biodiversity

Objective

To understand the relationship between bottom water temperature and lobster health.

CT Science Content Standards

TO COME

NSES Content Standards

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Procedure

1. Explain that lobsters prefer colder water. When the water gets warmer 20.5 degrees Celsius (69 F), lobsters are stressed. They will move to colder water, if they can. This is not so easily done in a contained body of water such as Long Island Sound. If unable to get to colder water, lobsters suffer not only from the warmer water, but also from the changes that occur to the water near the bottom. More decomposition occurs, releasing more unhealthy chemicals into their surroundings. Some parasites, such as the lobster neoparamoeba, can become more numerous in warmer water.
2. Working in teams of 2-3, have students decide on a way to graph two sets of data: the Mean Bottom Water Temperature of Long Island Sound from 1993--2003, and Lobster Landings (number of lobsters caught) from 1993–2003. They can use an x-y graph, blocks, columns or other visual aids to plot the two sets of data.

3. Have students write brief explanation of the trends observed answering the following questions:
    a. In what year did the lobster landings drop the most?
    b. What relationship do you see between the drop in lobster landings and water temperature?
    c. How might you explain what happened to the lobsters in this time?
    d. What do you think causes the water temperature to go up in the bottom of Long Island Sound?
    e. What other information would you like to have about lobsters and their environment to help you understand what they need to survive?
4. Have students read the Discovery Files: Greenhouse Effect and About Climate Change.

Scoring Rubric

- The student's graph of lobster landings and temperature trends is reasonably accurate and titled and labeled properly. The explanation of the graph is well written and addresses all required topics completely and accurately. 3 points
- The student's graph of lobster landings and temperature trends is partially accurate or incompletely titled and labeled. The explanation of the graph is complete but shows some lack of understanding of concepts and is not written clearly and properly. 2 points
- The student's graph of lobster landings and temperature trends is wholly inaccurate and incompletely titled and labeled. The explanation of the

graph is incomplete and shows significant lack of understanding of concepts or is not written clearly and properly. 1 point

Activity 5 Student Handout Temperature and Biodiversity

Data Tables

Mean Bottom Water Temperature of Western Long Island Sound from 1993 – 2003

Year	Temperature (C)
1993	20.3
1994	19.2
1995	19.6
1996	18.9
1997	18.9
1998	19.2
1999	20.3
2000	19.9
2001	20.2
2002	20.6
2003	19.3

Lobster Landings from 1993–2003

Year	Lobster Landings (mean catch per tow)
1993	11.6
1994	10.0
1995	8.0
1996	10.0
1997	19.8
1998	10.3
1999	11.3
2000	6.8
2001	4.2
2002	2.7
2003	4.1

Discovery File: Greenhouse Effect

Have you ever seen vendors selling roses around Valentine's Day? In February, here in Connecticut, my rose bushes are all covered in snow and certainly are not blooming. So, where do all of those roses come from? Today, most of those roses are flown in by airplane from warm places in Central America, but some are still grown in a big glass building called a greenhouse. In a greenhouse, sunlight comes in through the glass and turns into heat. The heat cannot escape back through the glass very well, so the whole building stays warm all winter. Here on planet Earth, the gases in our atmosphere act like the glass of a greenhouse. Sunlight comes in through our atmosphere and turns into heat, but it has trouble escaping back into space. Our atmosphere has been trapping heat in this way from very early in the Earth's history, but now it is trapping more heat than it used to. Some gases, like carbon dioxide and methane, are better at trapping heat than others. These gases are called greenhouse gases. Some greenhouse gases are created naturally. For example, volcanic eruptions and feeding cows both emit greenhouse gases, but, recently, scientists have noticed that human activities, like burning gasoline in a car's engine, produce much more greenhouse gas than natural activities do. More greenhouse gas means that more heat is trapped on Earth. What do you think more heat will do to the temperature on Earth?

As you might have guessed, the temperatures on Earth, all over the Earth, have been increasing quite a lot in the past hundred years. Now this might seem cool; after all, who doesn't like summer? But, consider the lobster. Lobsters need cool water to survive. As the temperature on Earth gets hotter, the water temperatures get hotter, too. Lobsters need cool water to live, so what happens to lobsters as their habitat changes and the water grows warmer?

Discovery File: About Climate Change

The Earth's average temperature has changed a great deal over the past 10,000 years because of natural causes. During the past 100 years, however, average global air temperature has increased sharply. A major part of the increase is the result of greenhouse gases released as a result of human activities.

Carbon dioxide is the most abundant and important greenhouse gas. It plays an important role in keeping the earth's temperature stabile. Fossil fuels, including coal, oil and natural gas, are largely made up of carbon. Carbon is an essential building block for life on earth and for our climate. In different forms it cycles through our atmosphere, biosphere, lithosphere and oceans. When fossil fuels, such as coal, oil and natural gas, are burned, carbon dioxide is released. This carbon dioxide can build up in the earth's atmosphere. The amount of carbon dioxide and other greenhouse gases in the atmosphere is increasing rapidly as a result of human activities that include fossil fuel combustion and deforestation. Trees take in carbon dioxide, so the massive destruction of trees results in more carbon dioxide being released into and remaining in the atmosphere.

Climate change is taking place at a much more rapid rate than at any other time in earth's history. Rapid climate change is altering ecosystems and the species that live in them. Some effects of rapid climate change include droughts, floods and storms, all of which can lead to human problems of disease, death, displacement and hunger. Even small changes in the global temperature can effect big changes in the climate.

(Adapted from *The Climate Change Backpack Presenter's Guide*, published by the New England Science Center Collaborative, Mary Lou Krambeer, Coordinator, Bethlehem, NH: 2003.)

Activity 6: A Microbial City

Objective

Using the column device of the 19th century microbiologist Sergei Winogradsky, students will create a skyscraper of mud, teeming with ancient microbes that are still dominating the earth today. Through manipulation, observation, recording, and discussion, students will understand the following concepts:

1. The Winogradsky column resembles flooded environments on earth. Its cities are essentially raised core samples of soil displaying what lives in its different layers and regions.

2. Various microorganisms live at different levels due to unique environmental conditions, and they have been dominating the earth for over 3 billion years.

3. There exists in the columns a downward oxygen gradient and an upward hydrogen sulfide gradient. Species of bacteria that use hydrogen sulfide and are sensitive to oxygen grow near the bottom of the column.

4. The colorful areas represent photosynthetic bacteria—observable without a microscope! The microbes are using different wavelengths of light to make their food.

CT Science Content Standards

5.2 Perceiving and responding to information about the environment is critical to the survival of organisms.

- Describe how light absorption and reflection allow one to see the shapes and colors of objects.

6.4 Water moving across and through earth materials carries with it the products of human activities.

- Explain how human activity may impact water resources in Connecticut, such as ponds, rivers and the Long Island Sound ecosystem.

9.8 The use of resources by human populations may affect the quality of the environment.

- The accumulation of mercury, phosphates and nitrates affects the quality of water and the organisms that live in rivers, lakes and oceans.

NSES Content Standards

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms
- Structure of the earth system

Background

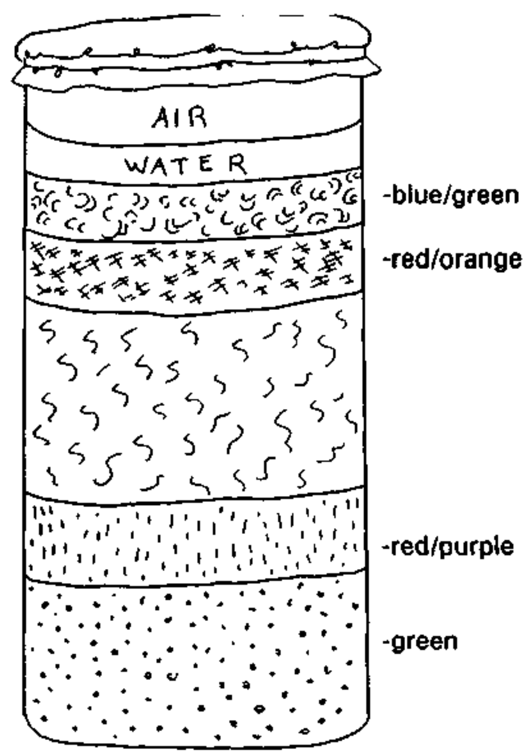
The Winogradsky column "city" that students will create bears some striking similarities to Earth: the energy source is the same size as ours; it possesses oxygen in its atmosphere; it is composed of soil and mud. And, like the earth, these factors support a diverse and extraordinary array of life. One difference is that the surface of our cylindrical "planet" is completely flat and flooded by a thin film of water.

The city consists of translucent column "buildings" populated by microbial life forms living in soil and water. These are the same life forms that exist in flooded environments on our own planet earth— pond bottoms, salt marshes, and flooded agricultural fields like rice paddies.

The "planet" at first appears lifeless, but with an influx of energy and some simple management, the cities and its spectacular microcreatures can be seen!

On the right is a picture of what one building in the Winogradsky "city" looks like.

The life forms pictured are bacteria. Students will discover that there are many different types of bacteria. Through the Winogradsky "cities," they can see that the bacteria look different and that they live in different places.



Environmental Factors in the City

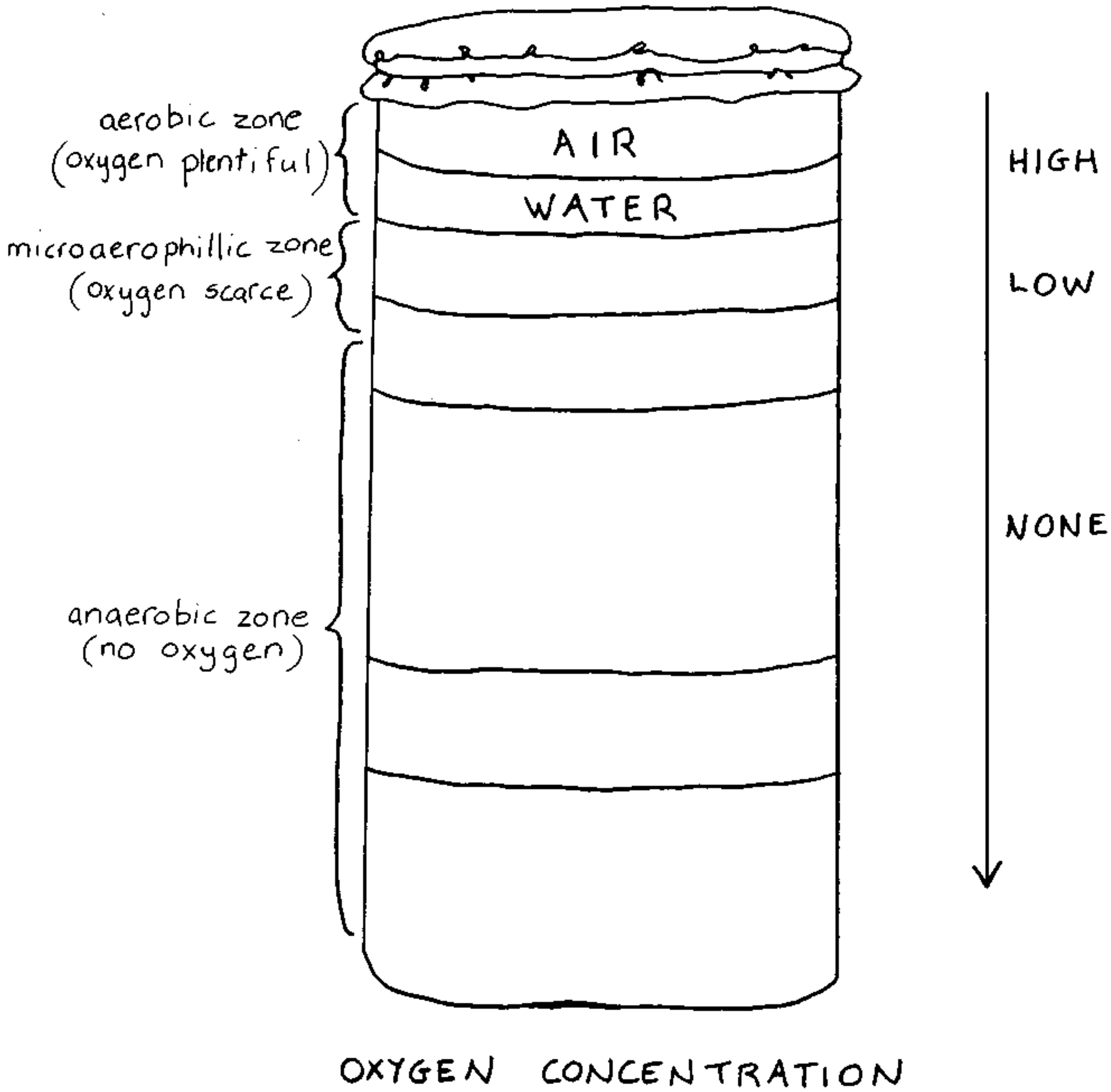
The bacteria in the Winogradsky column live at different levels in the buildings because the environmental conditions at each level are unique. The following elements help determine at which level or area specific bacteria within the city live.

The amount of oxygen present is a major determinant of microbial populations and their place in the column. Oxygen dissolves into water from air at the top of the buildings. As we go deeper down the skyscraper to the lower levels, the amount of oxygen decreases. We can even think of going downward in the building as going back in time! For many millions of years in Earth's early history, there was no oxygen in the atmosphere. The upper green level evolved more recently, and was responsible for producing the oxygen in Earth's atmosphere before algae and plants existed.

Most of the organisms with which you are most familiar require oxygen to live. Some live in the water at the top of the column. They are creatures that you might find in a pond on planet Earth—for example, fungi, green algae, and bacteria.

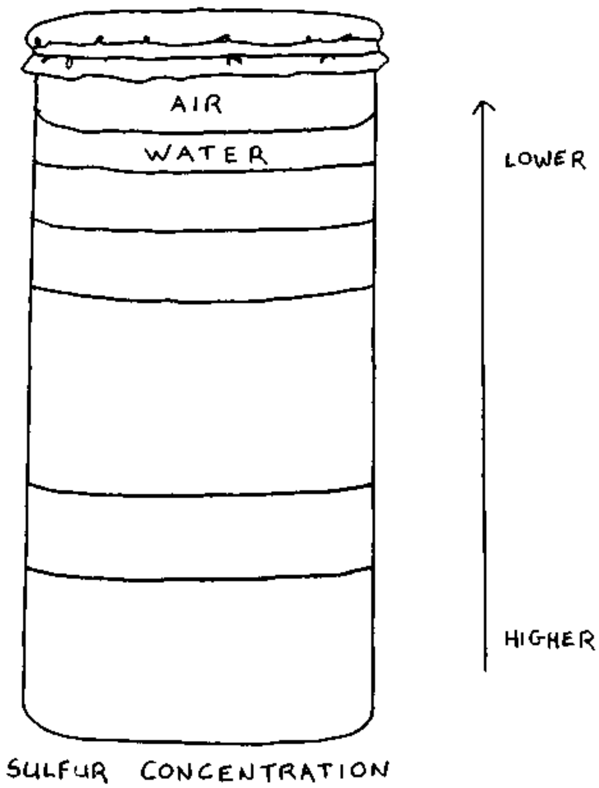
But certain types of bacteria that dominated the earth throughout most of its 3-billion-year life history, and which can be seen in the upper red layer, can live where there is only little or no oxygen. Still other bacteria live where there is no oxygen at all. These include bacteria living in the lower red and green layers.

There is an oxygen gradient in the buildings. A "gradient" is a steadily increasing or decreasing concentration of a substance over a distance. The oxygen gradient in one of the buildings is represented by the diagram on the following page.


aerobic zone
(oxygen plentiful)
AIR
WATER
HIGH
microaerophillic zone
(oxygen scarce)
LOW
NONE
anaerobic zone
(no oxygen)
OXYGEN CONCENTRATION

Sulfur (Hydrogen Sulfide)

Another elemental gradient in the microbial skyscraper is sulfur. Sulfur is released after living organisms die, as bacteria and fungi decompose the tissue and body parts. Often these dead parts are buried by falling particles, so the sulfur is released from below the soil and diffuses upward. A sulfur gradient in the columns looks like this:

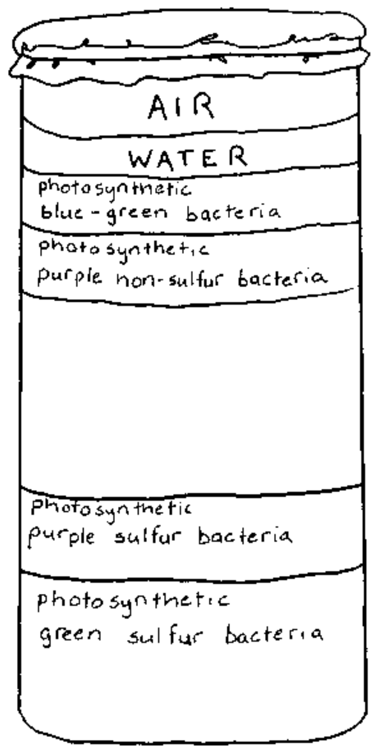


Sulfur is released in a form called hydrogen sulfide, which has the familiar smell of rotten eggs. You may have smelled this while walking by the edge of a pond, stream, or mudflat. You smelled this because the hydrogen sulfide gradient reached the surface of the water and diffused into the air.

Some bacteria need to live where the concentration of hydrogen sulfide is high. The bottom three layers in the buildings use hydrogen sulfide gas to make food from sunlight. The upper green layer is using water to make food from sunlight, just like plants and algae do. The process of making food from sunlight is called "photosynthesis."

Photosynthesis in the Winogradsky Column

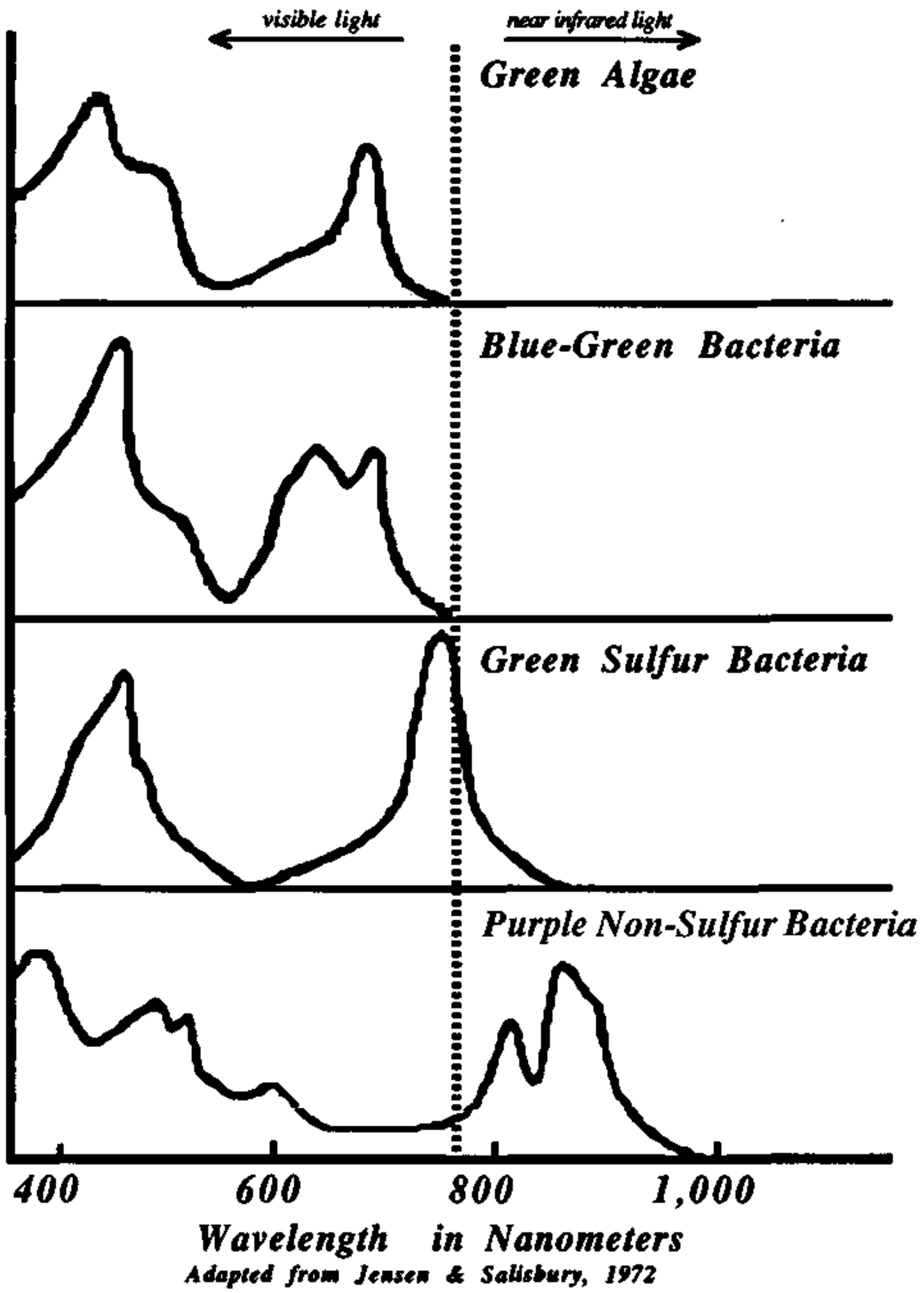
All the colored layers in the buildings are making food from sunlight. We can label them as follows:



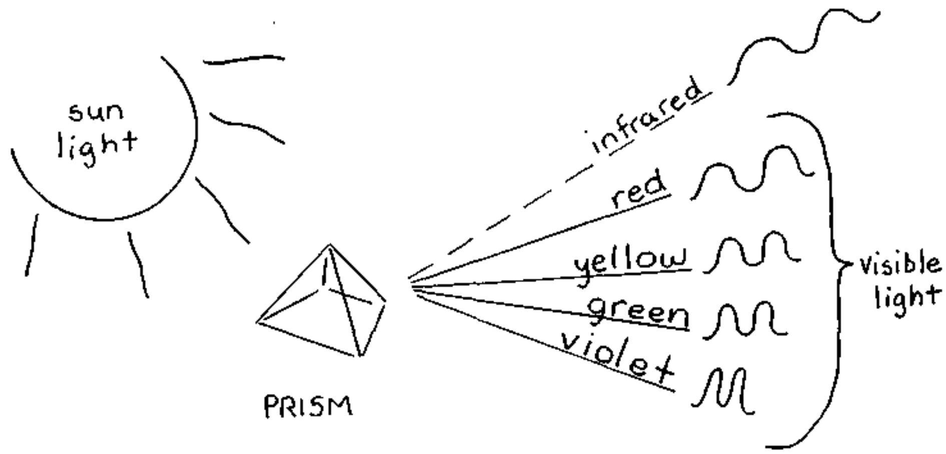
In addition, there may be a layer of green algae above the cyanobacteria (blue-green bacteria). You might ask: how can enough sunlight for photosynthesis penetrate below the soil? To us, it is dark underground, or deep underwater, because our eyes see only light that is in the colors of the rainbow. The different colors of the rainbow that we see are really light rays that are moving at different wavelengths. We can see light only in the wavelengths from purple to red; yet beyond purple, and before red, there is still light. However, we cannot see these wavelengths. The lower level of green and the purple bacteria use some of these "invisible" wavelengths, the infrared (or "before the red") wavelengths.

The bacteria in the upper layer do not use these wavelengths to make food, so the infrared light shines through to the lower levels.

Here is a diagram of the wavelengths used by different photosynthetic microalgae and bacteria that may be seen in the cities:



The peaks on each graph show which wavelength is used primarily for photosynthesis. The peak for each microbial population is different, which results in the whole spectrum of light, rather than only a small fraction, being used to make food. This arrangement, along with the abundance of water, sources of hydrogen sulfide gas, and carbon make the Winogradsky column "city" fertile, much like environments on earth, such as salt marshes, ponds, and rice paddies. These are among the most productive on our planet.


sun light
PRISM
infrared
red
yellow
green
violet
visible light

Materials

Two-liter soda bottle prepared as described below

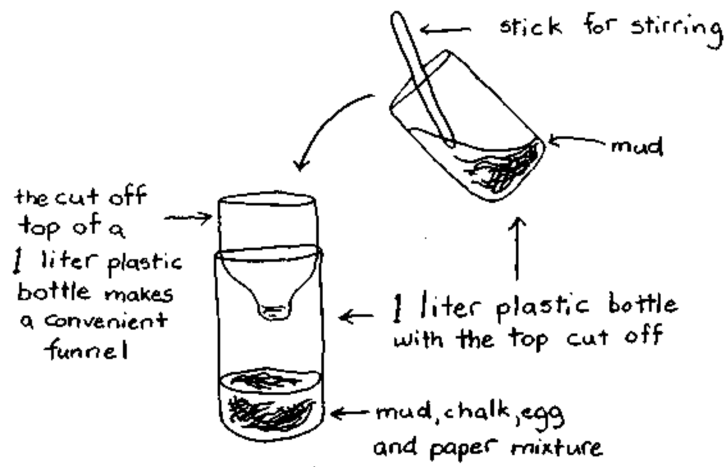
Large bucket or two of soil, mud, or sand

Water

Food Source for organisms in the column. See below.

Procedure

1. Have students bring in different soil samples from home and other local environments. Soils from shallow pond bottoms, mudflats (salt marshes are optimal), or beachfronts (the gooier and smellier the better) may form the layers more rapidly because they already contain large numbers of each kind of bacteria. Try also garden, forest, or field soil.
2. With good scissors or a razor blade, make a small cut (about 2-3 cm long) near the top of the plastic bottle, approximately at the level where the bottle significantly widens below the neck. This should be done before class, so that when you pass out the bottles to the students, all they must do is use sharp scissors to complete the cut all the way around. For younger students, you may want to cut the bottles completely yourself.
3. Collect the water. If your soil or sand comes from a marine environment, use seawater. Otherwise, use pond or stream water from where you collected the soil, or use tap water that has sat out for one day (allowing the chlorine to evaporate).
4. Finally, you will need a quick food source for the organisms in the column. Hard-boiled egg yolks or the entire raw egg provide an excellent sulfur and protein source. You can also use cheese, or powdered calcium sulphate. For a long-term carbon source to provide carbon dioxide, you can use shredded newspaper. A short-term carbon source in the form of calcium carbonate (lime) is helpful but not essential. You can also sprinkle in some chalk dust or plaster of Paris.
5. Be sure to go through the construction in a well-ventilated area. Open windows and even a fan or two are recommended. Although students will complain about odor, as soon as both the smell dissipates and the colors begin, they will happily accept the skyscrapers!
6. To fill the column, mix the soil with enough water to make it the consistency of heavy cream. Pick out most sticks, rocks, or leaves from the mixture so it is smooth. Mix your sulfur source and carbon source(s) with a little of the mud mixture and then pour it into the column. You may need to use a funnel along with a pencil (to poke the mixture through if the opening is narrow). We recommend using the top of the plastic bottle each student (or the teacher) removed with a razor blade or scissors as a funnel.
7. Pour a few centimeters of mud through the funnel; then, with one hand covering the top opening of the bottle and the other holding the bottle on the side, strike the base of the column firmly onto the table once to allow the mixture to settle evenly. Any air bubbles in the column will trap oxygen and prevent that area from becoming anaerobic.


stick for stirring
mud
the cut off
top of a
1 liter plastic
bottle makes
a convenient
funnel
1 liter plastic bottle
with the top cut off
mud, chalk, egg
and paper mixture

8. Continue filling the column, hitting the base on a table every few centimeters until the column is filled to within 4 or 5 cm of the top. Allow the column to settle for 24 hours so there is about 1 cm of clear water on the surface. If there is too much or too little water, add or remove some (you can use an eyedropper).

9. Cover it with clear plastic wrap fastened with a rubber band. Each student should write his or her name and the date on a small piece of masking tape and fasten it to the lower portion of the bottle. Place the microbial skyscraper in a well-lit place, such as a bright window that does not get too much sunlight (north-facing). Better still, set up an incandescent light(s) of 40-60 watts illuminating the top and sides (placed far enough away so as not to heat the column). One incandescent light fixture will be enough for five to ten columns. You can keep it lit continuously or on a 12-hour timer.

10. Have students observe the column at weekly intervals and record their observations.

11. Be aware that too much heat will kill some of the bacteria. Also, do not allow columns to dry out. Top them off with water as needed. Columns can take between three and six weeks to become established with the different layers or regions of colorful bacteria. The kinds of bacteria may change during this time. You may not get all the layers, and they may be more mixed together than in straight lines, but you will get to see different kinds of bacteria without a microscope.

12. Follow up by having students read the Discovery File: Sewage and Nutrient Loading.

Activity 6 Student Handout   A Microbial City

Observation Sheet

Student name ____

Soil habitat ____

Date column established ______________________________________

Date first colors ____

Number of cm color from top of mud layer________________

Week 2, fill in for each colored area/layer:

Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________

Observations/notes:

Week 3

Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________

Observations/notes:

Week 4

Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________
Number of cm _________   color from top of mud ____________

Observations/notes:

Discovery File: Sewage and Nutrient Loading

For many years, Connecticut has dealt with the runoff of rainfall, agriculture, and sewage in the same ways, diverting them into Long Island Sound. It is also the course of action for the other states that line the shores of the Sound. No one thought twice about it until recently when organisms from the bottom of the Sound began to die off in large numbers. It was at this time scientists were asked to investigate the problem causing the unhealthy conditions of the Sound.

One of the causes they found was nutrient loading. Nutrient loading is the increase of nitrogen and phosphorous compounds that are making it into our bodies of water due to the lack of wetlands and over-use of agricultural and developed lands. These compounds, when they are found in large quantities, prove to be harmful to aerobic aquatic organisms, organisms that grow only in the presence of oxygen. These organic wastes provide lots of nutrients for anaerobic organisms, organisms that grow in the absence of oxygen, bacteria and fungi. These organisms flourish in these nutrient-rich environments, taking all of the oxygen out of the water and adding methane gas. This type of oxygen-depleted environment is unhealthy for the other organisms that also live in the Sound. When environments are in this state, they are considered hypoxic.

Hypoxic environments exist when conditions contain the following factors: elevated water temperatures, organic carbon loading from agriculture, elevated sediment temperatures, poor bioturbation, dissolved oxygen levels and water stratification. These factors combined create a disastrous environment over a long period of time. The problem that persists in Long Island Sound is that this type of hypoxic environment, usually only present briefly in summer, is now taking place for longer time periods, killing off already distressed organisms.

Some measures can be taken to improve conditions in Long Island Sound. Safeguards can be put in place to protect the Sound from excess sewage and stormwater runoff. Wetlands can be re-established to catch nutrients and stop the free flow into the Sound. The Sound can be left alone to allow natural biotic and abiotic factors to balance themselves.

For more information on nutrient loading, its causes, and how to prevent it, see www.greenfacts.org/index.htm; and

www.dnr.state.md.us/coastalbays/water_quality/nutrient_load.html