Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2010 Volume III: Geomicrobiology: How Microbes Shape Our Planet

Life Underground

Curriculum Unit 10.03.03
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Introduction

We know what we know because we can see, hear, taste, touch, and smell! Our senses give us information throughout our days, informing us, teaching us, and satisfying us. But there is a whole world that we do not experience quite so noticeably it's under the ground. This underground world is dominated by life invisible to the naked eye, but this microbial life has a tremendous impact on the soil, animals, plants, and even the atmosphere. Through hands-on discovery, the students will learn about the many interactions that occur beneath their feet as they play at the park or playground.

Microbes are single-celled organisms so tiny that millions can fit into the eye of a needle. They are the oldest form of life on earth. Microbe fossils date back more than 3.5 billion years to a time when the Earth was covered with oceans that regularly reached the boiling point, hundreds of millions of years before dinosaurs roamed the earth. Without microbes, we couldn't eat or breathe. Microbes are everywhere. There are more of them on a person's hand than there are people on the entire planet! Microbes are in the air we breathe, the ground we walk on, the food we eat-they're even inside us! We couldn't digest food without them, plants couldn't grow, garbage wouldn't decay, and there would be a lot less oxygen to breathe. In fact, without these invisible companions, our planet wouldn't survive as we know it!

This unit is designed to introduce students, in a concrete way, to this microbial world.

Approach

Five activities will be used to provide a platform for teaching this unit. The students will grow plants from a variety of seeds, develop an aquatic habitat and build a terrarium, create and maintain an underground worm environment and an ant colony or farm. As scientists, the students will make observations and learn about organisms, including microorganisms, through inquiry and hands-on experiences and participation in these examples of life. Science journals will allow them to track and report the scientific findings while observing these five environments and to express different ways the organisms sustain life. How are they breathing?

Eating? There will be an obvious connection to human life as well. First graders learn best through concrete experiences and connections to themselves.

Learning that microbes are part of their daily lives gives an experiential connection for them, such as acidophilus in yogurt, yeast in bread dough, scrubbing bubbles in the bathtub, and even beneficial microbes in our soil. The microbial world includes microbes in foods, medicines people take when sick or with fever, microbes that live inside our digestive tracts, microbes on the skin, as well as another favorite spot for microbes to hang out, biofilms on teeth!

Microorganisms are important to life on Earth, living in all parts of the biosphere where there is water, acting as decomposers in various ecosystems and playing a vital role in the nitrogen cycle. Different types of microorganisms include bacteria, fungi, types of algae and plankton. Microorganisms exist in many different places and often where you don't expect, they make their home on food, plants, humans and lots of other living things. Bacteria live in decaying leaves, diseased cells/tissues (even pimples) and moldy fruit. There are different types of microorganisms, some are helpful and some that are harmful.

Rationale

As a first grade teacher in a self-contained classroom in New Haven, I have a class of 26 mostly six- and seven-year-olds. Our neighborhood/magnet school setting is a rewarding environment, with students coming to school each day from a variety of home circumstances and with differences in academic levels. As a result of these variables, the children have differing levels of background knowledge and life experiences.

First graders in our district learn about living organisms. The goal of the unit of study is to discover that living things have different structures and behaviors that allow them to meet their basic needs. This is an exciting subject and a terrific eight weeks of learning about changes for the students, and for me as well. These changes are an introduction to the cycles of life -- seeds grow roots, then stems and leaves, and possibly flowers; fish grow larger, lay eggs, and new fish appear! These are new experiences for many students. Bacterial life cycles can be added and are really different in being so short--E.coli can be as fast as 20 minutes!

The district curriculum involves building a terrarium, with various plants, worms, and bugs; creating an aquatic environment for guppies, snails and plants; and planting a variety of seeds. Young children are natural scientists with questions and curiosity. The objective of this unit is to provide students with the opportunity to learn about life on earth, including aspects of the microbial world, through relevant exploration and discovery of the five systems that will be used in the Life Science curriculum.

The Basic Requirements for Life

Whether larger than life or smaller that the eye can see, the most important goal for all living organisms is staying alive! It takes a constant input of energy to stay alive. In the most fundamental sense, in addition to water, all life requires three basic things in order to stay alive:

1. Energy--(e.g., from food, sunlight or can even get from eating rocks!)
2. Carbon--because all living creatures from bears to bacteria are ~ ½ carbon.

3.A way to breathe! OR a steep hill!--this is so that the energy can flow, like electricity through a wire or water over a dam and ultimately, make ATP. In a world with nothing moving/flowing (including energy), life would come to a grinding halt! The hill is needed, because the easiest, most natural direction of movement is downhill not uphill.

A basic understanding of atomic structure is essential to understanding the concept of how energy is extracted from the foods that living things eat and used to perform bodily functions like jumping and playing, and in order to introduce electrons as the way "energy" truly exists and gets transferred from food and light to cells and then converted to ATP.

Energy, Electrons, and.....Basic Atomic Structure

Matter is composed of atoms. Atoms themselves are composed of three basic particles: protons (with a positive electrical charge), electrons (with a negative electrical charge), and neutrons (with no electrical charge). Protons and neutrons are bundled together in the center of the atom, an area called the nucleus. Here, they are protected from the outside world and are not involved in ordinary chemical processes/reactions, only nuclear reactions like in an atomic bomb or nuclear power reactor. Electrons move around the nucleus in an orbit, like the moon around the earth. In these outer orbits, electrons in one atom can interact (e.g. swap/exchange) with electron orbits of neighboring atoms; this is basically how chemical reactions occur.

The atom made up of one proton and one electron is called hydrogen. The proton and electron stay together because just like two magnets, the opposite electrical charges attract each other. The particles in an atom are not still. The electron is constantly spinning around the nucleus. The centrifugal force of the spinning electron keeps protons and electrons from coming into contact with each other, much as the earth's rotation keeps it from plunging into the sun.

Positively and Negatively Charged Atoms -- "Ions"

Each atom of the same element is characterized by a certain number of protons in the nucleus, known as the atomic number. In pure elemental form, like on the periodic table, atoms have the same number of electrons in orbit around the nucleus, thus the amount of positive charge from protons exactly balances or cancels out the amount of negative charge from electrons to give a neutral atom with no net/excess + or -- charge.

Atoms can have electrical charges. This results when the number of protons and electrons is not exactly balanced. Some atoms can either gain or lose electrons (the number of protons never changes in an atom). If an atom gains electrons, the atom becomes negatively charged. If the atom loses electrons, the atom becomes positively charged (because the number of positively charged protons will exceed the number of electrons). An atom that carries an electrical charge is called an ion.

Cations (positively-charged ions) and anions (negatively-charged ions) are formed when atoms lose or gain electrons. The electrostatic attraction between the positives and negatives brings the particles together and creates an ionic compound, such as sodium chloride, NaCl, or table salt. [2]

In an electrically neutral atom, the positively charged protons are always balanced by an equal number of negatively charged electrons. Hydrogen is the simplest atom with only one proton and one electron. Helium is the second simplest atom. It has two protons in its nucleus and two electrons spinning around the nucleus. With helium, the third particle is introduced. Because the two protons in the nucleus have the same charge on them, they would tend to repel each other, and the nucleus would fall apart. To keep the nucleus from pushing apart, helium has two neutrons in its nucleus. As neutrons have no electrical charge on them, they act as a sort of nuclear glue, holding the protons, and thus the nucleus, together.

An electron shell may be thought of as the orbit followed by electrons around an atom's nucleus. Each shell can contain only a fixed number of electrons and must fill completely before electrons can be added to an outer shell. The electrons in the outermost shell determine the chemical properties of the atom. [1]

Electrons and the Chemical Reactions of Life

The most important chemical property of atoms controlled by electrons is whether or not and how an element reacts--no matter where it is--the soil, ocean or in our bodies! Elements with completely filled electron shells, those at the end of each row of the periodic table--He, Ne, Ar, are happily replete and thus, not willing to give up or take on any more electrons. These elements are very inert and do not like to participate in chemical reactions. They also all happen to be gases called the "noble gases".

Living organisms gain energy for life through "*Redox reactions*"

There are many different types of chemical reactions, but the basic and most important chemical reaction in living systems is the "redox" reaction. This term comes from the two concepts of reduction and oxidation. Oxidation is the loss of electrons, or an increase in oxidation state by a molecule, atom, or ion. Reduction is the gain of electrons or a decrease in oxidation state by a molecule, atom, or ion. Reduction and oxidation always occur together in the same reaction: they are 2 halves of a whole.

An example of a redox process is the formation of rust:

Fe (iron metal as in steel) + O_2 Fe_2O_3 (rust or iron oxide)

The Fe starts out with an oxidation number of zero (0) and ends up having an oxidation number of +3. It has been oxidized from a neutral iron atom to a positively-charged iron ion.

The O_2 also starts out with an oxidation number of zero (0), but it ends up with an oxidation number of 2--. It has been reduced by the Fe to give oxygen anions, O^{2--}.

The substance bringing about the oxidation of the iron atoms is the oxygen, making the oxygen the oxidizing agent. In other words, the oxidizing agent is being reduced (undergoing reduction). The substance bringing about the reduction of the oxygen is the iron metal, making the iron metal the reducing agent. In other words, the reducing agent is being oxidized (undergoing oxidation). Oxidation is always accompanied by reduction. Reactions in which oxidation and reduction are occurring are usually called redox reactions. [2]

It is through such redox reactions in which electrons (= energy) are swapped and transferred from one atom to another, that energy flows from food/sunlight/rocks to our cells!

An important and familiar example of a redox process is photosynthesis which involves the reduction of carbon dioxide into sugars coupled to the oxidation of water into molecular oxygen. The reverse reaction, respiration, oxidizes sugars to produce carbon dioxide and water all over again!

Metabolism

Metabolism is the term used to describe the chemical processes that fuel, or support, life (i.e. eating and digesting food to gain energy), and as described above, the most fundamental chemical process/reaction in metabolism is the redox reaction. Substances called metabolites (e.g. food, nutrients) that include both organic substances and inorganic matter such as oxygen, nitrogen and even metals like iron and manganese, are used during metabolism. Metabolism is linked to all other bodily processes by providing energy or by building and maintaining structures necessary for them to function. There are two components of metabolism.

Catabolism breaks down the large molecules that produce energy for activity. This basically works in three main stages. First, large organic molecules such as proteins or lipids are digested into smaller components outside the cells. Next, these smaller molecules are taken up by the cells and converted to yet smaller molecules, which release some energy. Finally, these smaller molecules are oxidized to water and carbon dioxide in the citric acid cycle and the stripped electrons are carried over to the electron transport chain by NADH (a soluble electron carrier in cells) where energy that is stored in NADH is released and converted to ATP (adenosine triphosphate).

Anabolism uses metabolites to build new tissue for healing, growth and reproduction. This process uses energy to construct complex molecules from simple ones. Anabolism involves three basic stages. First is the production of precursors, such as amino acids and monosaccharides. The next step involves their activation into reactive forms using energy from ATP. The third stage is the assembly of these precursors into complex molecules such as proteins and lipids. [3]

Metabolic Classification of Microbes

Unlike larger eukaryotic organisms which are classified based on their morphology and behavior (e.g. predator, prey, consumer), microorganisms--which are mostly prokaryotes=single--celled bacteria and archaea, are classified based on their metabolism. They are identified by their energy source (light or preformed molecules), by their electron donor (organic or inorganic compounds) and their carbon source (again, organic or inorganic).

Bacteria are classified based on what they eat (or carbon and energy sources). Autotrophs (Latin for self/grow) are able to make their own food from light or chemical sources of energy using only inorganic CO_2 and include plants, algae, diatoms and phototrophic bacteria like cyanobacteria and purple bacteria, as well as most bacteria that get their energy from inorganic chemicals, minerals and rocks called chemolithotrophs. Heterotrophs (other/grow) obtain their carbon from the tissues or body fluids of other organisms (animals and plants). Chemolithotrophs are organisms that get their energy from inorganic chemicals, rocks/minerals; most chemolithotrophs are also autotrophs and thus use CO_2 as a carbon source. Heterotrophs get their carbon from pre-formed organic matter; they may also get their electrons from the same organic matter (= chemoorganotrophs), if they instead get electrons from inorganic chemicals and carbon from organic matter, they are called "mixotrophs". They break down complex organic compounds that they take in from around them in order to make them more available (digestible) as food. Each type of heterotroph needs specific conditions and the right kind of organic material. Some bacteria can even decompose organic material at temperatures below freezing. If conditions are right, this heat will be enough to set the stage for the next group of bacteria that live at more moderate mid-range temperatures (~15- 40°C) called mesophiles. [4]

Saprobic bacteria are heteroptrophs that live on decaying material such as a dead body. By decomposing organic material for energy, these microorganisms help recycle nutrients like nitrogen and carbon back into the environment. If it were not for these decomposers, the organic carbon in dead and rotting organisms would remain locked underground, effectively stopping the carbon cycle. The carbon dioxide in the air would be quickly depleted, and there would be none left for plants to carry out photosynthesis. Saprobic bacteria are, therefore, one of the most important links in the carbon cycle.

Cellular Respiration

How life "breathes"--many variations on a theme

Cellular respiration allows organisms to use energy stored in the chemical bonds of organic compounds like glucose ($C_6H_{12}O_6$) (or inorganic substances like iron and sulfur). The energy in glucose is used to produce ATP. Cells use ATP to supply their energy needs. In respiration, glucose is oxidized and this releases energy. Oxygen is reduced to form water. The carbon atoms of the sugar molecule are released as carbon dioxide CO_2 . We exhale this water and carbon dioxide.

$$C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O$$

The citric acid cycle is a series of chemical reactions of central importance in all living cells that use oxygen or other substitutes in place of oxygen (e.g., sulfate, nitrate, Fe3+or rust-remember that anaerobic respiration also uses the citric acid cycle to make ATP) as part of cellular respiration. In eukaryotic cells, the citric acid cycle occurs in the matrix of the mitochondrion. In aerobic organisms, the citric acid cycle is part of a metabolic pathway involved in the chemical conversion of carbohydrates, fats and proteins into carbon dioxide and water to generate a form of usable energy, ATP. [5]

The focus now moves from the background information on the fundamental requirements for staying alive-energy in the form of electrons, electron transfers in the form of redox reactions and organic or inorganic fuels to drive metabolism, to the environmental context of living organisms on a large scale and the relevant nutrient/elemental cycles occurring in natural environments.

Photosynthesis

Photosynthesis is the process by which plants and mostly bacteria convert sunlight into energy. The organisms that carry it out are called phototrophs. Photosynthesis evolved early in the evolutionary history of life on Earth when all forms of life were microorganisms and the atmosphere had no oxygen and much more carbon dioxide. Plants are not the major primary producers on the planet--these are marine phototrophic bacteria. Phototrophic bacteria like the cyanobacteria use the energy from sunlight to make ATP, the fuel used by all living things. The conversion of sunlight energy into usable chemical energy is associated with the actions of pigments like chlorophylls--there are many different types of chlorophylls that come in many colors other than green (e.g., purple). Generally, the photosynthetic process uses water and releases the oxygen that we must have to stay alive. The first organisms to do this were the cyanobacteria over 2 billion years ago.

Plants are the only photosynthetic organisms to have leaves (and not all plants have leaves). A leaf operates as a solar collector crammed full of photosynthetic cells. The raw materials of photosynthesis, water and carbon dioxide, enter the cells of the leaf, and the products of photosynthesis, sugar and oxygen, leave the leaf.

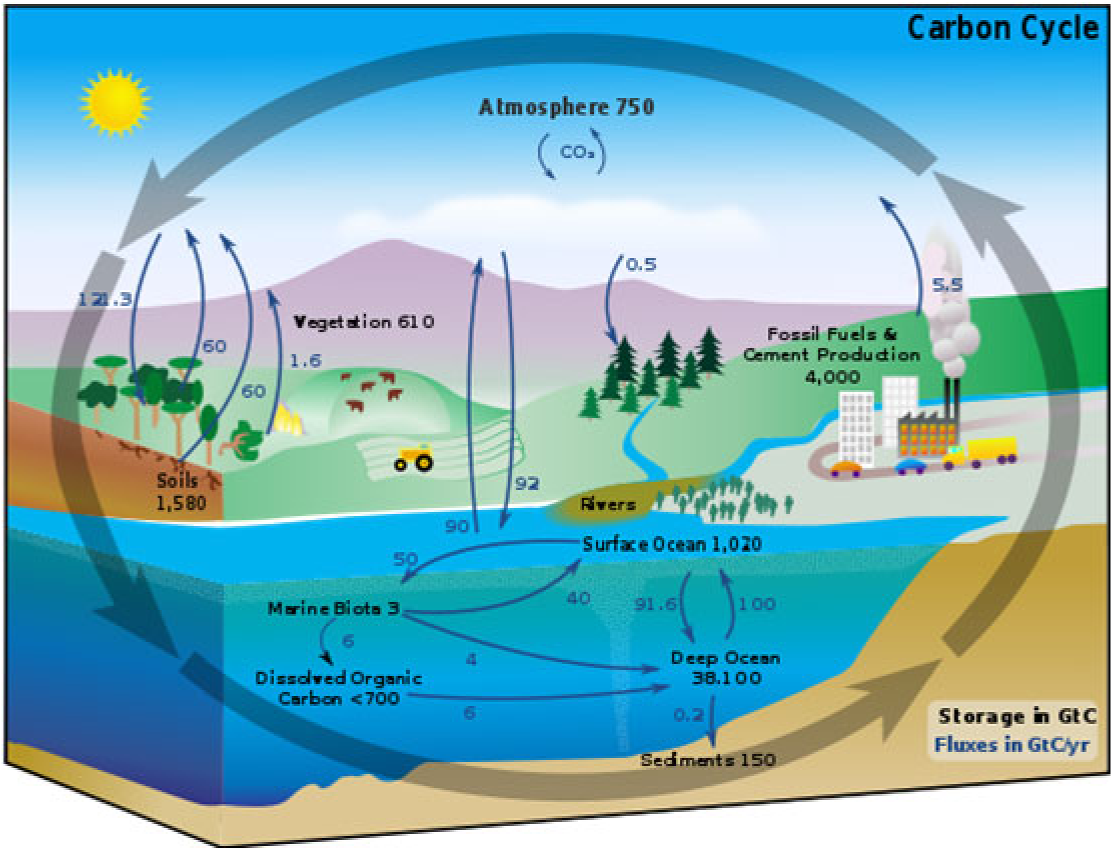
Water enters the root and is transported up to the leaves through specialized plant cells known as xylem. Land plants must guard against drying out (desiccation) and so have structures known as stomata to allow gas to enter and leave the leaf. Carbon dioxide cannot pass through the protective waxy layer covering the leaf (cuticle), but it can enter the leaf through an opening flanked by two guard cells. Likewise, oxygen produced during photosynthesis can only pass out of the leaf through the opened stomata. Unfortunately for the plant, while these gases are moving between the inside and outside of the leaf, a great deal of water is also lost. Scientists study fossil leaves and count the number of stomata to tell what the carbon dioxide level of Earth's atmosphere was in the past. [6]

Biogeochemical Cycles

"What is needed to sustain life" with emphasis on life underground

Plant Life and the Carbon Cycle

The building and maintaining of our classroom terrarium will demonstrate the interaction between organisms and their surrounding environment, and serve as an introduction to the carbon cycle. This cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of the Earth. It is one of the most important cycles of the earth and allows for carbon to be recycled and reused throughout the biosphere and all of its organisms. Plants, animals, and soil interact to make up the basic cycles of nature. [6] In the carbon cycle, plants absorb carbon dioxide from the atmosphere and use it, combined with water they get from the soil, to make what they need for growth. The process of photosynthesis incorporates the carbon atoms from carbon dioxide into sugars. Animals eat the plants and use the carbon to build their own tissues. Other animals eat these animals and then use the carbon for their own needs. These animals return carbon dioxide to the air when they breathe, and when they die, since the carbon is returned to the soil during decomposition. The carbon atoms in soil may then be used in a new plant or small microorganisms. Ultimately, the same carbon atom can move through many organisms and even end up in the same place where it began. [7]

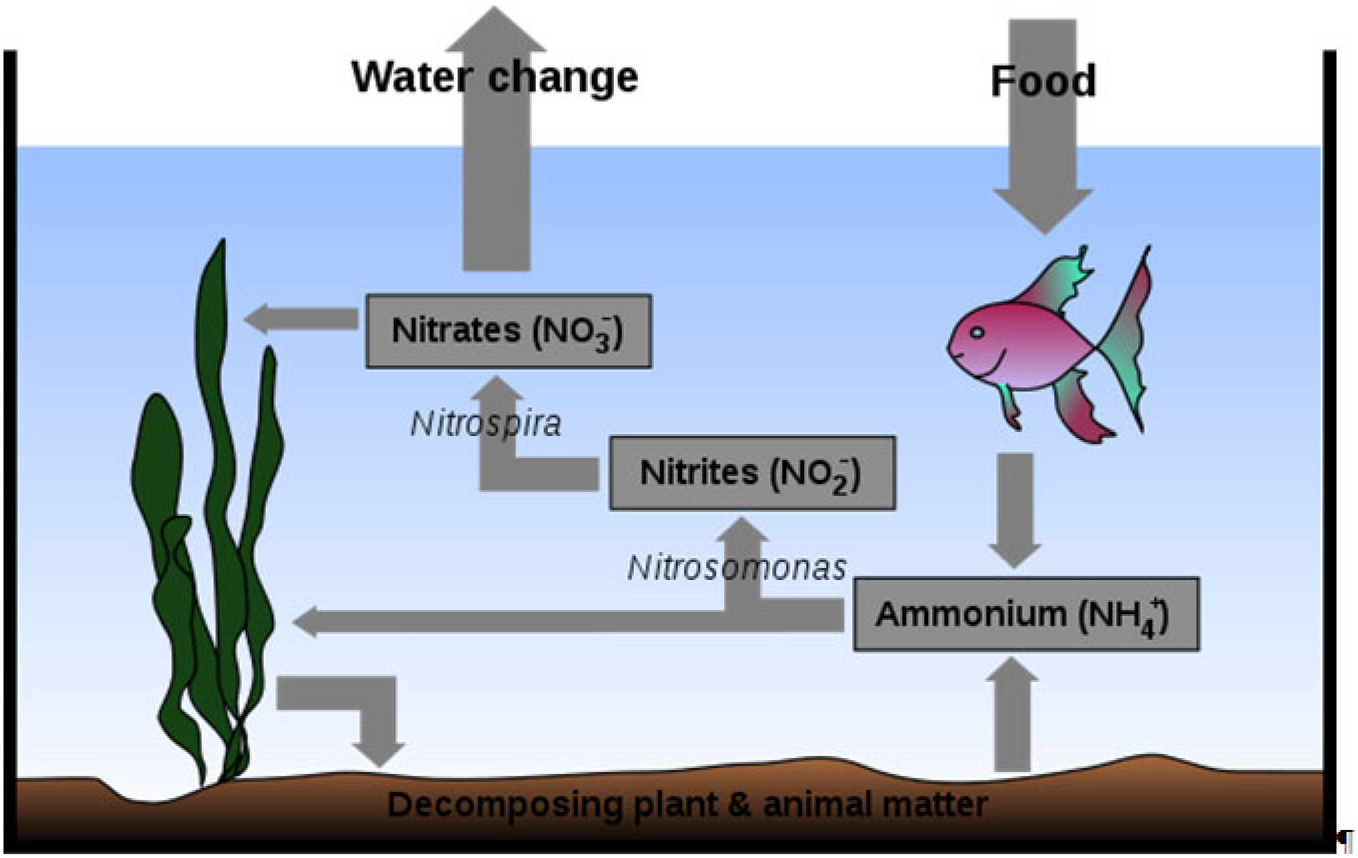


From wikipedia.org/wiki/Carbon_cycle

Aquarium Life and the Nitrogen Cycle

Three of the most important water chemistry parameters are ammonia, nitrite, and nitrate concentration. These chemicals are important because ammonia and nitrite are both very toxic to aquatic life, even at low concentrations. Nitrate, while much less toxic than either ammonia or nitrite, is toxic at high concentrations. More importantly, it is a great plant nutrient and thus causes algal blooms (even in your aquarium-algal overgrowth common). Most cases of green water are due to having huge amounts of nitrate (and phosphate) in the system. The best way to manage these potentially dangerous chemicals is to understand the nitrogen cycle, since this is the best tool for ammonia and nitrite removal.

All nutrient inputs into the system stay in the system unless they are removed by water changes or take on the form of gases like CO_2 that can escape into the atmosphere. The nutrient inputs (the proteins, carbohydrates, and fats in fish food) ultimately end up as ammonia (primarily from proteins). Whether the food is eaten by fish and expelled as urine and excrement, or simply decomposed in the gravel by nitrifying bacteria, ammonia is the end result. Without an active biological filter, food will lead to a rapid accumulation of ammonia.



From wikipedia.org/wiki/Aquarium

Food put into the system will go directly to ammonia as fish waste, or if left uneaten, will be decomposed to ammonia. The ammonia will then be broken down by ammonia oxidizing bacteria (Nitrosomonas) to nitrite. Nitrite is further oxidized by nitrite oxidizing bacteria (Nitrobacter/Nitrospira) to nitrate. Both ammonia and nitrate are taken up by plants. This means that plants are an excellent means of controlling both ammonia and nitrate. Unfortunately, nitrate also feeds algae. Plant and algal debris falls to the bottom of the tank where it is decomposed to ammonia and the cycle continues. Water changes remove all of these things from the water, and dilute whatever remains. [8]

Composting Life

In our classroom terrarium, worm environment and our ant farm, there will be microbes busy as well. If soil did not have microbes hard at work, the truth is we would not be alive! The work they do in our soil is quite complex, but the basics are if microbes eat, we eat! Plants are unable to take from the soil the nutrition they need without microbes working in the soil. Microbes consume the foods/nutrients they need and create nutrients like nitrogen, carbon, oxygen, hydrogen, phosphorus, potassium, and minerals for our plants. And it is the microbes that convert the nitrogen, phosphorus, potassium, and minerals in the soil into a form our plants can use to grow and produce food.

When living organisms that use oxygen feed upon organic matter, they develop cell materials from the nitrogen, phosphorus, some of the carbon, and other required nutrients. Carbon serves as a source of energy for organisms and is burned up and respired as carbon dioxide (CO_2). Generally, organisms respire about two-thirds of the carbon they consume as CO_2, while the other third is combined with nitrogen in the living cells. [11] Ratios of needed nutrients are roughly: C:N:P at 106:16:1, this is called the Redfield Ratio.

Several cycles of organisms are required to burn excess carbon. This is a complex chemical process. When organisms die, their stored nitrogen and carbon become available to other organisms. These new organisms form new cells which again need nitrogen to burn excess carbon and produce CO_2. Thus, the amount of carbon is reduced and the limited amount of nitrogen is recycled. This is amplified 16x in the case of phosphorus (P). When the ratio of available carbon to available nitrogen is low enough, nitrogen is released as ammonia. Under favorable conditions, some ammonia may oxidize to nitrates.

In nature, aerobic decomposition or burning of carbon is common in areas such as the forest floor, where droppings from trees and animals are converted into relatively stable organic matter. The products of aerobic decomposition do not smell when adequate oxygen is present. When oxygen is not present, such as in deeper layers of the soil or compost heap, decomposition of organic matter still occurs by the process of fermentation. We can try to imitate these natural systems when we plan and maintain our landscapes. As we learn more about the biology and chemistry of composting, we can actually hasten the decomposition process. [9]

When carbon/organic matter is oxidized to CO_2, energy is released as heat. There are many different kinds of bacteria at work in the process but the primary players are--heterotrophs and fermenters.

Strategies/Classroom Activities

Five systems will be set up in the classroom to achieve the following 4 objectives:

1. Students will construct and maintain a model of a natural habitat and use it to make observations and collect information about live organisms.
2. Students will suggest improvements to the model of the natural habitat to make it more realistic and habitable for organisms.
3. Students will demonstrate the processes of careful observation and recording for investigating how organisms survive in their habitat.
4. Students will realize that organisms not visible (microbes) in the habitat are essential and make the environment successful.

Activities One, Two, and Three are formatted to give procedural directions. Each activity can be used as a general classroom example. Another option is to use the procedure to create smaller versions of the habitats for groups of students to assemble, observe, and maintain. Based on the age and ability of the students, the lessons can be adjusted in this manner. The final activity is formatted for individual students. Throughout this unit, the students will keep and maintain science journals to document their observations for each habitat and activity using illustrations and text to share what they are learning. Scientists keep track of their experiments and activities to help them learn as they go and this is an important foundation for the students to become comfortable with and responsible for. Each lesson or activity should be documented in the students' journals as they will serve as an assessment tool.

Although much of the habitat observation will be what the students can see with their eyes, it is important in the unit to acknowledge the role of microorganisms in each activity. The use of a microscope in the classroom would provide tremendous enrichment even if it is borrowed for a day or so. Creating slides to show the microworld in each habitat will make the invisible visible and spark many scientific questions! It is because these microorganisms are in each environment that the environment is successful.

Activity One Setting up the Fish Tank

Materials: 10-- gallon tank/aquarium, gravel, filter, heater, power strip, aquatic plants, plate, bottled bacteria, aquarium test kit for nitrogen cycle, aquarium vacuum, fish food, fish net, bucket, kitchen strainer, 10-15 guppies

Procedure: Rinse out the tank with water only and decide on its location, away from heaters, vents, and direct sunlight. Rinse the gravel before placing it in the tank. After adding the gravel, place any plants or decorations in the bottom. To avoid disturbing the gravel and plants, place an overturned plate in the middle of the tank and pour the water directly onto it. Leave some room at the top to avoid overflow when finishing the setup process. Remove the plate and set up the filter and heater. Add the water to the top now, cover with the tank hood, and plug in all of the equipment. The water needs to sit to reach room temperature and to cycle through the nitrogen cycle. Add some beneficial bacteria and monitor the cycle using the test kit strips. Once the cycle is complete, it is time to add the fish. Adding the fish before the completed cycle will place unnecessary stress on them. Float the bag containing the fish directly in the tank for about 15 minutes so the fish will acclimate to the temperature of the water. After about 5 minutes of floating, add some aquarium water to the bag for the fish to get used to the pH level in the aquarium. Begin feeding the fish on day two but avoid overfeeding give them as much food as they can consume within a minute or two. Regular maintenance generally includes a 20% water change using the aquarium vacuum and a bucket, about every two weeks. Refill the tank with de-chlorinated water.

Activity Two Building a Terrarium

Materials: container (jar, fish bowl, tank, clear bottle with top cut off), pea gravel, clean potting soil, moss, several slow growing plants, science journals

Procedure: Clean the container with soapy water, rinse thoroughly, and dry. Cover the bottom with a layer of pea gravel about an inch deep for drainage. This mimics the bedrock found under our soils and allows excess water to drain from the soil. Next, fill the container to approximately one-third to one-half with moist potting soil. The moisture level of the soil when placed in the terrarium is very important. Pour the soil into a bucket and mix with water until the soil is moist enough to cling together in a ball when pressed into the hand. If water drips when the soil is pressed, it is too wet and more potting soil should be added. After adding the soil, begin placing the plants in an arrangement before actually planting. Be sure to allow for growth and avoid areas where the leaves will touch the sides of the container. After planting, use the moss to cover exposed areas of soil. In addition to plant material, small stones and sticks may add some interest. Attach the container lid or cover with plastic. Place the terrarium away from direct sunlight or the water will evaporate too quickly and the leaves may scorch. Observe the terrarium closely the first few days to ensure the proper moisture level. Droplets of water should appear on the sides and top when there is bright light on the terrarium. If there are no droplets, the terrarium is too dry. If it is too misty, uncover the top for a few hours to allow some evaporation to occur. Prune or remove plants with excessive growth. Occasionally sprinkle the terrarium with water.

Activity Three Ant and Worm Farms

Building the Ant Farm:

Materials: 1 large clear glass jar, 1 smaller jar or can, ½" deep tray for water, shovel, moist soil, cheesecloth, rubber band, dark construction paper, tape, about 100 ants, magnifying glasses, science journals

Procedure: Place the smaller jar or can upside down inside the large jar to encourage the ants to build their tunnels where the students can see them instead of tunneling in the middle. Ants can be collected outside using the shovel to carefully dig enough ants and dirt for the jars. For this unit, I will be ordering ants online to be delivered to the school. Fill the jars with soil 2-3" from the top and add the ants to the jar. Cover the jar with cheesecloth and a rubber band. Place the jar in a tray of water. Although the ants will likely not be able to climb up inside of the jar, they will not cross water. This tray will serve as a moat and they will return to the jar. To encourage the ants to begin working, make a cylinder with the construction paper to slide over the jar. The ants will be more likely to begin tunneling if there is less light it will seem more like underground. Ants like to eat small bread or cracker crumbs, or bread dipped in sugar or with a drop of honey or small bits of apple or other soft fruit and actually like variety in their diet. Feeding them every three days with tiny bits of food and a teaspoon of water twice a week should be sufficient. The farm should not be cluttered with old food or be too wet for them to work.

Building the Worm Farm

Materials: 1 large clear glass jar with lid, 1 smaller jar or can, moist soil, dry oatmeal, hammer and nail, piece of scrap wood, small amount of leaf litter, dark construction paper, worms, tape, magnifying glasses, science journals

Procedure: Place the smaller jar or can upside down in the center of the jar. This will encourage the worms to build their tunnels where the students can see them instead of tunneling in the middle. Put about an inch of moist soil in the jar. Measure about a teaspoon of oatmeal and sprinkle it around the top of the soil. Add another inch of soil and then another teaspoon of oatmeal. Continue layering in this manner, stopping about 2 inches from the top of the jar. Sprinkle some leaf litter around the top of the soil. Place the lid upside down on the scrap of wood and punch several holes into the jar lid with the hammer and nail. Put about 20 worms in the jar and close up the jar with the lid.

Activity Four What's in a Seed?

Materials: dried lima beans two per student, cups of water, hand lens, plastic bag, paper towel, science journals

Procedure: Each student will be given two lima bean seeds, ½ cup of water and a hand lens. Have them place the seeds in the water for twenty-four hours and examine them regularly. Start some seeds independently in case some seeds do not germinate. Have the students make some predictions on what they think will happen to the seeds while they are soaking. After twenty-four hours, have the students determine if the seeds have changed at all after soaking and whether these changes match their predictions. Is there something that could be happening inside the seed? Have each student carefully peel the outer coat from one of the seeds. Then guide them to pull the coatless seed in half with a fingernail. Have them discuss their observations and ask questions to guide them Does any part of the inside of the seed look like a familiar part of a plant? Do you think the seed is alive? Have the students place their seeds, both the whole bean seed and the seed that was split apart, in a plastic bag with a moist paper towel for a week. Have the students record their predictions. Continue observing \ the seeds daily for a week and recording the changes. At the end of the week, have the students share their findings. How did different parts of the seeds change during the week? What happened first? What happened next? Did everyone's seeds change at the same rate or the same order?

Vocabulary: roots, shoots, stem, leaves

If you germinate one bean seed every day for seven days, you will end up with all the stages of germination at one glance.

Endnotes

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1 http://www.chem4kids.com/files/atom_structure.html

2 http://en.wikipedia.org/wiki/Redox

3 www.textbookofbacteriology.net/metabolism.html

4 www.textbookofbacteriology.net

5 http://chemistry.about.com/od/biochemistry/ss/citricacidcycle.htm

6 D. L. Royer Stomatal density and stomatal index as indicators of paleoatmospheric CO2 concentration in Review of Palaeobotany and Palynology, 1-28.

7 http://chemistry.about.com/od/geochemistry/ss/carboncycle.htm

8 http://www.fishlore.com/NitrogenCycle.htm

9 http://www.composterconnection.com/site/chemistry.html

Teacher Resources

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Student Resources

Bial, Raymond. A Handful of Dirt. New York: Walker Books for Young Readers, 2000.

This highly readable, informative book introduces readers to various creatures who live in the dirt, all depicted in large color photos. Emphasizes respect for soil and includes basic instructions for setting up a home compost heap.

Bourgeois, Paulette, and Valerie Wyatt. The Amazing Dirt Book. New York: Addison Wesley Publishing Company, 1990.

This book explores humankind's associations with dirt throughout history. It discusses anthropology, the science of detergent, and geophagy (eating dirt). Also includes activities and recipes.

Bourgoing, Pascale De. Under the Ground (First Discovery Books). New York: Scholastic Trade, 1995.

This spiral-bound book introduces wildlife ranging from moles to ants, as well as animals that live underground in different ecosystems such as the desert, seashore, and river bank. Includes colorful illustrations with transparent overlays.

Cole, Joanna. The Magic School Bus Meets The Rot Squad: A Book About Decomposition (Magic School Bus). New York: Scholastic Paperbacks, 1995.

Based on the animated television series, this book follows Ms. Frizzle's class as it takes a field trip inside a rotting log to learn about how nature recycles through decomposition.

Himmelman, John. An Earthworm's Life (Nature Upclose). New York: Children's Press (CT), 2001.

With simple text and illustrations, this book describes the daily activities and life cycle of the earthworm.

Lavies, Bianca. Compost Critters. 1st ed. New York: Dutton Juvenile, 1993.

What humans throw away is a feast for a host of creatures who quietly perform some of nature's most important work. This informative book, with exceptional photographs, reveals these small but mighty recyclers in their own environment.

Pluckrose, Henry Arthur. Under the Ground (Walkabout). Childrens Press ed ed. Toronto: Childrens Pr, 1994.

This book uses full-page, full-color pictures to help relate interesting facts about life underground in a simple, straightforward way. Designed to fascinate young readers without overwhelming them.

Rodgers, Suzanne;, and Mary M. Winckler. Our Endangered Planet: Soil. Minneapolis: Lerner Pub Group, 1993.

From the award-winning "Our Endangered Planet" series, this book helps readers understand how soil is formed, how it has become endangered, and how they can protect this important natural resource.

Sabin. Amazing World Of Ants -- Pbk. 2 ed. New York: Troll Communications, 1997.

This book discusses ant biology and sociology and highlights several of the more interesting species with highly detailed illustrations.

Silver, Donald M.. Backyard (One Small Square). New York: W H Freeman & Co, 1993.

This book examines the lives of creatures that readers might find in one small square of their own backyard. It includes activities, journaling techniques for nature exploration and exceptional illustrations.

Silverstein, Alvin, and Virginia Silverstein. Life in a Bucket of Soil. New York: Dover Publications, 2000.

This book introduces readers to ants, earthworms, snails, slugs, beetles, and many other creatures that inhabit the world underfoot. Includes vivid descriptions of how they live, breed, and interact; their methods of movement, feeding and defense; and the effect they have on the soil in which they live.

Appendix -- Implementing District Standards

In accordance with the New Haven Public School District Science Standards, after completing this unit, the students will be able to:

A INQ 1: Make observations and ask questions about objects, organisms, and the environment.

A INQ 3: Make predictions based on observed patterns.

A INQ 4: Read, write, listen, and speak about observations about the natural world.

A12: Describe the different ways that animals, including humans, obtain water and food.

A13: Describe the structures plants have for obtaining water and sunlight.

A14: Describe the structures animals, including humans, use to move around.