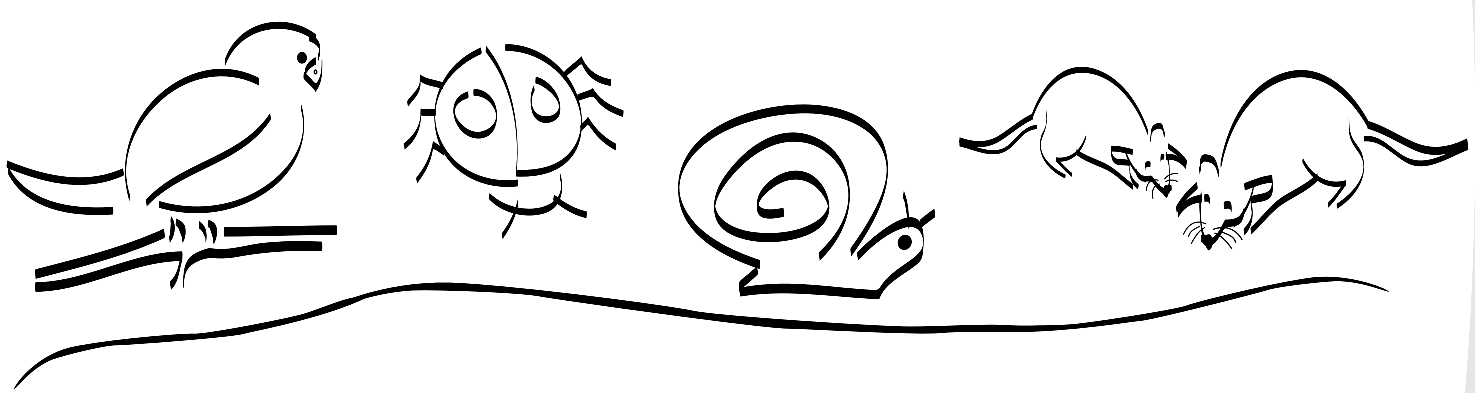
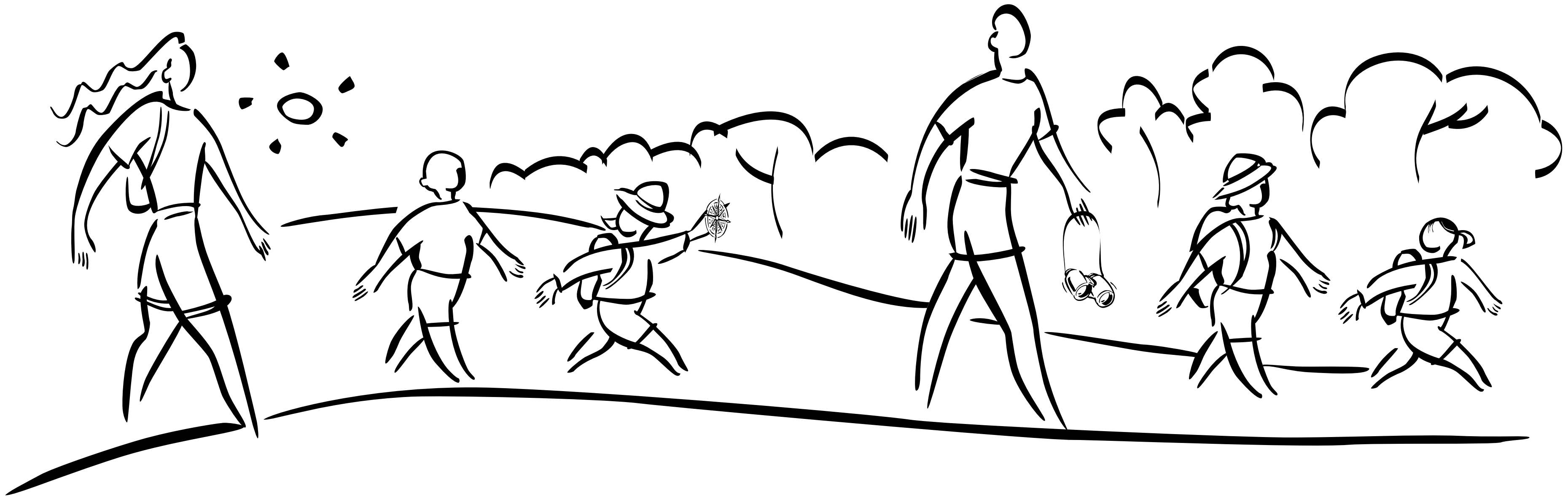
Take A Closer Look

Knowledge — Substrate for Sustainability

Issue Three





Knowledge – Substrate for Sustainability

The existence of plants and animals on Earth is dependent on the delicate interconnections of the Earth's primary elements – water, gases, and minerals. Most people understand that it's impossible to survive without air or water. But the role minerals play in plant and animal life is less obvious, although equally important.

In fact, the existence and survival of most life on Earth depends directly or indirectly on the nutrients and products from soil.

Simply consider:

- Each acre of soil provides a home to between five and 10 tons of living organisms. Some are quickly recognizable – such as earthworms, slugs, ants, mice, and snakes. These animals feed off other organisms living underground, and help break down and aerate soil by moving around and burrowing.
- Most underground organisms are microscopic though – like bacteria, fungi, and algae. The role of these microscopic organisms is to decompose dead organisms into nitrogen, which is then used by plants.
- Most plants germinate in soil, and once they have sprouted, depend on it for water, nutrients, and support.
- In turn, many animals depend on plant life. Humans obtain almost all of their food supply either directly from plants or indirectly from animals that feed from plants.
- And both plants and animals – including humans – rely on soil's natural filtering properties for clean water.

Soil is the primary source for clothing, building goods, fuel, metal, and other materials that we depend on in our everyday lives. These products either come directly from the ground or are derived from plants and animals that depend on soil. However, the benefits of soil extend beyond food and shelter. For example, 85 percent of the treatment regimens of underdeveloped countries use plants as their traditional medicines, and 25 percent of prescription drugs in the United States are derived from plants.

Today, 29 percent of the Earth's surface – 58 million square miles – is land. The Earth's life-sustaining properties are the soil's minerals, water, air, and organic material. When one of these components is depleted or corrupted, the ability of soil to maintain life is compromised.

The primary threats to soil and the living organisms that depend on it include erosion, inappropriate use of chemicals to control insects and weeds, and the loss of plant biodiversity. Human actions are often the source of these problems. For instance, practices such as plowing, mining, overgrazing by livestock, logging, and building can reduce soil quality and cause erosion.

The devastation caused by these actions has brought the delicate relationship between mankind and "soil health" into prominence, and has resulted in widespread acceptance of soil-conservation efforts. Today, advances in biotechnology, the careful use of pest management systems and responsible soil usage are helping to ensure that soil can continue its amazing ability to sustain and promote life above and below ground on Earth. Soil is truly the substrate of life. Knowledge about soil is the substrate of sustainability.

Wallace H. Fuller on the Substrate of Life

"A cloak of looser soft material
held to the earth's hard surface by gravity
is all that lies between life and lifelessness."

Lesson 1

Soils — The Foundation for Sustainability

PART I Soil Types and Their Characteristics (Grades 1-3)

Objectives

By participating in this activity, students should be able to:

- Explain how and why soil functions as a sponge,
- Predict how well a soil will absorb water as a function of its texture (clay, silt, and sand content),
- Predict what type of soil texture will absorb water most readily and what type of soil texture will retain water most effectively,
- Explain why soil could be home to animals, based on the fact that animals need air, water, food, and shelter to survive, and
- Predict what type of soil texture will contain the most soil animals and explain why.

Background Notes

Soil is not just dirt. Soil is made of living and non-living things and contains air, water, and minerals that provide nutrients for supporting growth of plants and animals. The exact composition of soil varies from one area to another, due to such differences as rock type, slope of land, and climatic conditions. An "average" soil sample is composed of 45% minerals (clay, silt, sand, gravel, and stones), 25% air, 25% water, and 5% organic matter (both living and dead organisms and their products).

Soil particles of different sizes (clay, silt, and sand) give soil its texture. The proportion of each particle size determines the porosity (sponge-like openings) within the soil that stores air and water for supporting life. The interconnections of the pores determine the ability of water to percolate through the soil. The more interconnection of the pores results in greater permeability of the soil.

Plant roots and burrowing of animals also increase the permeability and mixing of the soil. Water and air within the soil promotes chemical reactions on the surfaces of mineral particles, which release nutrients. Plants and animals

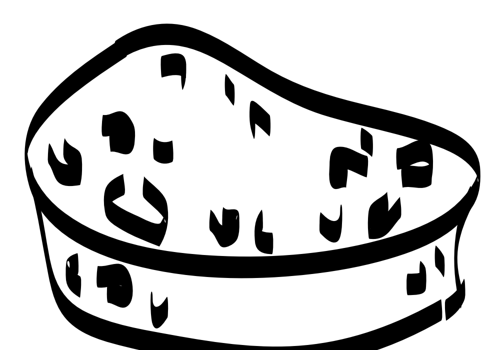
within the soil aid in the physical breakdown of particles, which increases the surface area of the particles for chemical reactions to take place. Organisms secrete acids and other fluid that contribute to the chemical reactions. Temperature and moisture levels of the soil also affect the rate of chemical reactions.

Concepts for Consideration

clay	organic matter	soil
decomposition	permeability	structure
dissolve	porosity	substrate
mixture	sand	surface area
nutrients	silt	texture

Materials Needed

1. Four small paper cups. (Use a nail to make holes in the bottom from the inside, in equal numbers and symmetry.)
2. Jar with holes in lid to be used to "rain" on soil samples
3. Sand, silt, and clay (three bags of each)
4. Shallow pan for collecting water poured through the perforated cups
5. Sponges (natural preferred)
6. Jar, clear, filled with marbles
7. Jar, clear, filled with BBs
8. Jar, clear, filled with sand
9. Stop watch or watch with second hand



Instructional Strategy

1. Have students look closely at a sponge and think about how a sponge absorbs water.
2. While holding up the sponge, carefully pour a small quantity of water on top of it, but not so much that it flows out the base of the sponge. Ask students why the water does not leak out of the base of the sponge. Ask students what would happen if a knife was pushed all the way through the sponge.
3. Suggest that soil functions similarly to a sponge. Establish the focus using a series of questions, e.g. "Where does rainwater go when it lands on the soil?" "If there is no rainwater in the soil, what is found in those spaces instead?" "Where do soil animals go as the soil is filling up with rainwater?" "Does every type of soil absorb the same amount of rainwater?" "What determines the size of the spaces (pores) in the soil?"

4. Fill one small, clear jar with marbles. Fill another small, clear jar with BBs. Fill a third small, clear jar with sand. Have students look closely at the size of the air spaces between the marbles, BBs, and sand.

5. Establish the focus using a series of questions, e.g. “Which jar would allow the water to pass through fastest? Slowest?” “Which jar could be the home to the largest animals?”

6. *Observations and Reporting.*
   Hand out bags of pure sand, pure silt, and pure clay to groups of three to four students. Have the students predict which material will allow water to pass through easiest and which material will absorb and hold water most effectively.

Student Activity

Ask each group of students to perform the following activities.

1. Pour one bag of sand into one of the perforated paper cups, one bag of silt into another, and one bag of clay into a third cup. Make sure each cup has approximately the same volume of material.

2. Fill a small paper cup with water to approximately the halfway mark.

3. While holding the cup of sand over a pan, slowly pour the water into the cup of sand. Note how long it takes the water to flow through the sand and begin to drip from the bottom.

4. Refill the cup of water and repeat the experiment, first for the cup containing silt and then for the cup containing clay.

Texture of Soil	Soil Types		
	Sand	Silt	Clay
Texture 1	50%	25%	25%
Texture 2	25%	50%	25%
Texture 3	25%	25%	50%
Texture 4 - Student Mix	_____%	_____%	_____%

Table 1. Soil Textures Based on Combination of Three Soil Types.

5. Record which material allowed the water to pass through the fastest. Slowest.

6. Rinse out each of the perforated cups.

7. Discuss with students that soil is a combination of sand, silt, and clay. The combination is referred to as soil texture. Demonstrate how to prepare the textures in Table 1.

8. Within the groups each student should prepare one of the combinations in Table 1 so that each group has all four textures. Then transfer the textures to the perforated cups.

9. Predict which texture will allow the water to pass through the fastest, which will allow it to pass the slowest, and which will allow an intermediate rate. Record the predictions in Table 2. Each group should develop the mixture that they think might be the slowest of all. (No ingredient should be less than 10% of the mixture.)

10. Repeat the experiment of pouring the water through each of the prepared soil textures while holding the cup over a pan. Record the results in Table 2.

Discussion Points

1. Which texture would hold water the longest? Which would probably drown soil animals living within it?

2. Which texture would not hold water very long so that plants would not have water available in the soil on days that it did not rain?

3. If plants will not grow due to a lack of water, how will this affect the animals?

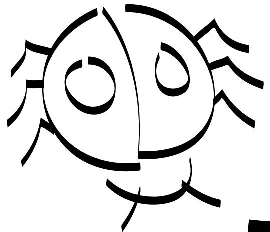
4. What job might soil animals perform while living in soil?

5. Soil contains nutrients for plant growth. How do nutrients get into the plants? How might soil animals help plants get nutrients from the soil?

6. Where would you likely find soils that are sandy, have a lot of clay, or have a lot of silt?

Soil Texture	Speed of Water Flowing Through Soil Texture (Fastest – Medium – Slow – Slowest)
1.	
2.	
3.	
4. Students’ Mixture	

Table 2. Effect of Soil Texture on Speed of Water Flow.



PART II

Increasing Soil Surface Area – Smaller Is Bigger

Objectives

By participating in this activity, students should be able to:

- Demonstrate that soil with a finer texture will dissolve faster and release nutrients more rapidly,
- Describe the role of soil animals in contributing to physically breaking down soil particles into smaller pieces, and
- Demonstrate how different soil temperatures and soil moisture content affect the rate of decomposition.

Concepts for Consideration

affects	physical change
area	rate
dissolve	soluble
nutrients	surface area

physical (mechanical) breakdown

Materials Needed

1. Rock salt
2. Small paper cups
3. Plastic spoons
4. Heavy-duty sealable plastic sandwich bags
5. Small diameter un-opened canned goods (e.g., small can of tomato paste)

Instructional Strategy

1. Explain to students that most needed plant nutrients become available through 1) dissolving the soil with rain water and fluids secreted by soil organisms and 2) decaying plant and animal matter. The more surface contact between the soil and the water and fluids, the more nutrients will become soluble for plants to utilize.

2. Prepare three paper cups for each group of students. With a marker, draw two lines encircling the cup, one at one-third of the way up from the base and the other at three-quarters of the way up. Label one cup "A," one cup "B," and the third cup "C."

Student Activity

1. Fill three paper cups (A, B, and C) to the lowest line marked on the cup with rock salt.

2. Pour the rock salt from the cup labeled "B" into a plastic bag, and seal the bag. Carefully break up the rock salt to about the size of rice, using the small can as a hammer. Pour the contents of the bag back into the cup labeled "B."

3. Pour the rock salt from the cup labeled "C" into a plastic bag, and seal the bag. Carefully break up the rock salt to about the size of table salt, using the small can as a hammer/grinder. Pour the contents of the bag back into the cup labeled "C."

4. Compare the height of the salt in each cup. Are the levels of the salt in cups "B" and "C" the same as cup "A"? Why does the uncrushed rock salt take up more room in the cup than the crushed salt?

Rock Salt Size	Dissolving Rate (Fastest - Medium - Slowest)
Cup "A" Large	
Cup "B" Medium	
Cup "C" Small	

Table 3. Particle Size and Dissolving Rate.

5. Fill each cup containing the rock salt with water up to the upper line drawn in each cup. Stir each cup briskly until the salt disappears (dissolves). In Table 3, record which cup contains the salt that has the fastest, slowest, or medium rates of dissolving.

Discussion Points

1. Why does the salt dissolve in each cup at different rates?

2. What does the experiment suggest about how rapidly nutrients become available for the plants as a function of particle size?

3. What sized particles of soil probably dissolve the most easily for releasing plant nutrients?

4. Since water was needed to do the experiment, what sized particles of soil will hold the water longest for the water to dissolve the nutrients?

Follow-Up Activities

Explain to the students that the rate of decay of organic matter in the soil depends on a number of factors: the moisture content of the soil, the temperature of the soil, the texture of the soil, and the work of soil organisms. To reinforce this concept, prepare and conduct the following activities.

1. Ask students to figure out a way that they could determine the saturation levels of the four soil types (amount of water "rained" on the sample before the first droplets appear through the perforations).

2. Have students bury a small slice of apple in a cup containing soil. In half of the cups, add water to moisten the soil, and then cover the cups with plastic wrap to retain the soil moisture. Place half of those cups in the refrigerator and the other half in a warm place. Place half of the cups that have not been moistened with water in the refrigerator and the other half in a warm place. Check the cups between one and two weeks later to observe the progress of decomposition.

3. To show students that soil animals have jobs to do, set up an ant farm in the room for the students to observe.

4. To show students that a variety of animals exist in the soil, set up a Berlese funnel to collect the animals found within different soil samples.

Leonardo De Vinci on the Substrate of Life

"...we might say that the earth has the spirit of growth; that its flesh is the soil..."

PART III Soil's Partners in Productivity – Macroscopic Animals Living in Soil (Grades 4-6)

Objectives

By participating in this activity students should be able to:

- Extract macroorganisms that are living within the soil,
- Classify the macroorganisms according to their obvious physical attributes,
- Quantitize various types of organisms in soil, and
- Hypothesize what role organisms play in soil productivity.

Background Notes

Soil is home to between five and 10 tons of living organisms per acre. Most of these are microscopic, such as bacteria, fungi, protozoa, nematodes, and algae. They change raw plant material (complex organic insoluble compounds) into simpler, inorganic compounds that are soluble in soil water, and in the process release nitrogen, an essential nutrient that plants need in large quantities.

The microbes in the soil decompose dead organisms and waste eliminated by organisms into organic materials called humus. Microbes and humus residue from the decay they produce act like a kind of glue to hold soil particles together in aggregates that help retain soil moisture. Humus ultimately provides nutrients (nitrogen, etc.) to organisms in the soil, including plants. Additionally, it aids in water retention in the soil and makes the soil more arable (fit for cultivation).

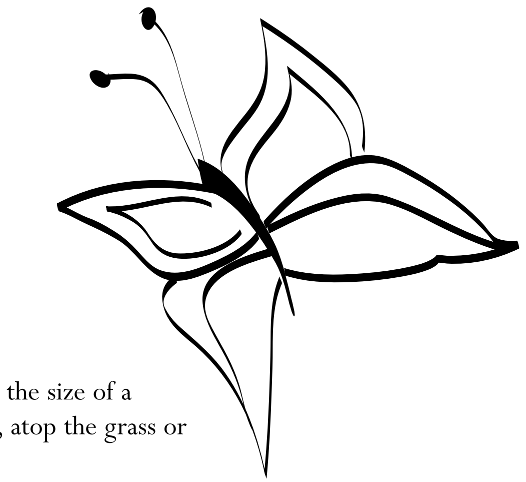
Macroscopic animals such as spiders, ants, earthworms, beetles, sow bugs, and insect larvae also occupy the soil, mixing surface material such as leaf litter in the soil, which then allows microbes to convert it into humus. They also help to break up large soil particles into small ones. An earthworm can ingest and excrete up to 36 tons of soil in a year, leaving channels that increase permeability and aeration of the soil. Approximately 75% of all insect species spend part of their lives underground. Burrowing animals such as mice, prairie dogs, snakes, toads, some birds, and others rely on the soil for food and protection from predators and harsh weather conditions.

Concepts for Consideration

biodiversity	invertebrates	nutrients
classification	macroorganism	phototropism
decomposition	microbes	substrate
food web	microorganism	variety
humus		

Materials Needed

1. Two-liter plastic bottle, cut in half with paper labels and bottle cap removed
2. Goose-neck lamp (≈60-watt bulb)
3. Shallow pan, lined with white paper
4. Grass or straw
5. Soil sample from beneath a tree in forest or soil from compost pile
6. Toothpicks
7. Seven small pill viles with caps
8. Soil Critter Identification Guide



Instructional Strategy

1. Have students write what they feel it would be like to live within the soil as a tiny animal.
2. Establish the focus using a series of questions, e.g., "Why would anything want to live in soil?" "What would a soil animal eat?" "What would a soil animal look like? Would it have ears? Eyes? A nose?" "Do you think that a wide variety of animals could/would live together in the soil?"
3. Explain that animals live in the soil to escape the heat and light of the sun and to be in a moist environment.
4. Show how to assemble and prepare the Berlese funnel. Using a lamp as an energy source, demonstrate that soil animals will migrate away from the light and heat, and migrate down through the soil to where it remains moist.
5. Ask students to pay attention to the varieties of animals that collect in the funnel. Some are worm-like, some have three pairs of legs, some have shells, etc.

Student Activity

Finding Macroscopic Animals in Soil

1. Construct a Berlese funnel.
   a. Place the top half of a plastic bottle upside down into the bottom half.
   b. Loosely put some grass or straw inside the top portion of the bottle to cover the opening in the neck of the bottle. This will prevent soil from passing through the opening. Do not pack the grass tightly.
2. Place a sample of soil (about the size of a grapefruit) inside the funnel, atop the grass or straw.
3. Place the funnel in a place where it will not be disturbed for six to eight hours. Position the lamp several inches above the funnel, turn it on, and do not disturb the system for six to eight hours.
4. After six to eight hours, remove the funnel from beneath the lamp. Carefully separate the top of the funnel from the bottom. The heat from the lamp will have dried out the soil and the animals that were living in the soil will have crawled through the neck of the funnel and into the bottom portion.
5. Carefully pour out the animals into the paper-lined pan for inspection.
6. Save the soil from the funnel for Part IV.
7. Use the following guide to group each soil animal, and place the animals in small pill viles according to their physical attributes:
   a. Worms (such as earthworms or night crawlers that have no legs)
   b. Grubs (any worm-like animal with legs)
   c. Snails (Snails without shells are called slugs.)
   d. Insects [any hard-shelled, soft-bodied, or winged (not all have wings) animal with three pairs of legs]
   e. Spiders, mites, ticks, and other animals with four pairs of legs
   f. Animals with more than four pairs of legs
   g. Others (any animal not falling into one of the groups)

Extension of Exploration

1. Make a bar graph to indicate the number of animals found in each of the seven groups described on the previous page.

2. Use reference books or Internet searches to have students try to name each animal found.

Discussion Points

1. How many different animals did you find within the soil sample?

2. Do you think that the number of different animals is a lot for such a small amount of soil?

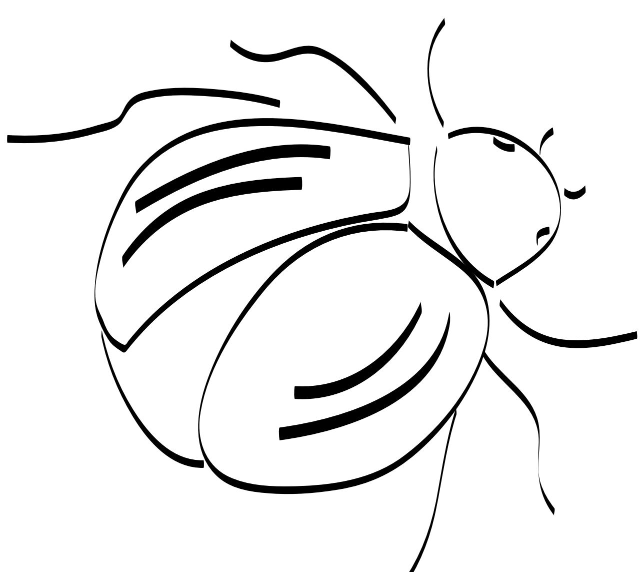
3. How many different animals can you think of that live in a part of a forest the size of your backyard?

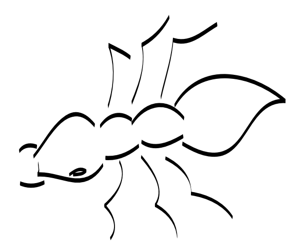
4. What do you think is meant by the phrase "diversity of species"?

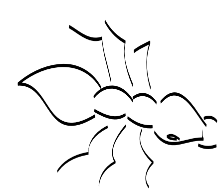
5. Why do you think there are so many different kinds of animals living in the soil?

Follow-Up Activity

Have students select one of the following soil animals and research the role of that animal in the process of decomposition: nematode, sowbug, earthworm, bacteria, pseudoscorpion, mite, springtail, snail, slug, rotifer, ant, tardigrade, foxfire fungus, honey mushroom (Arnillaria mellea), crowned earthstar (Geastrum indicum), shaggy mane (Corprinus comatus), oribatid mite, rove beetle, carrion beetle, millipede, or fly larvae.







PART IV

More Life in the Underworld – Microorganisms Living in Soil (Grades 4-6)

Objectives

By participating in this activity students should be able to:

- Identify the presence of varieties of microorganisms (molds, yeast, and bacteria) that are living within the soil,
- Distinguish between macroorganisms and microorganisms,
- Understand the role that the macro and microorganisms play in the soil, and
- State the relationship between soil organisms and soil characteristics.

Materials Needed

1. Two shallow, clear plastic cups

2. Plastic wrap

3. Two rubber bands

4. Cottage cheese, four tablespoons

5. Soil sample remaining in the funnel after Part III is completed, one tablespoon

Instructional Strategy

1. Ask students if they think there are any organisms remaining in the soil after using the Berlese funnel and extracting the macroscopic animals in Part III. If so, why can't they be seen?

2. Since no "visible" organisms remain in the soil, discuss how they might be made visible. Ask the students about growing them into groups, perhaps as whole colonies of tiny, microscopic organisms.

3. Have students explain how microscopic organisms may be made visible and identified using cottage cheese. What role does the cottage cheese play in this process? Ask students why cottage cheese is being used in the procedure.

4. Allow students to suggest ways in which they can determine if there are any microorganisms in the soil samples.

5. Ask students why one of the two cups containing cottage cheese will not contain soil.

6. Ask students why plastic wrap is to be placed over the top of each of the cups.

7. Ask students why soil from the Berlese funnel was used rather than a "fresh" sample.

8. Discuss the process of decomposition and its importance.

Student Activity

Locating Microscopic Animals in Soil

1. Have students label two plastic cups with their names and the date.

2. Place two tablespoons of cottage cheese in each of the two cups. It should be placed to one side of the cup's interior.

3. To one of the cups containing the cottage cheese, add one tablespoon of soil from the Berlese funnel, placing it along side the cheese without mixing them together. Do not put soil in the second cup.

4. Secure plastic wrap over the top of each cup with rubber bands.

5. Place the cups in a dark, warm place for three days.

6. After three days, inspect both cups.

Organism	Description
mold	appears fuzzy in a variety of colors
yeast	appears soft and slimy, usually yellow, orange, or white
bacteria	appears moist and shiny, usually cream, yellow, or red

Table 4. Three Types of Microorganisms and Their Descriptions.

7. Identify the different microscopic animal colonies present in each cup based on the above descriptions, completing Table 5 as observations are made over several days.

8. When finished with the activity, be sure to dispose of the cups in a healthful and safe manner. Add a 10% bleach solution to each cup, and follow your school's regulations for disposal of biological waste.

Follow-Up Activity

Have students pretend that they are various soil organisms. One student interviews another student as if a reporter preparing a newscast. The student being interviewed can speak to the importance of his/her job and the dangers faced from other organisms, people, and the environment.

Independent Variable Sample Cup	Dependent Variable Colors of Colonies		
	Mold	Yeast	Bacteria
Without Soil			
With Soil			

Table 5. Observations of Microorganisms in Soil.

Discussion Points

1. What are the microscopic organisms doing within their colonies atop the cottage cheese?

2. Why are there more varieties of microscopic organisms in the cup containing the soil than in the cup without the soil?

3. Where did the microscopic organisms come from that were in the cup without the soil?

4. If soil contained no material from living or past living things, could microscopic organisms make a home in the soil?

Additional Resources

Teaching Soil and Water Conservation: A Classroom and Field Guide, USDA Soil Conservation Program Aid Number 341.

Unearthing Soil Secrets: The Underground Adventure Educator's Guide, 1999. The Field Museum Education Department, Chicago, Illinois.

John Muir on Interdependence

"Whenever we try to pick out anything by itself, we find it hitched to everything else in the universe."

Lesson 2

The Substrate for Health – Looking at Foods and Nutrients

We rely on organisms from all taxonomic kingdoms to enhance and sustain our way of life. These organisms have unique ways to produce foods necessary to sustain their life. Our position in the food chain utilizes these organisms in various ways to supply key nutrients, energy, and structural material for growth and development of our own bodies. It is important for us to preserve biodiversity on the planet for our own survival needs in the future.

In this lesson, we will explore how plants use sunlight to produce food in a process known as photosynthesis. We will learn how organisms such as decomposers utilize food. Finally, we will look at why we need a rich source of biodiversity in order to improve the health and wellness of life.

PART I Photosynthesis - How Plants Make Food (Grades 6-8)

Objectives

By working through these activities students should be able to:

- Understand how a plant gathers light,
- Develop hypothesis on how a plant makes food,
- Discover differences/similarities among different plants, and
- Understand the plant carbon cycle.

Background Notes

We eat plants because they provide us with proteins (amino acids), carbohydrates, lipids, and vitamins. Our bodies cannot synthesize some of these on our own, and therefore plants are essential to our diets. Plants have the ability to produce all of these things. But, a plant also needs food. A plant uses many basic raw materials, but we will focus on the utilization of carbon dioxide, water, and sunlight in a process known as photosynthesis to produce energy for the plant.

To build proteins, plants take nitrogen and sulfur from the soil and convert them to amino acids that can be used for building proteins. Some plants have a special relationship with bacteria that "fix" the nitrogen into a useable form. However, to make carbohydrates, plants have a unique way of converting carbon dioxide (CO_2) in the air and water (H_2O)to carbohydrates ($C_6H_{12}O_6$)$_n$.

Photosynthesis is the process that a plant uses to make the components it needs to live. We call plants autotrophic, or self-nourishing. Plants use sunlight, water, and carbon dioxide to produce carbohydrates (sugars and starches). The plant can then use these carbohydrates for growth or store them in organs, such as leaves, stems, seeds, roots, or tubers to be used at a later time. Animals eat these storage organs to generate energy for growth. Ultimately, the entire food chain depends on photosynthesis for its energy.

Chlorophyll – the green pigment in the leaves of plants – is part of a photosystem that allows the plant to harvest light. When light strikes the photosystem, one of its electrons becomes energized and is passed through the photosystem. Ultimately its energy is captured by transferring the energy to ATP (Adenosine Triphosphate). The plant will use some of the ATP generated for the conversion of CO_2 to carbohydrates. Every year more then 150 billion tons of sugars are produced using this process. A very important byproduct of the conversion of CO_2 to carbohydrates is oxygen (O_2). Photosynthesis was instrumental in creating the Earth's atmosphere where oxygen makes up about 22%. In the last two billion years, the concentration of the Earth's oxygen has increased 50 fold.

Plants also will utilize the carbohydrates they produce. This process uses oxygen to produce chemical energy in the process called respiration. The byproduct of this conversion is carbon dioxide, which can be recycled by the plant. Excess carbohydrates that are not used by the plant are available for other organisms to ingest and use. This exercise will demonstrate what happens to the plant during photosynthesis when one of these components is removed. A generalized formula for this process is:

$$6CO_2 + 6H_2O + \text{Light Energy} \xrightarrow{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2\uparrow$$

Look at Figure 1, and see if you can determine what aspects of the process of photosynthesis are missing.

Materials Needed

1. Plant leaves
2. Rubbing alcohol
3. Paper clips
4. Container
5. Clear (colorless) nailpolish
6. Cardboard
7. Scissors
8. Petroleum jelly
9. Plant (healthy, rapid growing variety)
10. Lugol's solution (3g of potassium iodide in 200ml of water, add 0.65g of iodine; or buy povidone iodine at the drug store and dilute 1:10 in water.)

Concepts for Consideration

carbon dioxide (CO_2)
chlorophyll
energy (light)
extract
oxygen (O_2)
photosynthesis
pigment
products
starch
sugar($C_6H_{12}O_6$)$_n$
water (H_2O)

Instructional Strategy

1. Extract the chlorophyll from some leaves by putting a fresh leaf in a container with a small amount of alcohol. Wait a few hours, and then examine the solution. What is the green coloring? Do leaves from different plants produce the same results?

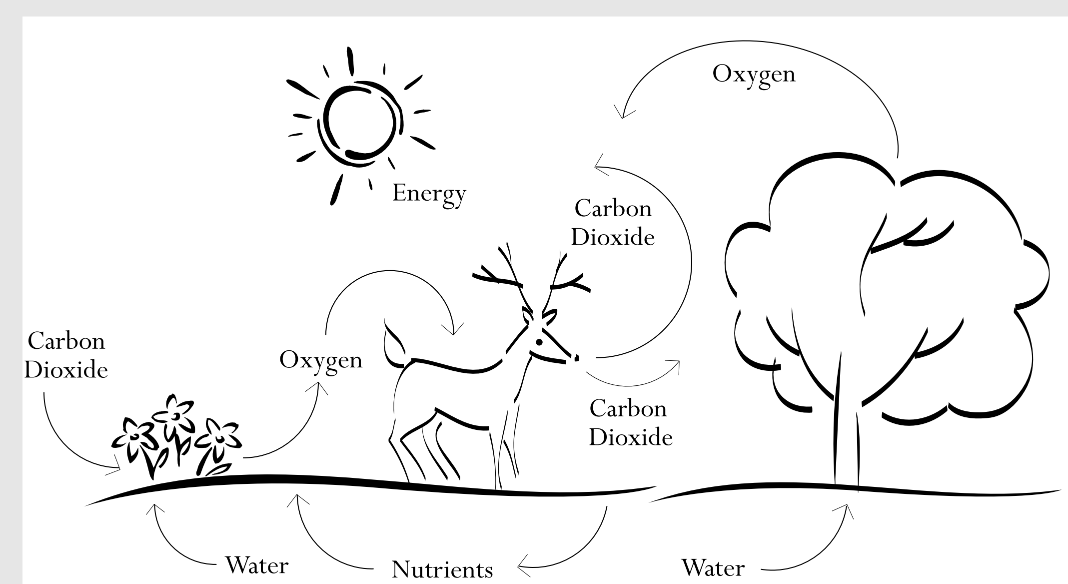


Figure 1. Photosynthesis – Can you label the components, and tell what they do?

2. Using a healthy plant with leaves still attached, cut pieces of cardboard to make a small patch that can be placed on the surface of a leaf. Use paper clips to attach the patch to the leaf on the plant. After about a week remove the patch, and examine the leaf. Is the covered part of the leaf green? Extract the chlorophyll from the leaf, and compare it to a leaf taken from a plant without the patch. Are the extracts different? What kind of cause-and-effect relationship can you imagine for what you see?

3. Take three healthy, green-leafed, non-waxy plants. Using clear (colorless) nail polish, paint the bottom of a few leaves on the plant roughly the size of a dime. On the second plant do the same, but paint the tops of the leaves. On the third plant do nothing. Place all three plants in sunlight, and treat with normal growing conditions. Leaves take in CO_2 necessary for photosynthesis through small pores called stomata. This exercise will give evidence for the location of the stomata on the plant. If the stomata are blocked, the plants will be unable to obtain CO_2 for producing its food (sugars and starches).

After a week or so, remove the individual leaves, keeping track of the treatments and gently peel off the nail polish. Using a hot plate, cautiously boil the leaves in 95% ethanol until all the pigment is removed. **Be careful when doing this since ethanol is highly flammable. Do not use an open flame. Wear eye-protective goggles and appropriate clothing. Be sure to follow the safety rules and precautions of your school.**

Remove the leaves, and place in iodine. If starch is present it will react with the iodine to produce a dark-blue pigment. Which leaves produced starch and which did not? Why? Where are the stomata located on the plant? (Note: an interesting exercise would be for the student to paint their name on the leaves and repeat the experiment.)

World Wildlife Fund -

"Biologists have realized only fairly recently that no plant or animal can be truly considered in isolation. Every living thing forms part of a community, and can be properly understood only within this context. The human being is only one species among a multitude which is inextricably involved."

The Living World of Animals
Reader's Digest Association

PART II

The Consumption of Food and the Byproducts Produced

Objectives

By working through these activities, students should be able to:

- Understand how microorganisms function to degrade food,
- Understand the carbon cycle (from solid to gas), and
- Learn more about how the environment affects the decay process.

Background Notes

In this part, we will use yeast as a tool to look at food consumption and utilization and the waste products that are produced. Yeast is a type of fungi or decomposer and has huge economic and social value to humans. Yeast is used to convert barley malt into beer and causes bread to rise. In this section, we will explore common baker's yeast (Saccharomyces cerevisiae) and take a closer look at what are some of its growth requirements and what are some of the end products that are produced during its growth and reproduction.

Activity A. Food for Thought

Materials Needed

1. One package baker's yeast
2. Two short bottles with lids
3. Banana

Instructional Strategy

Cut a banana in half and place one half in each of the two jars. Sprinkle yeast on only one banana in one jar. Replace the lids loosely on both jars, and place in a warm place. Observe the jars over a time period of a few days. Ask the students to record their observations each day and list any questions that come to mind from their observations. Are both banana pieces decaying at the same rate? What might be causing the banana without the added yeast to decay? What do you think is causing this breakdown? Why did we use two different jar setups?

Follow-Up Activities

Some extensions of this investigation might include the following questions:

1. Does the banana decay as fast if the lid is tightly placed on the jar?
2. What other food sources can be tested with the yeast?
3. What happens if the containers are placed in a dark location? How about in direct sunlight?
4. What happens if the containers are placed in a cold environment?

Activity B. A Carbohydrate Diet

Materials Needed

1. One package yeast
2. Warm water
3. Sugar or Karo syrup, four tablespoons per liter
4. One-liter bottle

5. Cap from the bottle with hole (large enough to add liquid using syringe) drilled through center and covered securely with tape

6. Jar (mouth should be able to fit over bottle)

7. Tray large enough to hold jar and one liter of liquid

8. Lime water (Add an excess of calcium hydroxide to a bottle of water; cap and shake. Let stand for 24 hours and pour off clear fluid. Keep clear fluid in well-stoppered bottle.)

9. Syringe or equivalent

Instructional Strategy

Add warm water, sugar, and yeast to fill the bottle half full. Mix contents well, and fill the bottle to the top with additional warm water. Cover the bottle with the jar, and invert so that the bottle is upside down and supported by the jar. Be careful not to let any of the water spill. The seal between the bottle and the jar should be sufficient to keep the water in the bottle. If not, add some water to the jar to prevent the water from leaking. Place in a warm place and observe. Within a few hours you should see some of the water displaced from the bottle into the jar. After a day or so most of the water should be displaced from the bottle. Without disturbing the seal between the bottle and the jar, decant off the liquid from the jar. Quickly remove the bottle and firmly tighten the cap. The cap should have a hole drilled through it large enough for an eye dropper. The bottled gas can be used for additional explorations.

Consider the following generalized formula for the process of respiration.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{Enzymes}]{} 6CO_2 + 6H_2O + \text{Energy (ATP)}$$

What does this equation have in common with the generalized photosynthesis equation in Part I? What aspects are different? What relationship can be established between the two?

Follow-Up Activities

1. Pose the following questions for the students to consider. Why was the water displaced from the jar? What type of gas was formed in the bottles? How might we test for the type of gas formed?

2. Prepare lime water. Quickly remove tape securing the hole, and pour 20-30 ml of lime water through the hole. What happens to the clear lime water when it comes in contact with the gas? If the clear lime water is CaO, and the cloudy mixture is limestone ($CaCO_3$), what gas was used to make the $CaCO_3$? Knowing the requirements for photosynthesis how might this waste product be recycled?

3. After completing the activities in Part II, can you add more information to Figure 1 to make it complete? What title might now be more appropriate for the drawing?

4. Alternatively, remove the cap, and add some bean seeds and a thin layer of water to the jar. Quickly replace the cap. Add some bean seeds and a thin layer of water to a second bottle but do not put on the cap. Place bottles in sunlight. In which bottle do the seeds germinate? What are some requirements for seeds to germinate? Have the student propose an explanation for their observations.

5. Can mold grow in the jar containing the gas? Take a piece of bread and sprinkle a few drops of water on it. Quickly add the bread to the bottle, and place on the cap. Repeat the experiment in a separate bottle without sealing with the cap. Place bottle in a warm, shady place, and observe after a few days. What happens? What can be concluded from the exercise?

Chief Seattle on Humans and Nature

"This we know: the earth does not belong to man, man belongs to the earth. All things are connected like blood that unites us all. Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself."

PART III

Biodiversity of Plants – A Basis for Sustainability

Objectives

By working through these activities, students should be able to:

- Develop a better understanding of biodiversity and why it is so important,
- Learn how to prevent loss of biodiversity, and
- Learn how genetic engineering is used to take advantage of the existing biodiversity to improve food and nutrition.

Background Notes

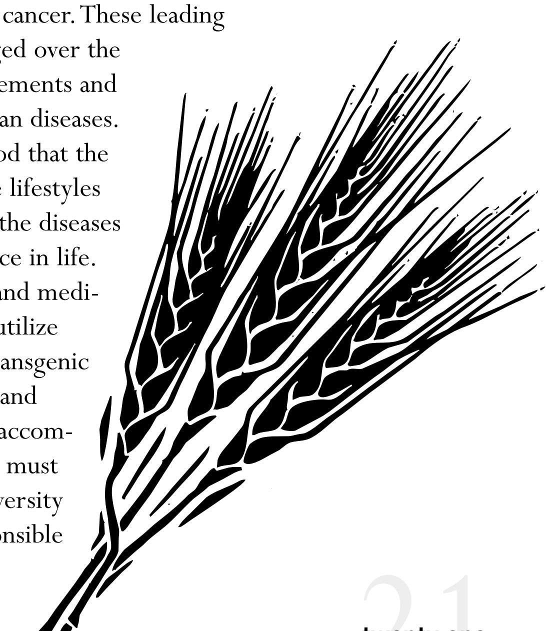
It has been estimated that there are between 300,000 and 500,000 species of higher plants, of which 250,000 have been described or identified. Of these, about 30,000 are edible and about 3,000 are cultivated for foods for humans and animals. Of these 3,000 species, about 120 species are important food sources on a national scale, and only 30 species represent 90% of the world caloric intake. The three most important crops worldwide are wheat *(Triticum aestivum)*, rice *(Oryza sativa)*, and corn *(Zea maze)*. However, depending on the geographic location, the importance of the crops for human caloric intake change. For example, wheat is more important in Europe, rice is more important in Asia, and cassava *(Manihot sp.)* is a very important food source in Africa.

The genetic characteristics of the plants are valued for the benefits they provide to animals and humans. These benefits include agronomic qualities such as resistance to pests or disease, adaptations to stresses such as drought or cold, factors affecting quality and productivity such as higher oil or protein content, and a number of other culinary factors that may have some cultural importance. Many of these important genetic characteristics have been derived from exotic plants that have been forced to evolve and adapt to their natural native environments. In almost all cases, these exotic plants were not suitable for agriculture, but contained gene pools that could significantly improve the genetic diversity of modern agricultural plants.

The available biodiversity of plants not only provides sources of food but also provides a pharmacy of nutrients and molecules that are the basis for curing or treating many illnesses and diseases. It is estimated that 85% of the treatment regiments of underdeveloped countries utilize plants as their traditional medicines, and 25% of the prescription drugs in the United States are derived from plants. It is very important that we preserve the biodiversity of plants so new discoveries can be made and we can continue to mine this biodiversity to improve modern agriculture and medicine.

The huge resource of genetic information available in the world today is shrinking due to extinction of species and utilization of only a few selected species for food cultivation. The world population keeps growing at a tremendous pace, while the available land for cultivation of food for animals and humans declines. Modern medicine allows us to live longer, healthier lives, yet the leading causes of death in the world today are cardiovascular disease and cancer. These leading causes of death have changed over the past decade due to advancements and our understanding of human diseases.

It is generally understood that the foods we consume and the lifestyles that we live contribute to the diseases and health problems we face in life. In the future, agriculture and medicine will cross paths, and utilize genetic engineering and transgenic plants to deliver healthier and more nutritious foods. To accomplish these tasks, scientists must rely on the available biodiversity to identify the genes responsible



for producing beneficial nutrients. For example, a rare plant may be discovered in the tropical rainforest that possesses a unique protein capable of lowering cholesterol. Instead of destroying the plant and its natural habitat to extract the protein, this protein could be engineered into the fruits, vegetables, and other foods we consume on a daily basis. We would receive the benefit without the destruction of the species and native habitat.

Instructional Strategies

1. Have students think about biodiversity and develop a working definition.
2. Ask students to name geographic locations around the world they feel are rich sources of biodiversity. Then have them develop a collective list of reasons why they believe these are probable locations. What do these locations have in common?
3. Have students list threats to biodiversity in these locations.
4. Have students develop conservation plans to save the biodiversity.
5. Can the students give some example on how genetic engineering can be used to improve the food we eat? What sources of genetic diversity do the students recommend to achieve their goal?

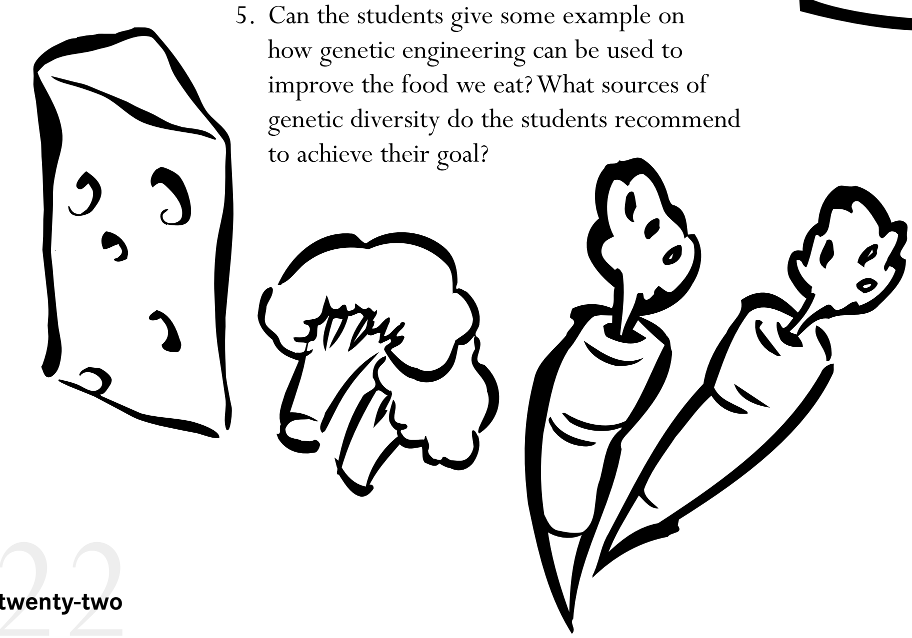
References and Other Resources

Excellent sources of information on nutrition with links include:

- www.about.com/health/nutrition
- www.nal.usda.gov (National Agricultural Library)

Several biotech brochures and videotapes produced by Monsanto are available to the public. One copy of each can be made available to teachers.

- *Exploring a New World of Discovery* (A booklet that explains the research that goes on at Monsanto)
- *10,000 Years of Food Production* (Flyer explaining how biotech has been used in food production; designed for elementary/Jr. High students)
- *The Path to Better Foods* (Flyer explaining how biotech is in the next step in agriculture; designed for elementary/Jr. High students)

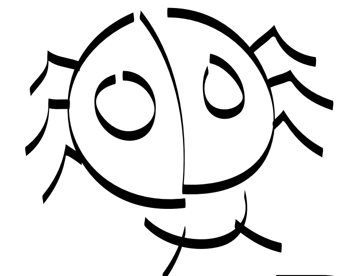


Dr. Seuss on Variation

"Now, the Star-Belly Sneetches
Had bellies with stars.
The Plain-Belly Sneetches
Had none upon thars.
Those stars weren't so big. They were really so small
You might think such a thing wouldn't matter at all."

– The Sneetches and Other Stories

Lesson 3



Enhancing Sustainability Through Biodiversity (Grades 9-12)

PART I Observations on Genetic Variation

Objectives

By working through these activities students should be able to:

- Define intraspecies variation,
- Perform standard microbial streaking procedures and data collection, and
- Determine whether intraspecies variation occurs in microbes by examining experimental data.

Background Notes

The connotation placed with the meaning of biodiversity has generally restricted our thinking to the variety of species of plants and animals one can find. However, in a broader context it also can mean the diversity or variation one can see within a species. Perhaps we should think in terms of inter-species diversity (among species) and intra-species diversity (within species). This would be useful as we try to engineer the best possible environment and resources to enhance the quality of life, while at the same time maximizing the opportunity for sustainability of our biosphere.

Concepts for Consideration

biodiversity	genetic change	strain
control	inter-species	synergism
diversity	intra-species	variation
experimental	species	

Materials Needed

1. Bunsen burner
2. Bacterial Synergism Demonstration Kit (Carolina Biological #AA-15-4744)
3. Disinfectant
4. Inoculating loop
5. *Serratia marcescens* WCF (colorless mutant strain)
6. *Serratia marcescens* 933 (colorless mutant strain)
7. Sterile petri dishes (three plastic)
8. Synergism agar (5g peptone, 10ml glycerol, 20g agar in 1L distilled water)
9. Parafilm or wide clear tape

Instructional Strategy

This activity will introduce the concept of biodiversity within a species, intra-species variation. By the end of the activity, students will be able to determine that the interactions between two variations in a species are able to affect a change in resulting offspring while each of the originals are genetically unchanged.

Student Activity

Set up the laboratory experience through the following procedure.

1. Give students three petri dishes with sterile synergism agar.
2. Have them label one petri dish "strain WCF" as a control plate.
3. Label the second petri dish "933 strain;" it also will serve as a control plate.
4. Using a wax pencil, mark a line on the bottom of the third petri dish so as to divide it in halves. Label one side WCF and the other side 933; this will be the experimental plate.
5. Using proper bacteriology methods, streak one half of the first dish with the WCF culture of the bacterium *Serriatia marcescens*. Streak one half of the second plate with the 933 culture of *Serriatia*.
6. In the experimental plate, streak both bacteria cultures on their appropriate sides, being careful to streak the two bacteria within one centimeter of each other at their closest point.
7. Seal each inoculated dish with a strip of Parafilm or wide clear tape.
8. Incubate these plates **right side up** (cover on top) at room temperature, and observe each plate for three to four days.
9. After three or four days, take a small sample from each of the now pigmented bacteria on the experimental plate and streak them back to the appropriate control plates. Use the following procedural outline:

   a. Remove the Parafilm from all three plates.

   b. Using proper bacteriology methods take a small sample of the pigmented WCF on the experimental plate, and streak it on the unused half of the WCF control plate.

   c. Repeat step 9.b. for 933 and its control plate.

   d. Reseal in Parafilm; continue to incubate; and make observations for two to three more days.

   e. When finished, be sure to sterilize the plates with 10% bleach before discarding in an appropriate manner.

Discussion Points

1. After the three- to four-day incubation period, compare the control plates to the experimental plate, and make a hypothesis as to what you think is happening. Give reasons to support your thoughts.
2. After the seven days of incubation, describe what has happened in each of the control plates. Does this indicate that the change that occurred in the experimental plate is a genetic change in the two bacteria or one influenced by its environment? Explain your response.

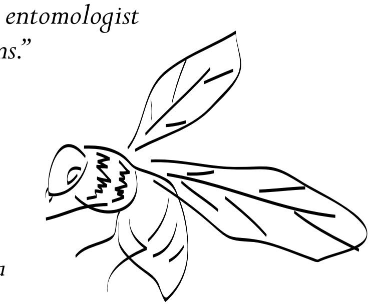
Follow-Up Activity

- Design an experiment that would test your hypothesis as to whether your explanation for what you saw was genetic or environmental in basis.

Howard E. Evans on Insect Diversity

"Today at least half of the kinds of organisms existing on earth are insects. The diversity of form among insects boggles the mind. There is not much resemblance among a louse, a butterfly, and a beetle. Even the life stages of single species may appear utterly dissimilar. A beginning entomologist is likely to vacillate between bewilderment and fascination with this vast array of forms."

- Insect Biology



PART II A Process for Enhancing Biodiversity

Objectives

By working through these activities students should be able to:

- Perform preliminary studies to determine efficacy of insect control proteins in transformed cotton lines,
- Record average plant damage reading and mortality of insect pests, and
- Perform preliminary studies to determine efficacy of herbicide-resistant cotton lines.

Background Notes

Insects have existed on Earth for more than 350 million years, long before human beings inhabited this planet. There is no animal or plant that surpasses insects based on their numbers and biomass. It has been estimated that nearly one million species of insects have been identified with thousands yet to be identified. The class – Insects – makes up around three-fourths of all known living species, and members of the 30 orders live in almost every environment possible.

Insects compete with humans for plant food and grain products, cause injury to us and our livestock, and transmit diseases and viruses. Yet, there are many benefits we incur from insects. Insects are food sources for fish, birds, and many other animals. They are important pollinators in agricultural areas, and produce silk and honey. Many insect parasitize or prey upon pest insect species, and even serve as food for man in some areas of the world. They have been used as model systems in many areas of science (e.g. *Drosophila* in genetics).

Since the advent of the agriculture, humans have used numerous approaches to alleviate insect damage to crop plants. The era of synthetic insecticides began with the discovery of DDT in 1939 by Paul H. Müller. In fact, Müller was awarded the Nobel Prize for his discovery of DDT. Synthetic insecticides are very effective in controlling many insect species, but they are generally neurotoxic to both insects and other animals, including humans. Hence, inappropriate use and excessive reliance on insecticides to control pests in certain crops has led to problems that threaten production, sustainability, health, and the environment, and insects have developed resistance to these products in many instances.

What has been principally a pesticidal approach to controlling insects is evolving into managing pests in an environmentally friendly manner. This sustainable philosophical approach to pest management is dynamic and depends on the crop, availability of resources, the pest, and the cropping pattern in the total agroecosystem. This successful system of pest control is termed integrated pest management (IPM), and its principles are applicable to the control of all pests.

Integrated pest management is fundamentally the use of all available advancements in technology in an ecologically sound manner to control pest populations. The reduction of pesticidal chemicals and protection of the environment is at the heart of this discipline. The old adage "the only good bug is a dead bug" is gone. Now, it is only necessary to bring populations of insects below a threshold level sufficient to protect the crop from economic injury. IPM methods may be either preventative or curative.

There are many tools available to growers for use in IPM including:

- **Pest-Control Chemicals** – They are used as a last resort since they have the potential to harm humans, livestock, and wildlife; can pollute the environment; and destroy beneficial organisms.
- **Biocontrol Agents** – There are three main types: parasitoids, predators, and disease-causing agents. These have been very successful in some instances. Preservation of these agents is key to IPM.
- **Cultural Control Practices** – These agronomic practices are used consciously or unconsciously by farmers to improve yields and/or reduce pest-induced damage.
- **Physical Control Methods** – Pests are physically collected and destroyed in areas where labor is cheap. Fences or screens are used to protect high-value crops from insect pests. Temperature, humidity, energy, and sound also are used.
- **Preventative Measures** – Quarantine laws are used in many countries to prevent introduction of unwanted pests.
- **Host Plant Resistance** – It is the inherited ability of a plant species to ward off or tolerate attack by pests.

A recent addition to this arsenal of IPM tools is transgenic technology. The introduction of transgenic plants to combat insects is the outcome of advances in molecular biology. In the context of IPM, transgenics are genetically modified plants. Biotechnology has already yielded herbicide-tolerant and insect-tolerant transgenic plants that are commercially available to growers.

Insect-tolerant crop plants have been obtained by transferring into them a gene that produces an insecticidal protein from a soil-dwelling bacterium, *Bacillus thuringiensis* (B.t.). These transgenic plants then have the B.t. gene that codes for a protein that is toxic to the insect which results in mortality or severe reduction in the pest species when they feed on the plants.

Concepts for Consideration

gene splicing	pesticide
herbicide	resistant
integrated pest management	transgenic

Materials Needed

1. Safety glasses with side shields
2. Latex or nitrile gloves
3. Lab coat
4. Surgical or dust masks
5. Insect-protected, Roundup Ready® seeds
6. Regular, nontransgenic seeds
7. Plastic pots (4" pots) to grow seedlings for six to eight weeks (A minimum of 24 pots per class are needed.)
8. Potting soil mix
9. Roundup® herbicide
10. Deionized water
11. Plastic spray bottle
12. Lepidopteran insect egg sheets from your state department of agriculture
13. Paint brush
14. Marking pen
15. Organdy for covering the pots
16. Mettler balance for weighing larvae (optional)
17. Petri dishes and filter paper

Instructional Strategy

Activity A. Insect Feeding Assay (Whole plant)

Utilizing simple pieces of equipment we can compare and contrast the effectiveness of transgenic vs. non-transgenic insect-tolerant and herbicide-tolerant cotton plants.

The first experience will be to compare transgenic and nontransgenic cotton plants with respect to insect invasion.

1. Have a minimum of six pots each for transgenic and nontransgenic seeds.
2. Choose cotton plants that are about six- to eight-weeks old with blooms.
3. Incubate egg sheets (received from the USDA) in small plastic containers at approximately 27ºC for about two to four days until the neonates emerge. The eggs will first turn dark brown or black in color and then will hatch out into the first instar larvae. It is advisable to practice with the incubation of the egg sheets for hatching at least once before the experiment is performed.
4. Apply the insects with a paint brush onto the plant structures in the following order:
    a. First choice, an open white bloom
    b. Second choice, a closed pink bloom
    c. Third choice, a square (the unopened bud)
    d. Fourth choice, a leaf
5. Place three to four larvae on each structure.
6. Cover each plant with organdy material to prevent escape of insect larvae, while at the same time allowing sufficient light for plant growth.
7. Observe the plants every two days. Let insects feed for two weeks, and then make observations.
8. Develop a table to record the data. Prepare the table so that it will take the results from both the control and experimental plants. Remember that the independent variable is recorded in the left variable column and the dependent variable(s) on the right vertical column(s). Include such observations as:
    - The total number of nodes on the plant.
    - The total number of damaged plant parts. (Look for any feeding indications.)
    - The total number of live larvae on the plant.
    - Weight of surviving larvae taken individually (optional if Mettler balance is available).

Activity B. Demonstration of Herbicide Tolerance

Herbicide-tolerant plants are those in which tolerance to certain herbicides has been incorporated through gene transfer. By introducing a gene which is responsible for the production of an enzyme that is not inhibited by the herbicide, the transgenic crop plant is rendered tolerant to

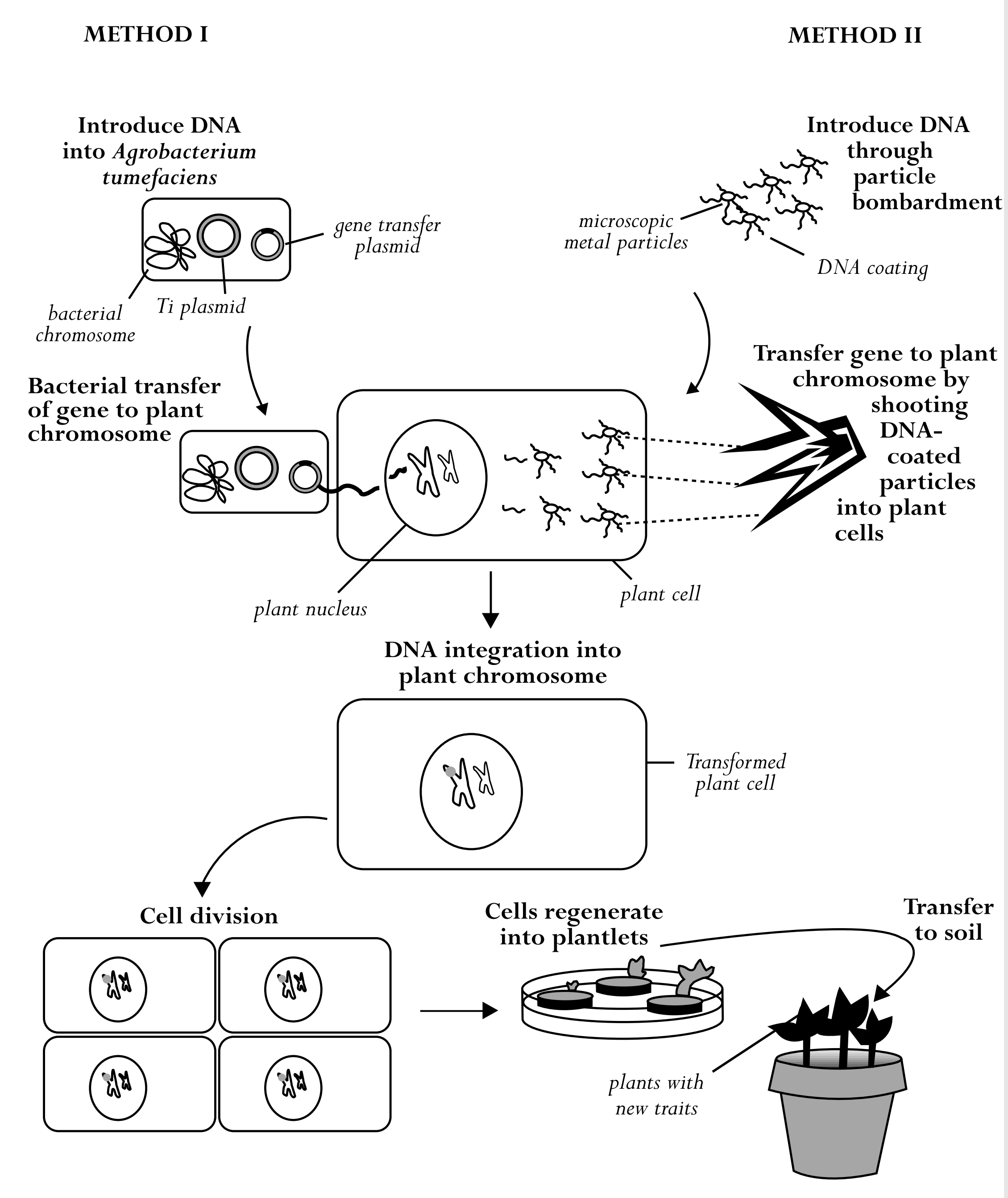


Figure 1. Pictoral Representation of Transformation.

the herbicide, while the weeds in the area are controlled. Usually, the bacterium *Agrobacterium tumefaciens*, which produces crown gall tumors in plants, is used for transferring the tolerance gene. The physical transfer of DNA also can be accomplished through a process of bombardment with accelerated particles. Both processes are illustrated in Figure 1.

The second component of utilizing genetic engineering for diversity involves developing and testing plants for herbicide residue. To carry out this observation, use a minimum of six pots each for transgenic and nontransgenic seeds. Plants to be sprayed with Roundup® are generally at the three- to four-true-leaf or greater stage of growth (approximately four weeks). Depending on what the measurements or evaluations are to be, you can spray at any growth stage if you accept the potential loss of fertility. Plants should be turgid and not stressed in any way. Ensure that the leaves are dry before applying Roundup® spray.

Instructional Strategy

1. Add 3.1 ml Roundup® to 250 ml distilled H_2O. Mix well. (A Roundup® Concentrate working solution contains 12.4ml Roundup® obtained from a hardware store with 1000ml distilled H_2O.)

2. Using distilled H_2O, adjust spray bottle nozzle to a fine mist setting.

3. Pour Roundup® solution into the adjusted spray bottle.

4. Spray solution onto plant leaves. (Wear gloves and masks.) Cover leaves with a fine mist. Do not over spray. The solution should not drip from leaves.

5. **Allow Roundup® solution to dry on the plants before moving, touching, or watering them.**

6. Check for results five to seven days after spraying.

7. Look for the following phenotypic observations in the plant sets:

   a. Burnt or black terminal damage

   b. Yellowing and bending of terminal leaves

   c. Bending of entire plant

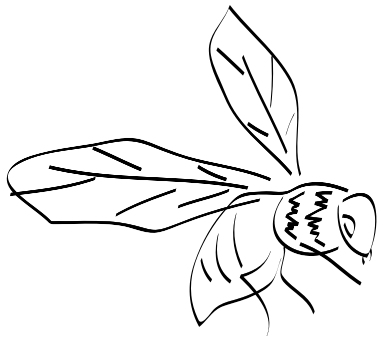
8. If results are not seen on non-transgenic control plants, repeat above application.

How can you combine this information in your table of data to help you and those who see your observations draw a valid conclusion on the usefulness and effectiveness of transgenic plants?

Follow-Up Activities

1. Mosquitoes are well-known disease transmitters (vectors). They transmit many deadly or debilitating arboviruses (viruses carried by arthropods) and protistan pathogens. Some of the better-known diseases include malaria, dengue fever, and many types of encephalitis. Additionally, mosquitoes are considered one of the most difficult pests to control because the larval stages of mosquitoes occur in almost any stagnant, shallow body of water. The adults can fly great distances, and the females of some species can lay eggs in any area that is moist.

   Have the students learn about the life cycle, behavior, and basic physiology of mosquitoes in general. Have them develop a basic IPM plan for a specific species or group of mosquitoes. They will have an opportunity to determine the various biocontrol agents (including B.t.), cultural controls, pest control measure, etc. Have them defend the merits and potential effectiveness of their IPM plan.



2. Although many people want to totally eradicate mosquitoes worldwide, have students debate the pros and cons of this philosophy.

3. Have the students do a search through the literature to determine where B.t. naturally occurs, how many different strains are documented, if it forms spores, how it exactly kills or is toxic to the insects it attacks, and if it is general or very species specific.

Further References and Resources

An Introduction to Biotechnology - Book One, A Unit for Fifth and Sixth Grade Students, 1996. Mathematics and Science Education Center, Kendall/Hunt Publishing Company, 220 pages. ISBN 0-7872-1638-0

In Introduction to Biotechnology -Book Two, A Unit for Seventh and Eighth Grade Students, 1996. Mathematics and Science Education Center, Kendall/Hunt Publishing Company, 195 pages. ISBN 0-7872-1639-9

An Introduction to Biotechnology - Book Three, A Unit for High School Students, 1996. Mathematics and Science Education Center, Kendall/Hunt Publishing Company, 406 pages. ISBN 0-7872-1640-2

Several biotech brochures and videotapes produced by Monsanto are available to the public. One copy of each can be made available to teachers.

- *Biotechnology Solutions for Tomorrow's World* (24-page color brochure explaining the science behind the applications of biotech; the most in-depth general brochure)
- *NewBioNews* (Eight-page general brochure on biotech)
- *Exploring a New World of Discovery* (A booklet that explains the research that goes on at Monsanto)
- *10,000 Years of Food Production* (Flyer explaining how biotech has been used in food production; designed for elementary/Jr. High students)
- *The Path to Better Foods* (Flyer explaining how biotech is in the next step in agriculture; designed for elementary/Jr. High students)

Knowledge – Substrate for Sustainability

For further information containing the activities and information in this booklet, you may contact the following individuals:

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