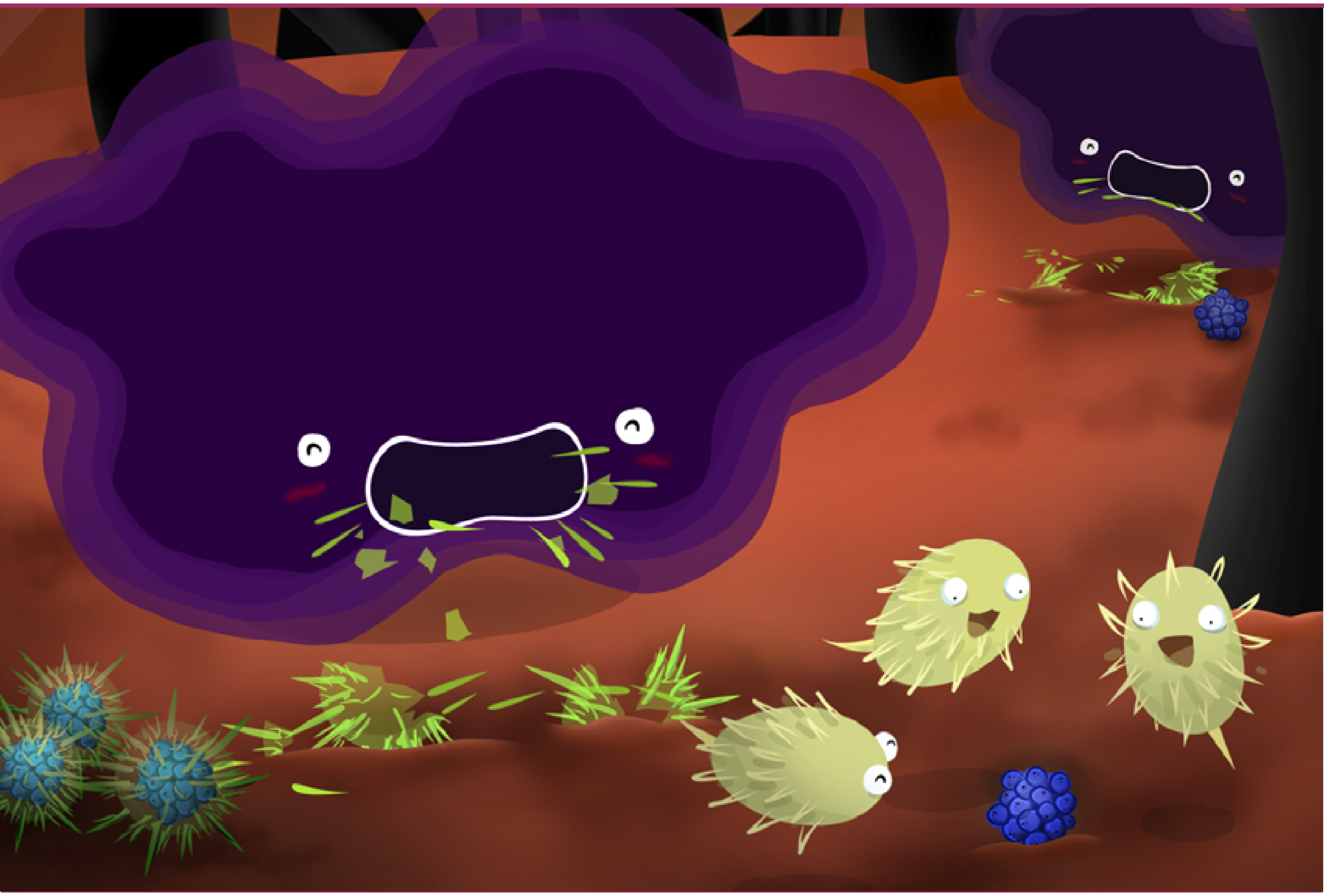
SUB-MODULE 3

MudWatt

NGSS TEACHER'S GUIDE

Soil Ecology and Nutrient Cycling



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INTRODUCTION

Teaching Rationale

Microbial fuel cells (MFCs) represent an exciting, emerging technology for generating electricity that is clean and reliable. In this module students will learn how electricity is produced by certain bacteria during their natural metabolic process and how a microbial fuel cell works.

The progression of lessons provided in this module has been designed to give students the background and instruction necessary to engage in their own exploration of microbial fuel cells. Each lesson builds upon the learning in the preceding activity and it is recommended that the lessons be done sequen tially.

The reading material and lab activities help provide concrete learning opportunities for abstract concepts. Students with minimal background knowledge in microbiology and electricity can perform these activities (see suggested prerequisites).

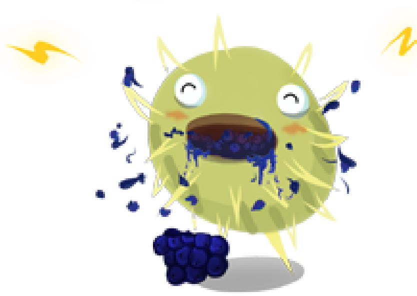
PREREQUISITES

Note: This module is intended for Middle School Students.

Prior to starting these investigations it is recommended that students have a basic understanding of:

- **Characteristics of all living organisms and microbes (specifically bacteria)**

If additional background information is required prior to starting this module students may complete **Sub-Module 1: Meet the Microbes and Sub-Module 2: Electricity and Circuits**.



Learning Objectives

1. To understand that soil health is important to all living organisms.
2. Soil is continuously being formed by geological and biological processes and the organisms that live in the soil create a unique ecosystem in which its inhabitants depend upon and interact with one another.

Essential Questions

1. **What is soil and why is it important?**
2. **How is soil formed?**
3. **What organisms live in soils?**
4. **What roles do organisms play or**
5. **What lives in soil and how do these organisms interact with one another?**
6. **What is decomposition and how is it important to soil formation and ecology?**

By The End of This Lesson...

Students will understand that:

- Soil is comprised of both living and non-living components
- Soil is created by the breakdown of rocks and organic matter
- The health of the soil is dependent on the amount of organic material and nutrient balance

Students will be able to:

- Identify and describe the components of soil.
- Identify the important players in the soil ecosystem and describe the different roles these organisms play in this ecosystem.

NGSS Alignment

CORE IDEAS

Core Idea LS1: From Molecules to Organisms: Structures and Processes

LS1.A: Structure and Function
LS1.C: Organization for Matter and Energy Flow in Organisms

Core Idea LS2: Ecosystems: Interactions, Energy, and Dynamics

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

Core Idea PS3: Energy

PS3.B: Conservation of Energy and Energy Transfer
PS3.D: Energy in Chemical Processes and Everyday Life

Core Idea ETS1: Engineering Design

ETS1.A: Defining and Delimiting an Engineering Problem
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

CROSS CUTTING CONCEPTS

- ☐ Patterns
- ☐ Cause and effect: Mechanism and explanation
- ☑ Scale, proportion, and quantity
- ☑ Systems and system models
- ☑ Energy and matter: Flows, cycles, and conservation
- ☑ Structure and function
- ☑ Stability and change

PRACTICES

- ☑ Asking questions (for science) and defining problems (for engineering)
- ☑ Developing and using models
- ☑ Planning and carrying out investigations
- ☑ Analyzing and interpreting data
- ☐ Using mathematics, information and computer technology, and computational thinking
- ☑ Constructing explanations (for science) and designing solutions (for engineering)
- ☑ Engaging in argument from evidence
- ☑ Obtaining, evaluating, and communicating information

Vocabulary

Bacteria	Erosion	Parasitism
Biodiversity	Fungus	Parent Materials
Carnivore	Herbivore	Pores
Clay	Horizon	Producers
Climate	Humus	Silt
Commensalism	Inorganic Matter	Symbiosis
Components	Mutualism	Texture
Decomposition	Omnivore	Weathering
Ecosystem	Organic Matter	

Glossary

Bacteria one-celled micro-organisms

Biodiversity a measure of the number of different types of organisms living in an ecosystem

Carnivore an organism that eats other animals

Clay the smallest size of the soil particles

Climate long term average of temperature and precipitation for a region

Commensalism when one organism benefits from a relationship with another organism but the other is not affected (it does not benefit, nor is it harmed)

Components an ingredient or one of many ‘parts’ that make up something

Decomposition the process by which organic material is broken down into simpler compounds

Ecosystem all the living and non-living things in an area

Erosion the wearing down of soil by wind, water, heating and freezing

Fungus a living organism which absorbs nutrients by decomposing its food source

Herbivore an organisms that eats plants

Horizon another name for the layers in soil

Humus the dark organic material in soil formed from the decomposition of once living plats and animals

Inorganic Matter materials that are not and never were alive

Mutualism where each organism benefits from the relationship

Omnivore an organism that eats both plants and animals

Organic Matter things that are living or were once living (leaves are 'dead' but were once alive)

Parasitism where one organism lives off of another organisms – typically one organism benefits while the other one is harmed.

Parent Rock Materials in soil, parent materials are the types of rocks and minerals that eventually become soil over time

Pores small openings or spaces between particles

Producers organisms that make their own food from inorganic raw materials

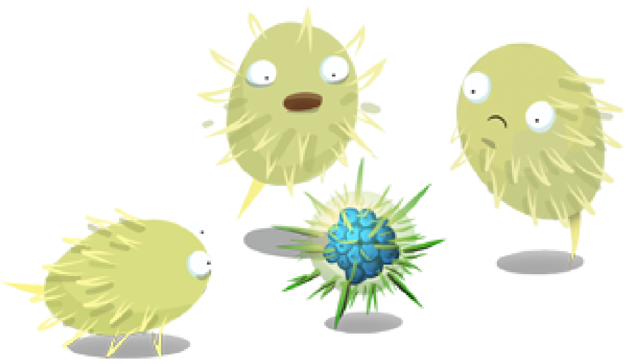
Sand the largest size of the soil particles

Silt a type of soil particle between the smallest (clay) and the largest (sand)

Symbiosis where two organism interact, typically in a way that is beneficial to both

Texture the varying structure of something, such as rough or smooth

Weathering the process by which rocks are broken down



Pre-Assessment: True or False

Ask students to answer the following questions using only what they already know:

1. **Soil covers all of the earth** True or False
2. **Soil is formed by wind and water breaking down rocks?** True or False
3. **Soils are the same everywhere** True or False
4. **Soil can affect climate** True or False
5. **Soil is made up of only one kind of material** True or False
6. **Soils are made up only of small pieces of rock** True or False

Pre-Assessment: Multiple Choice

Ask students to answer the following questions using only what they already know:

1. Circle the things that are organic: rocks leaves a dead insect

2. Circle the things that are part of the environment in an ecosystem?

a. plant

b. bird

c. rock

d. insect

3. Which of these is an organism found in an ecosystem?

a. plant

b. rock

c. water

d. sunlight

4. Which of these is a reason why soil is important in an ecosystem?

a. soil kills weeds

b. soil is very hard like a rock

c. nothing lives in soil

d. soil gives minerals to plants

Teacher Notes

In this module students will build an understanding of what **soil** is, how it is formed and how it is able to support the diverse population of organisms from macro- to microscopic that live in it.

Begin the unit by asking students what soil is. Accept all responses while guiding them towards the idea that soil is a mixture of living and non-living components. The non-living, **inorganic**, components consist of small pieces of broken down rock in varying sizes, or sediments, which are categorized by size (see size chart in student section). Sand, silt and clay are the most typical sizes of soil particles but larger sized particles (pebbles and boulders) are occasionally found as well.

In the first activity students characterize different **soil samples**. They will make qualitative observations of the color, smell and feel of the soil as well as quantitative measurements to determine the relative amounts of each type of sediment. For best results provide students with different soil types so that there can be an opportunity to compare results and see any relationships between texture and color or color and amount of organic matter in the soil. If time is limited, use **Lesson 1A** which gives a procedure for determining the composition of the soil sample. If time permits, use **Lesson 1B** where students are challenged to create their own procedure for determining the soil composition. Students may need to be guided by the teacher towards the solution of using settling rates to determine how much of each different sediment type is in the soil.

In **Lesson 2** students examine the **soil ecosystem** through several lenses. First students get a sense of the biodiversity within the soil ecosystem by collecting, counting and identifying the macro fauna. Depending on the amount of time available and the availability of resources to make the Berlese funnels, students may be directed to isolate the organism with a manual method or with the Berlese Funnel, which they must make prior to using. Students will use a simple identification key to identify the organisms found in their samples.

Next students will explore the characteristics and interactions of both **macro** and **micro fauna**.

Finally students investigate how microbes are essential to the recycling of essential nutrients through the microbes' role in **decomposition**. Students will construct decomposition jars with which they can monitor how quickly different materials decompose. As an extension, students can be challenged to test different conditions so that they can better understand what conditions allow the maximum decomposition to occur.

STUDENT HANDOUT

Soil Composition and Formation

Objective: In this module you will build an understanding of what soil is, how it is formed and what factors affect soil formation.

Soil Composition: What is Soil?

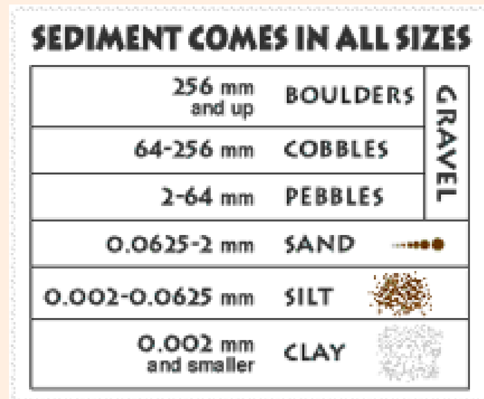
Introduction:

Soil is a natural substance that is made up of both living and non-living components. The non-living, **inorganic** components consist of small pieces of broken down rock in varying sizes. Sand, silt and clay are the most typical sizes of soil particles but larger sized particles (pebbles and boulders) are occasionally found as well, as shown in ***Figure 1***.

How much **sand**, **silt**, and **clay** is in the soil determines its **texture**.

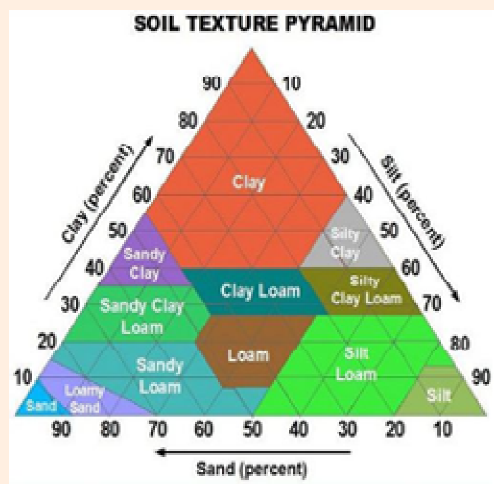
The percent of each type of sediment in soil is used to classify soils, using the Soil Texture Pyramid as Pyramid shown in ***Figure 2***.

In addition to sand, silt and clay soil contains dark **organic** (living or once living) matter called **humus** which is formed when materials such as dead leaves and dead organisms **decompose**.



http://geomaps.wr.usgs.gov/parks/rxmin/sediment.html

Figure 1. Sediment types and sizes

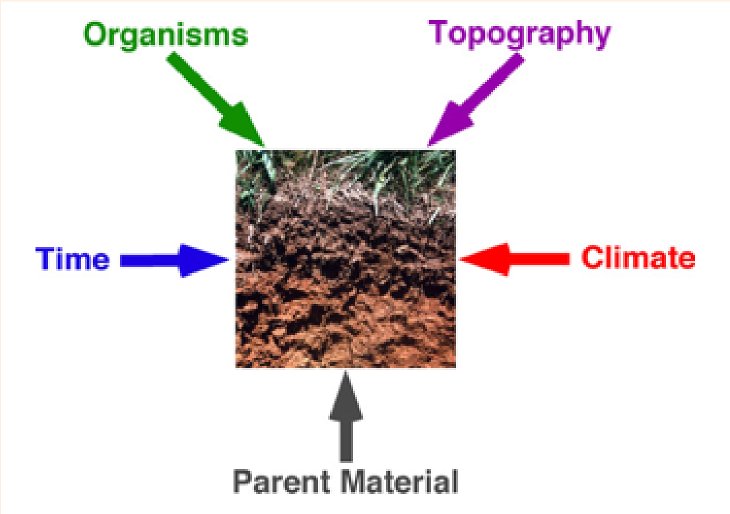


http://www.todayshomeowner.com

Figure 2. Soil Texture Pyramid

Soil Formation: How do soils form?

Soil is formed from the breakup of rock and the decomposition of once living (organic) material. Soils "evolve" through time. There are five main factors that control soil formation (***Figure 3*** below):



http://www.physicalgeography.net/fundamentals/10u.html

Figure 3. Five Factors of Soil Formation

original material, or **parent rock material**. Animals contribute to the break down of rock when they burrow and dig while plants such as lichens chemically dissolve rock material. When plants and animals die and decompose important nutrients are returned to the soil.

The amount of **time** required for soil to form varies depending on the other factors involved, but it can take 500 years for as little as 1 cm of soil to form!

The nature of **parent rock material** impacts soil formation. Soft rock materials, such as sandstone or limestone, can be weathered faster than much harder rock, such as granite.

The **climate** of an area determines how wet or dry an area is, and how many times the ground freezes and thaws, or gets wet and dries out again. Climate also affects how quickly rocks are weathered. For example, areas that have higher temperatures have a faster rate of breakdown of the underlying rock.

Quick Check:

Which parent rock material would form soil more quickly: **softer** or **harder** parent rock material?

The topography (how hilly or flat the area is) also affects how windy, wet or dry, and warm or cold the area is. Areas that have a lot of mountains and hills can experience very wet conditions in the valleys and dry conditions higher up. Conversely, snow is commonly found on the top of some mountains while deserts exist in the rain shadow of these same mountains.

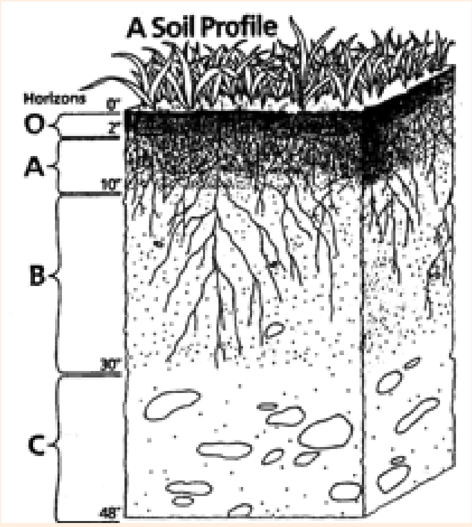
Living organisms also play a significant role in the formation and maintenance of soil. Some organisms burrow and dig helping to both aerate and further weather the soil.

When living organisms die they decompose and the resulting organic matter becomes part of the soil.

Quick Check:

Which location would have faster soil formation: the **Brazilian Rain Forest** or **Arizona**?

As more weathering occurs distinct zones or **horizons** form, creating the soil profile. From the surface each horizon contains progressively less organic material and more parent rock material. (See **Figure 4** below.)



http://printablecolouringpages.co.uk/?s=soil+horizons

Figure 4. Soil Horizons

"O" Horizon: mostly organic material (dark color)

"A" Horizon: has a mixture of organic and sand, silt and clay

"B" Horizon: layer has little organic matter (slightly lighter in color)

"C" Horizon: is primarily broken pieces of the parent material

The very top, the **"O" horizon** is comprised mostly of decomposing organic material and is usually very dark in color.

The next horizon is the **"A" horizon** which is still darker than the lower horizons because is has a mixture of organic material, sand, silt and clay. This layer is often referred to as "topsoil."

Water moving through the "A" horizon dissolves and carries away with it (leaches) many nutrients and other materials.

These leached materials travel further down into the **"B" horizons** where they stop flowing. The "B" layers layer has little organic material in it.

Usually there is a deeper **"C" horizon**, which is mainly broken pieces of the parent material. Parent material does not have to be a solid rock - it can be material that was deposited from a flood.

Activity 1A: What makes up soil?

Determining Soil Composition

You can find out what type and size particles make up your soil sample with this easy-to-do procedure. This method does not measure the sediment grain sizes directly, but instead relies on something called Stoke's Law, which accurately describes the speed at which particles of different sizes settle, or fall through water. Larger grains sink faster than smaller ones, and clay-size particles sink the slowest. Sand settles in less than a minute, silt in less than an hour and clay in a day.

Time

2 class periods

Materials

- Quart size jar or a 1000 ml beaker
- Ruler with millimeters
- Water
- 0.5 cup (100 ml)
- Small amount of dishwashing liquid (not regular soap)

Procedure: Day 1

1. Obtain a sample of soil
2. Record your observations about its color
3. Smell the soil and record your observations.
4. Touch the soil and make observations about the way it feels between your fingers (is it slippery, gritty, etc.)
5. Fill the jar or beaker mostly full of water
6. Add a few drops of the dish detergent (this helps keep particles separated)
7. Add the soil
8. Shake the jar thoroughly for a full minute or if you don't have a jar with a lid you can stir vigorously for 1 minute.
9. Set the jar or beaker down and leave it for 24 hours.

(continued on next page)

Procedure: Day 2 (after 24 hours settling time)

10. Measure the total thickness (in cm) of the sediment: Measure the thickness of the sediment on the bottom of the container and the thickness of the organic matter, if present, that has floated to the top.
11. This measurement is the total amount of sand, silt and clay and organic matter in the soil. (Note: Be sure the zero mark lines up with the floor inside the jar or beaker.)
12. Shake the jar again and set it down.
13. After 40 seconds, measure the height of the sediment. This is the sand fraction.
14. Leave the jar alone. After 30 minutes, measure the height of the sediment again. This is the sand-plus-silt fraction.
15. With these three measurements, you have all the information needed to calculate the three fractions of your sediment (equation given below)

Data Collection

Table 1. Observations of the soil's color, smell and feel:

Observations	Description
Color:	
Smell:	
Feel of soil:	

Table 2. Measurements and Calculations of layer thicknesses after settling:

Time	Description	Thickness (cm)
24 hours after initial mixing	Thickness of sand, silt and clay settled on bottom of container	
	Thickness of organic material floating on top	
SHAKE JAR again and record measurements below after given times:		

Data Collection (cont.)

Time	Description	Thickness (cm)
40 seconds after second mixing	Amount of Sand	
30 minutes after second shake	Amount of Sand + Silt	
Calculate	Amount of **Silt** = (Sand+Silt) – (sand)	
Calculate	Amount of **Clay** = (Total thickness) – (Sand+Silt thickness)	

Calculate the % of each type of material and record the percentages in Table 3 below:

$$\textbf{\% sand} = \frac{\text{sand thickness(cm)} \times 100}{\text{total thickness (cm)}}$$

$$\textbf{\% silt} = \frac{\text{silt thickness(cm)} \times 100}{\text{total thickness (cm)}}$$

$$\textbf{\% clay} = \frac{\text{clay thickness(cm)} \times 100}{\text{total thickness (cm)}}$$

$$\textbf{\% organic material} = \frac{\text{organic material thickness(cm)} \times 100}{\text{total thickness (cm)}}$$

Table 3. Soil composition by percentage:

Texture	Percentage (%)
% Sand	
% Silt	
% Clay	
% Organic	

Data Collection (cont.)

Use the percentages of each type of sediment you calculated for your soil sample above and the Soil Texture Pyramid in ***Figure 1*** to find how your soil sample would be classified.

Soil Type	

Table 4. Characteristics of Different Soil Types

Sandy soils	Silty soils	Clay Soils	Loamy Soils
Do not hold water well so can dry out in summer easily	Slightly difficult to drain. Keep water longer than sand	Very water tight, difficult to drain. Can get water logged	Not great drainage
Low in nutrients	Tend to be fertile	Tend to be rich in nutrients	Tend to be rich in nutrients
Warm up quickly in summer	Warm up not as quickly as sandy soils but more quickly than clay soils in summer	Warm up slowly in summer	Consist of sand, silt and clay mixture

Analysis

Compare your results with your classmates.

1. **If you used the same soil as another group, were your results similar? If not try to explain what caused differences in your results.**

Analysis (cont.)

2. **If you had different soil samples share results to learn about why different soils have a different look, feel, and smell.**

Sample	%Sand	% Silt	% Clay	% Organic	Color	Smell	Soil Type
Sample 1 (your soil sample)							
Sample 2							
Sample 3							

3. **Examine the class data. What is the relationship between the color of the soil sample and the texture? Do darker soils contain more sand, silt or clay?**

4. **What is the relationship between the color of the soil sample and the amount of organic material? Do darker soils contain more or less organic material than the lighter colored soils?**

Analysis (cont.)

5. The amount of organic matter in soil is an indicator of how fertile the soil is or what the soil's ability is to supply nutrients to the plants and other organisms that live in the soil is. **How fertile do you think your soil sample is? Use your data to support your answer.**

6. **Using the results of this activity explain why different soils have a different look, feel, and smell.**

Activity 1B: What makes up soil?

Determining Soil Composition - An inquiry approach

Have you ever wondered why soils look different in different places? What make one soil darker than another or one soil smellier than another. In this activity you will try to find a way to determine what makes up the different soil samples and try to explain the reason for their different appearances and smells.

Time

2 class periods

Problem

What is in soils that make them look and smell differently?

Claim

Write what you think the reason is that different soils look and smell different.

Introduction

What is Soil?

Soil is a natural substance that is made up of both living and non-living components. The non-living, **inorganic** components consist of small pieces of broken down rock in varying sizes. Sand, silt and clay are the most typical sizes of soil particles but larger sized particles (pebbles and boulders) are occasionally found as well well, as shown in ***Figure 1***.

How much sand, silt, and clay is in the soil determines its **texture**. Soil textures can be classified by the percentage of each type of sediment contained in the soil.

In addition to sand, silt and clay soil contains dark **organic** (living or once living) matter called **humus** which is formed when materials such as dead leaves and dead organisms **decompose**.

Questions to guide your thinking

1. Knowing that soil has many different size sediments (sand, silt and clay), can you think of a way to determine how much of **each type of sediment** your soil sample has?
2. How could you **separate** the different sediment types?
3. How could you determine the **percentage** of each type of sediment in your soil sample?
4. Do you need to record observations about the **color** and **feel** of the soil?
5. **Brainstorm** your ideas with your partner and **test** them to see if they work:
6. After testing your ideas **write a procedure** for determining the percentages of sand, silt and clay in the soil sample.

Procedure

What data will you collect? Draw your data table here:

How will you determine the percent sand, silt and clay form your data? Draw or explain here:

Analysis

Compare your results with your classmates.

1. **How were your methods different and how were they the same?**

2. **Do you think both methods would work equally well? Explain why or why not.**

3. Find a group who used the same soil sample. **Were your results similar? Why or why not?**

4. **If you had different soil samples share results to learn about why different soils have a different look, feel, and smell.**

Sample	%Sand	% Silt	% Clay	% Organic	Color	Smell	Soil Type
Sample 1 (your soil sample)							
Sample 2							
Sample 3							

Analysis (cont.)

5. **Examine the class data. What is the relationship between the color of the soil sample and the texture? Do darker soils contain more sand, silt or clay?**

6. **What is the relationship between the color of the soil sample and the amount of organic material? Do darker soils contain more or less organic material than the lighter colored soils?**

7. The amount of organic matter in soil is an indicator of how fertile the soil is or what the soil's ability is to supply nutrients to the plants and other organisms that live in the soil is. **How fertile do you think your soil sample is? Use your data to support your answer.**

8. **Using the results of this activity explain why different soils have a different look, feel, and smell.**

LESSON 2: BACKGROUND

STUDENT HANDOUT

Soil City – Find out what lives in the soil

Objective: In this activity students explore the different types of organisms that live in the soil.

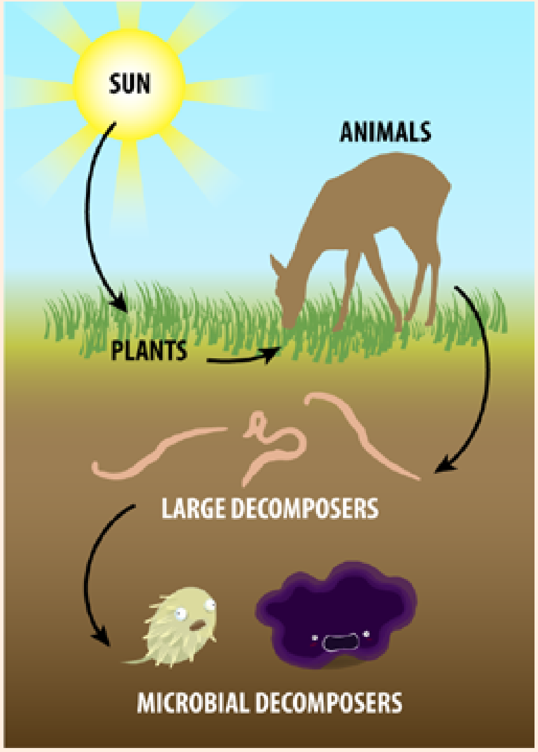
Soil Composition: What is Soil?

Introduction:
Ever wonder what lives in the soil? Most of us don't really know what lives in the soil. In this activity you will examine soil samples to determine what organisms live in it. Maybe you have dug in your garden and found an earthworm or a pill bug? Did it make you wonder what else lives in the soil? Soils contain a ***huge*** number of different organisms of all different types and sizes. The number of different types of organisms that live in a particular area is referred to as **biodiversity**. It is important to find out how many different types of organisms live in your soil, or what the biodiversity of the soil is. The degree of biodiversity is an indicator of how healthy the soil is!

If your soil has a high biodiversity (many different types of organisms), there tends to be better soil formation, better cycling of nutrients and greater energy production in the food web. Greater biodiversity can also help control flooding and prevent soil from eroding. Believe it or not having a diverse group of organisms in the soil can also help clean the soil and water by breaking down pollutants!

Some of the organisms that live in soil are big enough for you to see (they are **macroscopic**) but many are too small for you to see without a microscope (these are **microscopic**). This activity focuses on the macroscopic soil organisms. You will explore micro organisms in the next investigation.

Figure 5. The Soil Food Web



LESSON 2: STUDENT ACTIVITIES

Activity 2A: Let's Sort it out!

Find out what lives in the soil using a manual method.

Objective: In this activity students collect, count and identify the number of different types of macroscopic organisms living in the soil. Students will collect the organisms manually.

Time

1 class period

Materials

- Soil sample
- Magnifying glass
- Tweezers

Procedure

1. Obtain a sample of soil
2. Pour the sample out onto the table or into a sorting tray.
3. Using a magnifying glass and tweezers try to locate and separate the organisms in the soil.
4. Record your observations in the table below (create additional columns to record more organisms).
5. Use the identification key link: http://www.insectidentification.org/insect-key.asp to identify the organisms you found.

Table 1: Soil Organisms

	Organism 1	Organism 2	Organism 3	Organism 4	Organism 5	Organism 6
Soil sample type						
Sketch a picture						
Color						
Number of legs						
What is it? (use ID chart link)						

Reflection

1. **How many different types of organisms did you find in your soil sample?**

2. **Which organism was the most abundant?**

3. **Which organism was the least abundant?**

4. **Do you think that the soil sample used has a high biodiversity or a low biodiversity? Use your data to support your answer.**

Activity 2B: Let's Sort it out!

Find out what lives in the soil using a Berlese Funnel

(Adapted from: http://www.doctordirt.org/teachingresources/berlese. Credit: Thomas Loynachan, PhD, Soil Biologist, Iowa State University.)

Objective: In this activity students collect, count and identify the number of different types of macroscopic organisms living in the soil. Students will collect the organisms with the use of a Berlese funnel that they make themselves.

Introduction: Here's another way you can find out how many different types of macroscopic organisms are living in your soil: you can make a Berlese Funnel! A Berlese funnel is a device that is used to extract insects from soil samples. It uses a heat source (in this case a light bulb) to dry the sample, which forces the insects through a screen and into a temporary container (with air holes) or terrarium.

Time

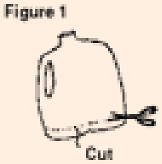
1 class period

Materials

- a one-gallon plastic milk container (empty)
- an empty jelly jar (or a one-pint Mason jar) with a tight lid
- a stick – about 25 cm long
- 1/4" mesh hardware cloth or aluminum window screen (15 X 15 cm)
- a pair of scissors
- masking tape or duct tape
- a gooseneck lamp (optional)

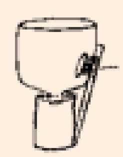
Procedure

Figure 1



1. Cut the bottom out of the milk jug (Fig. 1) and turn it upside down over the Mason jar to make a funnel.
2. Tape the stick to the handle of the milk jug (Fig. 2) so it is just long enough to reach the outside bottom of the Mason jar.

Figure 2



3. Bend down the corners of the hardware cloth so it fits snugly inside the wide end of the funnel. If using window screen, cut and pinch numerous slits so larger animals can crawl through.
4. Collect several handfuls of humus or leaf litter and put them on top of the wire mesh.
5. Carefully set the funnel on top of the jar and tape the stick to the jar so it won't tip over.
6. Leave the funnel in a warm, quiet place where it won't be disturbed.
7. Set a lamp over the funnel to speed drying (see Fig. 3). Keep the light bulb at least 10 cm away from the funnel.
8. In the table below record your observations of the organisms that are collected.
9. Use the online identification link: http://www.insectidentification.org/insect-key.asp to identify the organisms you found.

Figure 3 – Completely Set Up

Table 1: Soil Organisms

	Organism 1	Organism 2	Organism 3	Organism 4	Organism 5	Organism 6
Soil sample type						
Sketch a picture						
Color						
Number of legs						
What is it? (use ID chart link)						

Reflection

1. How many different types of organisms did you find in your soil sample?
2. Which organism was the most abundant?
3. Which organism was the least abundant?
4. Do you think that the soil sample used has a high biodiversity or a low biodiversity? Use your data to support your answer.

LESSON 3: STUDENT ACTIVITIES

Activity 3A: Ecosystem Extravaganza

What is an ecosystem?

Objective: Find out what lives in the soil using a manual method. In this activity students collect, count and identify the number of different types of macroscopic organisms living in the soil. Students will collect the organisms manually.

Introduction: An ecosystem is all the living (biotic) and non-living (abiotic) things in an area. There are many ecosystems in the world, but you don't have to go far to learn about them. All you have to do is go outside! In this activity students will make observations of biotic and abiotic components of a local ecosystem.

Time

1 class period

Materials

- Science notebook
- Outdoor area (15ft x 15ft)

Procedure

1. Select an area to observe (approximately 15ft x 15ft).
2. In your science notebook make a table with 2 columns, one labeled Biotic and the other labeled Abiotic.
3. Carefully look and record ***everything*** you see around you that is living (biotic). Record these in the Biotic Column of your table.
4. Next look around and record all the non-living (abiotic) features of the area. Abiotic features include things such as moisture, light, temperature. Record these in the Abiotic column of your table.

Sample data table:

Biotic	Abiotic

Reflection

1. After you have finished making your observations compare your list with one of your classmates. **How do your lists compare? Did you record the same things? What was the same? What was different?**

2. **Do you think your list would be the same if you went to the rainforest in Brazil or the Sahara Desert? Why or why not?**

3. **What types of living organisms do you think live in the soil?**

4. **Can you think of any abiotic factors that would be part of the soil ecosystem?**

Activity 3B: Roles and interactions of Soil organisms

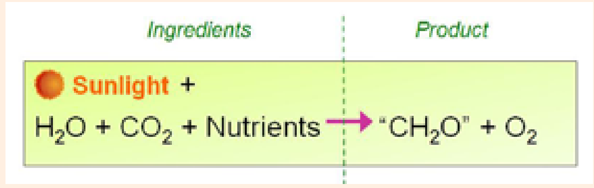
Objective: In this activity students learn about the roles of soil organisms in a healthy soil ecosystem and how they interact with one another.

Introduction:

All organisms need food to survive, but where does that food come from?

For most organisms the energy they get from their food came from the sun originally. Plants use the sun's energy to break apart and recombine CO2 and water to make food. This process is called **photosynthesis**. When plants photosynthesize, they give off oxygen into the atmosphere as a waste product.

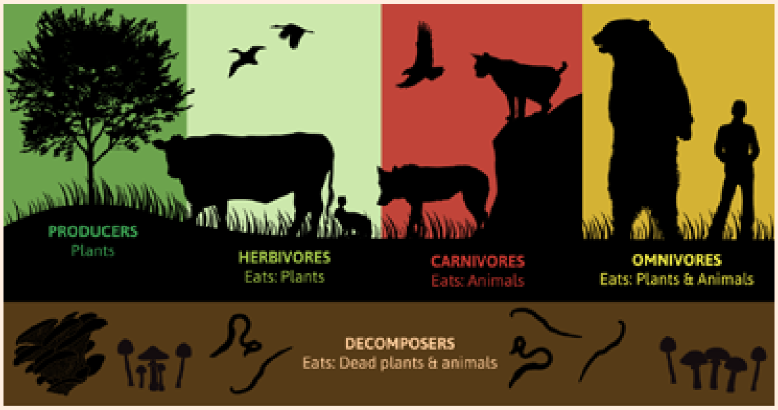
Photosynthesis



Organisms, such as plants and other photosynthetic organisms, that are able to use **inorganic** (non living) material to make food for themselves are called **producers**.

Animals cannot make their own food, so they need to eat other organisms to get the nutrients they need. Organisms that eat other organisms to get their food are called consumers. Some consumers just eat plants (**herbivores**) and other consumers just eat other animals (**carnivores**), while still other organisms eat both plants and animals (**omnivores**).

The Food Web

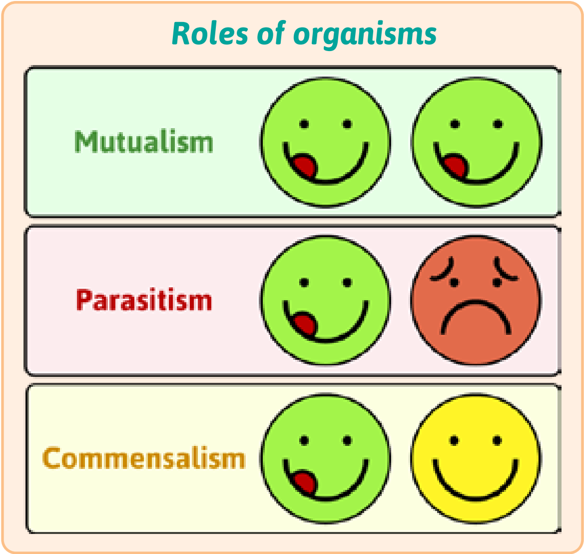


Any time an animal eats a plant or another animal they have to break down or digest the compounds in that plant or animal before the elements can be made into their own body compounds.

All during their lives plants and animals grow, adding more organic compounds to their bodies. When the plant or animal dies different organisms (**decomposers**) break down the organism into smaller and smaller compounds that gradually get returned to the soil for new plants to use, which starts the cycle over again. It is this cycle of taking inorganic material from the environment, incorporating those elements into organic compounds and then having the compound be returned to the environment when the organism dies and is decomposed which allows nutrients to be continuously recycled within the ecosystem.

Roles of organisms in the soil ecosystem

In addition to depending on one another as a food source, organisms can also interact in other ways. Two organisms living in **symbiosis** live closely together in a relationship over some period of time. In the soil ecosystem there are several different types of symbiotic relationships:



Mutualism exists where each organism benefits from the relationship. An example of mutualism is with the bacteria that live in plant roots and help the plant to get nitrogen in a form that is useable, while the bacteria get a source of carbon from the plant.

Parasitism exists where one organism lives off of another organism – typically one organism benefits while the other one is harmed. In the soil ecosystem, fungal disease is an example of parasitism. In this relationship the fungi invade a host plant and break down the plant they are living in. Larger examples examples include lice and tapeworms..

Commensalism occurs when one organism benefits from the relationship but the other is not affected (it is does not benefit, nor is it harmed). In the soil ecosystem commensalisms is seen between fungi and bacteria. Fungi break down difficult to break down plant materials (cellulose and lignin) and the bacteria are then able to finish the decomposition on these simpler compounds.

Time

1 class period

Materials

- Soil Organism Information Cards OR have students create their own cards
- Tape
- String
- Markers (3-4 per student group)

Make Your Own Organism Cards

1. Using the internet or other reference material, research each soil organism listed below. If working on a team, have each team member research 1-2 organisms.

Soil organisms:

bacteria	fungi
earthworm	beetles
beetles	pill bugs
mites	ants
millipedes	daddy long legs
nematodes	centipedes
spiders	

2. On each index card write the following information for each organism:
    - **Name of organism**
    - **What this organisms eats**
    - **What role this organism plays in the soil ecosystem?** (producer, consumer, decomposer)
    - **What relationship does this organism have with other organisms in the soil?** (how does it interact with other organisms)
    - **Write at least one interesting fact about that organism**

Food Web Game Instructions

1. Have one student begin. Typically this should be someone who has an organism that is a **producer** (such as a plant).
2. That student identifies **what eats that organism**, and **what is eaten by that organism**. Each student does the same with their organism, and each time a connection is made to another organism, a string is taped to both organisms' cards.
3. Connections may also be made on the basis of other relationships besides the food web.
4. **See how many connections you can make!**

Analysis

1. **Which organism, or type of organism had the most connections to other organisms?**

2. **What would happen if one organism were removed from the ecosystem? What would happen to the food chain? To other relationships within the ecosystem?**

   To demonstrate the effect of losing one organism, have one person drop the strings they are holding that connect it to other organisms. The organisms at the other ends of those strings will be affected if that particular organism leaves the ecosystem.

3. **What other organism should have been included in this game? Why do you think they should have been included?**

Activity 3C: A Closer Look at Decomposition

What is decomposition and how is it important to soil ecology?

Objective: In this activity students put different items in a soil-filled container and record changes that occur to the items and the soil over time. Students will gain an understanding of what types of items are able to be decomposed as well as the conditions that promote effective decomposition.

Introduction: What would happen if nothing ever decomposed? It would not take long before our Earth was completely covered with piles of dead things that never went away. When plants and animals die they are broken down into smaller and simpler compounds by other organisms. At the same time that the once living (organic) material is broken down, important nutrients are returned to the soil for use by new plants and animals. Each organism living in the soil ecosystem has a unique role in the decomposition of organic material.

Time

1 class period

Materials

- Several plastic soda bottles (cut off at the top), wide mouth glass jars, or large ziplock baggies
- Leaves, grass clippings, soil from outside
- Selected materials to put in the jars or baggies
- Water (to moisten the contents of the containers)
- Thermometer

Procedure

1. Prepare the decomposition jars by filling each one with materials collected outside
2. Note in your science notebook what materials were put into each jar.
3. Make initial observations of each jar. Include in your observations:
    - Height of the column's contents
    - Color
    - Odor
    - Temperature
    - Presence of any plants or animals
4. Continue to make and record observations for the next two weeks.
5. Variation: Create two, or more, identical jars and expose them to different conditions (moisture, light or air temperature for example) to see what factors affect decomposition rate.

Analysis

1. **Did any of the materials decompose? What evidence did you gather to support your answer?**

2. **Which materials decomposed the most? The least?**

3. **Which factor(s) affected the decomposition the most?**

4. **Based on your observations of factors that affect decomposition rate, do you think that organic material would decompose faster in a tropical rainforest or in a desert environment? Support your answer using information you gathered in this investigation.**

Activity 3D: The Nitrogen Exchange Game

Objectives

In this activity students see how nitrogen is gained or lost through different processes in a plot of soil. Students will also understand that certain organisms can only use nitrogen when it is in a particular form.

The object of the game is for you to end up with the **ideal amount of nitrates** in your plot of soil. The person with the ideal number of nitrate particles in his/her plot of soil will have the most abundant crop and will be the winner of the game! The ideal number will be revealed at the end of the game.

Introduction

We all know that living organisms need some type of food to live. Have you ever asked why organisms need food? **Nutrients** are the basic materials organisms need to grow and energy is what is needed to complete the biological processes that occur within an organism.

All living organisms are composed of one or more cells. Cells are made up of proteins and the elements that make up proteins are **Carbon**, **Hydrogen**, **Oxygen** and **Nitrogen**. In addition to these elements, organisms also need **Phosphorus** to make nucleic acids, which are the building blocks of the genetic material in organisms that provides instructions for making all the different proteins in that organism.

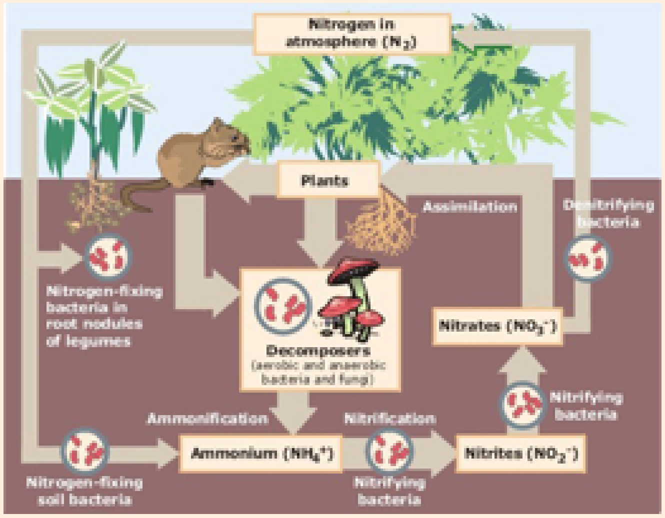
Where do organisms get these nutrients?

Even though all organisms need similar nutrients they obtain them from very different sources. For example, plants get their nutrients from the soil and air around them while animals get their nutrients from eating plants or other animals. Still other organisms get their nutrients from ingesting dead plants and animals.

If all organisms need these nutrients why don't they eventually run out?

The key is with cycles

Cycles in nature recycle materials over and over again. In this unit we will explore the **Nitrogen** and **Carbon Cycles**.



http://tolweb.org/notes/?note_id=3920

Figure 8. Nitrogen Cycle

Nitrogen is an essential element for living organisms since it is needed to make **proteins**. Seventy eight percent (78%) of our atmosphere is comprised of nitrogen (N^2) gas. Oxygen makes up only 21% of our atmosphere. We get oxygen directly from the atmosphere so you might think that we could get nitrogen from the atmosphere as well. Unfortunately, most organisms, including humans, cannot use the nitrogen gas that is abundantly available in the atmosphere! Nitrogen in the atmosphere is in a form that is unusable by most plant and animals! The majority of organisms need to have the nitrogen gas converted into a form that is usable.

Here is where soil and bacteria play a major role. Only a very special group of bacteria in the soil can use atmospheric nitrogen gas as their source of **nitrogen**. These bacteria, called **nitrogen fixing bacteria**, live in root nodules of legume plants such as peas, clover, soybean, and alfalfa and some live in the soil. The nitrogen fixing bacteria in the root nodules take convert the N^2 gas into another form, called **nitrates**, which plants are able to take up from the soil and use to make their plant proteins.

Other nitrogen fixing bacteria living in the soil (but not in root nodules) take N^2 gas and convert it into ammonia (NH^4) which get converted into nitrates by **nitrifying bacteria**. Ammonia (NH^4) is also produced during the decomposition of dead plants and animals,

Finally, the cycle continues when **denitrifying bacteria** living in the soil convert nitrates back into nitrogen gas, which gets released back into the atmosphere.

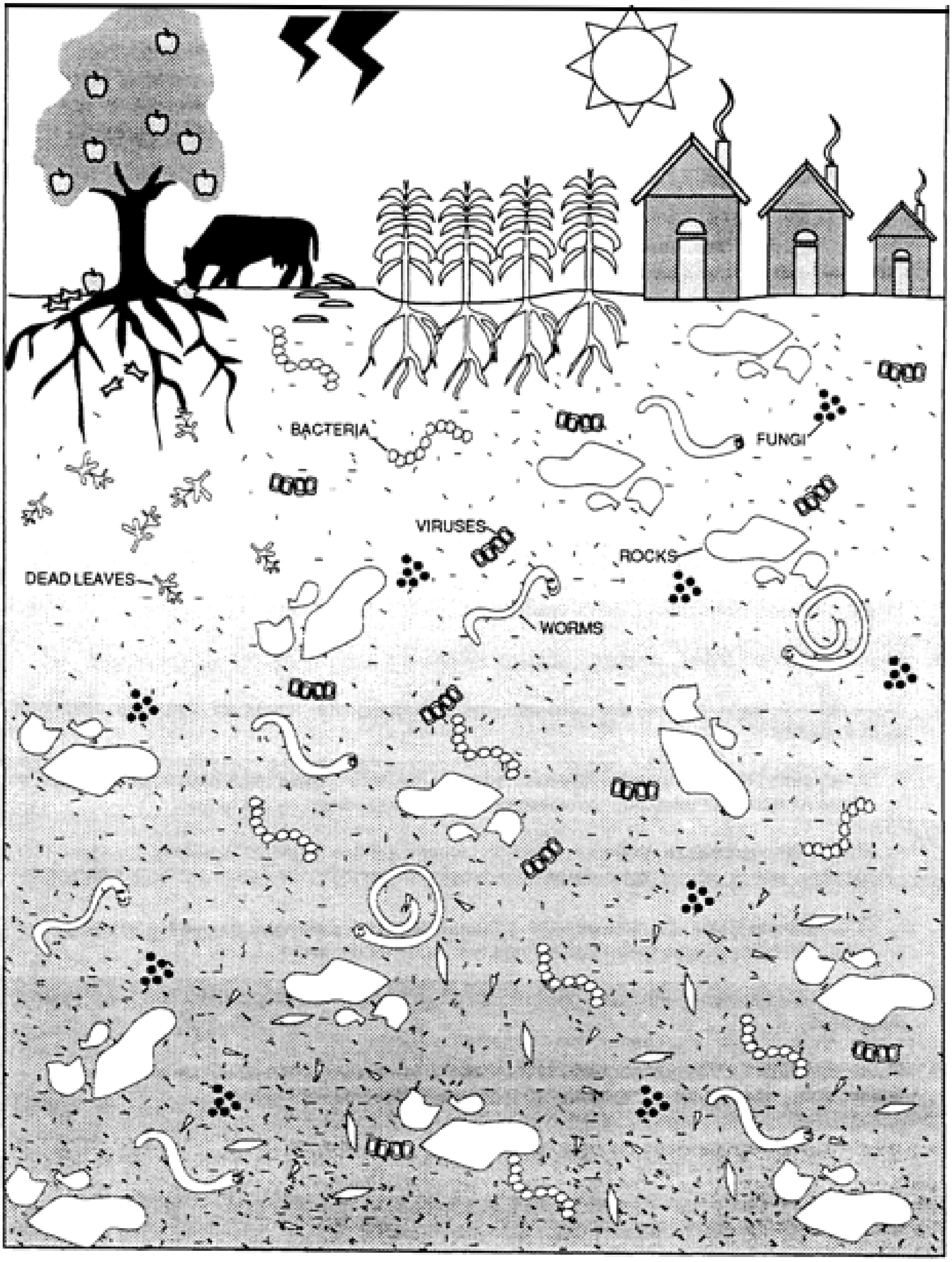
Game Instructions for groups of 3 or 4 people

1. Pass out **one soil plot** to each student.
2. **Shuffle the task cards** and put them face down in a place where everyone in your group can reach them.
3. Put **10 nitrate tokens** in each person's soil plot. The tokens represent nitrates, a source of nitrogen which is usable by plants.
4. Place the remaining tokens in a **central location** for use by the entire group. This central location will represent the Earth's atmosphere.
5. In a fair manner, determine which student will go first, which student will go second, etc.
6. Have the first player **draw a task card** and **read it to the group**. Have the farmer do what the card indicates.
   - If the card indicates to **add nitrates** to the soil, do so by taking the appropriate number of nitrogen particles from the "atmosphere" and placing them into the soil.
   - If the card indicates to **change one** of the nitrate particles into an unusable nitrogen particle, remove one nitrate particle from the soil and place it where the card indicates.
   - If the task asks you to **remove more nitrogen** from your soil than you have, remove as many particles as you can and then proceed to the next farmer.
7. Continue this procedure with each player until all of the task cards are gone OR your teacher calls time.
8. At the conclusion of the game, have each student count how many nitrate particles is in his/her soil.

Determining the Winner of the Game

1. The farmer with the **lowest number of nitrate particles** did not have enough usable nitrogen in the soil for a successful crop. Therefore, this farmer is not the winner.
2. The farmer with the **most nitrate particles** in his plot of soil added too much usable nitrogen to the soil and did not get an optimum crop yield. The plants "burned" from too much nitrogen being applied and the groundwater in the area contains a higher than normal nitrate level. This farmer is not the winner of the game.
3. **Of the remaining farmers**, determine who has the most nitrate particles in the soil. This farmer knows how to properly manage his/her land and is the **winner of the game!**

The Nitrogen Exchange Game Card
Soil Plot



The Nitrogen Exchange Game Card

Task Cards Set 1

A golf course owner adds the recommended amount of ammonium sulfate to the golf greens. **Add 2 nitrates to your soil.**	A septic tank leaks raw sewage (which is high in nitrates) into the water which you use to irrigate your fields. **Add 8 nitrates to your soil.**
A forest is left undisturbed and the soil contains denitrifying and nitrifying bacteria. **Remove 2 nitrates from your soil and then add 2 nitrates back into the soil.**	You grow corn on your land for 3 seasons straight without adding any type of fertilizer or organic matter. **Remove 3 nitrates from your soil.**
A farm using sustainable agricultural practices returns as many nutrients to the soil as are removed from the soil by crops. **Do not add or remove any nitrate particles.**	A peanut farmer inoculates the soil with Rhizobia bacteria. These bacteria can convert nitrogen gas to nitrates. **Add 4 nitrates to your soil.**
A large marine estuary was contaminated with oil from a leaky oil barge. A lot of the natural bacteria were destroyed. **Remove 6 nitrates from your coastal soil.**	An "El nino" (a warm water current) increased the water temperature of the Sacramento Delta waterways. Denitrifying bacteria began to rapidly flourish. **Remove 2 nitrates from your soil.**

The Nitrogen Exchange Game Card

Task Cards Set 2

A farmer plants a cover crop of beans, Beans are legumes. Legumes fix nitrogen into the soil. **Add 2 nitrates to your soil.**	A farmer buys manure from his neighbor's dairy to spread around his grapes. Manure is high in nitrogen which is decomposed into nitrates. **Put 1 nitrate in your soil.**
There is a big lightning storm in the Midwest corn belt. Lightning converts some nitrogen gas into nitrates. **Add 1 nitrate to your soil.**	It is late winter and there has been much winter rain. Nitrogen is lost due to leaching. Remove 3 nitrate particles. There are still some fallen leaves left under the trees. Decomposers live in these leaves. **Add 2 nitrates back into your soil.**
A classroom makes a compost pile. After two weeks, the students notice the organic matter decomposing and the soil is very warm. After one month, the class spreads the decayed organic matter into the school garden. **Add 1 nitrate to your soil.**	The farmer harvests the rice in his field but leaves the stubble from the plants. Many animals and decomposers eat and live in this stubble until it gradually rots away. **Add 2 nitrates to your soil.**
Early Native American farmers planted beans around their corn plants for natural fertilizing. Beans are in the legume family and can fix nitrogen. **Add 1 nitrate to the soil.**	Denitrifying bacteria convert nitrogen in animal manure to nitrogen gas. **Remove 2 nitrates from your soil.**

The Nitrogen Exchange Game Card
Task Cards Set 3

A farmer raises and puts millions of earthworms into the soil. **Add 1 nitrate to your soil.**	A farmer applies an ammonium sulfate fertilizer to his crop in the spring. This fertilizer was made by changing nitrogen gas particles to ammonia which changes into nitrate. **Add 3 nitrates to your soil.**
The lemon orchard, weighted down with lots of fruit, is ready for harvesting. No sooner does the crop get picked, than the trees are in bloom again to set more fruit. Not a lot of plant material is returned to the ground from which it came. **Remove 2 nitrates from your soil and return them to the atmosphere.**	A winter freeze slows down natural processes. Nitrogen-fixing bacteria die and the plants cannot absorb the nitrogen they need. Nitrogen gas is put back into the air. **Return 2 nitrates to the atmosphere.**
There is too much irrigating and nitrogen is leached beyond the root systems of the plants. The nitrogen can no longer be used by plants or decomposers. **Remove 2 nitrates from your soil.**	Fungi attack a corn crop and decompose a crop that was meant for humans. **Add 2 nitrates to your soil.**
A chemical spill kills all decomposers in a particular area. Denitrifying bacteria are quicker to return than other decomposers. **Return 2 nitrates to the atmosphere.**	A home gardener adds three times the recommended amount of fertilizer to a garden plot so the garden will grow quicker. The plants die, but the soil has lots of nitrates in it. **Add 6 nitrates to your soil.**

Reflection

1. **Was the game really fair? Do real farmers have more control over their land than the farmers in the game do?**

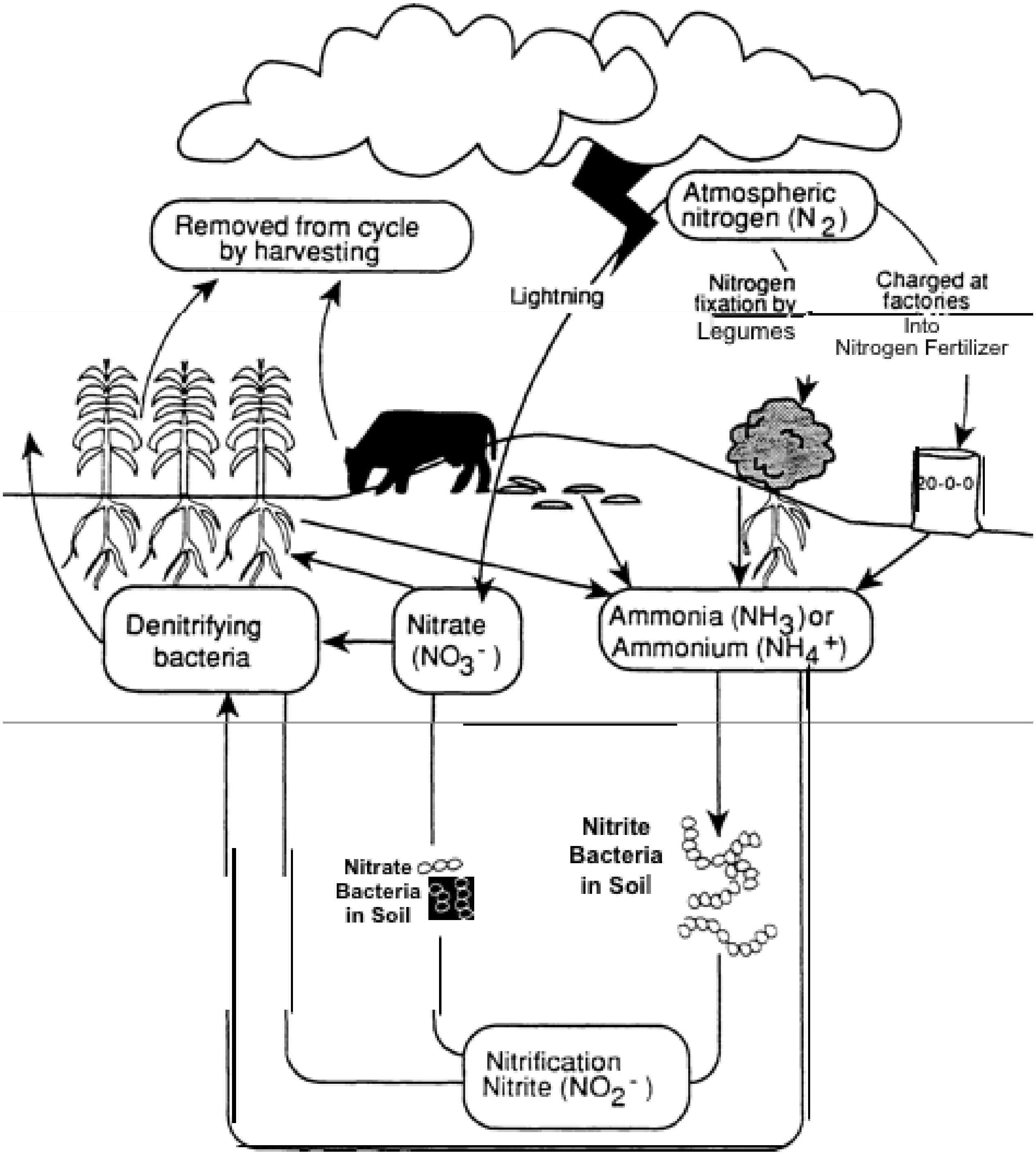
2. **Describe 3 ways that nitrogen can be added to the soil.**

3. **Describe 3 ways nitrogen is removed from the soil.**

4. **Explain how you would try to balance the amount of nitrogen in a real plot of soil – list all the things you could do to promote the right balance of nitrogen in the soil to keep it healthy.**

5. **Using your understanding of how nitrogen enters and leaves the soil and how it gets converted into different forms, draw a picture of the nitrogen cycle and label each step.**

Figure 10. Nitrogen Cycle



Activity 3E: The Travelling Carbon Game

Objectives

- Students will explore how carbon is stored and processed.
- Students will be able to describe the path a carbon atom through this cycle.
- Students will be able to identify sources and sinks of carbon and will be able to describe the processes that release and sequester carbon.

Key Concepts

- Carbon dioxide forms a weak acid, called carbonic acid, when it id dissolved in water
- Carbon dioxide is an important greenhouse gas.
- Carbon dioxide is constantly moving into and out of the atmosphere through different processes in the carbon cycle

Vocabulary

Source: anything that releases CO2 into the atmosphere

Sink: anything that removes CO2 from the air or water and/or keeps it

Sequester: to hold or set aside

Respiration: exchange of gases through breathing

Photosynthesis: the synthesis of complex organic materials, esp. carbohydrates, from carbon dioxide and water using sunlight as the source of energy, performed by plants.

Combustion: the act or process of burning

Decomposition: breakdown or decay of organic matter

Introduction

Carbon is the main ingredient in all living organisms. The term "organic" refers to anything that is or once was living. Living organisms get the carbon they need to live form their environment; from the air, water and soil as well as from other living organisms. Carbon takes many forms as it is taken up and used in different biological and chemical processes. As carbon is exchanged during these chemical and biological processes it take different forms. Carbon can be part of a carbohydrate or and a gas (CO_2) or can be part of a rock made of calcium carbonate.

The path carbon takes through the earth's spheres (oceans, atmosphere, land (lithosphere) and living things (biosphere) make up the carbon cycle. The processes by which carbon is taken in or released into each of these spheres are very complex and moving through the entire cycle may take millions of years. Each of these spheres can be both a source (supply) and a sink (removal)of carbon.

Carbon is moved from organism to organism through photosynthesis, respiration, and decomposition. Much of the carbon that is taken up and released by living organisms is in the form of CO_2. CO_2 is of concern to humans because it is a greenhouse gas, meaning that it traps heat reradiated from Earth in the lower atmosphere. The greenhouse effect is a good thing because without it our Earth's temperature would be a very cold -17°C, so the greenhouse effect helps keep our planet warm enough to support life. Currently CO_2 concentrations have risen rapidly to unprecedented levels which is raising concerns about additional warming effects and how the earth and living organisms will be able to adapt to such a rapid change in temperatures.

So how does CO_2 get removed and added to the atmosphere? In this activity you will explore the path of a carbon atom through the different sources and sinks. By the end of this activity you will have an understanding of what natural and human related activities are involved in CO_2 release and removal from the atmosphere and oceans.

Before starting your journey as a carbon atom go to this website to learn about the different sources and sinks involved in the carbon cycle:
http://online.wvu.edu/Faculty/demo/Module_2/carbon_cycle_animation.html

Questions to be answered after viewing the interactive:

1. **What are sources of CO_2 (processes that release CO_2 into the air or water?**

2. **What are SINKS of CO_2 (processes that remove CO_2 from the air or water or hold it?**

Now you are ready to Start the Travelling Carbon Game!

Travelling Carbon Game

Materials

- 7 Dice
- 7 Station Signs
- 7 Station Movement Directions
- Data record sheets for each student

Procedure

1. You are going to be carbon atoms moving through the carbon cycle.
2. The stations you will visit represent the places carbon can be found: Atmosphere, Plants, Animals, Soil, Ocean, Deep Ocean, and Fossil Fuels.
3. At each station you will roll the die and follow the instructions on the station sheet indicating where you should move to next.
4. Record your movements on the data sheet until you have completed 10 different rolls.

Carbon Cycle Data Record Sheet

Stop Number	Station Identification/ Description	What Happens	Destination (where you go next)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Reflection: Answer these questions on a separate sheet of paper.

1. **Where did you spend most of your time?**
2. **Did you get to every station?** **Yes / No**
3. **Did you follow a simple path moving from one station to the next or was your path more complicated?**
4. **Draw the path you took on the carbon circle diagram below.**

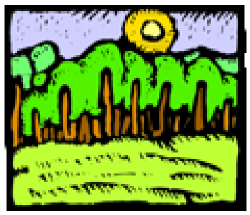
Collect data from your classmates showing the number of times they were at each station.

5. **Make a bar graph of the data.**
6. **Using the bar graph explain where the most and least amount of carbon was in the cycle.**
7. **Try to explain why the most and the least amounts of carbon were located where they were.** (Hint: think about the processes that release and use carbon)
8. **Do you notice any patterns from the class data?**
9. **What can you infer about the path carbon takes through the different spheres?**
10. **Based on your experience traveling through the carbon cycle, what do you think you could do to help minimize the release of excess carbon dioxide into the atmosphere?**

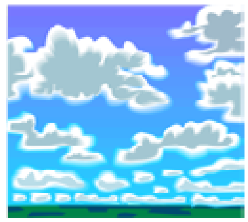
Reflection: Draw the path you took as a carbon atom

1. Label each station you went to by **number** and **draw an arrow** showing where you went next.
2. Bonus points for writing the **process** the carbon goes through when moving between two stations (write the process on the arrow)!

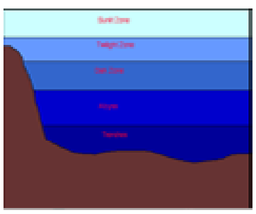
Plants



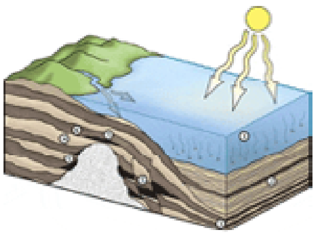
Atmosphere



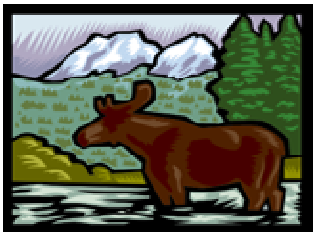
Deep Ocean



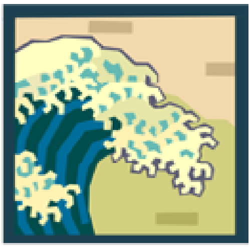
Fossil Fuels



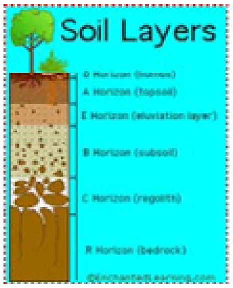
Animals



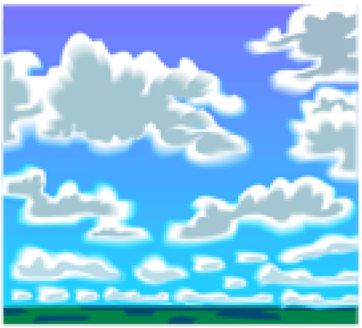
Surface Ocean



Soil



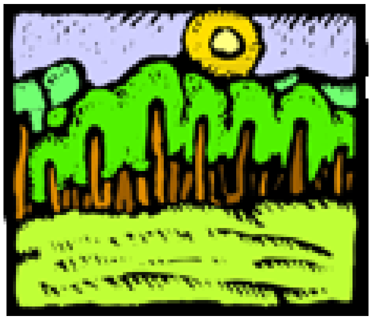
The Atmosphere



You are currently a molecule of carbon dioxide in the atmosphere.

Die Roll	Action Taken
1	Stay in the **atmosphere**. Much of the carbon dioxide in the atmosphere moves through the atmosphere.
2	Go to **plant**. You are used by a plant in photosynthesis.
3	Stay in the **atmosphere**. Much of the carbon dioxide in the atmosphere moves through the atmosphere.
4	Stay in the **atmosphere**. Much of the carbon dioxide in the atmosphere circulates through the atmosphere.
5	Go to **surface ocean**.
6	Go to **plant**. You are used by a plant in photosynthesis.

Plants



You are currently a carbon molecule in the structure of the plant.

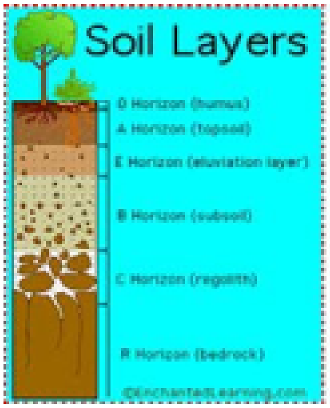
Die Roll	Action Taken
1	Go to **soil**. The tree shed its leaves.
2	Stay in **plant**. You are a carbon molecule in the tree's trunk.
3	Go to **animal**. The leaves and berries that the plant produced contain your carbon molecule and were eaten.
4	Stay in **plant**. You are a carbon molecule in the tree's roots.
5	Stay in **plant**. You are a carbon molecule in the tree's branches.
6	Stay in **plant**. You are a carbon molecule in the tree's trunk.

Animals

You are currently a molecule of carbon in an animal.

Die Roll	Action Taken
1	Stay in **animal**. The carbon molecule is stored as fat in the animal.
2	Go to **soil**. The animal that consumed you died and your carbon molecule is returned to the soil.
3	Go to **atmosphere**. The animal that consumed you respired (breathed) you out as carbon dioxide.
4	Stay in animal. You are eaten by a predator.
5	Go to **atmosphere**. The animal that consumed you respired (breathed) you out as carbon dioxide.
6	Go to **atmosphere**. The animal that consumed you respired (breathed) you out as carbon dioxide.

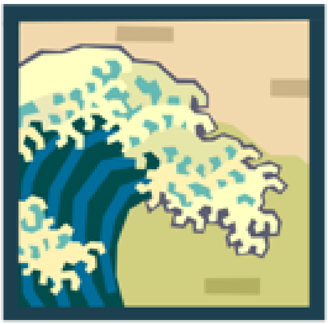
Soil



You are currently a molecule of carbon dioxide in the soil.

Die Roll	Action Taken
1	Stay in the **soil**. Much of the carbon in the soil is stored there.
2	Go to **plant**. You are used by a plant in photosynthesis.
3	Go to **fossil fuels**. Your carbon molecule has been in the soil so long it turns into fossil fuels.
4	Go to the **atmosphere**.
5	Stay in the **soil**.
6	Go to **fossil fuels**. Your carbon molecule has been in the soil so long that it turns into fossil fuels.

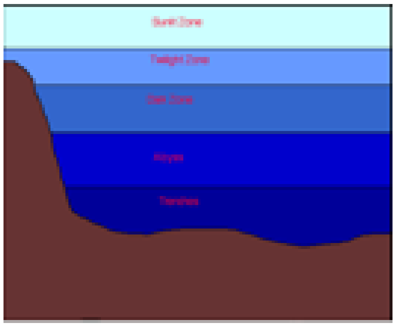
Surface Ocean



You are currently a molecule of carbon dioxide in the surface ocean.

Die Roll	Action Taken
1	Go to **deep ocean**.
2	Stay in the **surface ocean**.
3	Go to **deep ocean**. Your carbon atom was part of an ocean organism that has died and has sunk to the bottom of the ocean.
4	Stay in the **surface ocean**.
5	Go to the **atmosphere**.
6	Go to the **atmosphere**.

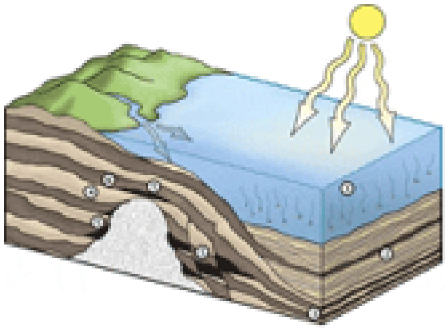
Deep Ocean



You are currently a molecule of carbon in the deep ocean.

Die Roll	Action Taken
1	Stay in the **deep ocean**.
2	Stay in the **deep ocean**.
3	Go to **surface ocean**.
4	Go to **surface ocean**.
5	Go to **surface ocean**.
6	Go to **animal**. An organism in the water has taken you up as food in the deep ocean.

Fossil Fuels



Fossil fuels are a rich source of energy that has been created from carbon that has been stored for many millions of years.

Die Roll	Action Taken
1	Stay in the **fossil fuels**.
2	Stay in the **fossil fuels**.
3	Stay in the **fossil fuels**.
4	Stay in the **fossil fuels**.
5	Go to the **atmosphere**. Humans have pumped the fuel that you are part of out of the ground and have used it to power their cars.
6	Go to the **atmosphere**.

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