It's a Gas!

The Exchange of Gases Between the Soil and the Atmosphere

Meet Dr. Keller *(with hat)*:
I like being a scientist because I get to follow my natural curiosity to learn how the Earth system works. My work is split between the field, the office, and the laboratory and I have a great deal of independence. I love to learn new things.

Dr. Keller

Thinking About Science

Chemistry is the science of the building blocks of all matter. Atoms are the most basic building block. Molecules are combinations of two or more atoms of the same chemical element. All matter is built from over 100 chemical elements. Examples of elements are nitrogen, hydrogen, oxygen, and carbon. Compounds are made up of two or more elements. To make it easier to

Glossary:

gaseous (**gash** us): In the form of gas.

greenhouse effect (**grēn** howls ē **fekt**): Warming of the Earth's surface that occurs when the sun's heat is trapped by the atmosphere.

climate (**klī** met): The average condition of the weather at a place.

bacteria (bak **tēr** ē uh): Living things that only have one cell and can only be seen using a microscope.

specialization (**spesh** ul ī **zā** shun): Special study of something or working only in a special topic or area.

compact (käm **pakt**): To pack closely and firmly together.

porous (**poor** us): Full of pores or tiny holes through which water, air, etc., may pass.

sample (**sam** pool): A part or piece that shows what the whole group or thing is like.

anaerobic (**an** ä **rō** bik): Existing in the absence of oxygen.

Pronunciation Guide

ā	as in ape	ô	as in for
ä	as in car	ū	as in use
ē	as in me	ü	as in fur
ī	as in ice	oo	as in tool
ō	as in go	*ng*	as in sing

Accented syllables are in **bold**.

imagine, think about the alphabet. Atoms are like different letters. There could be "A" atoms, "B" atoms, and "C" atoms, for example. Elements are like a single letter, such as A, I, or T. Molecules are like strings of the same letter (or element), such as BBB or MMMM. Compounds are like words, which are made from different letters (or elements). When elements interact and become compounds, their structure changes. Elements can form an almost limitless number of compounds, just as letters can form an almost limitless number of words. These compounds can be solid, liquid, or gas. Some scientists study the structure and behavior of *gaseous* compounds. In this study, the scientists were interested in studying the gaseous compounds that go into the atmosphere as greenhouse gases.

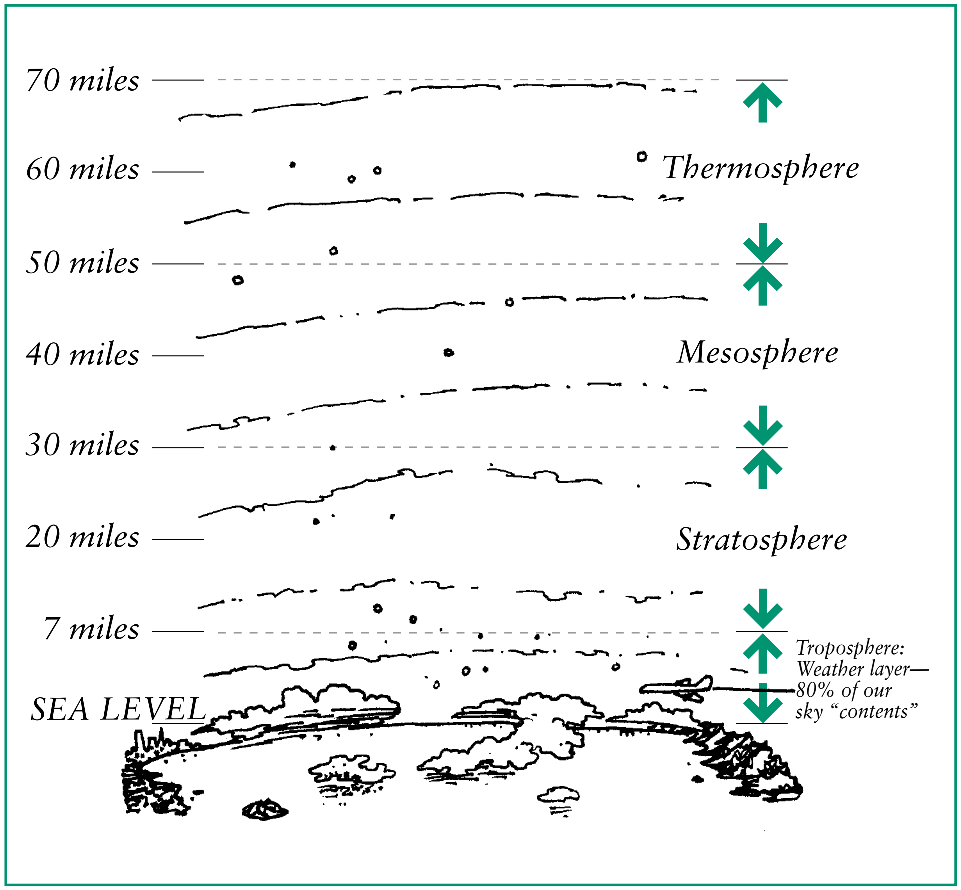
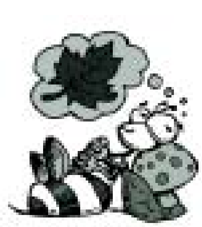


Figure 1. The Earth's atmosphere. The troposphere is the section of our atmosphere reaching from sea level up to 7 miles. Most clouds are contained within the troposphere. When you fly somewhere in a jet, you are flying through the middle and upper portions of our troposphere.



Thinking About the Environment

The *greenhouse effect* is caused by certain gases that act like glass in a greenhouse. They reflect heat in the atmosphere back down to earth (Figure 1). The amount of heat trapped in the atmosphere can vary, depending on the type of gas and how long it stays in the atmosphere. The major greenhouse gases are water vapor, carbon dioxide (**kär** bun di **ox** id), methane (**meth** an), nitrous (**ni** trus) oxide, and chlorofluorocarbons (**klôr** o **flôr** o **kär** buns), also called CFCs. We need a certain level of greenhouse gases to maintain a liveable *climate* on Earth. If we had too small an amount of greenhouse gases, the Earth's climate would get too cold. If we get too great an amount of greenhouse gases, the Earth's climate will get too warm. Human activities, such as burning fossil fuels like petroleum, can create greenhouse gases. The scientists in this study looked at greenhouse gases from another perspective. They looked at how human activities have enabled soil *bacteria* to increase the amount of nitrous oxide in the atmosphere.

Introduction

Tropical forests are sometimes cut down so that humans can use the trees for wood and other products. Then, the cleared land is made into a pasture so that cattle can be raised for human consumption. When forest land becomes pasture, the soil changes. It becomes more *compacted* and less *porous*. (Can you think of why this might happen? Think about the size and weight of cattle.) Previous research had shown

Thinking About Ecology

Often, scientists study one particular event or object. While such *specialization* helps scientists to understand a lot about that one event or object, it does not always help them to understand how that event or object relates to other events or objects. Ecologists (e **käl** uh jists) are scientists who study how living things relate to each other and to nonliving things. In this study, the ecologists were studying the nitrogen cycle (Figure 2). The nitrogen cycle explains the relationship of the element nitrogen with other elements, and with plants, animals, and bacteria. Bacteria are important in the cycle, because they convert nitrogen from the atmosphere into forms that plants can use such as nitrates and ammonia. These compounds are used by plants to make other compounds such as protein. Animals who eat plants can use the protein from the plants. Bacteria living in soil convert animal wastes and dead material from plants back into nitrogen compounds. The nitrogen is released back to the atmosphere, and the cycle begins again. This is an example of how life depends on relationships between living and nonliving things. What are some examples of how your life depends on living and nonliving things?

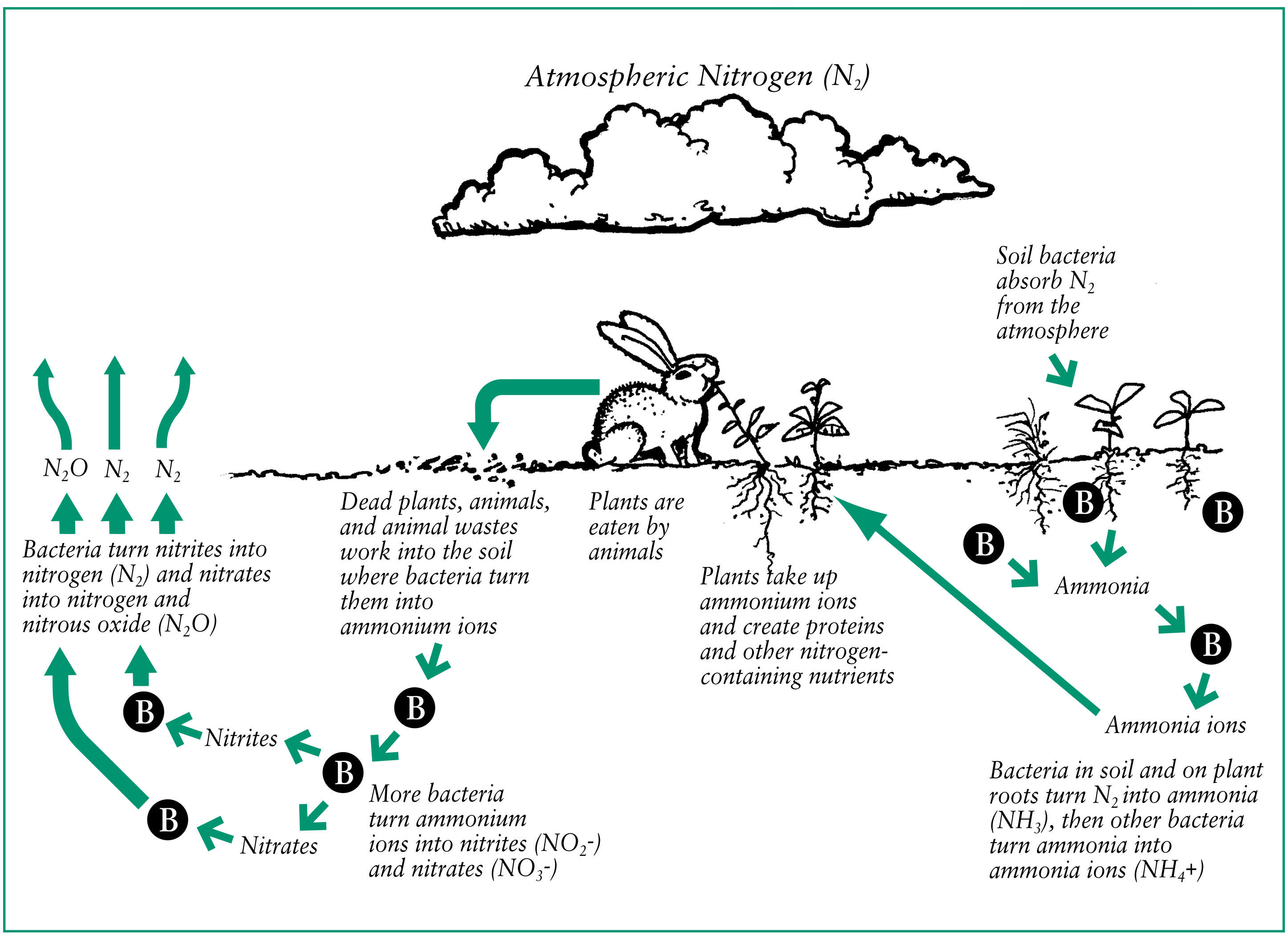


Figure 2. The nitrogen cycle.

that pasture soils release more greenhouse gases than forested land. Sometimes pastures are abandoned after a while. This is often because the soil can no longer produce enough plants to support the cattle. When pastures are abandoned, the forest begins to grow again. No one knew whether soils from these young forests would begin to release less greenhouse gases as the forest grew again. That is the question the scientists wanted to answer.

Reflection Section

- What is the question the scientists wanted to answer? What is the bigger problem their research might help to solve?

- Do you think the scientists needed to visit and study young tropical forests, or could they do all of their research inside a laboratory? Why or why not?

Method

The scientists selected four types of areas to study. They studied old tropical forests, young tropical forests, pastures that were currently being used for raising cattle, and recently abandoned pastures (Figures 3-5). They selected three different areas of each type to study as examples. (How many total areas did they study? Multiply 4 types of areas times 3 examples each.) Then, they picked eight spots in each area where they measured the amount of nitrous oxide (N_2O) in the

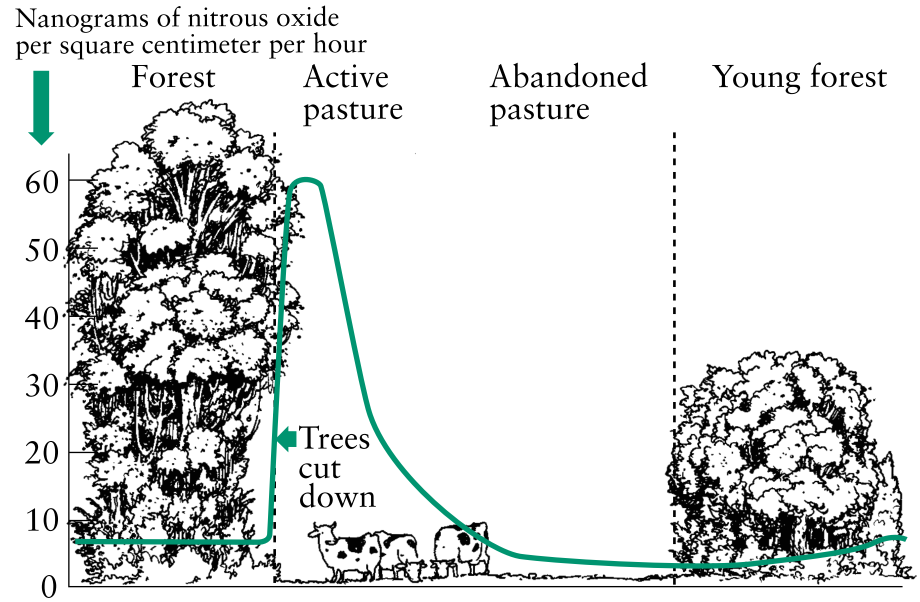
Figures 3-5. An old tropical forest, a current pasture, and a young tropical forest.

soil. (How many total spots did they measure? Multiply 12 X 8.) The scientists measured the amount of nitrous oxide at the top level of the soil at each spot once a month for 12 months. (How many total measurements did they collect? Multiply 12 X 8 X 12. How many measurements did they collect for each type of area? Divide the total measurements by the number of types.) The scientists collected *samples* of the gases that were in the soil by placing an instrument 2 centimeters into the soil (Figure 6). (To find out how many inches that is, multiply 2 X .393.) They took the gaseous samples back to a laboratory. There they measured now much nitrous oxide was in the samples collected from the top level of the soil.

Reflection Section

• Why do you think the scientists studied all four types of areas, instead of just studying young tropical forests?

Figure 6. Photograph of equipment used to collect nitrous oxide gas.



A nanogram is one-billionth of a gram. That's not very much weight! If you took a frito (Fritos® brand corn chip) and smashed it into 1 billion pieces, each piece would weight about one nanogram. At the rate of 60 nanograms per hour, about 60 grams of nitrous oxide would be released in an area 1 kilometer (.621 miles) square. In 1 day, 1,440 grams of nitrous oxide would be released in that square kilometer. How many grams would be released in a month? Although a nanogram is not much weight, you can see that over time, nanograms of nitrous oxide can add up!

Figure 7. The amount of nitrous oxide found in the top layer of the soil over the period of 1 hour in four types of tropical land.

• Do you think that the scientists found that more, the same, or less nitrous oxide was in the soil of young tropical forests compared with the soil in the pasture being used by cattle? Why?

Results

The scientists discovered that the amount of nitrous oxide near the top of the soil was different in the four types of areas (Figure 7). The amount of nitrous oxide is low in old tropical forests. When forests are cleared and used for pasture, the amount of nitrous oxide near the soil's surface rises. As pastures are abandoned and young forests begin to grow, the amount of nitrous oxide at the surface drops to levels even below the old forest levels. The scientists think that water is the key to understanding this pattern. Because cattle hooves compact the soil, pasture land is less able to absorb and drain water. This condition encourages *anaerobic* bacterial activity on plant and animal wastes near the soil's surface. This results in an increased amount of nitrous oxide near the soil's surface, which is then released into the atmosphere.

Reflection Section

- What are two things happening in tropical pastures that might be increasing the amount of nitrous oxide being released into the atmosphere?

- The scientists measured the amount of nitrous oxide 2 centimeters below the surface of the soil. Do you think that same amount of nitrous oxide is being released into the atmosphere? Why or why not?

Implications

The scientists discovered that nitrous oxide is being released into the atmosphere as a part of the nitrogen cycle. They do not know, however, what causes bacteria to turn some ammonium ions into nitrous oxide and others into nitrogen. Nitrogen is a necessary gas in the atmosphere, but nitrous oxide is a greenhouse gas that could cause harm in great amounts. There is still a lot to learn about tropical soils and greenhouse gases. This research shows that humans impact the Earth in ways that we may not be able to see. By making decisions to manage land in different ways, we affect what happens now and what will happen in the future.

Reflection Section

- What other things do you know about the effect of greenhouse gases?

- Do you think that no matter where they are on the planet, pastures cause more nitrous oxide to be released than would happen if the land were a forest? Why or why not?

Discovery FACTivity

In this FACTivity, you will answer the question: What are the similarities between a glass jar with soil and the Earth's atmosphere? The method you will use to answer this question is this: Get two thermometers, a large clear glass jar with a lid (be careful!), and 1 cup of dark soil. Put the soil into the glass jar to a depth of about 4 centimeters (or about 2 inches). Put a thermometer upside down in the jar, and close the lid. Turn the glass jar over, so that the soil is at the lid and the thermometer is right side up. Place the jar in the sunlight or under a high-intensity bulb for 1 hour. Place the second thermometer near the jar.

At the end of the hour, record the temperature outside of the jar using the second thermometer. Record the temperature of the air inside of the glass jar. Compare the two temperatures. Then consider the following questions:

- What part of Earth does the air inside of the jar represent?
- What part of the Earth does the glass represent?
- What part of the Earth does the black dirt represent?

You will see that the soil is heated by the light, which then radiates the heat back into the air where it is trapped by the glass. You have created a greenhouse effect! Now see if you can answer the question posed at the beginning of this FACTivity.

This FACTivity was adapted from Rodriguez, N., Kampen, A., and Dufresne, M. (2000). It's your planet: A study of global warming. An interdisciplinary curriculum designed for middle school students and their exploration of global warming. Visit this Web site for more information and activities: http://www.classtech2000.com/archno2/SessionB/Jesuit/gwarming.htm

From Keller, M. & Reiners, W. A. (1994). Soil-atmosphere exchange of nitrous oxide, nitric oxide, and methane under secondary succession of pasture to forest in the Atlantic lowlands of Costa Rica. *Global biogeochemical cycles*, 8(4): 399-409.