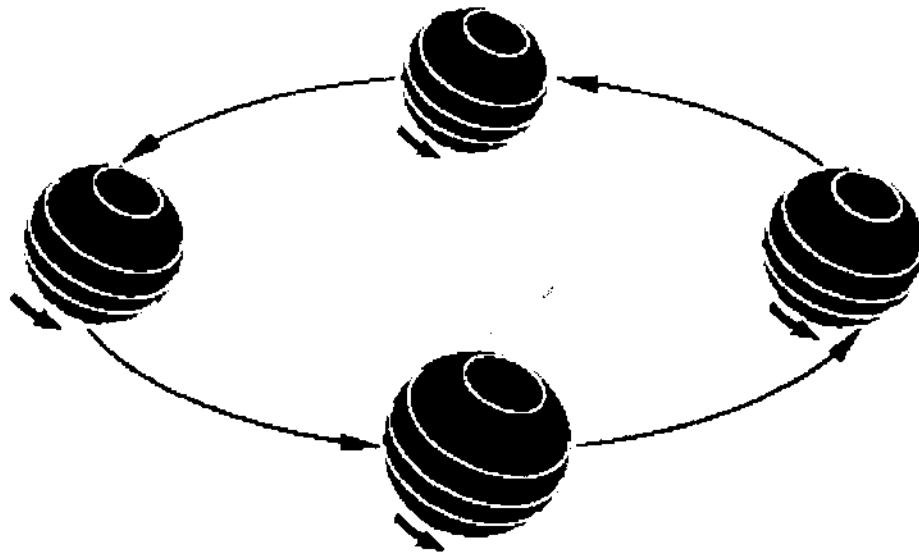


# CLIMATIC CHANGE



Project TELLUS: Interactive Science Videos on Global Change Issues

# CLIMATIC CHANGE



## LEARNING OBJECTIVES

Students should be able to:

1. Describe some of earth's past climate changes and cite reasons for those changes.
2. Compare earth's atmosphere to a greenhouse.
3. Name the greenhouse gases and identify factors contributing to their increase in earth's atmosphere.
4. Recognize some possible consequences of global warming.
5. Identify personal and corporate actions to control the volume of greenhouse gases and reduce the impact of climatic change on the environment.

## INTRODUCTION

The Gulf Coast region that we enjoy today ....

its meadows, marshes, and forests ....  
its lakes, rivers, and bays ....  
its rich biodiversity ....  
and, yes, its sunny, mild climate ....

is the result of changes that have occurred on the earth over billions of years. Climate has

been a driving force in shaping those changes in the earth. Climate continues to influence the contour of the land, the level of the waterways, and the types of vegetation and wildlife present. However, during this era of history, human activities may be accelerating the changes that nature would otherwise take thousands of years to accomplish.

Earth's history, as recorded in rocks, fossils, ice, and ocean floor sediments, shows that the dinosaurs of 150 million years ago lived in a warm, tropical environment. Conversely, our Cro-Magnon ancestors of 35,000 years ago experienced an ice age environment in which a third of the earth was covered by **glaciers**. (See *Geologic Timetable* on page 28.)

Historical examples of climate change seem to be caused by huge swings in temperature, because people tend to look at each period as a separate entity. Actually, during a climate change from cold to warm or vice versa, temperatures increase or decrease by small increments in a definite direction over long periods — thousands of years. This gradual change is good, because it allows species time to adapt through natural selection or to migrate, as their required habitat moves.

Earth's average temperature has increased by 1°F over the last 100 years. Relative to past records of change, this is rapid. However, this

increase has failed to alarm the public. Unfortunately, most people do not realize that it only takes a little change in the planet's average yearly temperature to upset the balance in nature.

The greenhouse effect and earth's position in relation to the sun are responsible for our planet having a climate that will support life. But, some people think the climate may be changing.

- Are human activities responsible for causing an **enhanced greenhouse effect** that may be fueling the current warming trend?
- How will rapid global warming affect life on earth?
- Can the warming be slowed or halted?
- Could the current warming trend be a mere quirk in the climatic pattern that will correct itself with time?
- Should we as citizens of the next century take a "wait and see" stance or should we change our lifestyles in terms of consumption of goods and energy to mediate the predicted effects of climatic change?

The answers to these questions are not clear, and drastically changing our consumption patterns could cause far reaching economic problems. Therefore, the issue of climatic change is a topic of hot debate. People on both sides — those who believe that imminent climatic change is too speculative to have credibility and those who believe that earth's environment, as we know it, is headed for drastic change, if not doom — are leading campaigns to sway public sentiment.

Only time will tell the outcome; however, today's students will be faced with making personal and political decisions that may affect the future outcome. To make intelligent, responsible choices, they must understand

- the greenhouse effect — its causes and consequences
- the need for maintaining a balance in nature
- the wisdom of using resources sustainably

This module will help your students to understand climatic change so they can make informed choices concerning their opinions and actions.

The background information which follows will be helpful in discussing climatic change prior to viewing the video and in guiding students toward logical and meaningful conclusions throughout the viewing and postviewing activities.

## BACKGROUND INFORMATION

### Change Happens

Earth's global climate is primarily determined by three conditions. The orbital pattern of the earth around the sun, the tilt of the earth toward the sun, and an atmospheric phenomenon called the **greenhouse effect**.

Earth's orbital pattern changes from circular to elliptical and back to circular in a 100,000 year cycle. Earth also tilts on its axis toward and away from the sun over a 40,000 year cycle. The coldest climate occurs when the most elliptical orbit coincides with the greatest tilt away from the sun. It was such a situation that probably triggered the beginning of the last major **ice age** about 80,000 years ago.

Because of these orbital and tilt cycles, the earth goes through cold periods, commonly called **ice ages**, followed by shorter times of warm climate called **interglacial periods**. During ice ages, much of the earth's water freezes and accumulates in glacial sheets of ice. Sea level is low. It was probably during an ice age that land bridges allowed early man to migrate from one continent to another. Conversely, during interglacial periods, when the climate warms, the ice melts, sea level rises, and migration is slowed or made difficult.



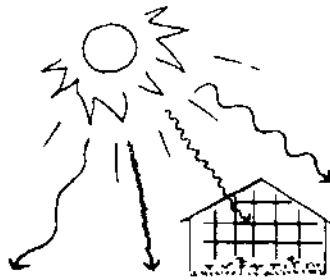
Scientists have learned a great deal about earth's past climate through studying the fossil record, the annual rings of trees, and most recently, by analyzing sediments from the floor of the ocean for the amount of silicate present.

(Silicates help grasses stand upright, therefore the amount of silicate in sediment samples indicates the extent of grasslands during various periods of history.) Scientists analyze deep core samples from permanently frozen areas in Antarctica and Greenland for relative amounts of a heavy isotope of hydrogen to learn more about atmospheric conditions of the past. (During warm periods, more water evaporates, causing the snow for those periods of time to contain more of the heavy isotope.)

These sources all show that climatic change is a regular occurrence. Ice ages last for tens of thousands of years (the last ice age lasted 70,000 years) and are followed by shorter interglacial periods of 10,000 to 12,500 years. During the last million years, the earth has gone through a series of ice ages; we are obviously in an interglacial period at present. Based on this pattern, climatologists say that temperatures should be cooling during the next few thousand years, as the earth moves into another ice age.

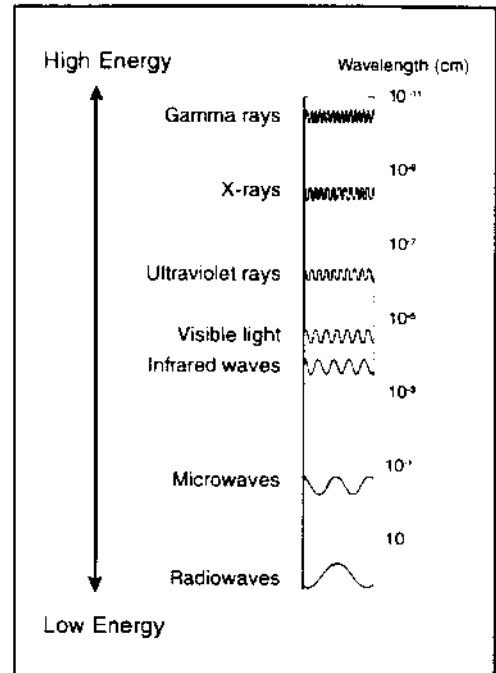
The third phenomenon, commonly called the greenhouse effect, modifies the earth's climate, making it suitable for life regardless of ice age or interglacial conditions.

### The Greenhouse Effect



Energy emitted from the sun moves through space as varying types of radiation. Each type has a different wavelength and a different effect on the matter that it contacts. The amount of energy possessed by each type of radiation corresponds to its wavelength — the shorter the wavelength, the greater the energy.

The energy in some types of solar radiation, such as short-wave gamma and ultraviolet rays, can harm living tissue, while radio waves, which have long wavelengths, are harmless to matter.



As the wavelength of radiation increases, the energy it possesses decreases.

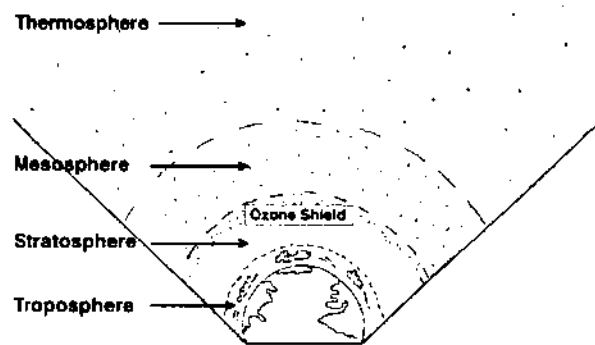
Fortunately, the combination of solar radiation reaching the earth affects matter in life-sustaining ways. For example, waves of visible light fuel photosynthesis and enable some animals to see, while warmth from **infrared radiation** heats the environment and drives the water cycle.

Earth's neighbor planets, Venus and Mars, receive enough radiation to support life, but the resulting temperature on Venus produces a blistering inferno while Mars resembles a desolate, frozen desert. The difference between earth and these two planets, besides their distances from the sun, lies in earth's unique **atmosphere**, a mixture of gases, droplets, and dust that serves as a heat trap and a shield. Without its unique atmosphere, earth's average global temperature would be about 27°F (-3°C) instead of a comfortable 59°F (15°C), and many life forms would die from exposure to the cold and to the sun's harmful forms of radiation.

Earth's atmosphere extends several hundred miles into space and contains four distinct layers. The layer closest to the earth and extending about six miles into space is called the **troposphere**; it is the only region of the atmosphere where life can exist and where the phenomena we call **weather** occurs.

The second layer, the **stratosphere**, contains a very special layer of gases called ozone. Ozone absorbs most of the harmful **ultraviolet radiation** entering earth's atmosphere and converts the energy into heat. (*Ultraviolet radiation that penetrates the atmosphere can burn or kill living cells, tissue, and simple organisms.*)

In the outer two layers of the atmosphere — the mesosphere and the thermosphere — the number of gas molecules decreases until they blend with the atoms of helium and hydrogen found in outer space.

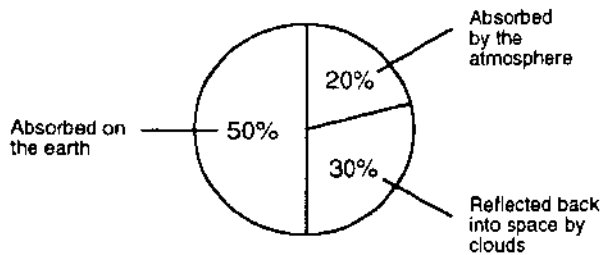


About 99 percent of the atmospheric gases are contained in the troposphere and stratosphere. Among the gases which make up the atmosphere, 78 percent is nitrogen and 21 percent is oxygen. Both nitrogen and oxygen, though vital to life, are not significant in terms of the greenhouse effect, because both are transparent to solar radiation.

The remaining one percent of the atmosphere is a mixture of trace gases that absorbs incoming and outgoing infrared radiation, thus warming the air and serving as a heat trap. Because these trace gases — carbon dioxide, methane, nitrous oxide, chlorofluorocarbons (CFCs), and ozone — prevent the escape of infrared waves in a manner similar to the panels of a greenhouse, they are called **greenhouse gases**.

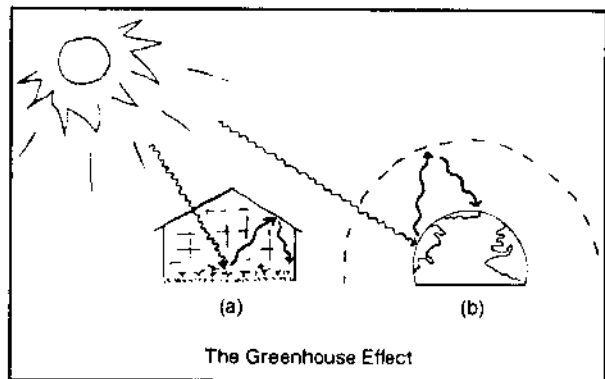
Earth depends on the work of the greenhouse gases to preserve a climate conducive to life. About 30 percent of the solar radiation moving toward earth is reflected by clouds and dust in the troposphere, another 20 percent is absorbed by the atmosphere. The remaining 50

percent reaches earth's surface and is absorbed by the water, ground, and living things.



The fate of solar radiation bound for the earth.

Matter that is warmed by solar radiation gives off infrared radiation which then returns toward space. At this point, the greenhouse gases play their major role, for the infrared radiation emitted from earth's surface (which would otherwise escape back into space insuring earth a subfreezing average global temperature) is absorbed by the greenhouse gases. This heat energy is then reradiated back toward earth, warming the air and raising the average global temperature.



The plants and soil inside the greenhouse (a) absorb sunlight and then emit weaker infrared heat waves. These weaker heat waves cannot escape the glass so the temperature of the air inside the greenhouse gets warmer. Matter warmed by sunlight on the surface of the earth (b) also emits infrared radiation. This heat is then absorbed by greenhouse gases in the atmosphere, preventing their escape into outer space. Thus, earth's surface temperature, like the inside of a greenhouse, stays warmer than it would otherwise.

It appears that the amount of greenhouse gases in the atmosphere is directly proportional to the amount of warming that occurs on a planet. Venus' atmosphere is 96 percent carbon dioxide. Therefore, virtually all incoming radiation is trapped, boosting Venus' surface temperature to an average 840°F (449°C). Mars, on the other hand, has very little atmosphere, so

virtually all of the solar energy it receives is reflected or radiated back into space, leaving the planet with an average surface temperature of  $-10^{\circ}\text{F}$  ( $-23^{\circ}\text{C}$ ). As the concentration of greenhouse gases increases, more heat is trapped and the average global temperature rises.

Geological records show that warm periods in earth's past have been accompanied by higher levels of atmospheric carbon dioxide and other greenhouse gases. During the warm Cretaceous Period, increased volcanic activity released huge amounts of carbon dioxide into the atmosphere.

The amount of greenhouse gases in earth's atmosphere is growing at an alarmingly rapid pace. Could this increase enhance the natural greenhouse effect to the extent of disrupting present environmental conditions? Many scientists think it can and will.

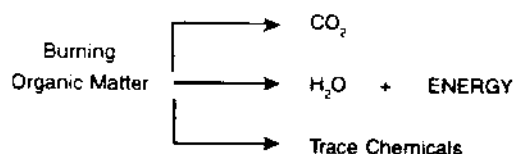
### The Enhanced Greenhouse Effect

Natural processes have generally kept the amount of greenhouse gases in balance. The amount being produced through **respiration**, decay, volcanic action, and natural forest fires has been used by plants and algae during photosynthesis or absorbed by the oceans.

However, with the advent of the Industrial Revolution in the late 1700s and the subsequent exponential growth of the human population, excessive amounts of the greenhouse gases have been added to the atmosphere through various human activities. The **enhanced greenhouse effect** is the term used to distinguish the natural greenhouse effect from the current warming that might be caused by these excessive amounts of greenhouse gases in the atmosphere.

A description of each of the greenhouse gases and their sources follows.

- **Carbon dioxide** ( $\text{CO}_2$ ) accounts for 50 percent of the greenhouse gases in the atmosphere. It is naturally emitted from decaying plants and animals, during volcanic eruptions, during respiration in living organisms, and anytime organic matter (especially the **fossil fuels** — coal, oil, natural gas, and wood) burns.



Carbon dioxide emissions are 25 percent higher today than they were 200 years ago, and human activities are mostly to blame. Today's highly mechanized world burns fossil fuels to produce the energy needed for transportation, manufacturing, and producing electricity. This energy is not recyclable. As these activities increase, more fossil fuel must be burned, and an increase in atmospheric carbon dioxide occurs.

**Deforestation** also adds to the increase in  $\text{CO}_2$  levels. When forests are cleared for agricultural, residential, and industrial development, fewer trees remain to use  $\text{CO}_2$  from the atmosphere during photosynthesis.

- **Methane** ( $\text{CH}_4$ ) is produced naturally as microbes break down organic matter in the absence of oxygen. This happens in water logged conditions such as rice paddies and marsh areas, and in the digestive tracts of farm animals and termites.

As human population growth has escalated during the past century, more and more rice and cattle have been raised, driving the emission of methane to higher levels. Today, methane accounts for 20 percent of greenhouse gases.

To make matters worse, methane has the capacity to absorb more heat per molecule than carbon dioxide, so its impact on global warming could be immense, should levels continue to rise.

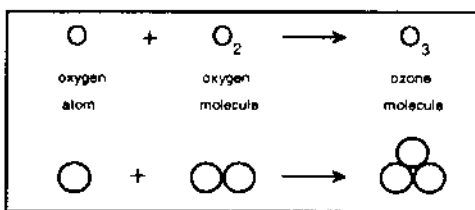
- **Nitrous oxide** ( $\text{N}_2\text{O}$ ), better known as "laughing gas" by those who depend on its anxiety-relieving properties in the dentist's office, is emitted during the burning of fossil fuels and the breakdown of nitrogen-containing fertilizers used in agriculture. It makes up 15 percent of the greenhouse gases.
- **Chlorofluorocarbons** (CFCs) are a family of manmade chemicals that have been used in a number of industrially important processes since their invention in the 1930s. The best

known CFC is freon, which is used as a coolant in refrigerators, freezers, and air conditioning systems. Other CFCs are used as foaming agents to produce materials such as styrofoam, as cleaning agents for sensitive electronic equipment such as computer chips, and as propellants in aerosol cans.

At the outset, these synthetic chemicals were heralded as a boon to modern life. They were easy and inexpensive to make, had a variety of useful applications, and appeared safe to use. Today, they account for 15 percent of earth's greenhouse effect and, like methane, have a greater heat-absorbing capacity than carbon dioxide, molecule for molecule.

CFCs have also been linked to a breakdown in the stratospheric ozone layer which protects organisms on earth from the harmful effects of ultraviolet radiation.

- **Ozone (O<sub>3</sub>)** is produced naturally in the outer reaches of the stratosphere. High energy solar radiation breaks apart free oxygen (O<sub>2</sub>). Some of these highly reactive oxygen atoms combine with oxygen molecules to form the three-atom molecules called ozone.



These three-atom molecules of oxygen form a thin, protective shield around the earth that absorbs and reflects most of the harmful ultraviolet radiation from the sun. Since ozone gains heat in the process of absorbing solar radiation, it is considered a greenhouse gas. It does not, however, contribute to the enhanced greenhouse effect, for the amount of stratospheric ozone appears to be decreasing rather than increasing.

- **Water vapor (H<sub>2</sub>O)** is part of the water cycle on earth, and as such, is vital to life. However, one of the properties that makes water so important to life — its ability to absorb and hold heat, thus modifying the

environment — also makes it a greenhouse gas in the atmosphere. As the climate warms on earth, liquid water evaporates, becoming water vapor in the atmosphere. This vapor, in turn, holds more heat energy radiating from the earth.

### Possible Consequences of Global Warming

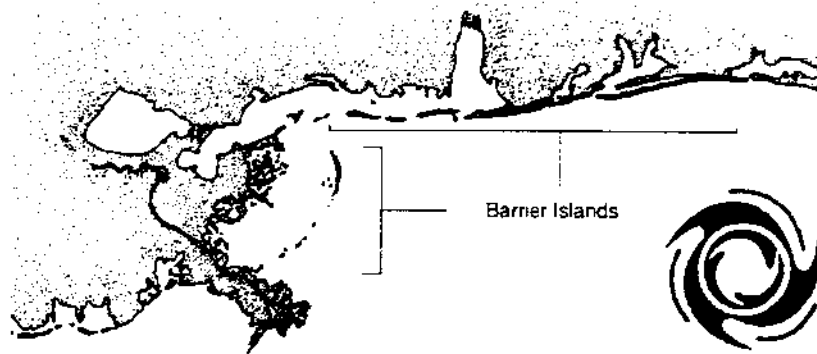
Past geologic records show a correlation between warm interglacial periods and higher levels of atmospheric greenhouse gases. As the emission of these gases continues to increase, a similar warming trend is likely to occur. A major difference between previous periods of **global warming** and today's occurrence is the element of time. Then, the change was gradual, over thousands, sometimes tens of thousands of years. The present warming trend is likely to occur in a hundred years or less.

The exact effect of the increased levels of greenhouse gases on the global climate and, ultimately, on aquatic and terrestrial habitats is uncertain. However, scientists have combined laws of physics, mathematical equations, and descriptions of natural physical processes such as cloud formation and deep ocean mixing to develop computer models that present a picture of possible change.

Models sometimes lack all variables of the systems they portray. Thus, they provide a glimpse of what might happen, rather than what is certain to happen. But, as models become more advanced, predictions become more reliable. Among the current predictions for climatic change in the next century are:

- Average global temperature increases of 5°F to 9°F (1.5°C - 4.5°C). This will vary depending on the insulating effect of clouds and the capacity of the oceans to absorb CO<sub>2</sub> from the atmosphere.
- A sea level rise of 2 to 7 feet caused by the melting of polar ice caps and mountain glaciers coupled with the effect of **thermal expansion** in the oceans. (*As molecules become warmer, they spread apart filling more volume.*)

The effects of such abrupt changes in average temperatures and sea level are for the most part negative.



*Sea level rise will initiate several negative effects.*

1. Many low-lying Gulf Coast lands will become inundated with water. Among the first to be affected will be the Florida Keys and other barrier islands. Flooding may drive people from homes and businesses in coastal cities such as Houston, Biloxi, Mobile, New Orleans, and Tampa. The cost of battling the onslaught of the sea will be enormous; options will include raising homes and buildings off the ground and building dikes, sea walls, elevated beaches and artificial barrier islands.
2. Some wetland habitats such as estuaries, salt marshes, mangrove swamps, freshwater marshes, and bogs will diminish, be partially displaced inland, or completely disappear. These habitats are home to many species of small animals, nesting or resting sites for migratory birds, and nurseries for a variety of fish and shellfish species. The fishing industry will be severely affected by the loss of these wetlands.
3. People living in coastal areas that depend on groundwater as a source of drinking water will find their water supply tainted as salt water seeps into coastal aquifers.

*Weather extremes may increase.*

1. The number and severity of tropical storms and hurricanes in the Gulf of Mexico may increase.
2. Forest fires may increase as drought makes the soil dry and vegetation brittle.
3. Winter storms resulting from the collision of air masses may increase in number and severity. When moist, warm air from the

Gulf of Mexico collides with a cold, polar, northern front, blizzard conditions result.

*Agriculture patterns will change.*

1. Higher atmospheric temperatures will cause more evaporation of water from lakes, rivers, oceans, and the soil. In areas where water bodies are few, the evaporation will lower water tables, deplete aquifers, and result in periods of severe drought. The opposite will occur in areas where surface water is abundant. Increased evaporation will produce more clouds, rain, and increased incidences of flooding.
2. Many of the crops that clothe and feed people — cotton, soybeans, corn, wheat, rice — are sensitive to changes in temperature and precipitation. As climate patterns change, the yield of these crops will decline.
3. Less land will be available for agriculture as sea level rise and flooding inundate and erode coastal and river delta crop lands.

*Biodiversity will decline as more species become threatened, endangered and extinct.*

1. A warming global climate will cause a change in the distribution of species. Forests will move away from the equators, toward the poles — some coniferous forests may become deciduous forests, while some deciduous forests may be replaced with grasslands. As the dominant vegetation in a habitat changes, so do the type of animal species that inhabit it.
2. As oceans warm, current patterns and the distribution of marine life will change. Some organisms will die in the warmer water.

Coral reef communities will be hard hit for two reasons. First, the survival of the tiny coral animals, which build the reef, depends on a symbiotic relationship with certain algae. When water temperature rises, the coral expel the algae and eventually die.

Second, rising sea level will cause the water to become deeper over the reef. This will prevent the penetration of light required by algae for photosynthesis. *(The algae provide food for the coral.)*

Coral reefs provide habitat for about a third of the ocean's tropical fish and other marine organisms. Thus, as the coral in the Gulf of Mexico decline, so will the entire reef community; this, in turn, will affect the commercial fishing industry.

3. Insect species will possibly benefit from global warming, for fewer will freeze during the winter. That means that more insects will survive to destroy crops and spread diseases such as malaria, yellow fever, and encephalitis.

### Can Anything Be Done To Slow Or Halt The Predicted Changes?

The consequences of global warming, described in the previous section, present a bleak picture. However, scientists are not certain about the duration of this warming trend or the effects on specific regions of the globe.

This uncertainty has made many people skeptical of the predictions. But to do nothing to deter global warming is to invite the worst consequences. Besides, many efforts to halt the possible causes of global warming are beneficial to individuals as well as the environment. The following are actions that may help.

1. Conserve energy and save money by
  - turning off lights when leaving a room.
  - driving less and walking more.
  - buying cars that get better gas mileage.
  - turning the thermostat down in the winter and up in the summer.
  - buying energy efficient appliances when replacing old ones.

- using fluorescent lights whenever possible. *(They use one fourth the energy of incandescent bulbs and last up to 10 times as long.)*

2. Reduce the emission of greenhouse gases by supporting or encouraging

- a tax on fuel and power consumption.
- research for chemicals that do not harm the environment to replace CFCs.

- a worldwide ban on using CFCs as a propellant in spray cans.

- less use of nitrogen-based fertilizers by the agriculture industry, farmers, and gardeners. *(Seek alternative methods for encouraging plant growth.)*

- the research, development, and use, when possible, of alternative, non-combustion energy sources such as solar, wind, and wave power.

3. Limit and recycle waste. This will reduce the landfill problem while cutting down on the amount of fossil fuels needed to manufacture new products.

4. Reduce deforestation, and plant trees in areas that have been previously clear cut.

5. Support research that may help humans and other living things adapt to the global changes that do occur. Examples are

- genetically engineering varieties of crops that are more resistant to drought and heat.

- designing irrigation systems that waste less water.

- setting up migration corridors, so animals can easily move to suitable habitats.

Climatic change is an issue of global concern. Efforts to avert possible hardships and loss from such a change can begin with individuals and progress to international action. Teachers have a unique opportunity to encourage actions in their students that can ultimately affect local, state, national, and international policy.

## TEACHING SEQUENCE

### DAY 1 Previewing Questions and Answers



1. To introduce this module, have students work independently to answer the previewing questions given on page 12. [10 minutes]
2. Discuss student responses, emphasizing the following concepts and the answers given in italics on page 12. [40 minutes]
  - The importance of earth's atmosphere as a life support system containing oxygen for respiration, carbon dioxide for photosynthesis, and solar radiation for powering the water cycle and photosynthesis.
  - The difference between weather and climate. (*See Vocabulary on pages 10 and 11.*)

Degrees Celsius ( $^{\circ}\text{C}$ ) is the internationally accepted standard for measuring temperature, however, Americans are usually more familiar with temperature measurements in degrees Fahrenheit ( $^{\circ}\text{F}$ ), since weather reports are issued in those terms. In the video, references to temperature are made in  $^{\circ}\text{F}$  so students will be able to focus on the message of global warming and climatic change rather than focusing on mentally translating from  $^{\circ}\text{C}$  to the more familiar  $^{\circ}\text{F}$ . The video guide, on the other hand, cites temperatures in both  $^{\circ}\text{F}$  and  $^{\circ}\text{C}$  so the teacher can choose the standard of measurement best suited to his or her particular classroom situation.

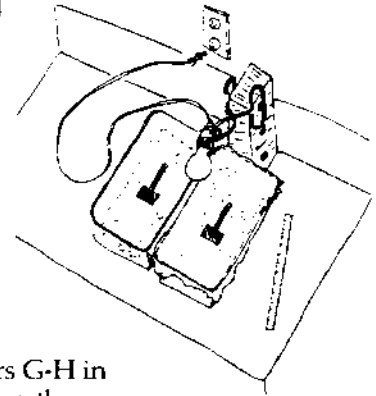
[Option: Have students do Extension #1 (page 14) following the viewing of the video to practice math skills in multiplying with fractions and to increase their familiarity with the Celsius system of measurement.]

- Climate changes during earth's history. Emphasize the three major factors that affect climate — earth's rotation pattern and tilt toward the sun plus the greenhouse effect. (*Refer to the Background Information on pages 2-3 and the Geologic Timetable on page 28.*)

[Option: Use all or part of Extension #8 (page 15) to demonstrate the current warming trend, to have students practice graph interpretation, and to distinguish between glacial (ice age) and interglacial periods in earth's history.]

### DAY 2 Begin Video and Activity I

3. Remind students that this module is about the climate changes that may occur in the Gulf Coast region as a result of global warming. Begin the video and continue watching until instructed to pause for the first activity. [7 minutes]
4. Using the procedure outlined in the Teacher Instructions (letters C-F) on pages 16-17, introduce Activity I: The Greenhouse Effect. [20 minutes]



5. Follow letters G-H in demonstrating the experimental setup and the zeroing of thermometers. [10 minutes]
6. Divide the class into groups of 4 students each and allow time for them to set up their experiment and determine who will be recorders and observers in the group (letters I-K). [13 minutes]

### DAY 3 Complete Activity I: The Greenhouse Effect

7. Make sure each group's apparatus is set up correctly, then follow steps L-O in leading the class through the experiment. [5 minutes]
8. Allow time for the students to graph their data and answer the Summary Questions. [15 minutes]
9. Discuss the results and answers to the Summary Questions. [10 minutes]

**DAY 4** Continue the Video and Begin Activity II

10. Ask students to comment on things they have learned about the importance of the atmosphere and climatic change.

Tell them that in the next part of the video they will be learning about ways that earth's atmosphere is like a greenhouse and types of gases that may be enhancing the greenhouse effect on earth. [5 minutes]

11. Continue the video until instructed to stop for Activity II: Lafitte's Island. [10 minutes]
12. Follow the Procedure outlined in the Teacher Instructions on page 24 to have groups compose and rehearse Jean's daydream. [35 minutes]



**DAY 5** Read or Dramatize Daydreams and Complete the Video

13. Allow each group 3-5 minutes to read or dramatize Jean's daydream. [20 minutes]

Option: List on the board the consequences of sea level rise mentioned in the daydreams.

14. Lead the class in a brief discussion about actions individuals can take to control the volume of greenhouse gases and reduce the impact of climatic change on the environment. (Refer to Background Information on page 8.) [5 minutes]
15. Watch the remainder of the video program. [8 minutes]
16. Have students work cooperatively in their group to answer the Postviewing Questions on pages 12-14. [10 minutes]
17. Discuss answers to the Postviewing Questions. [7 minutes]
18. At the teacher's discretion, the Evaluation section (pages 29-32) may be assigned for homework or used to accompany the next unit test. There are also activities in the Extension section (pages 14-15) that may be used for further study.

**VOCABULARY**

The following terms are used at various times throughout the module. The definitions should be adapted to suit the students' grade level.

**Atmosphere:** The mixture of gases that surrounds a planet. Earth's atmosphere, which is primarily nitrogen and oxygen, goes several hundred miles into space and is composed of four distinct layers — the troposphere, stratosphere, mesosphere, and thermosphere.

**Barrier islands:** Long, narrow, low-lying ridges of sand that develop parallel and close to a shoreline. They help break the force of tropical storms and hurricanes and therefore serve as a protective shield for the mainland.

**Biosphere:** The living portion of the earth — microbes, fungi, algae, plants, and animals.

**Climate:** A description of the average weather conditions — rainfall, temperature, humidity, etc. — for a region over an extended period of time (several years).

**Cryosphere:** The frozen part of the earth — snow, ice, glaciers, icebergs, and polar ice caps.

**Deforestation:** Clearing a forest of all its trees. This is usually done to provide space for agriculture or construction, or to provide the raw materials for wood products.

**Enhanced greenhouse effect:** Global warming attributed to human activities that are increasing greenhouse gas concentrations beyond that caused by natural means.

**Fossil fuels:** Energy sources — coal, oil, and natural gas — derived from the remains of organisms that lived millions of years ago.

**Glacier:** A slowly moving mass of ice that covers mountains or large areas of land.

**Global warming:** The current increase in average temperatures worldwide.

**Greenhouse effect:** The warming of earth's atmosphere, as solar energy is trapped by certain atmospheric gases.

**Greenhouse gases:** Atmospheric gases that cause the greenhouse effect by absorbing infrared radiation, then radiating it toward earth. Although these gases — carbon dioxide, methane, nitrous oxide, water vapor, ozone, and chlorofluorocarbons (CFCs) — comprise only a small portion of the atmosphere, they account for virtually all of the atmosphere's ability to trap heat.

**Hydrosphere:** All of the earth's lakes, rivers, streams, seas, oceans, and groundwater.

**Ice ages:** Long periods of cold climate during which glaciers expand worldwide. The last ice age began about 80,000 years ago and lasted 70,000 years.

**Infrared radiation:** Solar radiation just beyond the range of visible light; often identified as heat.

**Interglacial periods:** Periods of warm climate between ice ages; these periods usually last 10,000 to 12,500 years.

**Lithosphere:** The earth's land mass — rocks, soil, and minerals.

**Respiration:** The process used by all organisms to take in oxygen and release carbon dioxide.

**Sea level rise:** An increase in the amount of saltwater covering the earth's surface.

**Solar (electromagnetic) radiation:** Waves of energy emitted from the sun. Types of solar radiation are identified by their wavelength and energy — the shorter the wavelength, the higher the energy. They range from short, high energy gamma rays to long, low energy radio waves.

**Stratosphere:** The second layer of the earth's atmosphere. It extends about 30 miles into space and contains a thin layer of ozone gas that protects the earth from most of the sun's harmful ultraviolet radiation.

**Sustainable use:** Managing earth's resources in ways that will ensure a supply of the resources for future generations.

**Thermal expansion:** An increase in the amount of space occupied by a substance as its molecules absorb heat and spread out.

**Transpiration:** The movement of water vapor out of a plant through its leaves.

**Troposphere:** The layer of the atmosphere closest to earth's surface. It extends about seven miles into space and is the region where living things can survive and weather phenomena — clouds, thunderstorms, hurricanes — occur.

**Ultraviolet radiation:** A form of high energy radiation that has the ability to burn living tissue. The earth is shielded from most of the sun's harmful UV radiation by the ozone layer in the stratosphere.

**Water vapor:** The gaseous state of water.

**Weather:** Atmospheric conditions that occur at a particular place and time, for example, the temperature, humidity, precipitation, and wind velocity in a city on a certain day or an event such as a blizzard or thunderstorm.

## PREVIEWING QUESTIONS AND ANSWERS

1. Earth's atmosphere (air) is part of the sky. Name as many things in the sky as you can.

*Some responses include:*

- Clouds, rain, fog, sleet, and snow
- Sun, moon, and stars
- Birds, bats, and insects
- Airplanes, hot air balloons, kites
- Gases (oxygen, nitrogen, argon, and carbon dioxide)
- Dust and chemicals from factories (pollution such as ozone, nitrous oxide, carbon monoxide and sulfur dioxide)

2. A resource is something that is useful. For example:

- Water is used for drinking and cleansing.
- Forests provide food and shelter for animals and raw materials for building.
- Oil is used to make gasoline, crayons, deodorant, bubble gum, and many other useful products.
- When burned, oil provides energy for producing electricity and running engines.

Why is the atmosphere (air) a valuable resource?

*The atmosphere contains:*

- Gases necessary for life.

*[Carbon dioxide is used by plants to make food. Oxygen is used by organisms during cellular respiration (the breakdown of food that releases energy, carbon dioxide, and water). Nitrogen is used by some bacteria to make nitrates. These compounds are then used by other organisms to produce cells and the chemicals necessary for life.*

- Water vapor that condenses to form clouds — part of the water cycle.

- Solar energy that drives the water cycle and fuels photosynthesis.
- Wind that spreads seeds, enables the flight of insects and other flying animals, and can be used to generate electricity.

3. The climate of a particular place is a description of its average weather conditions — rainfall, temperature, humidity — over an extended period of time (many years). Describe the climate where you live.

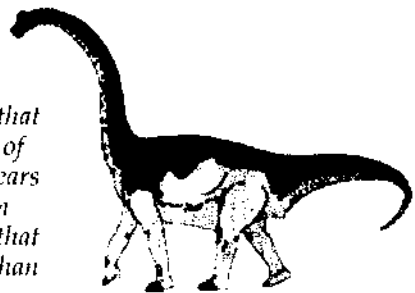
*The climate of the states bordering the Gulf of Mexico tends to be mild and dry in the winter — very few days of freezing temperatures and rain. Summers are hot, humid, and rainy — high temperatures often range from 95°F to over 100°F (33°–38°C) and daily afternoon showers are common along the coast.*

*Hurricanes periodically occur from June through November and the threat of tornadoes is present during the spring and fall.*

4. Has the climate on earth always been like it is today? Explain your answer.

*No. The fossil record and other geologic studies show that the dinosaurs of 100 million years ago lived in an environment that was warmer than today. These*

*records also show that the earth has gone through many ice ages followed by periods of warming.*



## POSTVIEWING QUESTIONS AND ANSWERS

1. Describe ways that a greenhouse and earth's atmosphere are similar.

**Basic:**

- The roof and walls of a greenhouse are made of a substance (usually glass or plastic) that is transparent to solar radiation; earth's atmosphere (air) is also transparent to solar radiation.

- A greenhouse protects tender vegetation from the cold of the outside environment by trapping warm infrared radiation inside its glass or plastic walls and roof. Similarly, certain gases in the atmosphere keep earth's surface temperature at a level that will support life by absorbing infrared radiation and radiating it toward earth.



**Advanced:**

Solar radiation enters a greenhouse and is absorbed by the objects and organisms inside. In turn, the warmed objects and organisms give off radiation in the form of infrared waves. However, the infrared radiation does not have enough energy to move out through the roof and walls of the greenhouse. As a result, the environment inside the greenhouse stays warmer than the environment outside the greenhouse. Certain gases in earth's atmosphere act like the transparent panels of a greenhouse. They allow a portion of solar radiation to move through the atmosphere to earth's surface but then absorb warm infrared radiation emitted from the earth that would otherwise radiate into outer space. This warmed air allows earth to maintain a temperature that will support life.

2. Name the type of greenhouse gas being described in each of the following sentences.
  - a. Manmade chemicals used as coolants in refrigerators and air conditioners and as propellants in some aerosol cans.
  - b. Its concentration in the atmosphere rises as deforestation increases and as fossil fuels are burned.
  - c. This gas is produced naturally in oxygen-poor, water-logged areas such as swamps, marshes, and rice paddies.
  - d. The breakdown of nitrogen-containing fertilizers releases this gas into the atmosphere.

- e. A layer of this gas in the stratosphere provides a shield around the earth that blocks out most of the sun's harmful ultraviolet radiation.
- f. This gas can both cool and warm the atmosphere. It is part of the water cycle.
  - a. Chlorofluorocarbons (CFCs)
  - b. Carbon dioxide (CO<sub>2</sub>)
  - c. Methane (CH<sub>4</sub>)
  - d. Nitrous oxide (N<sub>2</sub>O)
  - e. Ozone (O<sub>3</sub>)
  - f. Water vapor (H<sub>2</sub>O)

3. How would your state be affected if the average global temperature warmed by about 5°F? What might happen to the land, the water, the vegetation, and the weather patterns? Give reasons for your responses.

Answers will vary. Refer to the Background Information on pages 6-8. Some responses are:

Increased temperatures would cause water in the Gulf of Mexico to occupy more volume leading to sea level rise. Land along the coast may become flooded with saltwater. This saltwater intrusion may kill many of the plants and animals adapted to freshwater wetlands.

Lands upstate from the coast (where there is less surface water) would become drier because the extra heat would cause more evaporation of water from the soil. The land would crack and there would be more erosion because the plants that hold the soil together would die from lack of water.

Streams and ponds would dry up because of increased evaporation. The water level in rivers and lakes would recede. The amount of freshwater available for consumption by people would decrease.

Plants that require a lot of water such as rice, corn, irises, ferns, and azaleas would die. They may be replaced by plants such as tumble weeds, mesquite, and cactus that do not require as much water.

Weather along the coast where water is plentiful would be warm and balmy, because the increased heat and subsequent evaporation rate would cause the relative humidity (amount of moisture in the air) to increase. The increased humidity

may lead to more cloud cover and thunderstorms.

Upstate areas, where surface water is not as plentiful as it is along the coast, might experience times of drought that are more severe and longer in duration. Humidity would decrease as the air lost its moisture.

4. The average global temperature is rising. Many scientists believe this warming trend is being caused by an increase in human activities that add excessive amounts of greenhouse gases to the atmosphere. Name four things that you can do to help reduce the volume of greenhouse gases.

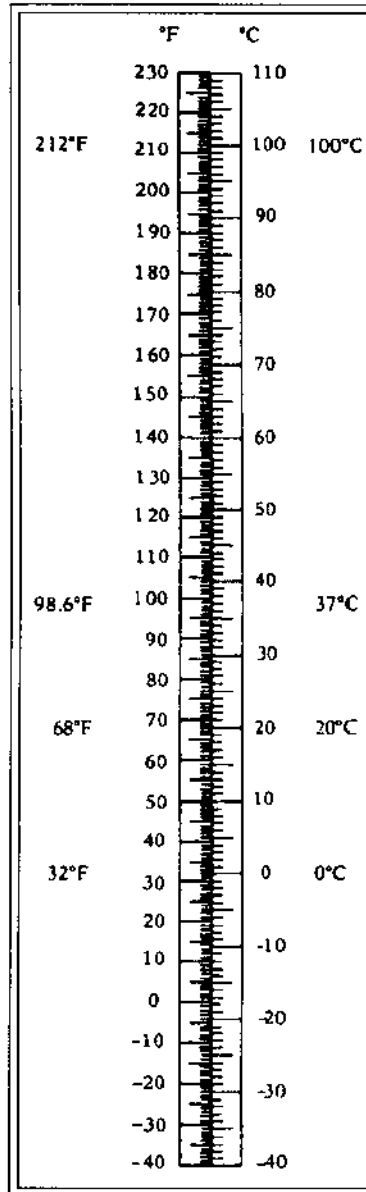
Answers will vary. Refer to the list on page 8 of the Background Information.

### EXTENSIONS

1. **Math:** Have students note temperature references made in degrees Fahrenheit during the video. Tell them to use the following formula to convert those measurements to degrees Celsius.
 
$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 5/9$$
2. **Set a goal:** Ask your students to list several practices that, if followed, would reduce CO<sub>2</sub> emissions in your community (See page 8 in the Background Information for suggestions.) Ask each student to commit to practicing at least three.
3. **Field trip:** Plan a trip to the local power company or invite someone from the power company to talk to your class. Ask the students to compile a list of questions to ask such as the following.
  - a. Is the power company doing anything to cut down on their emission of CO<sub>2</sub>?
  - b. Is the company researching ways to

supplement fossil fuel-generated electricity with renewable energy sources such as solar power, geothermal power, and wind power?

- c. Does the company have a rebate program for households that save energy?



4. **Debate:** Have students research and then debate the following questions.

- a. Currently, oil companies pay royalty taxes to the federal government when they pump oil from the land, and consumers pay both state and federal taxes on gasoline purchases. Should taxes on the extraction and use of fossil fuels — oil, natural gas, coal — be increased? What might be the advantages and disadvantages to further taxation?
- b. Should the use of renewable, non-combustive forms of energy — solar, wind, and geothermal power — be encouraged by federal and state governments through tax breaks?
- c. Should the U.S. government take measures to curb CO<sub>2</sub> emissions, even though the effects of rising atmospheric CO<sub>2</sub> levels on the global climate are not certain?

5. **Keep a record:** Clouds can modify average daily temperatures by trapping heat that radiates from the earth at night and by blocking solar radiation from the earth during the day; thus, the

temperature range over a 24 hour period is smaller (warmer nights and cooler days). Have students:

- Record the daily temperature range (high and low temperatures) and the amount of cloud cover (clear, slightly cloudy, mostly cloudy, heavy cloud cover) for your town for two weeks to a month.

- Graph the data.
  - Compare the amount of cloud cover vs. daily temperature range.
  - Write a summary of the results.
6. **Modeling:** Have students research the physical and chemical layering of the atmosphere. After the information has been collected, have them prepare a scale model of the atmosphere and identify the position of the ozone layer, auroras, plane flight, altitudes of the shuttle, and any other zones of interest.
  7. **Sea level rise:** Prepare a mound of dirt in a plastic storage box. Add water to create a shoreline around the dirt — ask students to note the water level and the contour of the mound. Add a block of ice (*representing a glacier*) to the soil and allow it to melt. Periodically, as the ice melts, ask students to observe and comment on changes in the water level and contour of the land. (*Water level will rise and some erosion should be evident.*)
  8. **Interpreting graphs:** Have students use the activity on pages 15, 16, and 19 in *Global Warming and the Greenhouse Effect*, a GEMS publication. (*The address for this publication is found in the References on page 34.*) The activity contains two graphs — one shows changes in the average global temperature during the past 130 years to demonstrate the current warming trend, and the other depicts average surface temperatures of the ocean for the past 450,000 years to compare temperatures during ice ages and interglacial periods.
  9. **Bulletin board:** Ask students to collect newspaper and magazine articles on climatic change and prepare an informative, interactive bulletin board display using the articles.
  10. **Alternative energy sources:** Ask students to research and report on one of the following alternative energy sources: nuclear power, solar energy, wind energy, hydroelectric power, geothermal energy, and tidal (wave) power. Have them include information such as:
    - How the alternative source produces usable energy.
    - The advantages and disadvantages of using the alternative source of energy (*for example, its effect on the environment, the cost of building the power plant, the amount of land needed, the time required to generate the power, and the number of employees needed to maintain the facility*).
    - The amount (percent) of the United States' energy needs currently derived from the alternative energy source.

## ACTIVITY I

### THE GREENHOUSE EFFECT (Teacher Instructions)

#### Objectives

- To describe earth's atmosphere.
- To simulate the greenhouse effect in a controlled experiment.

#### Description

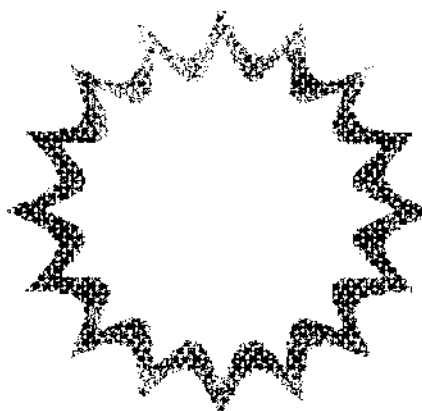
The teacher will briefly describe the concepts covered in the activity — earth's atmosphere, types of solar radiation, models in science, and the greenhouse effect. (*The Background Information on pages 3-5 will be helpful.*) Afterwards, students will work in small groups to carry out a controlled experiment that demonstrates the greenhouse effect. The students will graph their collected data, and answer questions regarding the design of the experiment and the trends shown in the results.

#### Materials (per group)

- 2 Plastic storage boxes (6" x 12" x 3")
- 12 Cups potting soil (6 cups per box)
- 2 Thermometers (*aquarium thermometers are inexpensive and show both °C and °F*)
- 2 Strips of lightweight cardboard (2" x 3")
- 1 Clamp lamp with 100 watt light bulb
- 1 Brick or block of wood
- Ruler
- Plastic wrap to cover one container
- Rubber band
- Blue and red map pencils or pens

#### Procedure

- Make enough copies of the Student Instructions and Data Sheets (pages 20-23) for each student to have a set.
- Separate the required materials for each group's experiment prior to class. (*Put the required amount of potting soil in the storage boxes before class.*)
- When directed by the video narrator, stop the tape and distribute the Student Instructions and Data Sheets.



- Have students read the Introduction in their instructions.
- Using Background Information from pages 3-4,
  - Describe the four layers of earth's atmosphere. Explain the importance of the troposphere and the stratosphere.
  - Distinguish among the types of solar energy and explain the relationship between wavelength and amount of energy. Cite the effects of ultraviolet, visible light, and infrared waves on living things.
  - Describe how infrared radiation reacts with greenhouse gases to warm the air around the earth — the greenhouse effect. (*Use a transparency of the diagram shown on page 4 of the Background Information.*)
- Explain the significance of models in science.

*A model is a means of describing something by using diagrams, formulas, or representative structures. Examples are road maps, bridges made from toothpicks, and 3-D models of molecules made of wire and jellybeans. When dealing with an object or idea that in reality is very difficult to work with (because it is large, small, or complex), scientists often experiment with models in order to learn more about the phenomenon.*

Tell the students that they will be making and using a model of earth's atmosphere to investigate the greenhouse effect.

G. Following the diagram in the Student Instructions, demonstrate how to set up the experiment. While demonstrating:

- Ask students to correlate the various parts of the model — light, soil, air, plastic wrap — to the corresponding parts of the earth system — sun, surface of the earth, atmosphere, greenhouse gases.
- Have students distinguish the experimental setup (*covered container*) from the control setup (*open container*).
- Ask students to predict whether temperatures will vary between the two containers. Have them give reasons for their predictions.
- Explain how and why the thermometers used in the experiment must be zeroed.

*In order to get a true picture of the difference in temperature change between the control and experimental setups, both thermometers must have the same initial reading (room temperature) at the beginning of the experiment.*

*(See letter L below for a description of how to zero the thermometers.)*

- H. Temperature readings will be taken from both containers every minute for 15 minutes. The teacher will keep track of the time and alert students when to read the thermometers.
- I. Divide the class into groups of 4 students each. Each group will choose two persons to read the thermometers (the observers) and two to record data (the recorders).
- J. Ask one person from each group to get the materials for the experiment.
- K. Allow time for the students to set up their equipment.
- L. Tell students to take an initial temperature reading (time - 0), before covering the experimental setup with plastic. If the thermometer readings do not agree:

- Determine the difference between the high and low reading.
- Add the difference to the low thermometer's reading so the initial reading for both thermometers will be the same. (*This is called zeroing the instruments.*)
- This number must be added to each reading taken from the low thermometer throughout the experiment.

*(Tell the recorders for each group to add the number of degrees for zeroing into each box under the low thermometer on the Data Sheet, now, so they will not forget as the experiment progresses.)*

- M. Make sure each group's experiment is set up correctly.
- N. Make the classroom as free of drafts and light as possible — close windows, window shades, doors, and turn off the lights.
- O. At the signal to begin, each group will turn on its light. Alert the class as each minute passes. At each signal, the observer will determine the thermometer's temperature to the nearest 0.5 °C and the recorder will write the temperature in the appropriate box on the Data Sheet.
- P. After the experiment is finished, have students within the same group swap data so they have results from both the control and the experimental containers.
- Q. Allow time for students to graph their data — control data in blue and experimental data in red — and answer the Summary Questions on the back of the Data Sheet.
- R. Call on one student from each group to summarize the changes observed during the experiment.

*The temperature in each container warms and then levels off. The temperature in the covered container (experimental setup) levels off at a higher temperature. Explain that when the amount of heat and light entering the container is equal to the amount leaving the container, an equilibrium temperature has been reached.*

S. Discuss the answers to the Summary Questions at the end of the Data Sheet.

T. Continue the video program.

**Extension**

Have students vary the experiment to test the effect of the following:

- Moist soil.
- Soil type — garden soil, sand, and sod (soil and grass).

- Increasing the amount of carbon dioxide. *(Place a dish of marble chips and dilute hydrochloric acid on the soil to produce extra CO<sub>2</sub> in the experimental setup; cover both containers with plastic wrap).*

- Amount of ventilation. *(Vary the amount of covering on several containers — one-fourth, one-half and three-fourths open.)*

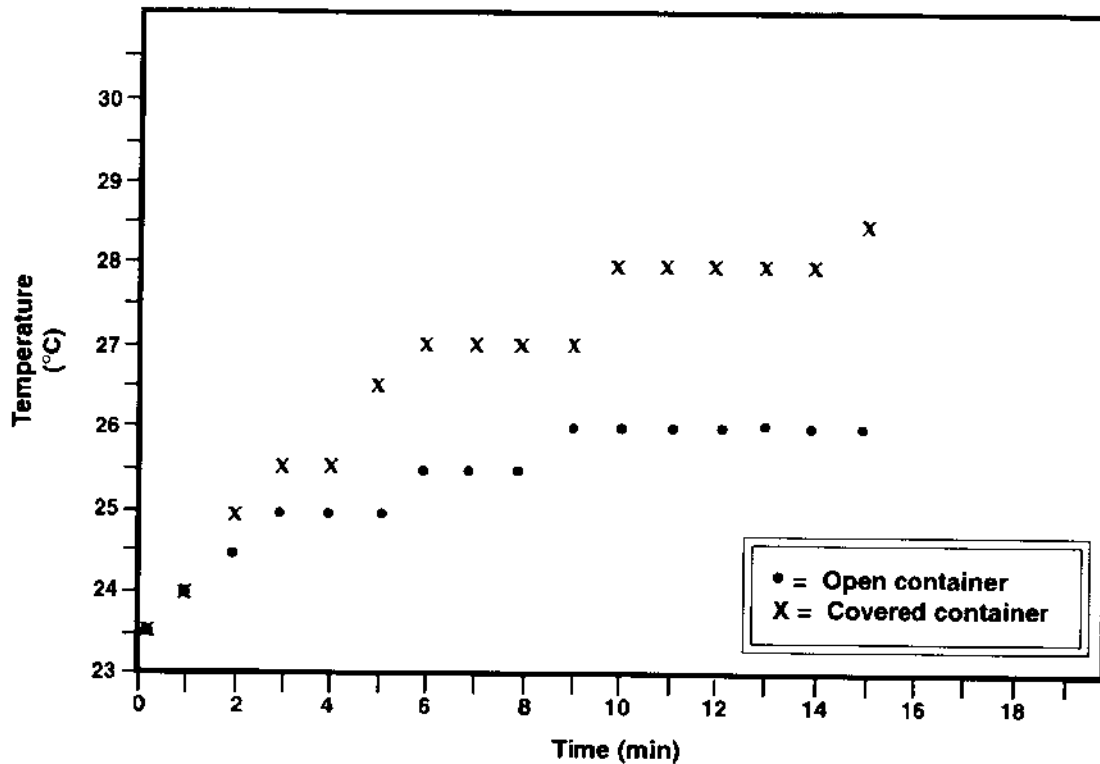
[This activity was adapted in part from Session 2: "Modeling the Greenhouse Effect" which is part of *Global Warming and the Greenhouse Effect*, a GEMS Project published by Lawrence Hall of Science, University of California at Berkeley, 1990.]

**TEACHER KEY — ACTIVITY I**

Data will vary slightly depending on room temperature and type of thermometers used, however, the trend should be similar to the one shown on the table and graph that follow.

**THE GREENHOUSE EFFECT**

Time (min)	Control Setup (°C)	Experimental Setup (°C)
0 [initial reading]	23 (+ 0.5) = 23.5	23.5
1	23.5 (+ 0.5) = 24	24
2	24 (+ 0.5) = 24.5	25
3	24.5 (+ 0.5) = 25	25.5
4	24.5 (+ 0.5) = 25	25.5
5	24.5 (+ 0.5) = 25	26.5
6	25 (+ 0.5) = 25.5	27
7	25 (+ 0.5) = 25.5	27
8	25 (+ 0.5) = 25.5	27
9	25.5 (+ 0.5) = 26	27
10	25.5 (+ 0.5) = 26	28
11	25.5 (+ 0.5) = 26	28
12	25.5 (+ 0.5) = 26	28
13	25.5 (+ 0.5) = 26	28
14	25.5 (+ 0.5) = 26	28
15	25.5 (+ 0.5) = 26	28.5



### Summary Questions

1. Why did the temperature rise in both containers?

*Light and heat energy from the light bulb entered both containers warming the air around the thermometer.*

2. Why did the temperature in the container covered with plastic wrap rise higher than the temperature in the open container?

*The warm air in the open container mixed with cooler air outside the container, but the warm air inside the closed container was separated from the cooler air by the plastic wrap.*

3. How was this experiment similar to what happens inside a closed car parked in a sunny location on a cold, winter day.

*Light and heat energy from the sun move into the car, but because the windows are closed, the heat energy cannot escape, so the air inside the car becomes warm even though the temperature outside the car is cooler.*

4. In this activity you made a model of the earth and its atmosphere. Tell what each of the following parts represented.

The light bulb — *the sun or solar energy*  
 The potting soil — *the earth*  
 The air in the container — *earth's atmosphere*  
 The plastic wrap — *greenhouse gases*

5. Did your group observe other similarities between the greenhouse model (the covered container) and the real earth's atmosphere?

*Condensation collected on the inside surface of the plastic wrap similar to the way water droplets condense in the atmosphere to become clouds — part of the water cycle.*

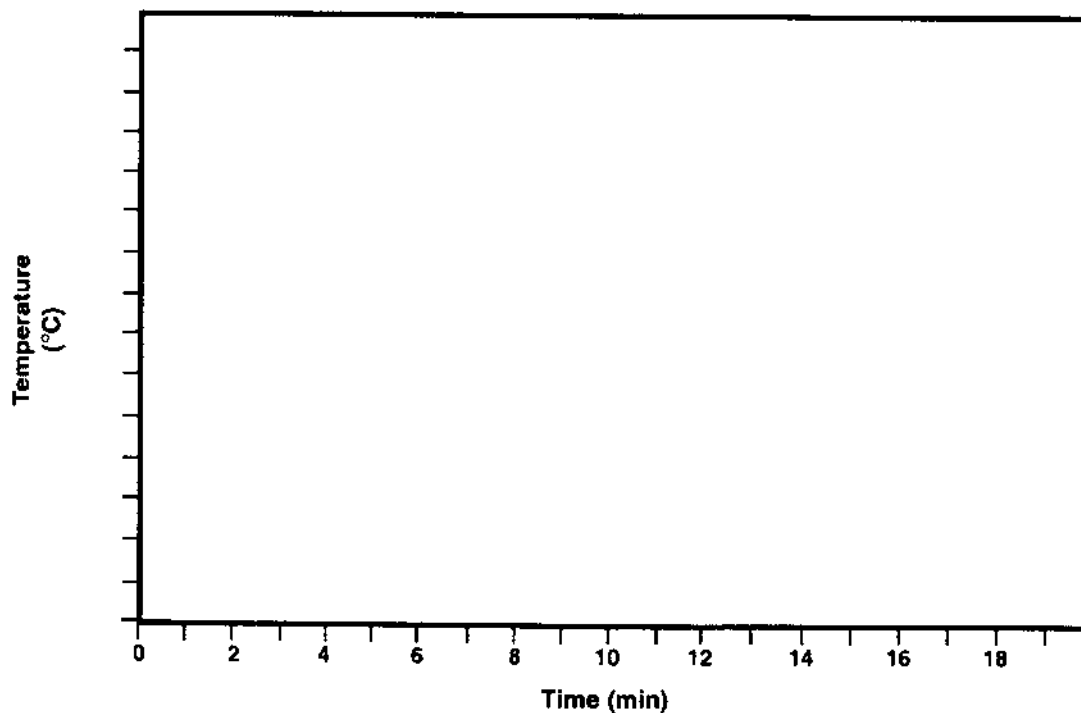
6. Models, though useful, are not perfect examples of the phenomena they represent, because variables are often involved that cannot be represented in the model. In what ways was this model different from the real earth's atmosphere.

- *Earth's atmosphere does not have a solid barrier, like the plastic wrap.*
- *The light bulb emitted visible light and infrared radiation; the sun emits these plus cosmic rays, gamma rays, ultraviolet radiation, and radio waves.*
- *Weather conditions such as wind and rain, which are a part of the real earth's atmosphere, could not be included in this model.*

# STUDENT DATA SHEET

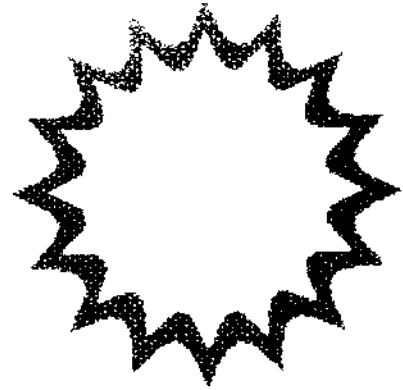
## THE GREENHOUSE EFFECT

Time (min)	Control Setup (°C)	Experimental Setup (°C)
0 <small>[initial reading]</small>		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		



## Summary Questions

1. Why did the temperature rise in both containers?
2. Why did the temperature in the container covered with plastic wrap rise higher than the temperature in the open container?
3. How was this experiment similar to what happens inside a closed car parked in a sunny location on a cold, winter day.
4. In this activity you made a model of the earth and its atmosphere. Tell what each of the following parts represented.  
The light bulb —  
The potting soil —  
The air in the container —  
The plastic wrap —
5. Did your group observe other similarities between the greenhouse model (the covered container) and the real earth's atmosphere?
6. Models, though useful, are not perfect examples of the phenomena they represent, because there are often variables that cannot be represented in the model. In what ways was this model different from the real earth's atmosphere?



The greenhouse effect allows the earth to maintain an average temperature warm enough for living things to survive. What would happen if the atmosphere contained more greenhouse gases? Some scientists believe that the greenhouse effect is becoming stronger. Continue watching the video to find out more about the enhanced greenhouse effect.

## ACTIVITY II

### LAFITTE'S ISLAND

#### (Teacher Instructions)

#### Objectives

- To brainstorm possible consequences of global warming
- To practice creative writing skills.


#### Description

Students will work in small groups to brainstorm possible consequences to a small **barrier island** and its inhabitants should average global temperatures rise by 5°F (2°C) during the next 50 years. They will use their predictions to write an ending for the scenario described in "Lafitte's Island." Someone from each group will read the ending to the class.

#### Materials (per group)

One copy of the Student Instructions for Activity II — Lafitte's Island

#### Procedure

- A. Make copies of the Student Instructions (pages 25-27) for each group.
  - B. When cued by the narrator, stop the video and divide the class into groups of 4 to 5 students each.
  - C. Ask the students to close their eyes and imagine that they are Jean while you read the story. (*Jean is both a male and female name.*)
  - D. Keeping their eyes closed, have the students silently reflect on the story by considering the following:
    - How did the story make them feel?
    - Would they like living on Lafitte's Island? Why?
    - What were some of the characteristics of the island that might be affected by sea level rise?
- 
- E. Working within their group, have the students follow the directions in their Procedure section:
    1. Estimate how much the Gulf of Mexico might rise if there is an average temperature increase of 5°F (2°C) over the next 50 years. (*This is a hypothetical situation, but students should try to be realistic — advise them to choose between one and twelve feet.*)
    2. Predict how this sea level rise will affect Lafitte's Island and the people who live there. (*Encourage students to reread the story for ideas.*)
    3. Write a description of the daydream that includes possible consequences to the island and its inhabitants. Bring Jean back to the present and relate a possible course of action in response to his/her futuristic thoughts.
    4. Have each group choose one person to read the ending to the class. If time permits, groups could act out rather than read the ending.
  - F. Return to the video for the remainder of the program.

## ACTIVITY II

### LAFITTE'S ISLAND (Student Instructions)



Imagine that you are a teenager who lives on a **barrier island** along the coast of the Gulf of Mexico. Your name is Jean. Your family has lived on this sandy, marsh island since your great-great grandparents settled here in the late 1800s. Your family members are not the only inhabitants of the island. Your village has a population of 556 people.

The island is 20 miles long and 5 miles wide. At its highest point, it is only four feet above sea level. The water surrounding the white-sand island is clear and has a deep blue color. A coral reef teeming with anemone, starfish, sponges, and a huge variety of tropical fish has formed atop several sunken oil platforms. This artificial reef borders the gulf side of the island. On the mainland side, the land curves inward to form a quiet lagoon frequented by playful dolphins and, occasionally, sea turtles.

Weather on the island is usually warm and breezy — even during the winter, there are very few cold days. The air is humid and smells of the salty, gulf spray. Tropical storms and hurricanes come in the summertime and fall, but the village people have learned, through the years, to prepare for the strong winds, waves, and rain. Damage can usually be repaired within a few days after a hurricane passes.

The island is so beautiful and rich in biodiversity that tourism has begun to grow. People boat to the island for snorkeling, sunbathing, picnicking, and shopping for crafts. In fact, the island has become so popular that the state is planning to build a bridge to connect the island to the mainland. Presently, the only way to the mainland is by ferry, by private boat, or in emergencies, by helicopter.

Small as the island is, it has provided a means of livelihood for the village for many generations. With the exception of a few store owners, most families make a living by fishing the coral reef, lagoon, and bay waters. When not in school, you help your dad set crab traps, gig in the lagoon for flounder, and trawl for

shrimp and fish. He sells most of the catch on the mainland at the fish market. The remainder becomes gumbo, etoufee, or bisque in the family's stock pot. Modern conveniences such as radios, televisions, and bicycles are purchased on the mainland with money made from fishing.

Vegetables for the family are grown in a community garden located in the center of the island, where the saltwater rarely intrudes. Several people from the village make reed baskets from the smooth cordgrass that grows on the bayside of the island. Tourists are eager to buy these baskets when they visit the island.

The growth of plants on the island depends on freshwater from daily afternoon showers. The people of the village also depend on these showers, because the rain keeps the island's pond and cisterns full of fresh water. The pond and cisterns are the source of fresh water for the entire village. The pond also provides habitat for frogs, freshwater fish, and wading birds. During the spring and fall, many colorful migratory birds stop along the grassy edge of the pond to rest and eat as they fly to and from nesting sites on the mainland.

Experiences on the island teach you many things about life, but you must also go to school. Nine months out of each year you and your friends climb aboard a ferry at 6 am in the morning to make the 8 mile trip to a school on the mainland. There, you learn history, math, science, and English. You also learn about ways the world is changing. Every village is not exactly like yours.

Further inland, there are huge cities. People zoom by in automobiles, driving hurriedly to and from work and shopping. Airplanes fly through the sky, taking people to and from far away places. Factories smoke with activity, producing all sorts of modern

conveniences — appliances, plastics, gasoline, and fertilizer. Even the fields between cities are full of activity as tractors plow and plant rows of crops such as cotton, soybeans, corn, and rice. Yes, life on the mainland is quite different from life on the island.

Although you enjoy learning about city life, you are most happy back on the island. After school and on weekends, your time is spent mending nets, washing down boats, laughing with friends, and searching for treasures that might have washed up on the beach. Life on the island is slow paced, peaceful, predictable, and safe. But that, too, may be changing.

You have learned at school that the average global temperature is rising. Some scientists are

predicting that, as the temperature rises, polar ice will begin to melt into the ocean and seawater will warm. Both of these events will cause the sea level to rise, covering more land. Some scientists are also predicting that hurricanes will occur more often and with more severity in the Gulf of Mexico. Because you live on an island, sea level rise could threaten your whole way of life. You begin to read books and watch television programs concerning this global warming trend.

One afternoon on the boat ride home from school, you begin to daydream ....

What if the earth's average temperature does rise 5°F by the middle of the next century? How will this affect Lafitte's Island? What will life on the island be like then?

### Procedure

1. Estimate how much sea level will rise (*choose a number between 1 and 12 feet*) if the average global temperature increases by 5°F during the next 50 year period.  

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2. Using your estimate as a guide, answer the following questions about possible changes to Lafitte's Island.
  - a. How might some of the island's physical characteristics (amount of land, location and amount of salt and fresh water, type of weather) change?
  - b. How will plant species be affected?
  - c. How will animal species be affected?
  - d. How will the change affect recreation (swimming, sailing, picnicking, etc.) and tourism?

e. Will the fishing industry be affected? How?

f. Will Jean's community be more crowded than it is now? Why?

3. Using your responses to these questions plus any other ideas discussed in your group, write a description of Jean's daydream in the space provided below. At the end of the daydream, bring Jean back to the present, and relate what course of action could be taken in response to his/her futuristic thoughts.

4. Choose one person from your group to read Jean's daydream to the class. (If time permits, your group may choose to act out the daydream.)

**JEAN'S DAYDREAM**



## GEOLOGIC TIMETABLE

[with important events in earth and life history]

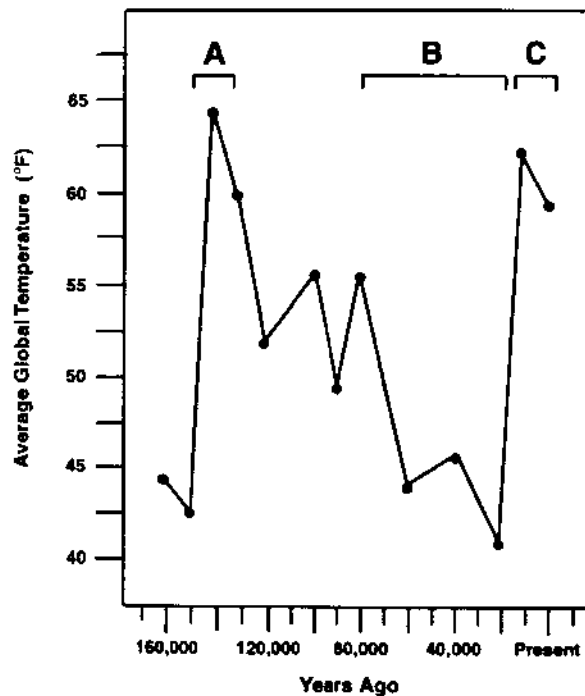
ERA	PERIODS AND EPOCHS	MILLIONS OF YEARS AGO	AVERAGE SURFACE TEMPERATURE OF OCEAN	GEOLOGICAL EVENTS	BIOLOGICAL EVENTS
<b>Cenozoic</b>	Quaternary				
	Recent	10,000 to present	15°C (59°F)	Last ice age ends	<i>Homo sapiens</i> spread over planet; many birds and large mammals
	Pleistocene	2	0-2°C (32-36°F)	Numerous ice ages	<i>Homo sapiens</i> evolve
	Tertiary				
	Pliocene	6	2°C (36°F)	Drastic cooling	Large extinction of early mammals
	Miocene	23	7°C (45°F)	Climate drying; cold	First hominids
	Oligocene	36	13°C (55°F)	S. America separates from Antarctica	Modern flowering plants; primitive apes
	Eocene	54	13°C (55°F)	Formation of Alps	Seed plants dominate
<b>Mesozoic</b>	Cretaceous	135	13°C (55°F)	Asteroid collides with earth; dust obscures sun	Massive extinction; dinosaurs die out
				Africa and S. America separate; seas over Europe	Dinosaurs reach peak
	Jurassic	197	13°C (55°F)	Continued mountain building; inland seas	Earliest angiosperms; first birds
	Triassic	225	8-13°C (46-55°F)	Continental drift begins (Pangaea breaks up)	Gymnosperms; first dinosaurs
	<b>Paleozoic</b>	Permian	280	1-8°C (34-46°F)	Very cool; glaciation; seas drain
Carboniferous		345	13°C (55°F)	Pangaea; lowlands, shallow seas	Coal age forests; first winged insects; Age of Amphibians
Devonian		405	11-13°C (52-55°F)	Appalachians forming; atmospheric oxygen stabilizes at present level	First seed plants; first amphibians; Age of Fishes
Silurian		425	11-13°C (52-55°F)	Flattened landscape	First terrestrial plants and invertebrates
Ordovician		500	10-13°C (50-55°F)	Sea level low	First vertebrates (fish)
Cambrian		570	0-10°C (32-50°F)	Steady increase in temperature	Algae and marine invertebrates dominate
<b>Precambrian</b>		1 billion years ago		Earth cooling (algae, fungi?)	Multicellular life
		2 billion years ago		Tropical climate	First eukaryotes
		3 billion years ago		Accumulation of free oxygen (O <sub>2</sub> )	Photosynthetic prokaryotes
		4 billion years ago		Oldest rock formation	Origin of life
		4.5-5.7 billion years ago		Chemical evolution	Organic synthesis

[Dates and events are based on a geologic timetable in *Biology the Science of Life*, second edition, by Robert A. Wallace, Jack L. King, and Gerald P. Sanders, 1996.]

## EVALUATION QUESTIONS

**MULTIPLE CHOICE:** Select the **BEST** answer for each statement.

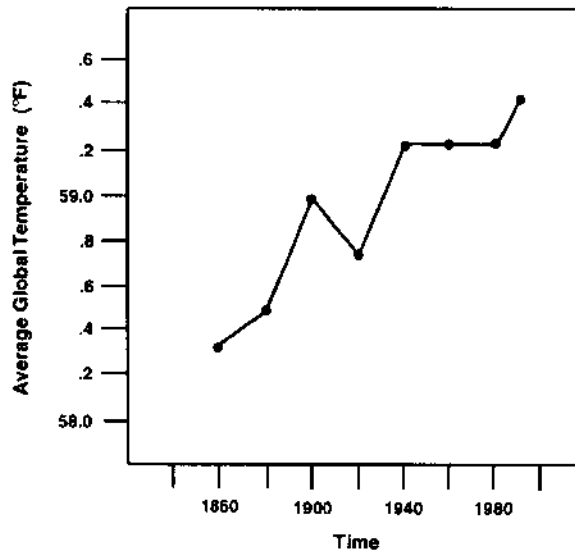
- The phenomenon that explains how certain gases trap heat in earth's atmosphere is called the  
  - hot house syndrome.
  - hydrologic cycle.
  - greenhouse effect.
  - thermal incline.
- Which area on the graph below represents a glacial (ice age) period?  
  - A
  - B
  - C



- Infrared radiation is  
  - felt as heat.
  - a type of solar radiation.
  - absorbed by greenhouse gases.
  - all of the above.
- Which of the following situations might cause the earth's climate to warm?  
  - Earth tilts on its axis away from the sun.
  - The amount of atmospheric oxygen increases.
  - The amount of carbon dioxide dissolved in the ocean increases.
  - Chlorofluorocarbon (CFCs) levels in the atmosphere increase.

5. Water vapor is considered a greenhouse gas because it
  - A. absorbs heat.
  - B. condenses to form clouds that, in turn, prevent some solar radiation from reaching earth.
  - C. is part of the water cycle.
  - D. combines with sulfur dioxide in the atmosphere to form sulfuric acid.

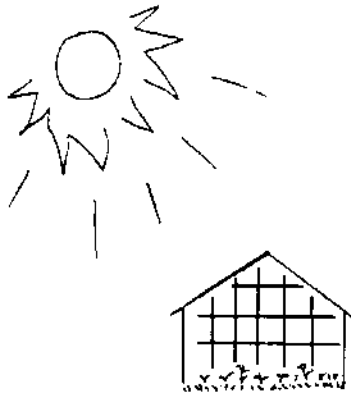
6. The graph below shows



- A. the greenhouse effect.
  - B. what the temperature will be in the year 2000.
  - C. an increase in the average global temperature during the last 100 years.
  - D. that global warming is being caused by an increase in atmospheric carbon dioxide.
7. Deforestation is the mass removal of trees from an area. Deforestation contributes to global warming by
    - A. reducing the amount of oxygen produced during photosynthesis.
    - B. increasing the amount of carbon dioxide released during respiration.
    - C. reducing the amount of carbon dioxide used by trees for photosynthesis.
    - D. increasing the amount of water vapor released into the atmosphere during transpiration.
  8. The layer of the atmosphere where weather — rain, snow, wind, hurricanes — occurs is called the \_?\_.
    - A. thermosphere
    - B. mesosphere
    - C. stratosphere
    - D. troposphere
  9. Ozone in the upper atmosphere protects the earth from the harmful effects of
    - A. ultraviolet radiation
    - B. visible radiation (light)
    - C. infrared radiation
    - D. radio waves

10. Which layer of the atmosphere contains the protective ozone shield?
- thermosphere
  - mesosphere
  - stratosphere
  - troposphere
11. Besides coal, another example of a fossil fuel is
- geothermal heat
  - wind
  - natural gas
  - sunlight
12. If used more often, which energy source listed below could help reduce the amount of carbon dioxide accumulating in the atmosphere?
- electricity
  - sunlight
  - gasoline
  - coal
13. The Gulf Coast mainland is protected from the full force of hurricanes by natural formations that form parallel to the shoreline. They are called
- barrier islands
  - levees
  - sea walls
  - spoil banks

Use the diagram and chart below as a reference in answering questions 14 and 15.



Time	Outside Temp. (°C)	Greenhouse Temp. (°C)
6 am	12	12
8 am	13	14
10 am	14	18
noon	17	22
2 pm	21	26
4 pm	19	24
6 pm	17	23

14. The highest temperature was recorded at
- noon, outside the greenhouse
  - noon, inside the greenhouse
  - 2 pm, inside the greenhouse
  - 2 pm, outside the greenhouse
15. At what rate did the temperature rise inside the greenhouse between 10 am and noon?
- 1 °C/hour
  - 2 °C/hour
  - 3 °C/hour
  - 4 °C/hour



## EVALUATION ANSWERS

### MULTIPLE CHOICE:

- |      |       |       |
|------|-------|-------|
| 1. C | 6. C  | 11. C |
| 2. B | 7. C  | 12. B |
| 3. D | 8. D  | 13. A |
| 4. D | 9. A  | 14. C |
| 5. A | 10. C | 15. B |

### SHORT ANSWER:

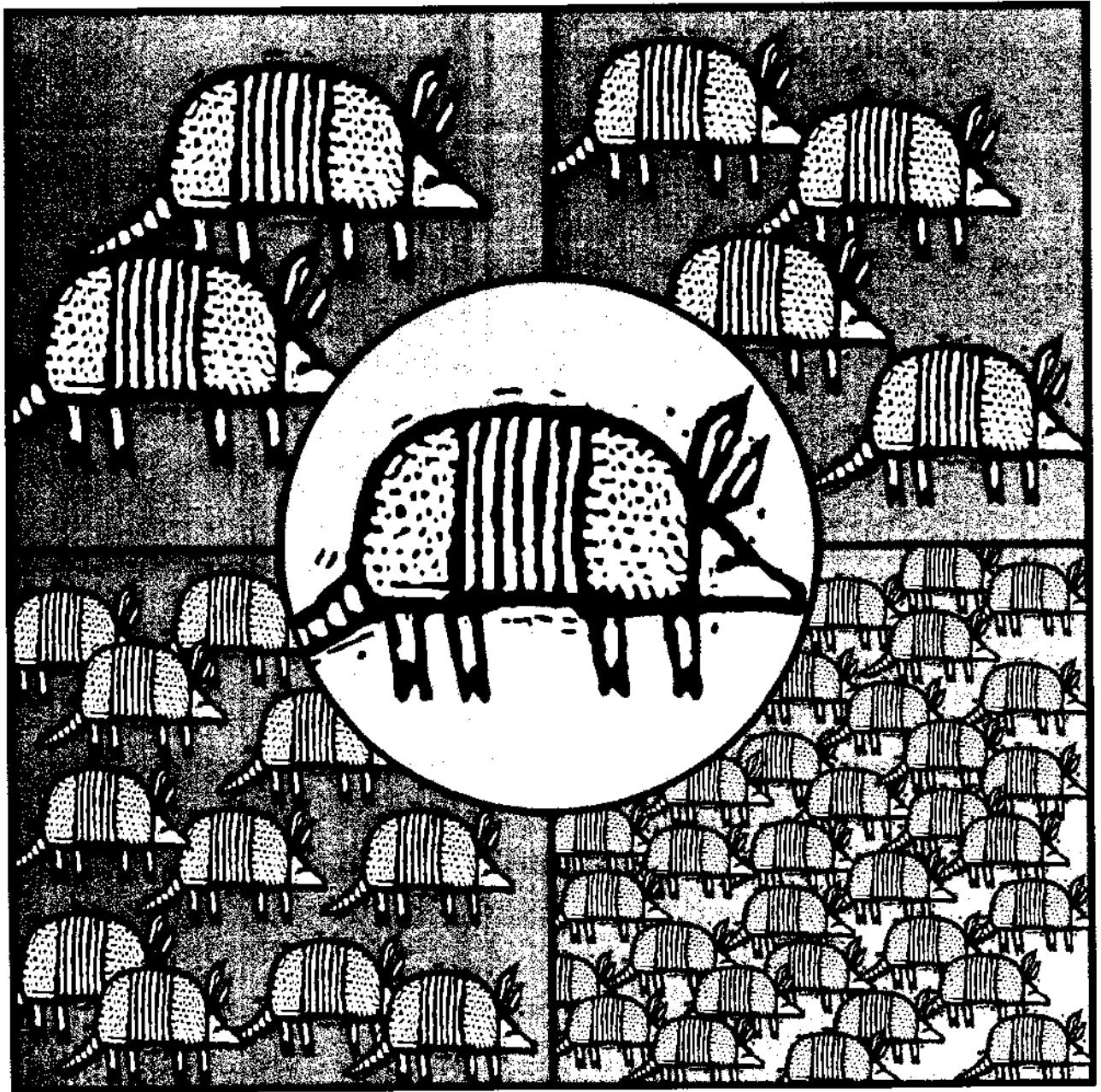
- Similarities between earth's atmosphere and a greenhouse include:
  - The glass (plastic) panels of a greenhouse and earth's atmosphere are both transparent to solar radiation (sunlight).*
  - Light that hits plants and soil in the greenhouse is absorbed and then emitted as infrared radiation; the same phenomenon occurs as light hits earth's surface, objects, and living things.*
  - The air inside a greenhouse is warmer than the air outside because infrared radiation is trapped inside by the glass panels of the greenhouse. In a similar way, the air around the earth is kept warm because carbon dioxide and other greenhouse gases absorb infrared radiation (heat), preventing its escape into outer space.*
- Possible consequences of global warming and climatic change include: (*Refer to Background Information for further explanation.*)
  - Sea level rise will cause flooding, loss of wetland habitats, and saltwater intrusion into drinking supplies.*
  - Severe weather may increase — tropical storms, hurricanes, winter storms, drought.*
  - More forest fires will occur during droughts.*
  - Agriculture patterns will change.*
  - Biodiversity will decline.*

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The following books, pamphlets, and journal articles were used in producing the "Climatic Change" module. Some of the resources are available to educators upon request or at a low cost; addresses of those resources are given in the reference citation.

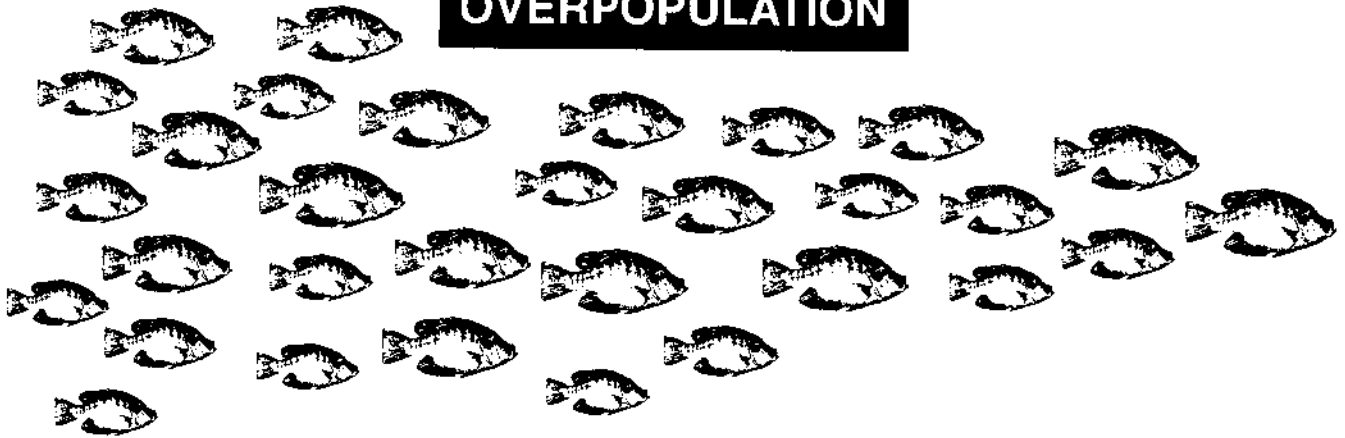
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# OVERPOPULATION



Project TELLUS: Interactive Science Videos on Global Change Issues

# OVERPOPULATION



## LEARNING OBJECTIVES

Students should be able to:

1. Name the living and nonliving components of an ecosystem and explain some interactions between them.
2. Recognize the earth as an ecosystem with finite resources.
3. Explain the impact of birth rate, death rate, and migration on population growth.
4. Explain the relationship between limiting factors and carrying capacity in a given habitat.
5. Distinguish between a population in dynamic equilibrium and one growing exponentially.
6. Correlate human population growth and overconsumption of earth's resources with other global change issues.
7. Cite actions that reflect a personal commitment to conservation and using earth's resources sustainably.

## INTRODUCTION

A scheme of checks and balances sustains life on earth. Through intracommunity relationships — competition, predator-prey, and symbiosis — and biogeochemical cycles, lifestyles of a huge variety of species are woven together to create a unified whole. However, just as a woven basket often has irregularities

in its design, so, at times, some species play havoc with nature's balanced design. Overpopulation is such an irregularity.

Through the previous *Project Tellus* lessons on global change issues, your students have learned of environmental problems occurring in the Gulf Coast region:

- Declining biodiversity.
- Upheaval in habitats caused by invasive exotic species.
- Deteriorating water quality in the lakes, rivers and estuaries.
- Anticipated sea level rise and climatic change.

All of these environmental problems stem from or are aggravated by two much deeper problems covered in this module on overpopulation, namely,

- The current exponential growth of the human population, and
- Overconsumption and waste of earth's resources, especially by people in developed nations.

The lessons on overpopulation will build on some concepts covered in previous lessons — populations, communities, food webs, predator-prey relationships, interdependence among species, and sustainable use — while it focuses on concepts central to understanding overpopulation — limiting factors, carrying capacity, dynamic equilibrium, and exponential growth.

Overpopulation is not a phenomenon restricted to the human species. It is recurrent in nature. The difference between human

overpopulation and overpopulation in other species, though, is that humans have been able, through ingenuity and the development of modern technology, to delay natural adjustment.

Other species are not so adept at modifying their environment. When their populations exceed the habitat's carrying capacity, disease, famine, and sometimes violence (cannibalism) occur to bring the population back into balance.

By examining overpopulation in Gulf Coast species other than humans, students will be able to understand the consequences that are possible if the human population continues to grow exponentially. They will also learn that the painful adjustments for overpopulation can be avoided if humans act now to stabilize population growth and use earth's resources sustainably.

The Background Information and Activity suggestions that follow will be helpful in discussing population concepts and issues prior to viewing the video and in guiding students toward logical and meaningful conclusions throughout the viewing and postviewing activities.

## BACKGROUND INFORMATION

### Everything Is Connected

Some say that the First Law of Ecology can be summarized in the statement "everything is connected to everything else." This truism is evident as one considers the number of interdependent relationships that occur within an ecosystem. The term **ecosystem** itself reflects connectedness for it is defined as a place where living (biotic) things interact with each other and with their nonliving (abiotic) environment.

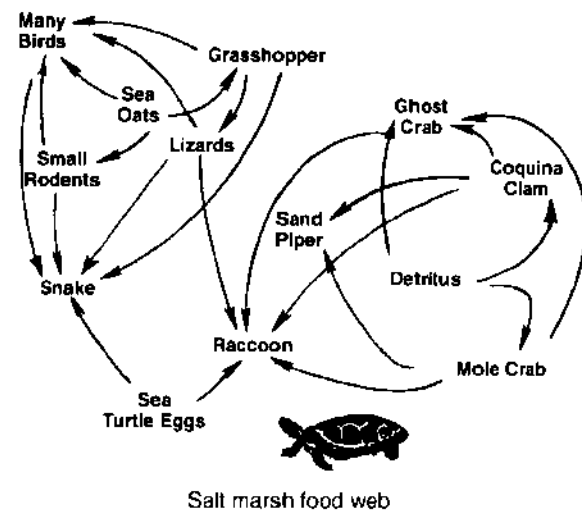
The organisms that inhabit an ecosystem can be separated into smaller groups called **species**. All the members of the same species that live in the ecosystem comprise a **population**, and the specific area where the population lives is called its **habitat**. All the various populations living and interacting in the ecosystem form a **community**.

Interactions in an ecosystem are of two types. One type occurs within or between species. The other type occurs between organisms (species) and the nonliving environment — air, water, minerals, weather, etc. These two


types of interactions provide a means for both survival and balanced population growth among the ecosystem's inhabitants.

Some community interactions include:

- *The transfer of the sun's energy from **producers** to **consumers*** —Photosynthetic plants and algae produce food using energy from the sun and inorganic materials (carbon dioxide and water) in the environment. **Herbivores** eat plants and they, in turn, are eaten by **carnivores**. Scavengers and decomposers (**detritivores**) eat or break down organisms after they die. These interconnected feeding relationships in an ecosystem form **food chains** and **food webs**. The energy transferred as food at each junction in the chain or web fuels the life processes (growth, reproduction, movement, etc.) in the consuming organism.



- *Predator/prey relationships* — One animal (the **predator**) kills and eats another animal (the **prey**). In this relationship the predator obtains food and the prey population is kept at a level the ecosystem can support.
- *Competition* — Members of the same species or different species vie for the same habitat needs — food, shelter, water, space, etc. Competition insures that those organisms most suited to the environment will survive and provide offspring for the next generation.
- *Symbiotic relationships* — Two different species live together in a close, long-term



association. A classic example of symbiosis is the algae-fungi association known as lichen; the fungus provides a moist place for the algae to live and the algae provides nutrition (food) for the fungus.

In some symbiotic relationships both species benefit (mutualism), in others one benefits at the expense or harm of the second (parasitism). In the third (commensalism) one species benefits and the other species is neutral — neither helped nor harmed. These relationships allow at least one of the participating species to live in an environment that would otherwise be inhospitable.

Some interactions between living things and the nonliving environment include:

- *Cycling of materials necessary for life* — water, oxygen, carbon, nitrogen, phosphorus, sulfur, etc. These cycles are called **biogeochemical cycles** because organisms (producers and consumers) interact with the air, water, and soil of earth to recycle the chemicals.
- *Use of solar energy* — Organisms use infrared radiation for heat and visible light for vision and photosynthesis.
- *Use of water* — Water is a major component in cells and is a transport medium in all organisms. Surface water (lakes, rivers, estuaries, etc.) provides habitat for many species.
- *Intake of oxygen from the air or from the water* — Most organisms require oxygen to chemically break down food to release energy for life processes.

Generally, the earth is considered a closed system, so the substances that are vital for life are **finite** — in limited supply. That means that all the matter that will ever be on the earth is here now; no material is being created, and none is being destroyed; it is merely changing form (the Law of Conservation of Mass) as it cycles from elements to organisms then, through decomposition, back to elements.

Some of the interactions previously described insure that these finite substances are recycled and reused generation after generation.

The concepts of finite resources and interconnectedness among species are pivotal in understanding the impact of overpopulation on an ecosystem. When more resources are used by one group, less are available for other organisms and for the nonliving part of the environment.

Since everything is interconnected, if one part is depleted, weakened, or missing, balance is lost and the entire ecosystem suffers. Limiting factors generally keep each species' population growth in check.

### Growth Patterns in Nature

The growth rate of a population is determined by three factors — birth rate, death rate (mortality), and, if the organisms are mobile, migration.

**Birth rate** is the number added to the population through reproduction during a year per 1000 individuals. **Death rate**, is the number that die in a population during a year per 1000 individuals.

For most animal groups, **migration** (the movement of individuals into or out of the population in a given area) also affects population size. A population of raccoons, for example, may be increased by individuals moving into the habitat from another place — immigration — or decreased by individuals leaving the habitat — emigration.

High birth rates and immigration serve to increase a population while high death rates and emigration reduce population size.

Additionally, a number of habitat conditions affect birth rate, death rate, and migration. These **limiting factors** in a habitat (which often hinge on the interactions listed in the previous section) help keep population sizes in check — equal to what the habitat can support with its resources. They include the amount or type of:

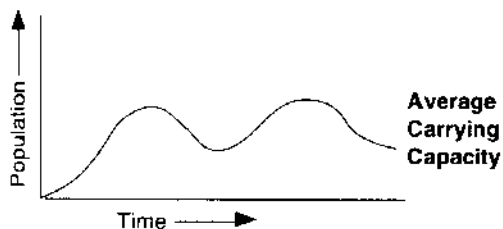
- nutrients (food)
- fresh water
- living space
- minerals

- interactions with other organisms (predation, competition, and symbiosis)
- climate and weather (precipitation, temperature, wind, and weather events such as hurricanes, tornadoes, and floods)
- disease

Population size is dynamic (continually changing) as limiting factors in the habitat change from season to season and year to year. When habitat conditions are favorable for growth, a population increases, but when food, water, and space begin to grow scarce, or adverse weather conditions occur, death rate increases and the population size declines. Once the habitat recovers, a period of growth begins again.

Limiting factors determine the **carrying capacity** of a habitat — the maximum number of individuals the habitat can support. Generally, a species' population size fluctuates (rises and falls) as the carrying capacity varies.

A population that shows this fluctuating pattern around the average carrying capacity of the habitat is said to be in **dynamic equilibrium** (changing but balanced) with its environment.



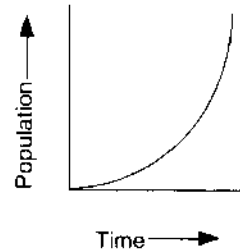
Growth pattern for a population in dynamic equilibrium with the environment.

A different growth curve forms when a population is not being affected by limiting factors. Because nothing impedes its growth, birth rate is high, mortality is low, and the number of individuals in the population increases by a large percentage each generation.

**Exponential growth** is similar to the growth of money earning interest in a savings account. The base amount grows by a certain percentage each time the interest is compounded. Although the initial amount may be small, and growth may be slow at first, over

a period of time, the sum in the account grows quite large, if no money is withdrawn.

The graph of a population growing exponentially slowly begins to curve upward then suddenly bends and goes straight up to form a J-shape.



Applying that analogy to a population, consider that a pair of field mice migrate into a meadow where there are no other mice and no mouse predators — snakes, hawks, cats, etc. Food is abundant and places to find shelter for protection and nesting are plentiful.

At first, the population increases from the offspring of the pair alone. (*Field mice generally produce 6 babies per litter and may have up to 17 litters per year — that's potentially 102 baby mice in one year from one pair!*) But, once offspring begin to reach reproductive maturity (between two to three months after birth), and have litters of their own, the number of mice quickly swells. By the end of a year, the population would be in the thousands and the meadow would be overrun with mice!

Examples of exponential growth in populations include:

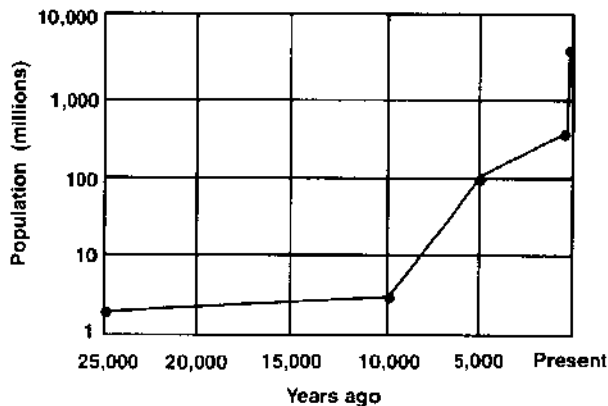
- mold growing on a piece of bread
- weeds growing in a newly plowed field
- an exotic species in a habitat where resources are abundant and predators are few (zebra mussels and nutria)
- the current worldwide growth of the human population

Ultimately, all populations are controlled by some limiting factor because the resources in any habitat are finite. When the number in a population exceeds the carrying capacity, famine, starvation, disease, and violence may result in a decline or crash of the population.

Unfortunately, the natural corrective action sometimes comes after much damage has been inflicted on the habitat by the population growing out of control. The current exponential growth and overconsumption of resources by the human population is a case in point.

### Human Population Growth and Overconsumption

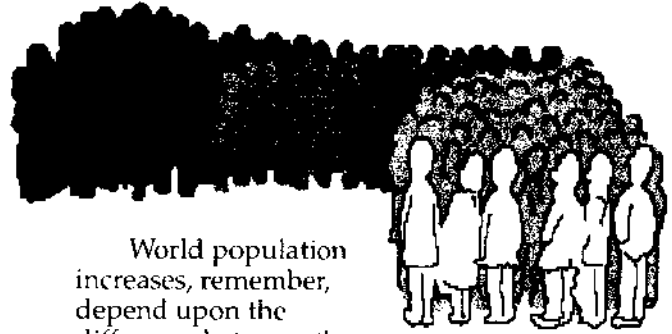
The growth curve for *Homo sapiens*, modern man, reflects the classic exponential pattern. It is estimated that 25,000 years ago humans may have numbered about three million. Over the next 15,000 years (until the end of the last ice age, about 10,000 years ago), population growth was slow (indicated by the gentle slope upward in the human population graph). The estimated human population 10,000 years ago was about five million. However, the population has increased at an accelerated rate since that time — 5,000 years ago it reached 100 million and by 1850 AD it was one billion.



About two hundred years ago the human population's growth pattern began to turn straight up forming the characteristic J-shaped exponential curve.

- By 1930 the world population had doubled to 2 billion.
- By 1975 (45 years later) it had doubled again to 4 billion
- In 1995 the population was 5.7 billion.
- At the present growth rate of 1.7% per year, the human population is expected to reach 6 billion by the turn of the century.

The reasons for this change from slow, stable growth to exponential growth are written in the social and economic history of man.



World population increases, remember, depend upon the difference between the number of births and deaths (if the birth rate is higher than the death rate, the population increases; if the opposite is true, the population decreases). Limiting factors in the environment influence both the birth rate and the death rate.

*Homo sapiens* of 25,000 years ago lived as nomadic hunter-gatherers. Weather conditions were harsh (ice age) and the availability of food varied seasonally. Poor nutrition and disease resulted in high death rates that kept the average life span at about 28 to 30 years.

Birth rates, on the other hand, were low. Studies suggest that females in primitive hunter-gatherer societies did not reach child-bearing age until 19 or 20. Children were breast-fed for three or four years, and during that time, the women did not ovulate. This increased the interval between children and therefore reduced the birth rate. Since birth rates and death rates were about equal, the population grew slowly for 15,000 years.

Approximately 10,000 years ago, *Homo sapiens* began to raise animals and grow crops; agricultural communities replaced hunter-gatherer societies. With this change came improved nutrition, longer life span, and higher birth rates. The population curve began to turn upward.

Growth rate increased steadily until about 200 years ago when the Industrial Revolution together with advancements in science and medicine drastically changed human society and its relationship to nature.

- People began to leave the farm and cluster in cities to work in factories; in industrialized nations, a more affluent middle class developed.
- Communication and transportation advancements allowed the sharing of ideas and goods.
- The cause of disease was discovered and vaccines and antibiotics were developed to

control or eliminate once fatal diseases — small pox, diphtheria, tuberculosis, etc.

- Improved agricultural practices — the use of commercial fertilizers and pesticides and the invention of modern farm equipment — increased food productivity. Human nutrition improved and fewer died from famine and starvation.
- New methods of solid waste disposal and sewage and water treatment provided better sanitation and living conditions.

These examples represent a few of the advancements in science and technology that have improved human living standards, driving the birth rate up (less infant mortality) and the death rate down (increased life span). The increased difference between birth and death rates has, in turn, accelerated the population growth rate of the last 200 years.

Fortunately, the need to reduce population growth has been recognized by people and governments worldwide. Population statistics are beginning to show decreased birth rates in most countries.

**Overpopulation**, however, is more than just a problem of too many individuals. These individuals are living longer and, therefore, placing an increased demand on the earth's finite resources by consuming more food, water, materials for shelter, and fossil fuels.

Plus, humans now use resources for things other than subsistence. For example, grain, the basic ingredient in bread, is also used to make snacks, fuel, and pet food, while oil, the basic ingredient in gasoline, is also a major ingredient in plastics and synthetic fabrics.









Although the rate of population growth in some nations has begun to level off (and in some cases decline), the rate of consumption is still growing exponentially. People in **developed (industrialized) countries**, especially the United States, are consuming a disproportionate share of the resources. A child born into a middle-class American family, for example, will consume in his or her lifetime twice the amount of food and five times the amount of energy as a child born into an average family in a **developing (non-industrialized) country** such as India.

Both problems, rapid population growth and overconsumption, are causing stress on earth's life support systems — biogeochemical

cycles, food webs, ozone protection. As the human population increases, demand for earth's resources of water, food, materials to build shelter, fossil fuels, minerals, and space also increase.

With the increased use of these resources, more pollution occurs, more habitat becomes degraded or destroyed, and more opportunistic species dominate at the expense and decline of the less aggressive species.

These forms of stress are evidenced by the environmental problems discussed in previous *Project Tellus* modules:

- *Declining biodiversity* — caused by habitat degradation from pollution, deforestation, residential and commercial development, wetland drain-and-fill projects, and the introduction of exotic species. 
- *Ozone depletion* — from the release of chlorofluorocarbons used to make products such as Freon and foam packaging. 
- *Depletion of aquifers* — as groundwater is pumped for crop irrigation, industrial use, and human consumption faster than it can be renewed through the water cycle. 
- *Pollution of surface waters* — due to fertilizers, pesticides, and toxic substances from agricultural, residential and industrial runoff and dumping. 
- *Air pollution* — from the burning of fossil fuels in vehicles, factories, and power plants. 
- *Possible global warming and climatic change* — from the excessive release of heat-trapping greenhouse gases into the atmosphere. 
- *The erosion of soil and depletion of its nutrients* — through poor management of agricultural and forested areas. 
- *Overfishing, overhunting, and overgrazing* — as demands for food and recreation increase, the world's oceans, forests, and grasslands are depleted. 

## Managing Population Growth and Consumption

Continued population growth and overconsumption have placed man on a collision course with limiting factors in nature. Some **demographers**, people who study population dynamics, predict that the earth's simple carrying capacity for humans (maximum number for which it can meet basic needs) is between 10 and 14 billion.

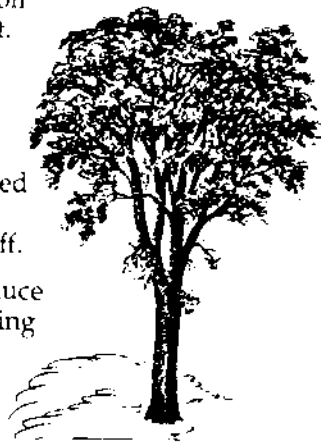
However, if the planet is stressed with 5.7 billion people, what will be the impact of twice that number? What will the living standard for humans be like with that many people competing for resources?

If humans are truly wise, as our species name, *sapiens*, implies, then we must each

- recognize the limits imposed on all of us by exponential human growth.
- encourage people to slow population growth.
- manage our resources sustainably.

Individuals can help sustain resources by reducing waste and overconsumption. As consumers, they must make conscious choices to:

- Buy reusable products rather than disposable ones.
- Reuse or recycle packaging items such as wrapping paper, grocery bags, ribbon, etc.
- Buy products made from recycled materials.
- Try to drive less. Plan meals and other household needs to avoid multiple trips during the week to the supermarket; walk, bike, or carpool as much as possible.
- Compost yard clippings to produce garden soil rather than buying it.
- Use water wisely, without waste.
- Use pesticides and fertilizers as instructed on the packaging to avoid excess in runoff.
- Think of ways to reduce energy used for cooling and heating. Plant trees to shade property and help reduce cooling costs.



- Wear extra clothes when it is cold so the thermostat can be set lower in the house, at school, and at work.
- Before buying, ask the question, "Do I need this, and will I use it, or do I just want it?" Practice buying more of what is needed and less of what is simply desired.

*Homo sapiens*, just like any other species, are subject to limiting factors in the environment, but they have some power to manipulate those factors. This power can be used to sustain life on earth at a comfortable level, or it can result in a decline in the quality of living conditions.

Life as we know it could end if people do not take steps to conserve resources. It also could end if the exponential increase in population worldwide is not recognized and controlled. If waste and consumption are replaced by conservation and wise use, existing resources can support the *Homo sapiens* population for this and future generations.

## TEACHING SEQUENCE

### DAY 1 Previewing Questions and Answers



1. Divide the class into cooperative learning groups and have them answer/brainstorm the Previewing Questions given on page 10. [20 minutes]
2. Discuss student responses. Emphasize the meaning of the following vocabulary terms during the discussion: ecosystem, species, population, community, producers, consumers, detritivores, competition, predator/prey relationships, symbiotic relationships, and habitat. [20 minutes]
3. **Collect the previewing questions and answers; question # 4 will be the basis for a class discussion at the end of the module.** [5 minutes]

### DAY 2 Begin the Video and Do Activity I

4. Watch the video until instructed by the narrator to pause for Activity I: Rats and Armadillos in a Salt Marsh Habitat. [10 minutes]

5. Set the stage for this activity by telling the students a little about the natural history of each species (Teacher Instructions pages 15-16). [5 minutes]
6. Follow the procedure outlined in the Teacher Instructions (numbers 4-6) to clarify terms, review graphing skills and explain the activity. [15 minutes]
7. Have students work independently to complete the graph on page 20 and answer the Summary Questions. (*The questions may be assigned for homework, if time runs short.*) [20 minutes]

**DAY 3** Discuss Summary Questions to Activity I, Watch Video, and Begin Activity II

8. Discuss the population growth patterns and the answers to the Activity I Summary Questions. [15 minutes]
9. Watch the video until instructed by the narrator to pause for Activity II: 'Beat Ya' To the Beads. [5 minutes]
10. Do Extension #1 (pages 12-13) to emphasize the finite nature of earth's resources. This may be done as a demonstration or as a teacher-guided group activity. [10 minutes]
11. Explain the procedure for the game, Beat Ya' to the Beads and play GAME 1.
12. Have the students complete the Summary Questions to GAME 1 for homework.

**DAY 4** Discuss Summary Questions to GAME 1 and Complete Activity II

13. Discuss the Summary Questions for GAME 1. [10 minutes]
14. Introduce and play GAME 2. [15 minutes]
15. Allow time for the students to answer the Summary Questions. [10 minutes]
16. Discuss the Summary Questions. [10 minutes]
17. Assign each student a term from the Vocabulary section (pages 9-10). For homework, have them draw and color a scene that represents the term. [5 minutes]

**DAY 5** Continue the Video, Discuss Human Population Growth, Do Postviewing Questions

18. Allow time for the students to show and explain their drawings depicting the vocabulary terms. Clarify any misconceptions regarding the meanings. [15 minutes]
19. Watch the remainder of the video. [10 minutes]
20. Using a transparency of the Human Population Growth Curve (page 29), explain reasons for the exponential growth of the human population since the beginning of the Industrial Revolution. (*Refer to the Background Information on pages 5-6.*) [10 minutes]
21. Have students work in small groups to answer the Postviewing Questions. [10 minutes]
22. Discuss answers to the Postviewing Questions. [15 minutes]

**DAY 6** Show and Discuss the Film *World Population*

23. [OPTION] Show the 4 minute film, *World Population* (*See Extension #5 on page 14.*) Discuss the need:
  - for becoming a sustainable society
  - to reduce waste and overconsumption
  - to reduce population growth [20 minutes]
24. At the teacher's discretion, the Evaluation section (pages 30-33) may be assigned or used to accompany the next unit test. There are additional activities in the Extension section (pages 13-14) that may be used for further study.

## VOCABULARY

The following terms are used at various times throughout the module. The definitions should be adapted to suit the students' grade level.

- Biogeochemical cycles:** A repeating sequence of events occurring between organisms and the physical environment (soil, water, air) as elements and compounds move from the physical into the biological and back to the physical environment. For example, in the carbon cycle, plants use carbon dioxide from the air and water from the soil to produce food (glucose). When the plant dies and decomposes, the carbon dioxide and water are returned to the air and soil, and are available for reuse.
- Birth rate:** The annual number of births per 1000 individuals in a population.
- Carnivores:** Animals that eat other animals (meat-eating).
- Carrying capacity:** The point at which an ecosystem can no longer support additional members of a species with the food, water, shelter, and space they need to survive.
- Community:** All the organisms — plants, animals, fungi, and microbes — living in the same area during a particular time.
- Consumers:** Organisms — animals, fungi, and bacteria — that ingest other organisms to obtain food.
- Death rate:** The annual number of deaths per 1000 individuals in a population.
- Deforestation:** The removal of all or most of the trees in a forest or wooded area.
- Demography:** The study of populations, their characteristics, and what happens to them over time.
- Detritivores:** Organisms — scavengers and decomposers — that eat dead or decaying organic matter (dead leaves, roots, carcasses, and feces).
- Dynamic equilibrium:** Population size fluctuates but is in balance with the habitat's average carrying capacity.
- Ecosystem:** An area where living things interact with each other and with their nonliving surroundings. Substances essential for life such as oxygen, water, and nitrogen are cycled, and energy flows from producers through consumers.
- Exotic species:** Foreign plants, animals, or microbes that are introduced to a habitat.
- Exponential growth:** Rapid, uncontrolled growth in a population. The growth pattern produces a J-shaped curve, when graphed.
- Finite resources:** Substances such as water, soil, minerals and air that are in a fixed or limited supply. These resources can be recycled and reused, but none can be created.
- Food chain:** The organisms involved in a flow of energy from producer through consumers. (Producer — Herbivore — First Carnivore — Top Carnivore)
- Food web:** The complex, intertwining feeding relationships among the organisms in an ecosystem. It includes producers, herbivores, carnivores, and detritivores.
- Habitat:** The area where a particular species lives. It provides all the species' requirements for life — water, food, shelter, and space.
- Herbivores:** Animals that eat plants.
- Industrialized (developed) countries:** Nations with advanced economies and social structures that provide for most people's basic needs (clean water, food, shelter, space) and have available health and welfare services. (The U.S., Japan, Canada, Australia, New Zealand, and most European countries are examples.)

**Limiting factors:** Conditions in a habitat which control the rate at which population size changes. (Availability of food, pollution, adverse weather conditions, disease are examples.)

**Migration:** The movement of individuals into or out of an ecosystem.

**Non-industrialized (developing) countries:** Nations with agricultural and small manufacturing economies that are striving to provide for most people's basic needs (clean water, food, shelter, space). Health and welfare services are available only to a few at the top of the economic and social ladder. (South Africa, Kenya, Asia, Mexico, and many Latin American countries are examples.)

**Overpopulation:** When a population's size exceeds its habitat's ability to supply enough water, food, shelter, space, or other requirements for survival.

**Population:** All members of the same species living in particular area during a specific time.

**Predator/prey relationships:** One animal serves as food for another animal. The predator kills and eats the prey.

**Producers:** Organisms that make their own food (autotrophs).

**Species:** A group of similar organisms that interbreed in nature to produce fertile offspring.

**Sustainable use:** Using earth's renewable resources in a way that will neither alter nor reduce their availability for future generations.

**Zero population growth:** When growth stabilizes in a population because the number of births equals deaths.

## PREVIEWING QUESTIONS AND ANSWERS

1. An ecosystem is an area where living things (plants, animals, microbes, etc.) interact with each other and with their nonliving environment (water, air, minerals, soil, etc.). All the members of a particular species living in an ecosystem at the same time make up a population. All the different populations in the ecosystem combine to form a community.

a. Name ten different populations you would expect to find in a pond ecosystem of the Gulf Coast region. Be as specific [common names] as possible.

Answers will vary. Encourage students to include producers, herbivores, carnivores, and detritivores. For example: *bald cypress trees, algae, duckweed, water lilies, snails, grass shrimp, dragonflies, mosquitoes, minnows, perch, catfish, bass,*

*water moccasins, diamond-back water snakes, bullfrogs, salamanders, common egrets, great blue herons, wood ducks, nutria, muskrats, raccoons, crawfish, and bacteria.*

b. Describe some interactions that might occur between these populations.

- *Food interactions — Snails eat algae, perch eat snails, raccoons eat perch, bacteria decompose all of these organisms after they die.*

- *Competition — Members of the same species compete with each other for food, hiding and nesting spaces, and mates. Sometimes members of different species compete for the same food, space, and shelter — egrets and blue herons both eat fish, frogs, snakes and crawfish.*

- *Cooperation — Some species provide shelter for other species — wood ducks nest in cypress trees.*

- c. Name some ways that the nonliving environment (soil, water, air, climate) and the living environment interact.

Answers will vary. Encourage students to think back to previous *Project Tellus* modules for answers.

- *Plants and algae use carbon dioxide, water and minerals from the pond to make food (photosynthesis).*
- *Most organisms take in (breathe) oxygen from the air or water.*
- *Plants release oxygen into the water and atmosphere during photosynthesis.*
- *Solar energy provides light for photosynthesis and infrared radiation to warm the earth.*

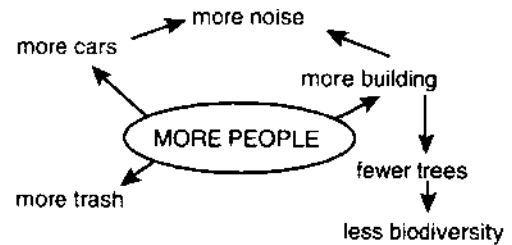
2. Name at least four resources or conditions that a habitat must supply for plants and animals to survive. What would happen if any one of these resources or conditions became depleted through overuse or degraded through pollution?

Answers should include some of the following: *food, water, space, oxygen, places for shelter and hiding (for animals), light and soil minerals (for plants), suitable climate.*

*If a condition required for survival was depleted, fewer individuals could survive. If the resource (air, water, soil) was degraded, the species would either die out, become weak, or if mobile, migrate to a new location where conditions were better.*

3. Consider the following scenario. A large ship-building company plans to build a factory on some land along the river just outside your town. A thousand new families will be moving into the area. How will these changes negatively affect your community? (Consider social, economic, and environmental effects.)

Write "more people" on the chalkboard then have students offer ideas about how life in the town would change. Use arrows pointing away from the central theme "more people" to list the ideas on the board. If one effect is an outgrowth of another, link the two with an arrow as shown:



Answers are numerous some suggestions are:

- more noise
- more trash
- more traffic
- more pollution
- less available housing
- fewer trees
- less animal habitat
- more crime
- dirtier water
- crowded schools in the fall
- more building
- crowded recreational sites

4. List 10 things you would like to have, to be, or to have done by the time you are 30 years old.

Answers will vary. List some of the student responses on the board. Tell students that they will have a chance to add to or take away from the list at the end of the module.

**Collect the previewing questions and answers; question # 4 will be the basis for a class discussion at the end of the module.**

## POSTVIEWING QUESTIONS AND ANSWERS

1. Ground level ozone is emitted from industries and vehicles that burn fossil fuels. This type of pollution interferes with photosynthesis in plants — when ozone levels are high, plant growth decreases. How would a reduction in plant growth affect other parts of a food web?

*Fewer plants would be available for herbivores, therefore there would be less prey for predators (carnivores). All populations in the habitat would decline because all are directly or indirectly dependent on the energy stored in the food that plants make.*

2. Name some ways that the human population has negatively altered earth's environment.

Responses will vary. The following are a few suggestions.

- *Habitats have been degraded and lost due to industrial, residential and agricultural development in areas that were previously forest, wetlands, meadows, etc.*
  - *Exotic species have been introduced that out-compete native species for food, space, and shelter, thus weakening the established ecosystems. (Argentine fire ants, nutria, zebra mussels, kudzu, and water hyacinths)*
  - *Water pollution from industrial, residential, and agricultural runoff has led to the decline of many aquatic and marine species.*
  - *Overconsumption of groundwater for irrigating crops, industrial uses, and residential purposes has led to water shortages and depleted aquifers in some areas of the world.*
  - *The excessive emission of greenhouse gases is possibly causing the current worldwide warming trend.*
3. How have industrialization and human population growth caused the environmental problems mentioned in question #2?
- *As the human population grows, people require more of the earth's supply of water, food, space, and shelter. This reduces the amount available for other species and, therefore, leads to declining biodiversity.*
  - *Because transportation between continents is common, exotic species find their way into foreign habitats more easily.*
  - *The amount of pollution from industry, agriculture, and residential areas increases as the population grows.*
  - *More people means more burning of fossil fuels to supply energy for transportation, manufacturing, and agriculture. This increases greenhouse gases in the atmosphere.*
4. Discuss question #4 from the Previewing Questions.
- *Return the Previewing Questions and Answers to the students and allow a few minutes for students to revise their aspirations (add or take away).*

- *Draw 3 columns on the board.*
- *List the student responses in the first column and tally the results for each suggestion in the second (the number that want a car, VCR, stereo, TV, boat, home, children, wealth, health, a degree from college, to eat dinner out every night, travel to foreign countries, etc.)*
- *Have the class decide whether each response is a "want" or a "need." Write the consensus in the third column.*
- *Have each student identify three "wants" from the list that s(he) would be willing to do without in order to become less consumptive. Encourage them to refrain from those three consumptive behaviors during the coming week.*

## EXTENSIONS

### 1. "Earth: the Apple of Our Eye" — modeling the earth's finite land resources:

- Show your students a globe or a poster of the earth in space. Emphasize that the earth is a closed system (*with the exception of solar energy, everything is contained within the boundary of earth's atmosphere*) with finite resources (water, soil, minerals, and air are in a limited supply).
- Tell the students to think of the earth as an apple.
- Using a kitchen knife, cut a large apple into quarters. Set aside three of the quarters and ask, "What do you think the three quarters represent?" (*Oceans cover three-fourths of the earth's surface.*)
- The fourth quarter represents all the land area of the earth. Cut this "land" in half and set aside one of the pieces. The part set aside represents all the land on earth that is inhospitable to humans — polar areas, deserts, very high or rocky mountains. Ask, "What fraction of the whole apple (earth) is left?" ( $1/8$ )

*This  $1/8$  portion represents the land where people can live, but only part of the land can be used to grow food.*

- Cut the 1/8 piece into four sections. Set aside three of these pieces and ask, "What fraction of the apple (earth) is left?" (1/32)

Ask students to suggest what the other 3 pieces represent. *(They represent areas that are too rocky, wet, cold, steep or with too poor soil to produce food. They also represent the cities, highways, shopping centers, schools, parks, factories, parking lots, and other places where people live but do not grow food.)*

- Carefully peel the 1/32 slice of apple. Show the students the very small, thin peeling. It represents the thin layer of earth — less than five feet deep — upon which humans depend for growing food.

Agricultural advancements — fertilizer, pesticides, machinery — have enabled the world to feed many of its people. But, with a fixed land resource and an ever-increasing number of people to feed from that land base, each person's portion becomes smaller and smaller as the population grows. Additionally, the land can be made unusable through pollution and erosion. Because earth's land, water, and air are finite, it is essential to protect them from pollution and overconsumption.

[Adapted and reprinted with permission from *For Earth's Sake: Lessons in Population and the Environment*, Zero Population Growth, Inc., c 1989. 1400 Sixteenth Street, NW Suite 32, Washington, DC 20036]

2. **Compare developed (industrialized) and developing (non-industrialized) countries:**

Network with social studies teachers to have student groups research and compare two different countries — one industrialized the other non-industrialized.

- Divide the class into groups.
- Have each group research and write a report comparing the resources and living conditions (availability of food, clean water, housing, clothes, medicine, education, and employment) in two countries — one a developing (third-world) country and the other a developed (industrialized) country.

(See Vocabulary definitions for examples in each category.)

- Have them conclude the report by suggesting ways that developed countries can help developing countries advance their standard of living.
- Have each group present their findings to the class.
- Allow time for the class to discuss the pros and cons associated with the suggestions for helping developing countries — money, technology, tax breaks on their exports, services provided by government (Peace Corps), religious, or private agencies.

3. **Ways to "reuse:"** Many household items, which are usually thrown away, can be reused. Reusing these items helps decrease overconsumption by reducing the demand for newly manufactured items.

- Have the class brainstorm ways to reuse each of the items below. Encourage them to be creative — no suggestion is too absurd. Ask them to suggest other items for the list.

plastic containers and lids from foods  
 such as yogurt and margarine  
 coffee cans and lids  
 baby food jars and lids  
 35mm film canisters and lids  
 toilet paper rolls  
 paper towel rolls  
 paper bags  
 plastic shopping bags  
 shoe boxes  
 small boxes with covers  
 popsicle sticks  
 ribbon, yarn, string  
 rug scraps  
 cardboard oatmeal boxes  
 clay or plastic flowerpots

- Encourage the students to begin a reduce, reuse, recycle, repair campaign in their homes.

4. **Math:** If the world's human population is 5.7 billion (1996), and it is growing at an annual rate of 1.7%, by how many will the population increase next year?

(5,700,000,000 people  $\times$  0.017 = 96,900,000 = 96.9 million additional people)

5. **Population explosion:** It took from the beginning of human history until 1960 for the world population to reach three billion. In less than 40 years that number has almost doubled to 5.7 billion. The human population is growing exponentially (increasing at an accelerated rate from year to year). The 4 minute video entitled *World Population* powerfully illustrates the human population's growth and distribution from 1 A.D. to the year 2020.

After watching the film, have the students discuss ways to reduce the growth rate of the human population to attain zero population growth. (The *Project Tellus* team is **NOT** advocating the following measures, but merely preparing the teacher for ideas that students may mention — pros and cons should be discussed for any suggestion.)

- medical means
- adjusting religious doctrines concerning family planning
- government restrictions on the number of births allowed per family
- adoption as an alternative to childbearing

[The 16 mm film or 1/2" VHS video can be obtained by contacting Zero Population Growth (ZPG), 1400 16th Street NW #320, Washington, DC 20036. The cost is \$29.95 plus \$3.00 for postage and handling. The film is often available through county, parish, or regional school board libraries.]

6. **Prepare a newsletter:** Have students work in groups to compile a newsletter reporting on the effects of human population growth on natural resources in your state (or the Gulf of Mexico region). Each student in the group will be responsible for researching and writing an article reporting on one of the following:

- water shortages
- water pollution
- habitat loss
- declining biodiversity
- climatic change
- air pollution
- deforestation

The newsletter may also include advertisements, cartoons, an editorial, diagrams, and graphs.

If your school has a computer lab and access to a desktop publishing program, network with the computer teacher to have the students format the newsletter in the computer lab.

Display the newsletters in a prominent place (*school library, front hall, cafeteria, etc.*), so the entire student body, faculty, and administration will be impacted by the news.

## ACTIVITY I

### RATS AND ARMADILLOS IN A SALT MARSH HABITAT

(Teacher Instructions)

#### Objectives

- To plot and interpret graphs of two animal populations.
- To compare a population changing in dynamic equilibrium with one growing exponentially.
- To describe factors that may limit population growth.

#### Description

This activity is based upon a hypothetical but believable situation in a Gulf Coast salt marsh habitat. The purpose of the activity is to demonstrate that populations living in the same geographical area during the same 10-year period may show different growth patterns due to differing sets of limiting factors. Students will plot population data on two species — marsh rice rats and nine-banded armadillos. The graph of the rat population will show a population in dynamic equilibrium (changing but balanced) while the armadillo graph will show a population growing exponentially. Students will use the graphed results, background information in their instructions, and teacher input, to answer questions and make inferences concerning the two populations.

The following information on the two species will be helpful in guiding students toward logical inferences.

#### Background Information

The Gulf Coast's salt marsh ecosystems provide valuable habitat for numerous species. Among the inhabitants of this grassy, wet environment are populations of marsh rice rats (*Oryzomys palustris*) and nine-banded armadillos (*Dasypus novemcinctus*).

The marsh rice rat is a small-sized rodent with populations well established throughout

the Gulf Coast states. As their common name implies, they prefer grassy, wet areas such as marshes, ditches, fields with damp soil, and edges of lakes and streams. They feed on aquatic plants, seeds, insects, and crustaceans such as small crabs.

As with most rodents, these rats are reproductively aggressive. A female reaches sexual maturity approximately 50 days after her birth. After that time, she may have up to seven litters per year, averaging four to five babies per litter. Although prolific, rice rat populations are generally kept in check by their numerous predators — owls, hawks, and water snakes. Because of the high rate of predation, the average life span for a rice rat is approximately one year.

Compared to the well-established marsh rice rats, armadillos are newcomers to the Gulf Coast states. The nine-banded armadillo (the only species of armadillo in the United States) migrated into Texas from Mexico about 100 years ago. By the 1940s, the species had expanded its range eastward to the Mississippi River, and today has spread into Florida.

The body of an armadillo is protected by hard, bony plates arranged in bands that slide against each other. Armadillos are primarily nocturnal, and when seen, appear to be completely preoccupied, nosing through leaves and debris in search of favorite foods — spiders, beetles, ants, snails, slugs, and earthworms. (Armadillos are also known to kill and eat poisonous snakes.)

Unlike many other exotic species, armadillos fill a very beneficial niche in their



habitat. Besides devouring huge quantities of noxious insects, their burrows provide a retreat for rabbits, skunks and other forms of wildlife.



Armadillos suffer high mortality due to predation by bobcats, wolves, coyotes, dogs, and from being struck by automobiles. Nevertheless, they have been successful in extending their range and growing in population size. Generally, female armadillos produce a litter of quadruplets (four offspring of the same sex and genetically identical) once a year, usually in February. The average life span of each offspring is four years.

### Procedure

1. Have the students read the introduction in their instructions.
2. Spend a few minutes explaining the concepts that are the focus of the activity: limiting factors, carrying capacity, dynamic equilibrium, and exponential growth. (Refer to pages 3-5 in the Background Information.)
3. Review graphing skills. (Refer to pages 3-4 in the Background Information of module 1 — "TELLUS About Science.")
  - Distinguishing the independent (manipulated) variable from the dependent (responding) variable.
  - Labeling the x- and y-axes.
  - Labeling the grid with appropriate scale numbers.
  - Plotting data.
4. Have students follow the procedure in their instructions to complete the graphing activity and answer the Summary Questions.
5. Discuss the results and the answers to the Summary Questions. (The answer key follows.)

6. Continue the video.

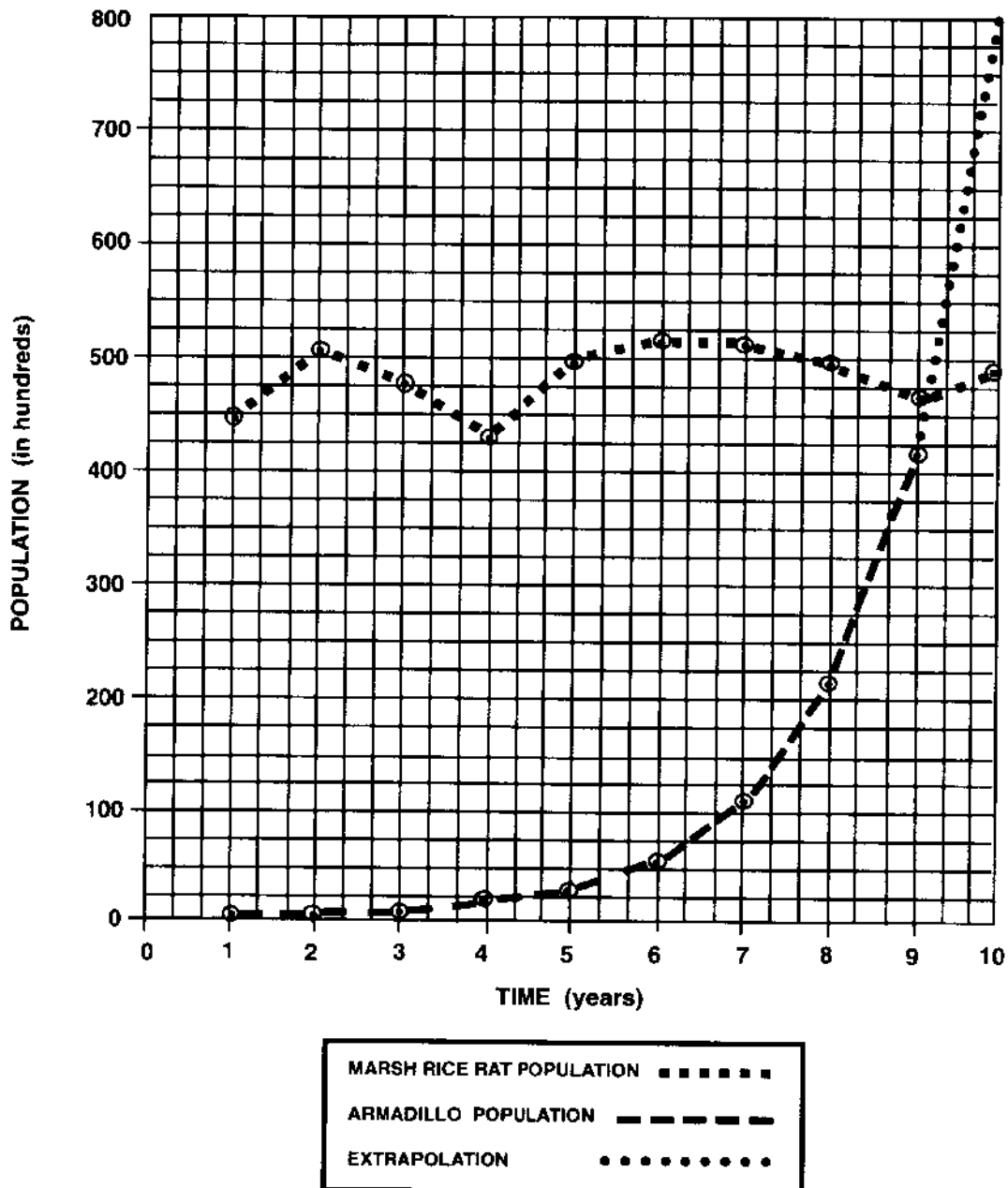
### Summary Questions

1. How are the two graphed lines similar?  
*Both are changing from year-to-year.*
2. How are the graphed lines of the two populations different?  
*The graph of the rat population is fluctuating up and down within a predictable range, while the graph of the armadillo population is only curving upward.*
3. Which population appears to be in balance (dynamic equilibrium) with the environment?  
*The rat population appears to be in balance with the environment because there are no extreme changes in population size.*
4. Draw a line to represent the average carrying capacity of the rat population over the ten year period.  
  
*What is the approximate carrying capacity for marsh rice rats?*  
*The carrying capacity is about 470 rats.*
5. What type of growth pattern is shown by the changes in the armadillo population?  
*The armadillos are showing exponential growth.*
6. Based on its current pattern of growth, estimate the size of the armadillo population for year 10.  
*The armadillo population appears to be doubling each year, so there should be about 800 individuals present in year 10.*
7. Suppose the armadillo population decreased to 300 in year 10. Name some possible reasons for the decline.  
*The armadillos may have reached the carrying capacity of the salt marsh ecosystem. If that was the case:*
  - A shortage of food may have caused some to starve.

- A shortage of places to dig burrows may have lead to increased predation as the armadillos roamed or slept in open view of predators.

Other reasons for a decline may be an incidence of disease, adverse weather conditions (hurricanes and tropical storms), or changes to the habitat caused by human activity such as pollution and development.

### GROWTH PATTERNS IN TWO SALT MARSH POPULATIONS



## ACTIVITY I

### RATS AND ARMADILLOS IN A SALT MARSH HABITAT

(Student Instructions)



#### Introduction

Salt marsh ecosystems line the Gulf Coast. These grassy areas are places where inland freshwater streams and rivers merge with the salt water of the Gulf or where the Gulf waters simply merge with the land. Diverse communities of plants, animals, and microbes depend on the habitat components — food, water, shelter and space — in these areas.

Sediment deposited by the rivers and streams provide a rich bottom in which many plants grow. The tall grasses and shrubs of the marsh provide cover as well as food for animals like crabs, shrimp, and clams that live in the shallow water and eat the decaying matter (detritus) trapped at the base of the plants. Birds nest on the stems of the plants, and insects eat the leaves. Long legged birds wade the muddy flats hunting for insects and crustaceans. Other water birds — ducks, gulls and pelicans — scoop fish from the water for food. Small marsh rodents — mice and rats — scurry beneath the tall grasses and shrubs, eating aquatic plants, seeds, insects, and small shrimp and crabs. They, in turn, are hunted by hawks, owls and snakes. Lizards stalk insects in the grass, and terrapins chase fish in the shallow waters.

Each population in the salt marsh is connected to others through competition, predator/prey relationships, or other interdependent links. These relationships

with each other coupled with other **limiting factors** such as disease and harsh weather serve to prevent each population from growing beyond what the habitat can support.

The number in a population that can be supported by the habitat's available resources is the **carrying capacity** for the particular species. As a population nears the carrying capacity, limiting factors — lack of food, shortage of hiding places, increased predation — begin to affect population size, bringing the number back within the range that can be supported.

A population number that is rising and falling from year-to-year around the carrying capacity of the habitat is said to be in **dynamic equilibrium** (changing but balanced) with the environment. Populations that are well established in their habitat generally show this type of growth pattern. However, when a species first moves into a habitat, limiting factors may not be in place to curb population growth. In that case, the population experiences exponential growth (it increases at an accelerated rate) until some limiting factor begins to define the number that can survive.

The following activity will help you to understand the effect of limiting factors on a populations' growth pattern.

## Procedure

1. The data table that follows gives annual population counts for two different species — marsh rice rats and nine-banded armadillos — living in the same salt marsh habitat over a ten year period.
2. Graph the data on the grid provided.
  - Label the x-axis (horizontal) with the name of the independent variable and the y-axis (vertical) with the name of the dependent variable.
  - Label appropriate scale numbers on each axis.
3. Based on the information in the introduction, your teacher's description of the animals, and the graphed results, answer the Summary Questions that follow.
  - a. Determine the range of data for the axis.
  - b. Divide by the number of grid marks on the axis
  - c. Round up to an easily manipulated number.
  - Using two different colors of ink or the line patterns given in the key, plot both sets of data on the grid.

## Summary Questions

1. How are the two graphed lines similar?
2. How are the graphed lines of the two populations different?
3. Which population appears to be in balance (dynamic equilibrium) with the environment?
4. Draw a line to represent the average carrying capacity of the rat population over the ten year period.

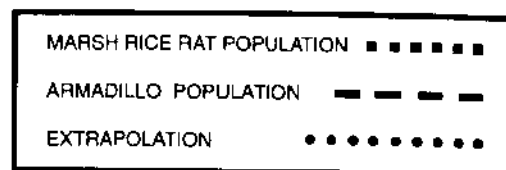
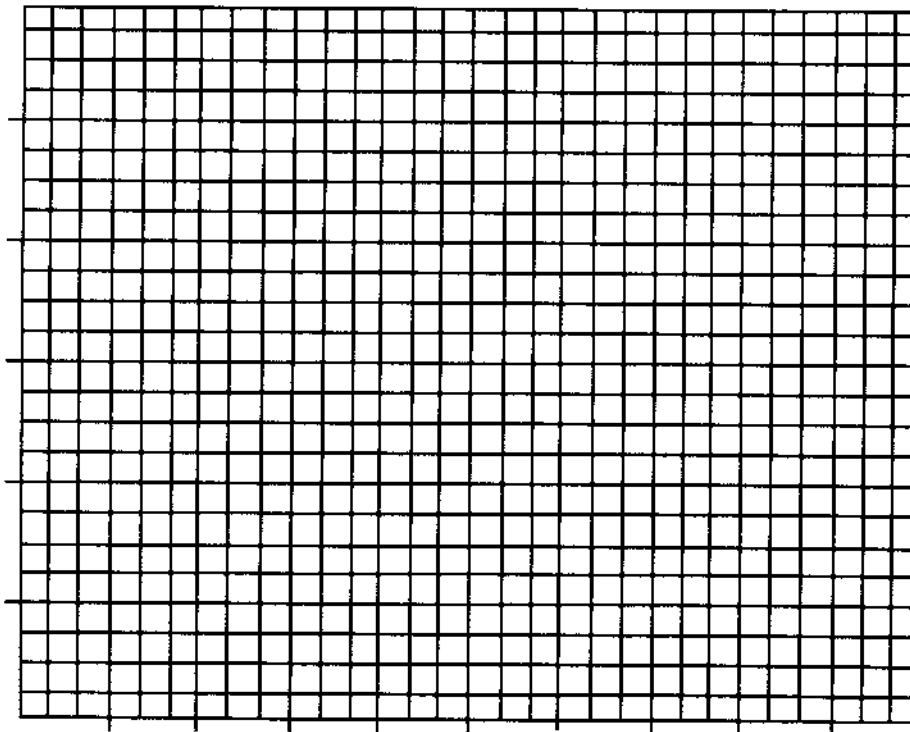
What is the approximate carrying capacity for marsh rice rats?

5. What type of growth pattern is shown by the changes in the armadillo population?
6. Based on its current pattern of growth, estimate the size of the armadillo population for year 10.
7. Suppose the armadillo population decreased to 300 in year 10. Name some possible reasons for the decline.

**STUDENT DATA SHEET**  
**TEN YEAR POPULATION STUDY ON MARSH RICE RATS**  
**AND NINE BANDED ARMADILLOS**  
**IN A FLORIDA SALT MARSH**

Year	Marsh Rice Rats	Armadillos
1	437	2
2	502	5
3	478	9
4	425	13
5	493	27
6	514	51
7	511	105
8	498	213
9	467	409
10	488	?

**GROWTH PATTERNS IN TWO**  
**SALT MARSH POPULATIONS**



## ACTIVITY II

### BEAT YA' TO THE BEADS (Teacher Instructions)

#### Introduction

The concepts of **finite** resources and interconnectedness among species are essential in understanding the impact of **overpopulation** on an ecosystem. When more resources are used by one group, less are available for other organisms. Since everything is interconnected, if one part of the environment is depleted, weakened, or missing, balance is lost and the entire ecosystem suffers.

Because earth's resources are limited (finite), every ecosystem has a carrying capacity — a point at which it can no longer support additional members of a species with the food, water, shelter, and space they need to survive.

This activity will help students to understand the finite nature of an ecosystem's food supply and will demonstrate the effect of overpopulation on available food in an area. Students will be able to correlate what happens in the game with what could happen to any population that exceeds the limits of its carrying capacity.

#### Objectives

- To understand the finite nature of an ecosystem's food supply.
- To demonstrate the effect of overpopulation on food resources in a designated area.

#### Description

The teacher will introduce the activity by explaining the finite nature of earth's resources. Then, working in small groups, students will simulate a growing population competing for a finite supply of food. They will collect data, graph the data, determine the carrying capacity for the environment, and answer Summary Questions that will help them identify the effects of overpopulation on the environment. The second part of the



activity — GAME 2 — will demonstrate the effect of competition from an exotic species. The extension activity — GAME 3 — may be used to demonstrate the effect of toxins in the environment on the population.

#### Materials (per group)

- Large rectangular cake pan
- 1 lb. box of corn meal
- 2-3 packages of yellow or clear seed beads
- 2-3 packages of red seed beads
- 4-6 small paper cups (numbered 1 through 6)
- 4-6 extra cups for GAME 2

#### Teacher Preparation

On the day of the activity, mix both packages of beads with the 1 pound box of corn meal and pour the mixture into the cake pan. (Do this for as many groups as will be participating.)

[NOTE: Upon completion of the activity, the corn meal and beads can be stored in airtight plastic containers and reused for several years.]

#### Procedure

- A. Explain the finite nature of earth's resources (Refer to Background Information on page 3.)  
  
Extension #1 (Earth: the Apple of Our Eye) on pages 12-13 is an excellent way to convey the finite nature of earth's land resource.
- B. Divide the class into cooperative learning groups of 4 to 6 students.

- C. Give each group a pan of the corn meal/ beads mixture and a number of cups equal to the number of group members. (The number of group members determines the number of rounds played during the game.)
- D. Explain the following:
- An ecosystem can only support a certain number of individuals. Once the carrying capacity has been exceeded, the ecosystem and the species begin to suffer.
  - In nature, a wide variety of food is available, but different species are adapted to eat different things; not all possible food sources are available to a particular species.
  - The pan of corn meal/ bead mixture represents an ecosystem, and the beads are food. Everyone in the group is of the same species and can "eat" only the yellow or clear beads. The red beads are a source of food, but not for their particular species, so they are to ignore the red beads.
  - At the teacher's signal to start, ONE student is allowed 30 seconds to "graze" through the commmeal to look for food. When time is called, the student must stop and count the number of beads collected, then put the beads in cup #1.
  - For the second round, TWO students will be given 30 seconds to look for food. At the end of the 30 seconds, they are to stop, count the total number of beads collected, divide by 2 to get an average number, and place the beads into cup #2.
  - Repeat the procedure adding one person for each round of play. Play as many rounds as there are people in the group. (During the last round, all students in the group are competing for food at the same time.)
- E. When each group is ready, give the signal to begin. Play as many rounds as are required to complete the game, then allow time for the students to complete the chart for GAME 1, graph their results, and answer the Summary Questions.
- F. Discuss the results and answers to the Summary Questions. (The answer key is on pages 23-24.)
- G. Repeat the game but vary it by adding a population of exotic species to the ecosystem. Relate the following information:
- The climate of the states bordering the Gulf of Mexico is generally mild. Thus, conditions are favorable for many species not native to the area to survive, thrive, and extend the range of their populations. In doing so, they often take over habitats and crowd out the native species. These non-natives are called exotic species.
  - One student in each group will play the role of an exotic species. As an exotic species, the student is able to "eat" all colors of beads. The student who represents the exotic species will keep his/her beads separated from the beads collected by the native species.
  - Have the students number the second set of cups 2-6 (these will hold the beads of the exotic species).
- H. When each group is ready, give the signal to begin GAME 2. Play as many rounds as are required to complete the game (4 to 6 rounds), then allow time for the students to complete the chart and answer the Summary Questions.
- I. Discuss the results and answers to the Summary Questions.
- J. Watch the remainder of the video program.

### Extension

#### GAME 3: Dealing With Toxins In The Environment

- Repeat the game. This time, all the students represent a native species, and pollution has made the red beads toxic. If a student accidentally picks up a red bead in getting to the yellow or clear colored bead, they have been poisoned and become ill. When counting the number of beads they successfully "ate," they must give up two beads for each red one handled. If they

handled five or more red beads during the 30 second period, they must consider themselves “killed,” and the activity proceeds without them.

- Play as many rounds as are required to complete the game, then allow time for the students to complete the chart for GAME 3, and answer the Summary Questions.
- Discuss the results and answers to the Summary Questions.

## ANSWER KEY - ACTIVITY II

### Summary Questions

#### GAME 1: Competition For Food

1. What happened to the number of beads you were able to collect as the number of individuals looking for beads increased?

*The number decreased as more people competed for food.*

2. Was it easier or harder to find beads during the last round when the entire group was searching at the same time and the “ecosystem” was experiencing over-population? Explain.

*Answers will vary. Some may say that it was easier because the corn meal was agitated more, exposing the beads; others will say that it was harder because everyone was crowded around the pan and aggressively hunting the beads.*

3. Suppose that in order to meet your energy requirements for survival, health, and growth, you require 10 beads per round. Would you have been able to survive through all the rounds? If not, how many rounds would you have survived?

*Answers will vary based on the results.*

4. Suppose you could survive on only 5 beads. Would you have survived all rounds?

*Answers will vary based on the results.*

If not, how many would you have survived?

*Answers will vary based on the results.*

What would be the condition of your health?

*Health would be in jeopardy. Hunger and disease would likely become problems.*

5. How do you think animals in the wild would be affected, if they had to compete for food in this manner? How did it make you feel?

*Answers will vary. Typically, animals become aggressive and hostile (more fighting) when others enter their territory. Competition causes stress. Smaller animals would get less food and would therefore have less chance of survival.*

6. Animals need more than food to survive and be healthy. What are some of their other needs?

*They need fresh water to drink and places to hide and nest (shelter and space).*

What would happen to a population if there was not enough food or other essential needs to go around?

*The population would decline, fewer would survive. Eventually, the population size would fall within the carrying capacity of the ecosystem and population size would stabilize.*

7. Carrying capacity is the average number of individuals in a population that an ecosystem can support with its available resources.

- Graph the data from your chart and determine the average carrying capacity of the ecosystem for the 4 to 6 rounds of play.

*Graphs will vary depending on the results and the number of players. The carrying capacity will be the average quantity.*

8. Apply the above situation to people. How might competition for resources in an overpopulated area affect the health of the human population?

*Answers will vary. Generally it causes stress which may present itself as greed, anger, and violent behavior. Among some people it can cause cooperative behavior — combining efforts as in communal living.*

*As long as food, water, shelter, and space are available, the health of the human population will not be in jeopardy. However, as competition for higher standards of living increase, the results of stress may become more apparent.*

How does this competition affect the environment?

*As the human population grows, humans consume more and more of the earth's finite resources — water, vegetation, minerals, and animals — leaving less for other organisms, less for the physical environment, and ultimately less for humans themselves. In the end, as the environment is altered to take care of human needs, the quality of life for all organisms decreases. This is evidenced by environmental problems such as a reduction in biodiversity, deforestation, and declining water and air quality.*

### **GAME 2: Invasion of an Exotic Species**

1. How does the feeding success of the exotic species compare to the success of the ecosystem's native species? (For each round, compare the number collected by the exotic species to the average collected by the others.)

*At first there may be little difference, but as competition and overcrowding occur, the exotic species should be able to collect more beads than the native species.*

2. Do you think that the results of this activity are similar to the consequences of exotic species invading an ecosystem in the wild? Explain.

*Yes, if an exotic species can eat a greater variety of food than the native species, their chances of survival and reproduction are much better. Eventually, they may take over much of the habitat, causing the decline of native species (as has occurred with the Argentine fire ants and nutria in some areas of the Gulf Coast region).*

3. Suppose the exotic species ate ONLY the red beads. Would the effects on the available food supply for the native species be the same? Explain.

*No, there would be no competition for food between the two species.*

4. What are some ways that exotic species compete with native species besides vying for food?

*They compete for space, shelter, and water.*

### **Extension**

#### **GAME 3: Dealing With Toxins In The Environment**

1. What did the introduction of a "poisonous" food source do to your attitude during eating?

*Answers will vary. They may mention attitudes such as fear and caution.*

2. Was the amount of food that you were able to collect affected by the presence of the poisonous food? Explain.

*Yes, because of caution, the search was slower and fewer beads were collected.*

3. Were you able to survive as easily as in GAME 1? Explain. (Remember, it takes 10 beads to thrive, and 5 beads to survive.)

*Answers will vary based on results. Generally, the answer will be no, because fewer beads were collected.*

4. Was your health affected by the presence of this poisonous food? Explain.

*Answers will vary. Generally, yes for fewer beads were collected.*

5. How might wildlife in an ecosystem be affected by toxins in their environment?

*There would be a decrease in population size due to illness, death, and migration from the polluted ecosystem.*

## ACTIVITY II

### BEAT YA' TO THE BEADS

(Student Data Sheet and Summary Questions)

#### GAME 1: Competition For Food

Average the number of beads collected during each round for your group. Do this by adding the total number of beads collected and dividing by the number of people participating during the round. Record the average in the chart below.

	Round					
	1	2	3	4	5	6
Average # of beads						

#### Summary Questions

1. What happened to the number of beads you were able to collect as the number of people looking for beads increased?
2. Was it easier or harder to find beads during the last round when the entire group was searching at the same time and the "ecosystem" was overpopulated? Explain.
3. Suppose that in order to meet your energy requirements for survival, health, and ideal growth and life-span, you require 10 beads per round. Would you have been able to survive through all the rounds? If not, how many rounds would you have survived?
4. Suppose, if necessary, you could survive on only 5 beads. Would you have survived all rounds?

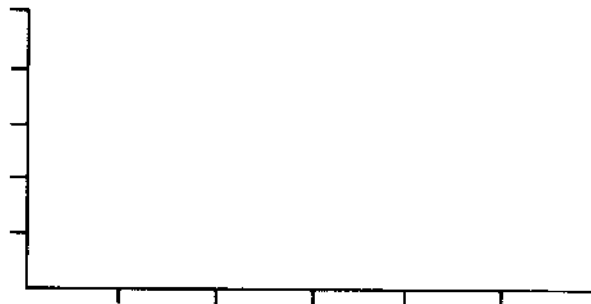
If not, how many would you have survived?

What would be the condition of your health?

5. How do you think animals in the wild would be affected, if they had to compete for food in this manner? How did it make you feel?
6. Animals need more than food to survive and be healthy. What are some of their other needs?

What would happen to a population if there was not enough food or space to go around? Consider each possibility.

7. Carrying capacity is the average number of individuals in a population that an ecosystem can support with its available resources.
  - Graph the data from your chart and determine the average carrying capacity of the ecosystem for the 4 to 6 rounds of play.



8. Apply the above situation to people. How might competition for resources in an overpopulated area affect the health of the human population?

How might this competition affect the environment?

### GAME 2: Invasion of an Exotic Species

During this game, one person is an exotic species and can eat all colors of beads. The exotic will begin playing in Round 2 and must keep his/her beads separate from the native



species. The native species will average the number of beads collected during each round as in the previous game. Record the results of each round in the following chart.

Average # of beads	Round					
	1	2	3	4	5	6
Native species						
Exotic species						

### Summary Questions

1. How does the feeding success of the exotic species compare to the success of the ecosystem's native species? (For each round, compare the number collected by the exotic species to the average collected by the others.)
2. Do you think that the results of this activity are similar to the consequences of exotic species invading an ecosystem in the wild? Explain.
3. Suppose the exotic species ate ONLY the red beads. Would the effects on the available food supply for the native species be the same? Explain.
4. What are some ways that exotic species compete with native species besides vying for food?

### Extension

#### GAME 3: Dealing With Toxins In The Environment

During this game, each player must try to avoid handling red beads because they are toxic (poisonous). Play as in GAME 1, but at the end of each round, each player must:

- Give up two beads for each red bead handled.



- If five red beads were handled, the person is considered “killed” and the activity continues without him or her.

Add the total number of beads collected, and divide by the number of people participating during the round. Record the averages in the chart below.

Average # of beads	Round					
	1	2	3	4	5	6

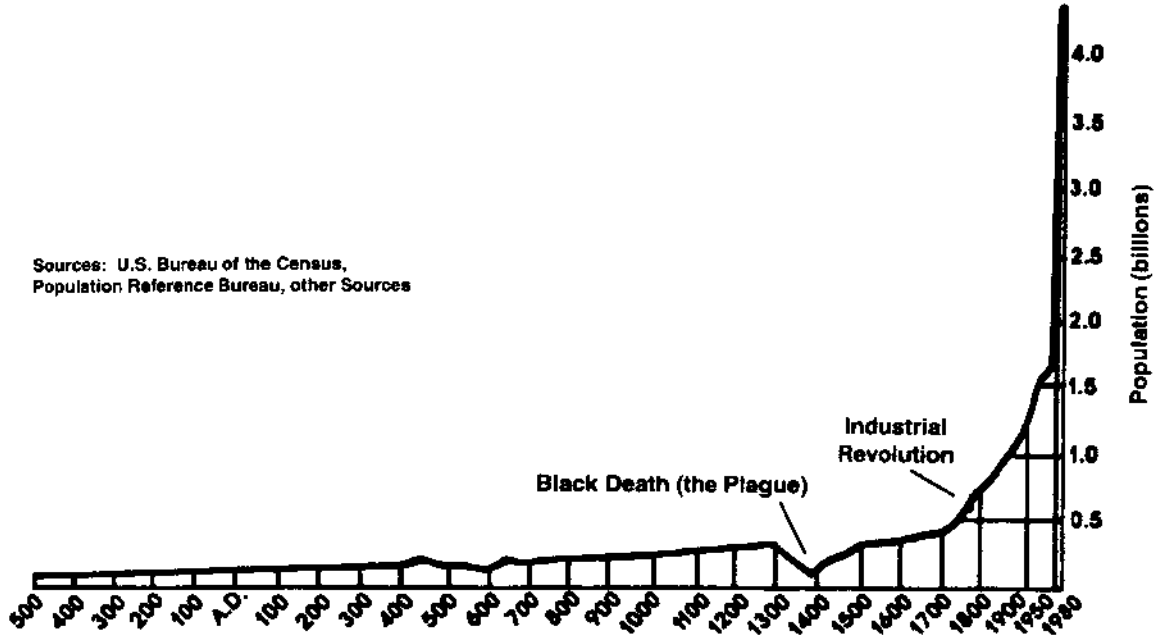
### Summary Questions

1. What did the introduction of a “poisonous” food source do to your attitude during eating?
2. Was the amount of food that you were able to collect affected by the presence of the poisonous food? Explain.
3. Were you able to survive as easily as in GAME 1? Explain. (Remember, it takes 10 beads to thrive, and 5 beads to survive.)
4. Was your health affected by the presence of this poisonous food? Explain.
5. How might wildlife in an ecosystem be affected by toxins in their environment?



# GROWTH CURVE FOR THE HUMAN POPULATION

Sources: U.S. Bureau of the Census,  
Population Reference Bureau, other Sources



[Adapted from For Earth's Sake: Lessons in Population and the Environment, by permission from Zero Population Growth, Inc., © 1989.]



## EVALUATION QUESTIONS

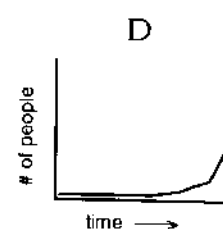
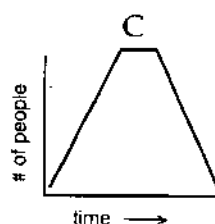
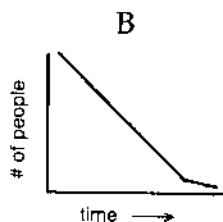
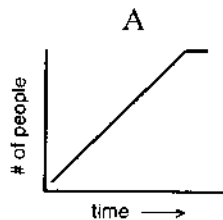
**MATCHING:** Match each definition or example in the left column with the correct term in the right column. Place the letter of the correct term in the space provided.

- |                                                                                   |                        |
|-----------------------------------------------------------------------------------|------------------------|
| ___ 1. Members of the same species in an area                                     | A. Community           |
| ___ 2. Organisms that make their own food                                         | B. Food chain          |
| ___ 3. The maximum number of individuals a habitat can support with its resources | C. Consumers           |
| ___ 4. Current growth pattern in the human population                             | D. Population          |
| ___ 5. Eat dead or decaying organic matter                                        | E. Detritivores        |
| ___ 6. Spiders, fish, and birds                                                   | F. Overpopulation      |
| ___ 7. Conditions in the environment that control the rate of population growth   | G. Migration           |
| ___ 8. More individuals are living than the ecosystem can support                 | H. Carrying capacity   |
| ___ 9. All the different species in an ecosystem                                  | I. Dynamic equilibrium |
| ___ 10. Animals entering or leaving an area                                       | J. Exponential growth  |
|                                                                                   | K. Producers           |
|                                                                                   | L. Limiting factors    |

**MULTIPLE CHOICE:** Select the BEST answer for each statement.

1. Today's worldwide population of humans is approximately \_?\_.
- A. 5.6 billion
  - B. 10.6 billion
  - C. 100 million
  - D. 12 billion

2. Which of the following graphs represents the growth curve for the human population?

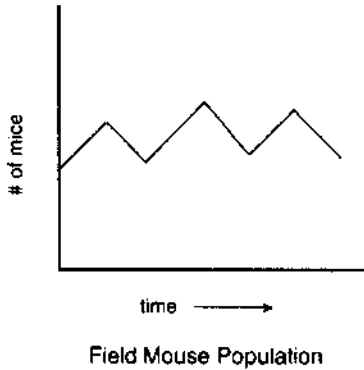


3. A coyote hunting and killing a rabbit for food is an example of a \_\_\_ relationship.
- A. symbiotic
  - B. predator/prey
  - C. competition
  - D. mutualistic
4. Which of the following would NOT be considered a limiting factor for bullfrogs living in a freshwater pond ecosystem?
- A. The amount of available food.
  - B. The introduction of an exotic species that eats large fish.
  - C. Toxic chemicals that enter the pond in runoff.
  - D. Clearing the land surrounding the pond to develop a residential area.
5. Which of the following countries consumes the most resources and energy per person?
- A. China
  - B. Peru
  - C. The United States
  - D. India
6. Which of the following situations does NOT produce competition in an ecosystem.
- A. Both nutria and muskrats build burrows in the banks of Gulf Coast rivers, ponds, and lakes.
  - B. Seventy different Gulf Coast species need decaying trees for shelter and nesting sites.
  - C. Snakes, hawks, and foxes all eat field mice.
  - D. Birds eat ladybug beetles, ladybug beetles eat aphids, and aphids eat plant juices.
7. The birthrate in the United States is decreasing, but population growth is still increasing. The reason for this is that
- A. the death rate is decreasing — people are living longer lives.
  - B. people continue to migrate into the United States.
  - C. couples are having more children today than they did forty years ago.
  - D. All of the above are correct.
  - E. A and B are correct.
8. An area where living things react with each other and with their nonliving surroundings to recycle substances essential for life and to channel energy from the sun through producers to consumers is called a(n) \_\_\_.
- A. ecosystem
  - B. burrow
  - C. nest
  - D. niche

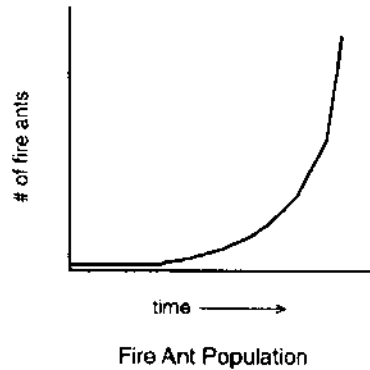
DISCUSSION: Use your best writing skills — spelling, punctuation, and grammar — in responding to the following statements.

1. The following graphs show the population growth of two different species living in a Gulf Coast meadow. For each population, describe the growth pattern and give reasons for the its changes.

a.



b.



a.

b.

2. Explain the connection between the rapidly increasing human population and declining water quality in the Gulf Coast rivers, streams, and lakes.

3. List three actions that you can take to reduce waste and overconsumption of earth's resources.

a.

b.

c.



## EVALUATION — ANSWERS

### MATCHING:

- |      |       |
|------|-------|
| 1. D | 6. C  |
| 2. K | 7. L  |
| 3. H | 8. F  |
| 4. J | 9. A  |
| 5. E | 10. G |

### MULTIPLE CHOICE:

- |      |      |
|------|------|
| 1. A | 5. C |
| 2. D | 6. D |
| 3. B | 7. E |
| 4. B | 8. A |

### DISCUSSION:

- a. The field mouse population shows a pattern of dynamic equilibrium — it is rising and falling around an average carrying capacity (the maximum number of mice the ecosystem can support with its available resources). This balanced change is likely occurring because predators — hawks, snakes, coyotes, etc. — keep the mice from overpopulating and essential habitat components of water, food, space, and shelter are available as long as the population stays close to or below the carrying capacity.

b. The fire ant population is growing exponentially — rapid, uncontrolled growth. The lack of dips or flat places in the curve (pattern) indicate that no limiting factors are hindering population growth. For this type of growth to occur, the ant's essential habitat needs of food, water, shelter, and space must be in ample supply and its predators must be few.
- Some explanations include:
  - People use water for bathing, drinking, cleaning, cooking, watering yards, and recreation.
  - Industry uses water in manufacturing goods.
  - Agriculture uses water to irrigate crops.

- Water is a solvent used to spray fertilizer and pesticides.
- Excessive fertilizer, pesticides, and toxic chemicals (such as the residue from petroleum products on streets and parking lots) flow into lakes, streams, and rivers in runoff after rains.

*As the human population increases, the use of water also increases. All these uses add to the decline in the quantity and quality of water in the Gulf Coast's lakes, streams, and rivers.*

- Answers will vary. Refer to suggestions listed in the Background Information on page 7. Accept all reasonable responses.

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The following books, pamphlets, and journal articles were used in producing the "Overpopulation" module. Some of the resources are available to educators upon request or at a low cost; addresses of those resources are given in the reference citation.

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