Where in the World Is Carbon Dioxide?

The Potential Impact of Rising Levels of Carbon Dioxide on U.S. Forests

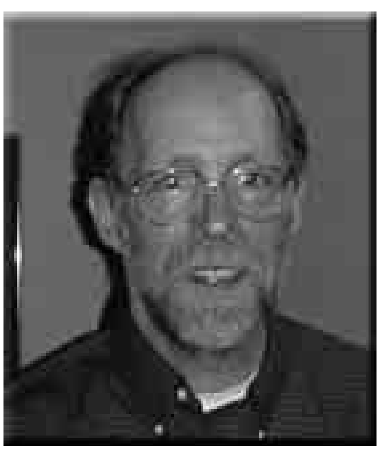
Meet Dr. Joyce:

I like being a scientist because I can explore how *ecosystems* work and use the power of mathematics to describe the processes in ecosystems.

Dr. Joyce

Meet Dr. Birdsey:

I like being a scientist because it is exciting to be involved in research that could help solve *climate* change, which is a global problem. It is quite a thrill to have the opportunity to make a difference.



Dr. Birdsey

Thinking About Science

Do you think that the climate of the Earth is changing? When scientists first reported that they had scientific evidence to show that the Earth's climate is changing, many scientists were *skeptical*. This is a normal reaction of scientists to new discoveries. Scientists check the accuracy of new scientific discoveries by questioning each other.

One way they question each other is to do more research that may or may not support the other scientist's findings. Science is a process of learning. When something new is discovered, it can take many years before the discovery is widely accepted as being true or false.

Thinking About the Environment

Can you guess what forests have to do with carbon dioxide in the atmosphere? Plants use *photosynthesis* to take carbon dioxide from the air and turn it into complex *carbohydrates*, which are part of the chemical makeup of plants. When a plant dies, the carbon in the plant goes into the soil or returns as carbon dioxide to the atmosphere. When large areas of forests burn, the carbon in the leaves, branches, and roots is released as carbon dioxide into the

Glossary

ecosystems (e ko sis temz): Communities of plant and animal species interacting with one another and with the nonliving environment.

climate (**kli** met): The average condition of the weather over large areas, over a long time, or both.

skeptical (**skep** tuh kul): Having or showing doubt.

photosynthesis (**fo** to **sin** thuh sis): The process by which green plants use sunlight to form sugars and starches from water and carbon dioxide.

carbohydrates (**kär** bo **hi** drat): Substances made up of carbon, hydrogen, and oxygen, including sugars and starches.

analyzing (**an** uh liz): Separating something into its parts in order to examine them.

weather (**weh** thür): The temperature, wind, cloudiness, rainfall or snowfall, and humidity of a place for a short period of time, such as a few days.

vegetation (vej uh **ta** shun): Plant life.

coniferous (kä **nif** ür us): Plants or trees that have cones.

species (**spe** sez): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

broadleaf (**brôd** lef): Plants or trees that have flat, broad leaves.

deciduous (de **sij** oo us): Plants or trees that shed their leaves every year; not evergreen.

average (**av** rij): The number gotten by dividing the sum of two or more quantities by the number of quantities added.

elevation (el uh **va** shun): The height above sea level.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

atmosphere. For green plants to take up carbon through photosynthesis and release carbon back into the atmosphere are normal processes.

When plants are growing and photosynthesis is greatest, the plants are absorbing the greatest amount of carbon dioxide from the air. The plants store the carbon dioxide in their leaves and wood, reducing the amount of carbon dioxide in the atmosphere. This reduction can be seen in the amount of carbon dioxide in the atmosphere measured over Hawaii from 1959 to 1998 (figure 1, page 9).

The burning of coal, oil, and natural gas, and the clearing of forests around the Earth has increased the amount of carbon dioxide in the atmosphere. You can see the rising amount of carbon dioxide in the figure. The levels of carbon dioxide in the atmosphere are now higher than they have been for at least 400,000 years.

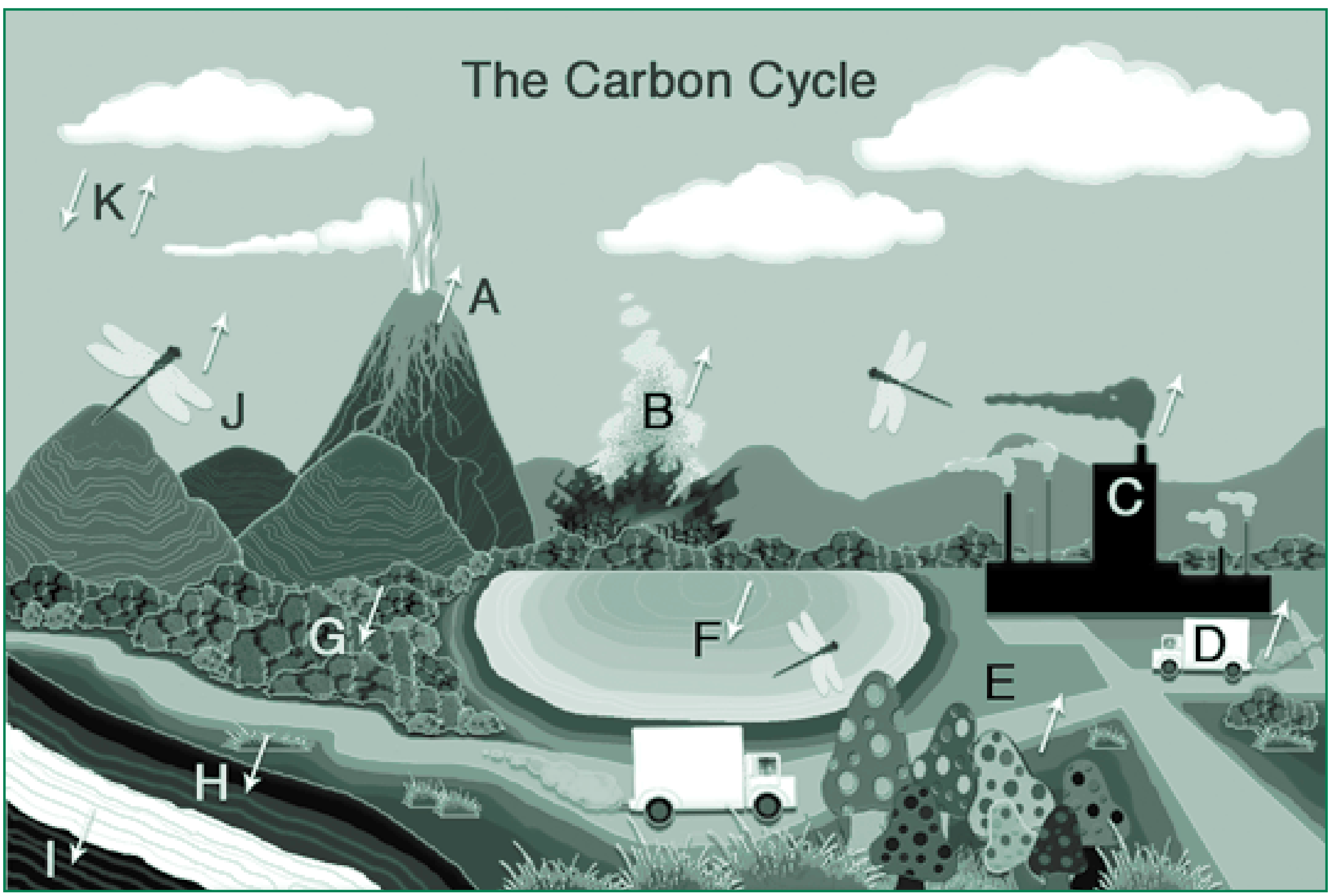
Introduction

Most scientists think that evidence from different studies shows that our global climate is changing in many ways, such as getting warmer, more rain falling in shorter amounts of time, and more drought. These scientists have studied the past climate by *analyzing weather* observations that have been collected over a long period of time.

Carbon Cycle Key

↑ = Released into atmosphere ↓ = Held on Earth

- A Volcanic eruptions release carbon held underground into atmosphere
- B Forest fires release carbon held in vegetation
- C & D Burning of fossil fuels from underground such as oil, gas, & coal, releases carbon
- E Decomposers like fungi use oxygen respiration to release CO2
- F Carbon is held in oceans & bodies of water
- G Photosynthesis from vegetation removes carbon dioxide from air
- H Carbon is held in soil
- I Coal & oil (fossil fuel) underground contain carbon
- J Oxygen-based respiration releases carbon dioxide
- K Carbon & mostly carbon dioxide in the atmosphere



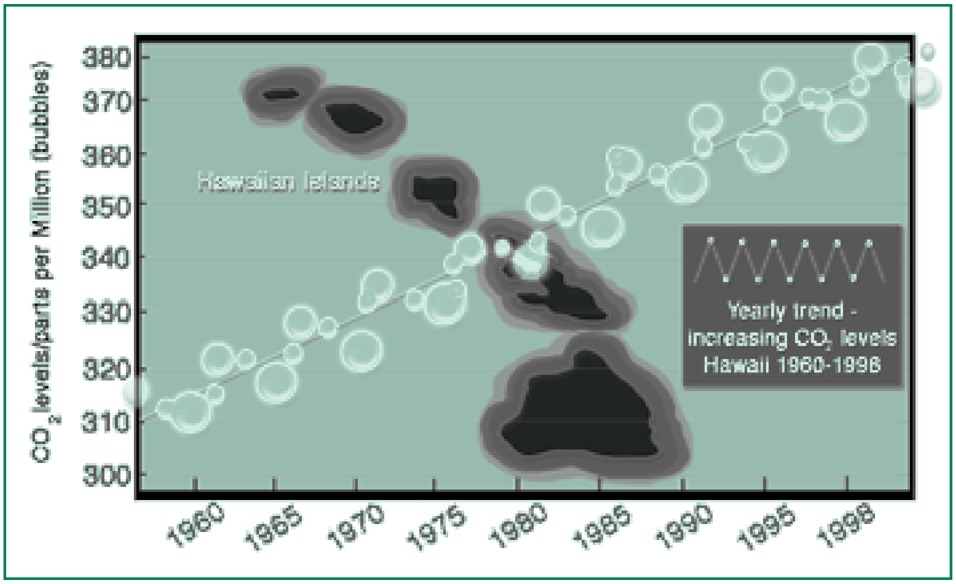


Figure 1. Amounts of carbon dioxide in the atmosphere over Hawaii.

Other scientists are studying the possible ways that climate could continue to change over the next 100 years by using mathematical formulas that run on computers. The scientists in this study used mathematical formulas to study what kind of impact these changes in the Earth's climate might have on *vegetation*.

Reflection Section

- What is the difference between weather and climate?
- If the global climate continues to change, do you think that there will be any change in the type of forests and other vegetation growing across the United States? Why or why not?
- What was the question the scientists were trying to answer?

Method

The scientists focused on 10 types of vegetation in the United States (table 1 and figure 2, pgs 10 and 11).

Information that described the environmental conditions needed by each type of vegetation were entered into a computer program. An example is the number of inches of rainfall needed over 1 year. Other environmental conditions included hot and cold temperature limits. Then, numbers representing higher temperatures and changes in rainfall and snowfall were put into the formulas in place of the current amounts.

The results from these new environmental conditions described how possible climate change might cause vegetation to change across the United States. For example, in one formula the *average* temperature for the United States was increased by 4 °C by the year 2100. The mathematical formulas predicted what kind of vegetation would grow in each area of the United States, if everything was the same as it is now except for the temperature and the amount of rainfall and snowfall.

Reflection Section

- How would you describe the climate where tundra vegetation grows? How is the climate there different from the climate where tropical broadleaf forests grow?
- Think about arid lands in the United States (see table 1). What might happen to the vegetation in arid lands if that area receives more rainfall in the future?

Findings

The mathematical formulas predicted that boreal forests and taiga-tundra vegetation will move northward and upward in *elevation*, and the southern areas of current boreal forests will die. For example, the boreal forest that now grows in Minnesota was predicted to disappear if the climate gets warmer. Forests in the Pacific Northwest and the Southeast will initially expand in size, then get smaller. This is because the increased amount of carbon dioxide will at first enable the trees to absorb more carbon dioxide and carry out more photosynthesis.

Table 1. The scientists examined 10 types of vegetation in the United States and North America.

	Type of Vegetation	Description	Location in the United States
A	Tundra	Permanently frozen soils with shrubs, mosses, grasses, and lichens.	Above the Arctic Circle in northern Alaska
B	Taiga-Tundra (**Ti** guh-**Tun** druh)	Cold or frozen soils. Contains mosses, grasses, lichens, dwarf shrubs, and short, herb-like plants.	Near the Arctic Circle in northern Alaska, and also in the highest mountain areas of the Western United States
C	Boreal (**bor** e ul) *coniferous* forest	Contains few tree *species*, such as spruce, fir, cedar, hemlock, and pine that can live in intense winter cold and drought. Contains a few *broadleaf* species, such as aspen and birch.	Just south of the arctic taiga-tundra in northern Alaska, and in the mountain areas of the Western United States
D	Temperate (**tem** pür et) evergreen forest	Contains large coniferous trees such as Sitka spruce, Douglas fir, and redwoods.	Along the northwest U.S. coast from Canada to northern California
E	Temperate mixed forest	Contains some broadleaf *deciduous* trees, such as oak, hickory, maple, poplar, beech, and sycamore; and some coniferous evergreen species.	Throughout the Eastern United States to the area of the great plains
F	Tropical broadleaf forest	Broadleaf forest that grows where it is hot and there is a lot of rainfall. Contains some deciduous trees and some evergreens.	Puerto Rico, the U.S. Virgin Islands, and Hawaii
G	Savanna woodland	Contains scattered shrubs and small trees.	Central United States
H	Shrub woodland	Contains dense cover of evergreen shrubs. May also contain a few trees that can live with little water, such as pines and scrub oak.	Mostly flat areas of the mountainous Western United States and the Southwest
I	Grasslands	Tall-grass, mixed-grass, and short-grass prairies that contain mostly grasses.	Central United States plains, Southwest United States, and flat areas of the mountainous Western United States
J	Arid lands	Desert lands, with warm to cool temperatures and low amounts of rainfall. Vegetation includes cacti and other plants that require little rainfall.	Southwestern United States and southern California

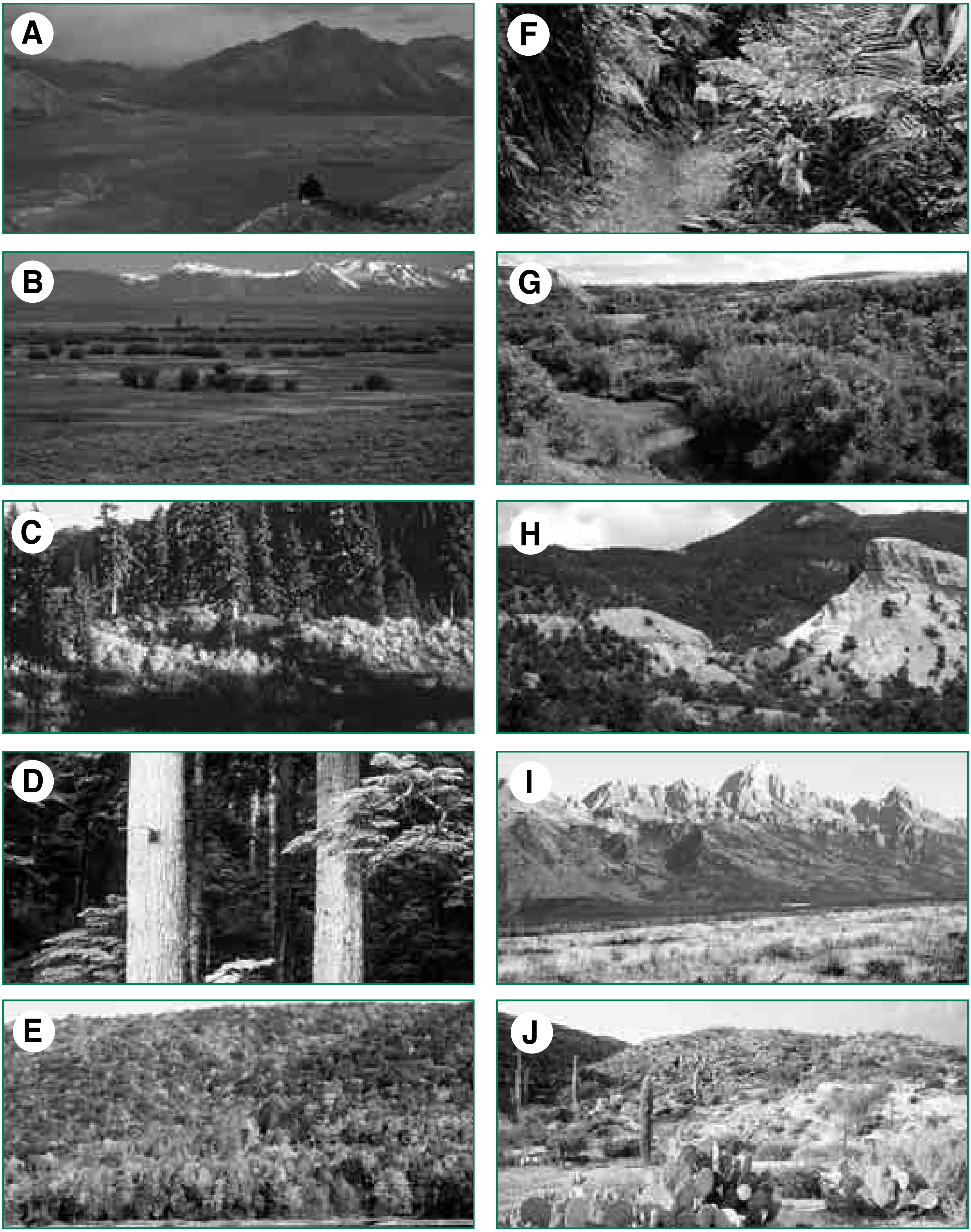
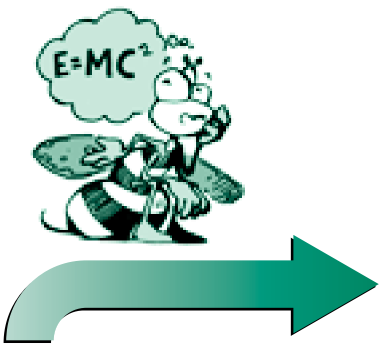


Figure 2a - 2j. The 10 types of vegetation.

If the temperature rises and the pattern of rain and snowfall changes, some trees would die from too little water. The large temperate mixed forest would break up into many smaller areas because of a lack of water in some areas. Many of the trees would die, leaving vegetation of a few trees and many grasses. In the Southwest, rainfall was predicted to increase. If that happens, the amount of arid land would shrink, and the area of grasslands would increase (figure 3).



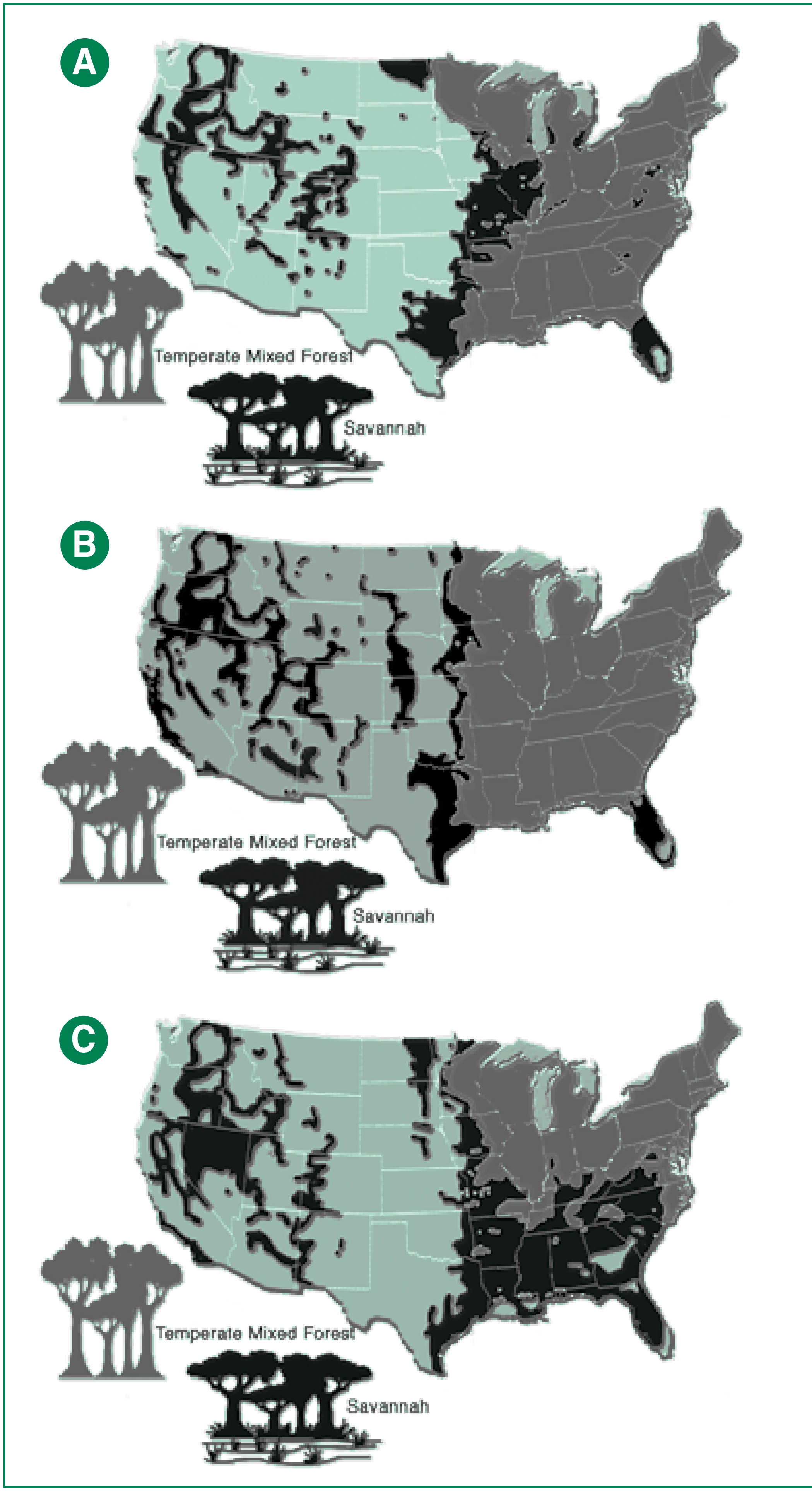
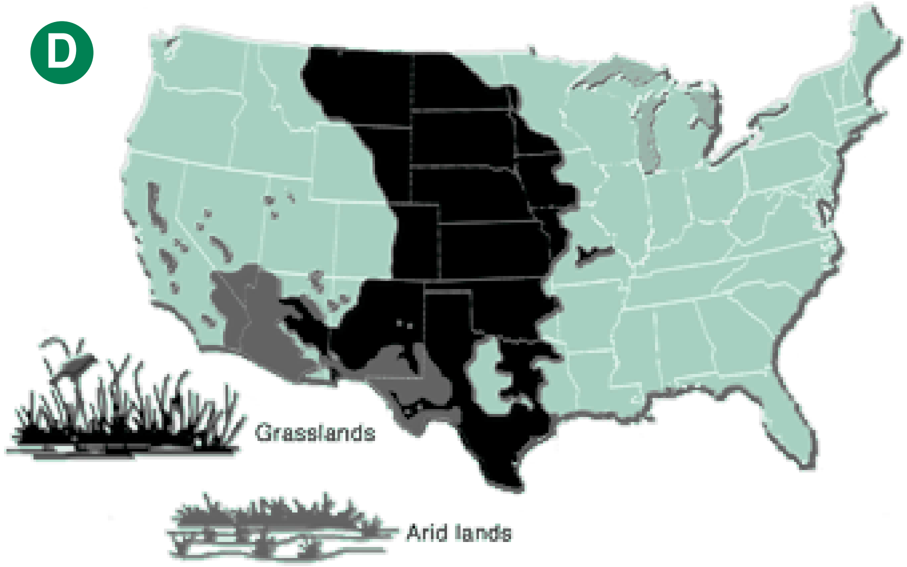


Figure 3. Current location of 4 (of the 10) vegetation types across 48 States (Figures 3a and 3d) and the potential change in the range of those vegetation types under two different possible future climates (Figures 3b, 3c, 3e, and 3f). In Figures 3c and 3f, the average future temperature is higher than in Figures 3b and 3e. Rainfall and snowfall increase in both possible future climates, but the pattern of rainfall and snowfall is different from what we know today. Rainfall and snowfall fall for shorter periods of time, leaving periods of drought in between.

D



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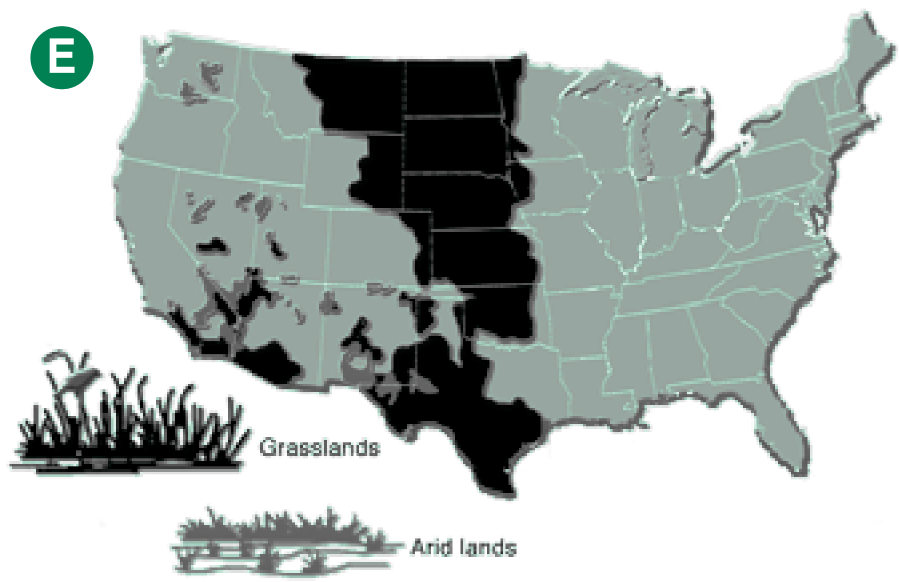

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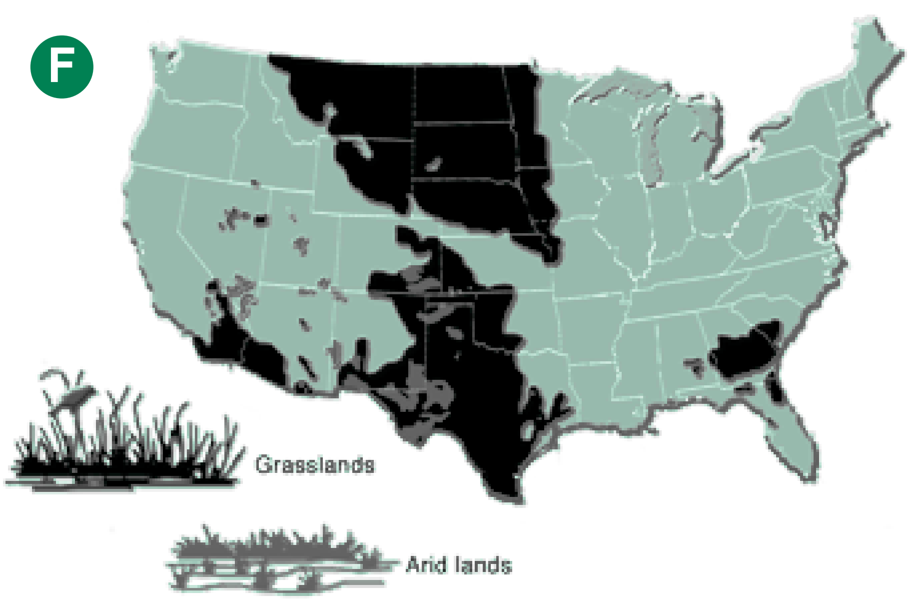


Reflection Section

- Select an area of the United States with which you are familiar. Compare the current vegetation type with predicted changes in vegetation (see figure 3). Is there a difference? If so, what is it? How might that change the environment for people who live there?
- Do you think that these changes will definitely occur in the future? Why or why not?

Implications

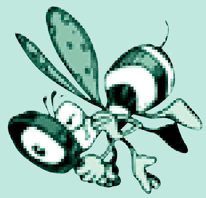
Although the mathematical formulas predicted changes in United States vegetation, the scientists said that the results must be considered with caution. First, these climate futures are possible futures and the actual future climate may be different. It may not be as warm or it may have more rainfall than predicted. Second, the predicted amount of carbon dioxide in the atmosphere may not be correct. Third, other effects, such as the pattern of rainfall and snowfall, may not happen the way the formulas predicted. Many other things might happen that the computer model could not predict.

The scientists suggest that there are things we can do today to lower the amount of carbon dioxide going into the atmosphere. For example, we could turn some of our poorer crop land and pasture land into forests. Forests absorb a lot more carbon dioxide than crop or pasture land. We could minimize the amount of forests that we are cutting down for other uses, such as for agriculture or for building homes and businesses. We can continually improve the way we take care of the forests that we have. We can recycle more paper and wood products, and we can plant more trees in urban and suburban areas.

Reflection Section

- It is hard to predict the future. The predictions made by the computer model may not be correct. How would you recommend that people use the computer model's predictions?
- The scientists identified things that can be done now to reduce the amount of carbon dioxide going into the atmosphere. Of those things, which can you and your classmates do?

From: Joyce, Linda A.; Birdsey, Richard, technical editors. 2000. *The impact of climate change on America's forests: A technical document supporting the 2000 USDA Forest Service RPA Assessment.* Gen. Tech. Rep. RMRS-GTR-59. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 133 pp.



FACTivity

In this article, you have learned that different climates have different kinds of vegetation. The question you will answer in this FACTivity is: Does it take much of a change in climate to cause a change in the type of vegetation growing in an area? In this FACTivity, the only measure of climate you will be considering is temperature. In reality, climate is composed of many other factors in addition to temperature.

The method you will use to answer this question is: Think about what scientists have said about possible future temperatures. In the Methods section, you read that "in one formula, the average temperature for the United States was increased by 4 °C by the year 2100." According to scientists at the Intergovernmental (**in** tür guh vürn **men** tul) Panel on Climate Change, the global average temperature of Earth's surface may increase by between 0.2 °C and 0.5 °C by the year 2020. (The panel is a part of the United Nations Environment Program.) Thus, the average temperature may increase slowly for the next 20 years or so, then the increase may become more rapid through the rest of the 21st century.

On the following page is a table of yearly average temperatures for some U.S. cities. Each of these cities lies in one of the vegetation types from the study. You can see that the last five columns of the table are empty. Your job will be to calculate possible future temperatures for each of these cities and complete this table.

To do this, you will first need to convert the possible increase in temperature from Fahrenheit to Celsius (Column 3 to Column 4). To convert Fahrenheit to Celsius, subtract 32 from the Fahrenheit number, then multiply by 5/9 and write that number in Column 4 for each city. Now that you have the temperature in Celsius, you can add the estimated numbers to the Celsius temperature. To complete Column 5, add 0.2 to the number in Column 4 for the lower end of the range, and add 0.5 to get the higher end of the range. To complete Column 6, add 4 to the number in Column 4. What do the numbers 0.2 and 0.5 represent? What does the number 4 represent?

To compare the temperature in Column 3 with the estimated increases in temperature, you need to convert the Celsius temperatures in

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
City and State	Vegetation Type	Average Yearly Temperature in °F	Average Yearly Temperature in °C	Possible Average Yearly Temperature Range in °C (Year 2020)	Possible Average Yearly Temperature in °C (Year 2100)	Possible Average Yearly Temperature Range in °F (Year 2020)	Possible Average Yearly Temperature in °F (Year 2100)
Fairbanks, Alaska	Taiga-Tundra	26.9	-2.83	-2.63 – -2.33	1.17	27.27 - 27.81	34.11
Los Angeles, California	Shrub woodland	63					
Wichita, Kansas	Grasslands	56.2					
Honolulu, Hawaii	Tropical broadleaf forest	77.2					
Des Moines, Iowa	Savannah woodland	49.9					
Charlotte, North Carolina	Temperate mixed forest	60.1					
Glenwood Springs, Colorado	Boreal coniferous forest	45.7					
Albuquerque, New Mexico	Arid lands	56.2					
Salem, Oregon	Temperate evergreen forest	52.1					
Barrow, Alaska	Tundra	9.42					

Columns 5 and 6 to Fahrenheit and complete Columns 7 and 8. To do this, multiply the Celsius number by 9/5, then add 32. Fairbanks, Alaska, is completed as an example.

Now compare the current average temperature with the possible future average temperatures for all of the cities. Does the difference seem very big? Read the Findings section again, and look again at figure 3. Are you surprised at the possible changes in vegetation, given the amount of temperature change? What does this information tell you about the relationship between average yearly air temperature and the type of vegetation growing in an area?