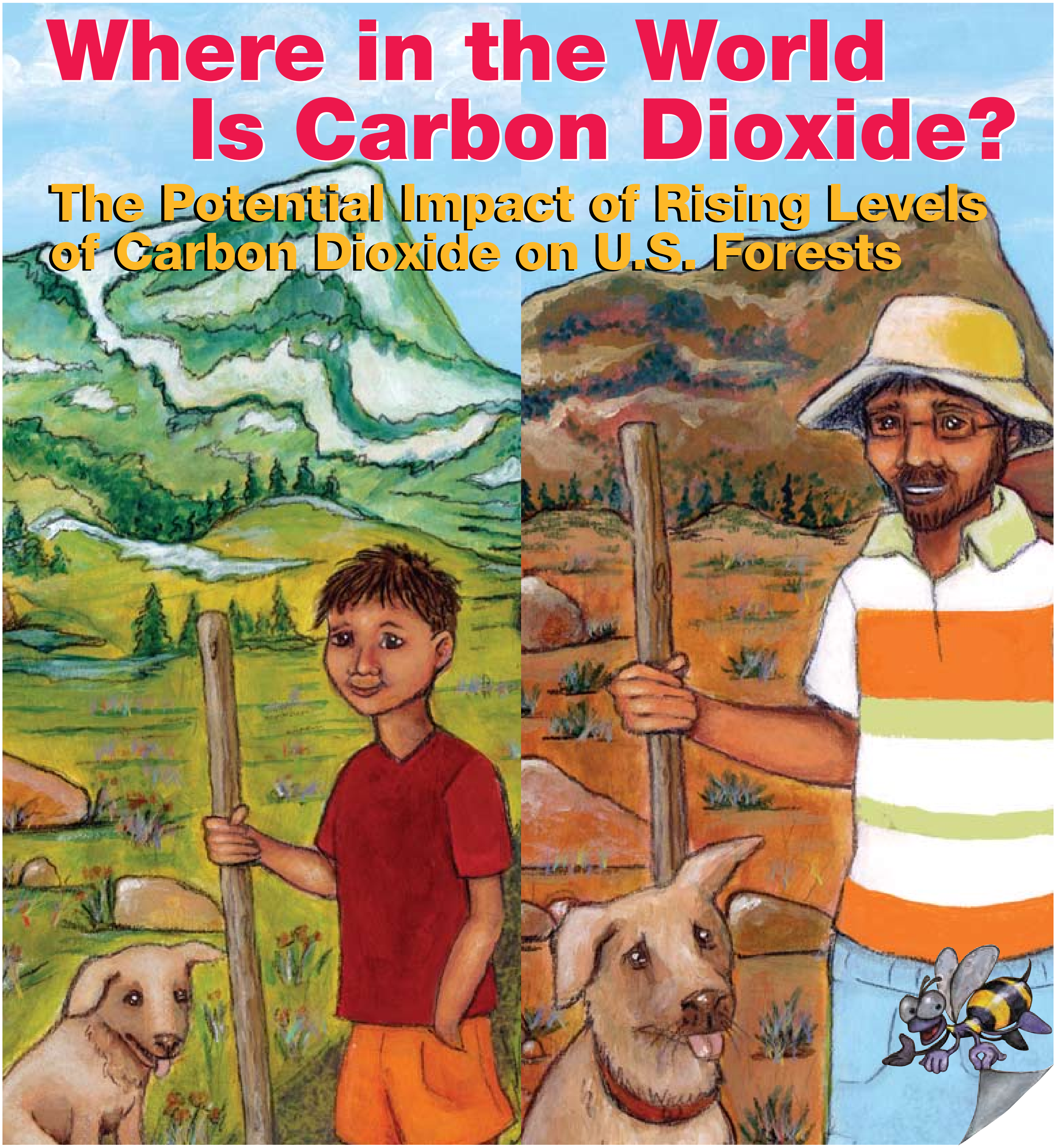
NATURAL INQUIRER

CLIMATE CHANGE EDUCATION COLLECTION • FALL 2008

Where in the World Is Carbon Dioxide?

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



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Climate Change Education Collection • Fall 2008

Where in the World is Carbon Dioxide?
The Potential Impact of Rising Levels of Carbon Dioxide on U.S. Forests

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Washington, DC

Contents

Feature

The *Natural Inquirer* is reproduced on recycled paper with soy-based inks.
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About the *Natural Inquirer*

Scientists usually report their research using a standard written form, called a scientific article. When a collection of articles are published together, the booklet is called a science journal. When a single article is published, the booklet is called a monograph. This *Natural Inquirer* is a monograph and includes one scientific article. This monograph was created so that scientists can share their research with you and with other middle school students. The monograph tells you about scientific research conducted by scientists in the Forest Service. If you want to know more about the Forest Service, you can read about it on the inside back cover of this monograph, or you can visit the *Natural Inquirer* Web site at http://www.naturalinquirer.org

All of the research in the *Natural Inquirer* is concerned with nature, such as trees, forests, animals, insects, outdoor activities, and water. First, you will "meet the scientist" who conducted the research. Next, you will read something special about science and about the natural environment. You will also read about a specific research project investigating climate change. Then, YOU become the scientist when you conduct the FACTivity associated with the article. Don't forget to look at the glossary and the special sections highlighted in each article. These sections give you extra information.

At the end of each section of the article, you will find a few questions to help you think about what you have read. The questions should help you to think more about the research. Your teacher may use these questions in a class discussion.

Welcome to the Natural Inquirer Climate Change Education Collection!

As a global citizen, you know that people around the world share similar environmental concerns. The changing climate is one concern shared by people everywhere. Some Forest Service scientists are interested in studying climate change and its relationship to forests, grasslands, air, and water. You will learn about one of these studies in this monograph.

As you know, scientific research is a continual process of discovery. Forest Service scientists are learning much about climate change, but there is still much we do not know.

This monograph is part of a collection of articles describing climate change research. You can order any of the *Natural Inquirer* monographs or journals by visiting http:www.naturalinquirer.org. The monographs and journals are free of charge.

Educators: Review "Note to Educators" on page 14 before using this *Natural Inquirer* monograph.

http://www.naturalinquirer.org

Where in the World Is Carbon Dioxide?

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

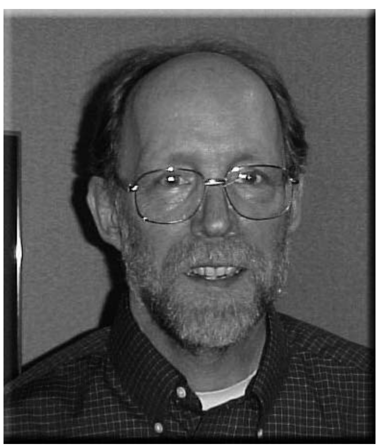
Meet Dr. Joyce:

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

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**.

dioxide into the atmosphere. Green plants take up carbon through photosynthesis and release carbon back into the atmosphere.

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 yearly cycle of carbon dioxide increase and decrease can be seen in the yearly trend (figure 1).

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 atmosphere measured over Hawaii (figure 1). The levels of carbon dioxide in the atmosphere are now higher than they have been for at least 400,000 years.

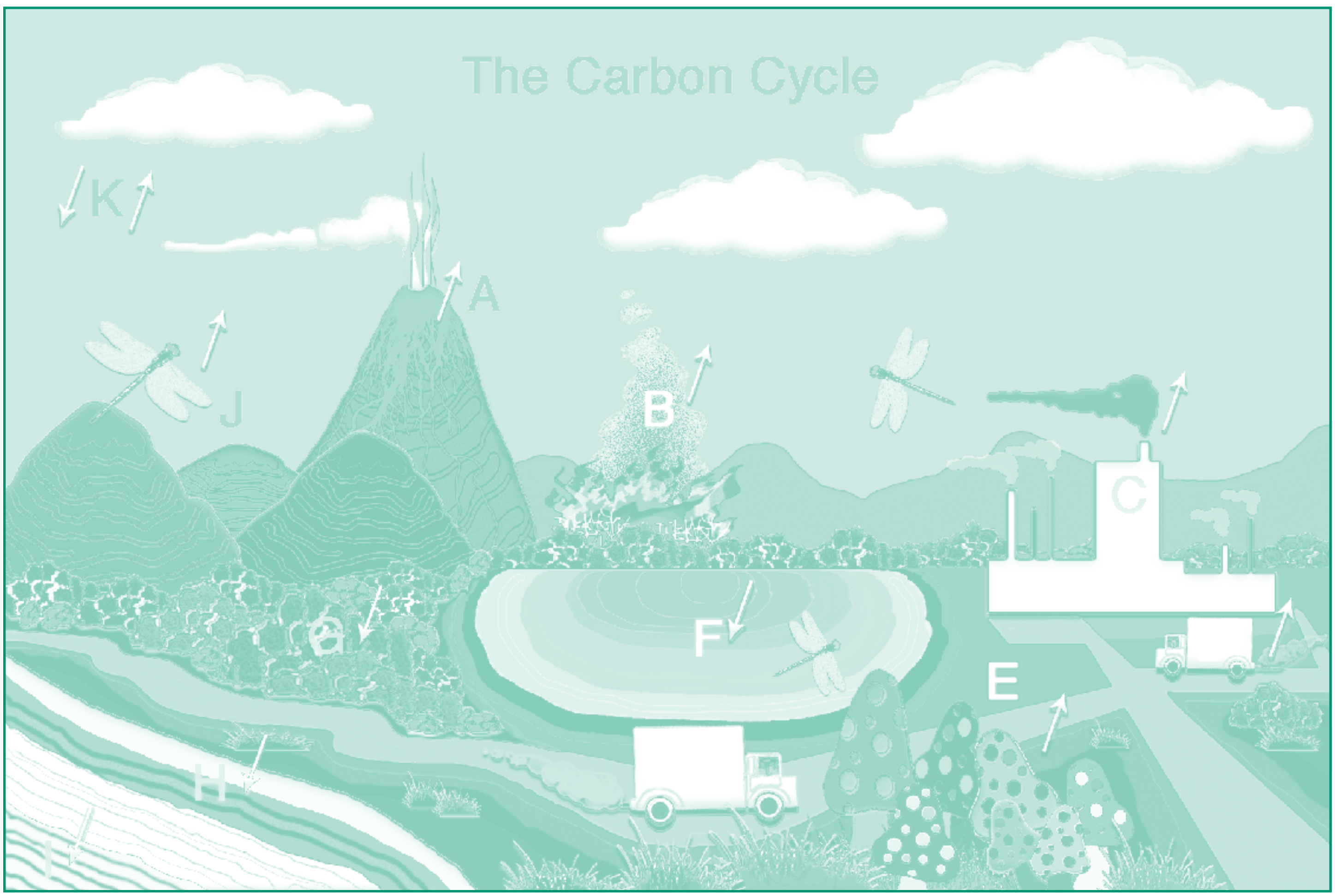
Introduction

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



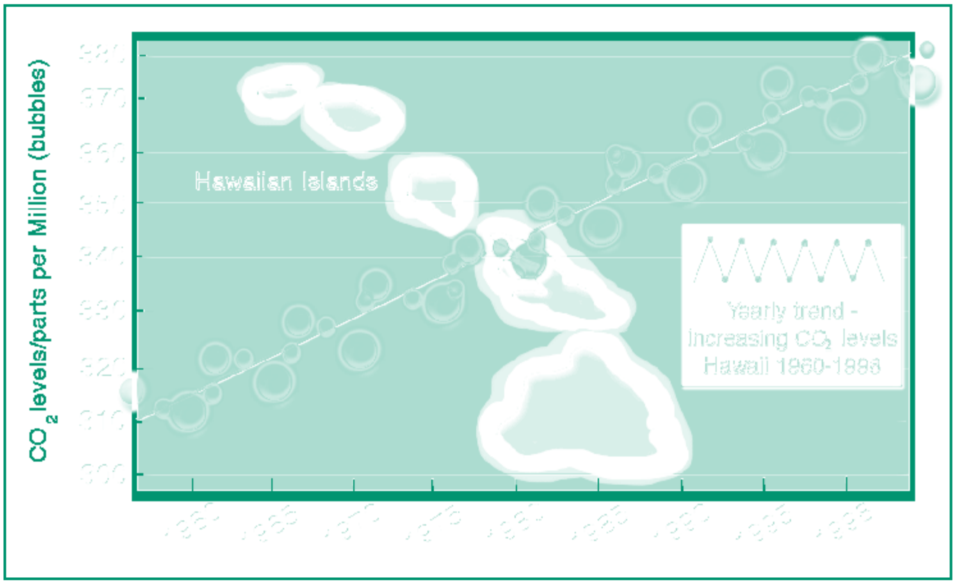


Figure 1. Amounts of carbon dioxide in the atmosphere over Hawaii.

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 8 and 9**).

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.

(Continued on page 10.)

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

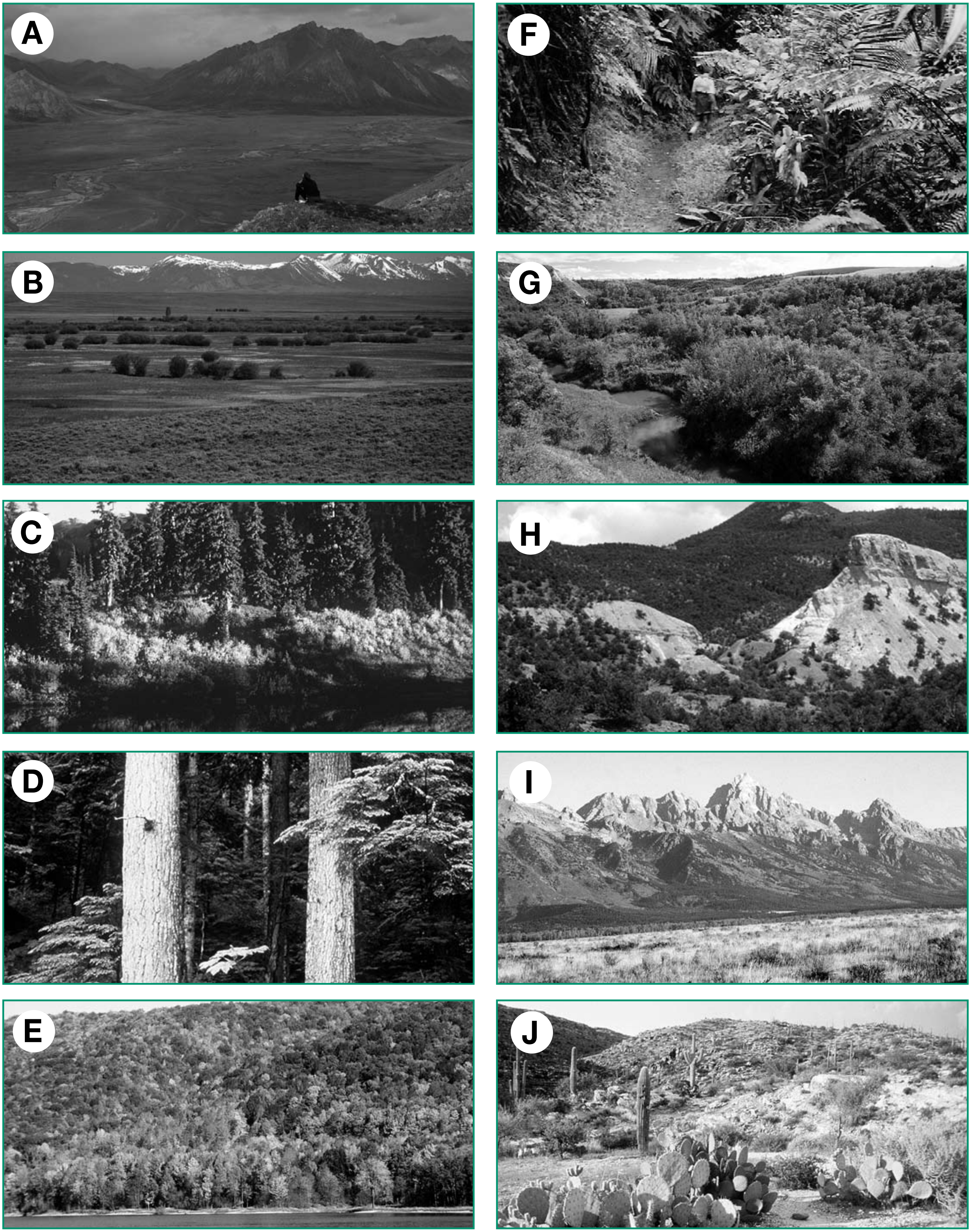
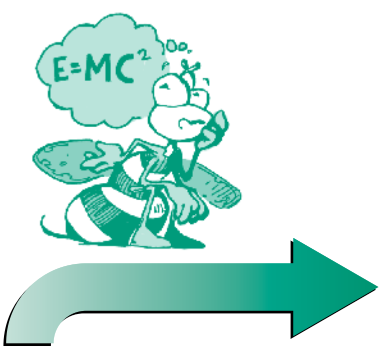


Figure 2a - 2j. The 10 types of vegetation.

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**).



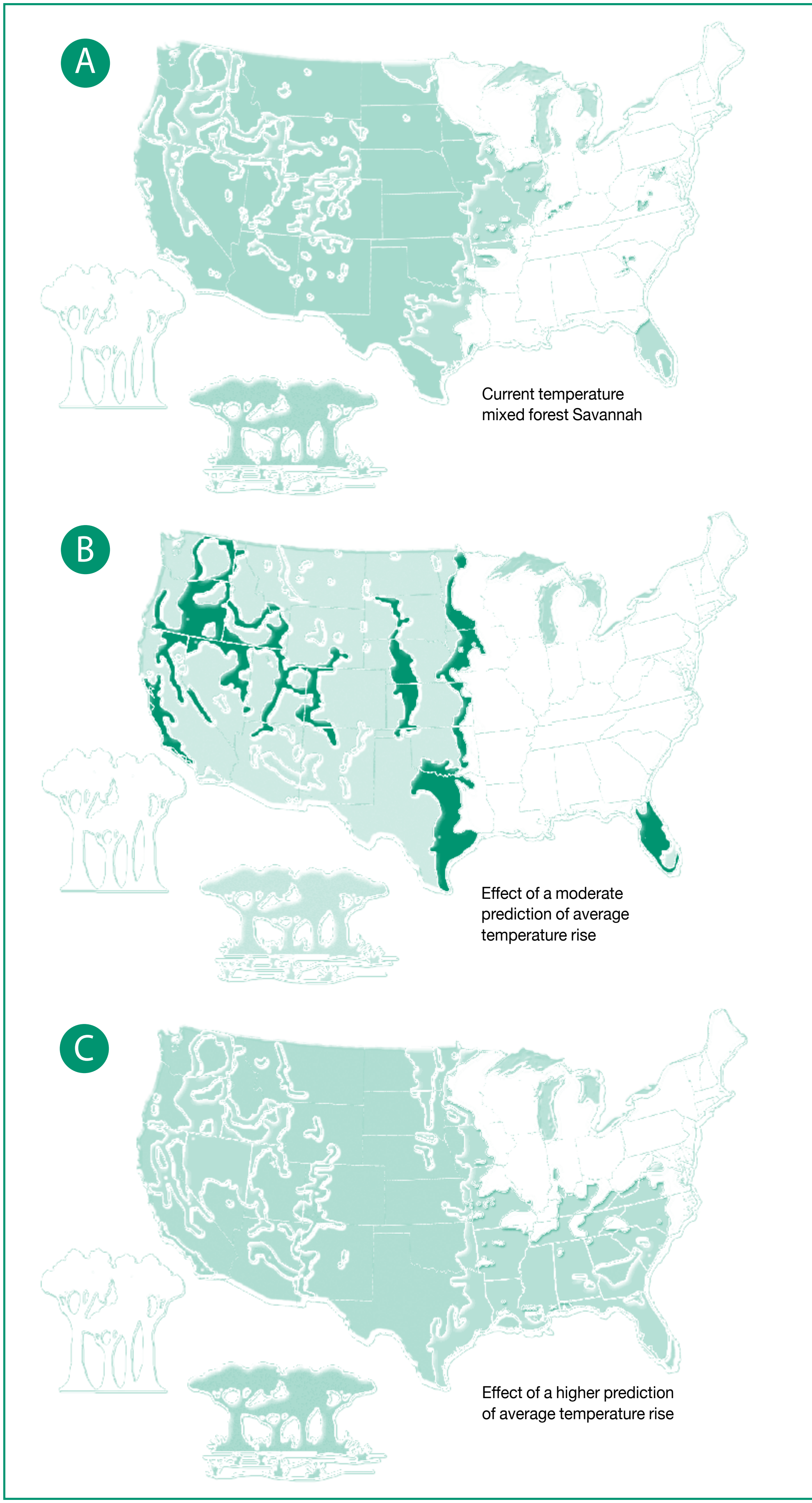
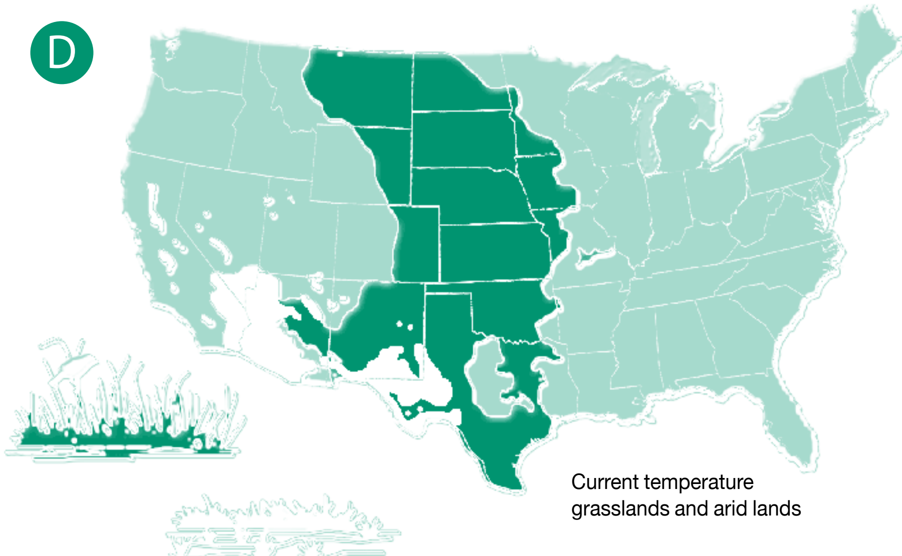
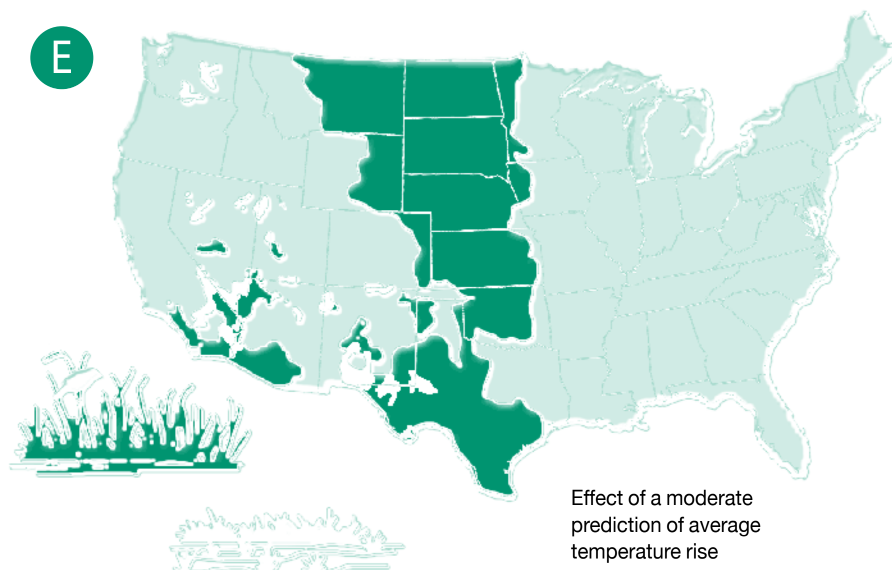


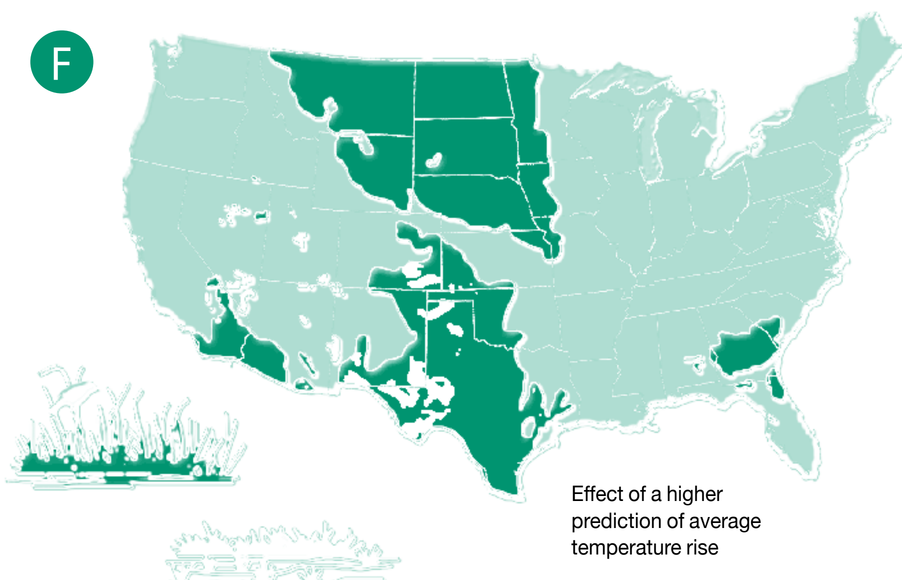
Figure 3. Current location of 4 (of the 10) vegetation types across 48 States (Figures 3a and 3d) and the potential change in the range of those vegetation types under two different possible future climates (Figures 3b, 3c, 3e, and 3f). In Figures 3c and 3f, the average future temperature is higher than 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.



Current temperature grasslands and arid lands



Effect of a moderate prediction of average temperature rise



Effect of a higher prediction of average temperature rise

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?

Discussion

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. Computer models may not always be exactly correct. They are, however, used as a tool that can help give us insight into a range of possibilities.

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 Columns 5 and 6 to Fahrenheit and

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					

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?

If you know the average yearly temperature for your own community, add your community to the list.

Note to Educators

The mission of the Forest Service is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. For more than 100 years, our motto has been caring for the land and serving people. We recognize our responsibility to be engaged in efforts to connect youth to nature and to promote the development of science-based conservation education programs and materials nationwide. We have developed the *Natural Inquirer* Climate Change Education Collection to help you and your students better understand climate change.

Forest Service researchers have studied the impacts of climate change and air pollutants on forests and grasslands for more than 30 years. This research has identified climate change trends and subsequent effects to ecosystems across the United States and worldwide. For their research contributions to the Intergovernmental Panel on Climate Change (IPCC) Report, 13 Forest Service scientists were recipients of the Nobel Peace Prize in 2007. The Nobel Committee recognized "efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change."

The articles in the Climate Change Education Collection will introduce students to several of these scientists and their climate-change-related research. Students will learn about the scientific process used by the scientists and will be engaged in hands-on activities on climate change topics such as the carbon cycle, invasive species, vegetation changes, and urban and world forests.

As teachers of science, you want your students to acquire abilities that will enable them to conduct scientific inquiry, and you want them to gain an understanding of the scientific inquiry process. Scientific inquiry can best be taught by integrating minds-on and hands-on experiences. Over time, such experiences encourage students to independently formulate and seek answers to questions about the world we live in. As educators, you are constantly faced with engaging your students in scientific inquiry in new and different ways. In an age of abundant technology, standard teaching strategies can become monotonous to today's learners. The *Natural Inquirer* provides a fresh approach to science and a view of the outside world that is larger than the classroom and can still be used while in the school setting.

The *Natural Inquirer* is a science education resource journal to be used with learners from Grade 5 and up. The *Natural Inquirer* contains articles describing environmental and natural resource research conducted by the Forest Service, U.S. Department of Agriculture scientists and their cooperators. These are scientific journal articles that have been reformatted to meet the needs of middle school students. The articles are easy to understand, aesthetically pleasing to the eye, contain glossaries, and include hands-on activities. The goal of the *Natural Inquirer* is to stimulate critical reading and thinking about scientific inquiry and investigation while learning about ecology, the natural environment, and natural resources.

The Format of a Natural Inquirer Article: Each *Natural Inquirer* article follows the same format. *Natural Inquirer* articles are written directly from a published science article, and all have been reviewed by the scientists for accuracy. Each article contains the following sections, which you may introduce to your students as they read:

Meet the Scientists: Introduces students to the scientists who did the research. This section may be used in a discussion of careers in science.
Glossary: Introduces possibly new scientific or other terms to students. The first occurrence of a glossary word is italicized in the text.
Thinking About Science: Introduces something new about the scientific process, such as a scientific habit of mind or procedures used in scientific studies.
Thinking About the Environment: Introduces the environmental topic being addressed in the research.
Introduction: Introduces the problem or question being addressed by the research.
Method: Describes the method used by the scientists to collect and analyze their data.
Findings: Describes the results of the analysis.
Discussion: Discusses the findings and places them into the context of the original problem or question.
Citation: Gives the original article citation.
FACTivity: Reinforces an aspect of the research through a hands-on activity.

Science Education Standards and Evaluations: In the back of the monograph, you will find a list that allows you to identify articles by the National Science Education Standards they address. You and your students may also complete evaluation forms online by visiting **http://www.naturalinquirer.org.** If you have any questions or comments, please contact:

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(Please put "Educator Feedback" in the subject line)

Educator Resources:
From the Web site, you can read and download lesson plans, word games, and other resources to help you use the *Natural Inquirer* in your classroom. You can also view and download a year-long lesson plan aimed at helping your students learn about the scientific process.

Visit the *Natural Inquirer* Web site at http://www.naturalinquirer.org.

For more climate change information, visit: http://www.fs.fed.us/climatechange/

Lesson Plan for This Monograph

Time Needed:
One class period (50-60 minutes)

Materials Needed:
- 1 piece of plain white 8.5 X 11" paper for each student; 1 piece of plain paper for each group of 4 students
- 3 X 5" sticky notes (enough for at least 7 per student)
- A monograph for each student

In class the day before:
Give each student a copy of the monograph, a piece of plain paper, and three sticky notes. The sticky notes should be placed on the paper and labeled "Science," "Environment," and "Prediction."

For homework:
Ask them to read "Thinking About Science" and "Thinking About the Environment." After they read each section, have them write the main idea of the section on the correct sticky note. On the third sticky note, they should predict what they think the article will address. Ask them not to read ahead in the monograph, but to use clues from the two sections to help them predict. They should also review the glossary before coming to class.

In class:
Introduce the *Natural Inquirer* monograph to the class. Include information about the sections they will be reading. (See "Note to Educator, The Format of a *Natural Inquirer* Article" on page 14.) (5 minutes)

On your whiteboard or clean chalkboard, label three areas "Science," "Environment," and "Prediction." Have each student place his or her sticky note in the correct area. Have a few students read some of the notes, one section at a time. Hold a class discussion about the similarities and differences of the notes in each section. Have students identify what clues they used to predict what the article would address and how the scientists might address it. (8 minutes)

Read "Meet the Scientists," "Introduction," "Method," "Findings," and "Discussion Sections" as a class. When you reach the end of each section, have students write the main idea of the section on a labeled sticky note. For now, skip the reflection questions. When the article has been completely read and all sticky notes completed, have students place their sticky notes on the whiteboard, under the correct heading (Introduction, Method, Findings, Discussion). (18 minutes)

Now, have each student select one sticky note from each category. They must not select their own sticky note. Place students in groups of four. Each group should compare and contrast their sticky notes for each section. On a sheet of paper, one student will write the four headings and under each heading, write the main ideas of each section as agreed on by the group. Each section's main ideas should be between 1 to 4 sentences long. (5 minutes)

Have each group read its main ideas for one or more sections (based on available time). Hold a class discussion to compare and contrast what each student group reported. (5 minutes)

Hold a class discussion about the research they have just read. What might happen to the environment in the future, given what they have learned? (5 minutes)

Make a list of actions they can take to reduce their carbon footprint (4 minutes). Examples include:

- Walk and bike more, ride in a car less.
- Eat more local produce; buy from local farmers' markets.
- Plant and maintain trees.
- Turn down the thermostat by 1-2 degrees in the winter.
- Turn up the thermostat by 1-2 degrees in the summer.
- Turn off appliances when not in use.
- Turn down the temperature in the hot water heater.
- Unplug your phones, etc., as soon as they have charged.
- Only do full loads in the dishwasher and clothes washer.
- Hang out clothes to dry.
- Consolidate car trips.
- Use energy-efficient light bulbs.
- Take shorter showers.

Day 2 (Optional): Do the FACTivity.

Lesson Plan Extension (This can be done in place of the FACTivity or as an extension on Day 3 if time allows.)

For homework, have students complete the reflection questions. They can use the same "sticky note" process to record their answers. In class on Day 2 (or 3, if you have done the FACTivity on Day 2), discuss their answers as a class. You may use the whiteboard to "mix up" the answers in the same manner as Day 1.

Reflection Section Answer Guide

Introduction

- **What is the difference between weather and climate?** Weather occurs on a day-to-day basis, and climate is composed of the trends and patterns in weather that occur over many years.

- **If the global climate continues to change, do you think that there will be any change in the types of forests and other vegetation growing across the United States? Why or why not?** This question has no right or wrong answer and has to be based on the student's own experience. Make sure students justify their answers. The question provides an opportunity to discuss similarities and differences between students' insight. Based on the scientists' predictions, global climate change will cause types of forests and vegetation to adapt to new climate temperatures and rainfall patterns that may lead to a change in species.

- **What was the question the scientists were trying to answer?** What kind of impact will climate change have on vegetation in the United States?

Methods

- **How would you describe the climate where tundra vegetation grows?** Tundra is permanently frozen soils with shrubs, mosses, grasses, and lichens. **How is the climate there different from the climate where tropical broadleaf forests grow?** Tropical broadleaf forests are hot, rainy, and have many trees, including evergreens and some deciduous trees. In comparison, tundra is cold and has less vegetation than the tropics.

- **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?** Think about the plants that have adapted to an area with little rain. If the plants receive too much rain, they may not be able to adapt and may die. If the rains continue, the plants thriving under more rainfall will eventually become dominant and the area's ecosystem will be permanently altered.

Findings

- **Select an area of the United States with which you are familiar. Compare the current vegetation type with the 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?** This answer will depend on the student's choice. Have students describe their answers with justification and evidence.

- **Do you think that these changes will definitely occur in the future? Why or why not?** This is an opinion question; there is no right or wrong answer. Have students justify their thoughts. Computer models are used by scientists to make their best prediction. Only time will tell if these predictions are accurate.

Discussion

- **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?** This is an opinion question that has no right or wrong answer. It is based on the student's own experience. Hold a class discussion to have the students hear each others ideas and comments. Computer models may not be correct, but they have allowed scientists to think more clearly about what could happen. The models generate better research planning and advancements in research.
- **The scientists identified things that can be done now to reduce the amount of CO_2 going into the atmosphere. Of those things, which can you and your classmates do?** This is an opinion question that has no right or wrong answer. Hold a class discussion to have the students discuss the scientists' suggestions and discuss other ideas from the students. The scientists suggested turning less productive crop and pasture land into forests. We can minimize the amount of forests being cut down and improve forest management. We can recycle more paper and wood products.

Where in the World Is Carbon Dioxide?
National Science Education Standards* Addressed With This Monograph:

	WHERE IN THE WORLD IS CARBON DIOXIDE?
Science as inquiry	
Abilities necessary to do scientific inquiry	X
Understandings about scientific inquiry	X
Physical Science	
Properties and Changes in Properties in Matter	X
Life Science	
Structure and Function in Living Systems	X
Diversity & adaptations of organisms	X
Earth & Space Science	
Structure of the earth system	X
Science in Personal & Social Perspective	
Populations, Resources, and Environments	X
Risks and Benefits	X
Science & technology in society	X
History & nature of science	
Science as a human endeavor	X
Nature of science	X

* National Research Council, Content Standards, Grades 5-8.

What Is the USDA Forest Service?

The Forest Service is a part of the U.S. Department of Agriculture. It is made up of thousands of people who care for the Nation's forest land. The Forest Service manages over 150 national forests and almost 20 national grasslands. These are large areas of trees, streams, and grasslands. National forests are similar in some ways to national parks. Both are public lands, meaning that they are owned by the public and managed for the public's use and benefit. Both national forests and national parks provide clean water, homes for the animals that live in the wild, and places for people to do fun things in the outdoors. National forests also provide resources for people to use, such as trees for lumber, minerals, and plants used for medicines. Some people in the Forest Service are scientists, whose work is presented in the journal. Forest Service scientists work to solve problems and provide new information about natural resources so that we can make sure our natural environment is healthy—now and into the future.

http://www.fs.fed.us/

What Is the Cradle of Forestry Interpretive Association?

The Cradle of Forestry Interpretive Association (CFIA) is a nonprofit organization. It was founded in 1972 by a group of conservationists to help the Forest Service tell the story of forest conservation in America. The CFIA helps people better understand forests and the benefits of forest management.

http://www.cradleofforestry.com/interpretive_association/

Editorial Review Board

Every *Natural Inquirer* article is reviewed by middle school science students. Student comments help to continually improve the *Natural Inquirer.* This is Mr. Todd Nickelsen's class in Athens-Clarke County, Georgia.

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