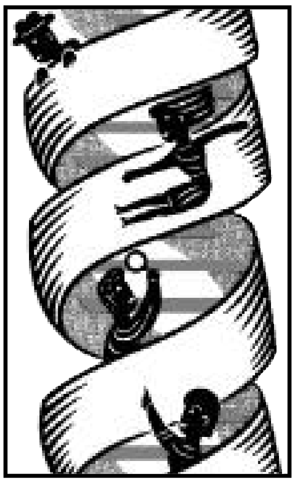
Winding
your
way
through
DNA



Produced by the
University of
California
San Francisco

On Becoming a Scientist

Teacher's Guide

Developed by teachers
for teachers and students

Distributed by

PYRAMID

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On Becoming a Scientist

Dedicated to the memory of Mary Jo Kelly

—Our colleague who cared so much about young people and whose contributions were invaluable.

Dear Educator

On the 25 and 26 of September 1992, the University of California San Francisco and the San Francisco Exploratorium presented a public symposium entitled "Winding your way through DNA." This program was designed to educate the public and to encourage a dialogue about the scientific possibilities and the social puzzles of recombinant DNA technology.

Following the symposium, a team of high school and college teachers, ethicists, historians, and scientists decided to create a series of videos that would provide a personal approach to science, its applications, and its ethical, legal, and societal issues. The second in this series is *Winding your way through DNA: On Becoming a Scientist*, a videotape intended for high school and college classes and public education programs.

This videotape is designed to portray science students and scientists as real, approachable individuals and to dispel the myth that they are all white men who wear glasses and pocket protectors and only work in dark laboratories. The video also examines the reasons why people choose a career in science and the skills that are needed to become a scientist.

Because the video focuses on several different aspects of science and scientific careers, the projects and activities in this teacher's guide have been grouped into three categories for easier use. The **Life of a Scientist** projects help students discover what it is like to be a scientist, how scientists work, and how scientists apply their knowledge to societal problems. The **Science Career** projects allow students to explore the wide range of career opportunities available in the biological sciences and show students ways in which scientific knowledge is used on the job. And the **Thinking Like a Scientist** activities are step-by-step activities that illustrate aspects of the scientific process and scientific thinking.

We invite you to use these materials to introduce the possibility of a career in science to your students and to give them a better understanding of who scientists are and what they do.

Supporters

We wish to thank the following individuals, corporations, and foundations for the generous funding that has made this educational videotape and curriculum project possible:

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Winding your way through DNA

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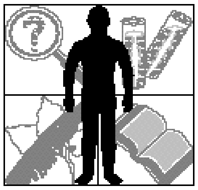

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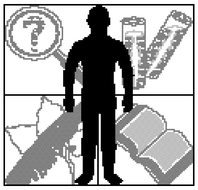


Video Guide

Video Objectives

- To give a basic understanding of who scientists are and what they do.
- To dispel some of the misconceptions that the general public may have about science and scientists.
- To convey what scientists find appealing and challenging in their jobs.
- To present some of the skills that scientists apply in their jobs.
- To interest student viewers in possible careers in science.

About the Video

On Becoming a Scientist provides a look at the work, lives, and motivations of three students and a lab manager who are pursuing careers in science. During the course of these interviews, the video helps dispel some of the misconceptions that many people have about science and scientists. Interspersed throughout the video are comments from already established scientists and people working in the scientific community about the reasons why scientists do what they do.

The video is divided into seven main segments—There's Always One Last Thing; Grades? What Grades?; Making a Difference; Cooperation is Key; Not a 24-Hour Thing; Managing a Career and Family; and Making Movies. Each segment focuses on one of the students and a particular aspect of that student's life and work.

There's Always One Last Thing introduces Aneil Mallavarapu. In this segment, Aneil reveals some of the qualities scientists have, such as being patient when dealing with problems and unexpected setbacks, and always being ready to try again.

Grades? What Grades? presents Aaron Straight, who points out that a person doesn't have to make straight A's in school to be a scientist. He also discusses why he enjoys doing science.

The **Making a Difference** segment focuses on Kirsten Bibbins-Domingo and how her work at a homeless medical clinic allows her to use science to contribute to and affect people's lives.

In **Cooperation is Key**, Aneil discusses how and why the scientists he works with cooperate with each other.

In the **Not a 24-Hour Thing** segment, Dana Smith and Aaron Straight discuss the types of things they do outside the laboratory, and how those activities help them maintain a sense of perspective about their work.

Managing a Career and Family returns to Kirsten, who is starting a family while she is still in medical school. In the segment, Kirsten talks about her decision to have a baby and how she thinks it will affect her career.

In the final segment, **Making Movies**, Aneil describes how he managed to overcome his earlier setbacks. He also summarizes his thoughts on what science is and what scientists do.

Discussion Questions

1. Before viewing the video, describe what you think a scientist is and what scientists are like. Then, after viewing the tape, discuss how your impressions may have changed.
2. Why might a person become a scientist? What are some of the advantages of doing science? What are some of the disadvantages?
3. What skills do you think that a scientist would need to have? Why? How might each of those skills be useful to a scientist?
4. Do you think you would like to be a scientist? Why or why not?

Video Profiles

Kirsten Bibbins-Domingo

Kirsten first became interested in science in the eighth grade, when she took a health sciences class taught by an inspiring teacher. She went on to study biology in college and graduate school. While in graduate school, Kirsten decided that she wanted to become a doctor because she was interested in disease and the processes that cause disease.

Kirsten is now in medical school at the University of California San Francisco. She is considering combining her medical knowledge with her previous research skills in order to obtain a position in medical research.

Aneil Mallavarapu

Aneil spent his first two years in college as a pre-med and philosophy student. Then he spent the summer of his sophomore year doing research in a lab, where he became interested in biology. He then switched his major and received a degree in biochemistry.

Aneil is currently a graduate student at the University of California San Francisco. He is using computers and video equipment to study nerve growth cone motility because this process helps in understanding how nerve cells connect to each other. When he finishes graduate school, Aneil plans to go into teaching or research.

Aaron Straight

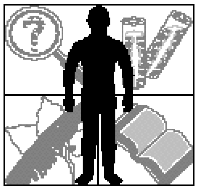
When Aaron started college, he was going to be an Art History major. While in school, however, he took many different types of courses and finally realized that his main interest was actually biology.

Currently, Aaron is a fifth-year graduate student at the University of California San Francisco, where he is working in a lab that investigates mutation during cell division and mitosis. After he finishes his PhD, Aaron plans to do a postdoctoral fellowship and then get a job in either academia or industry.

Dana Smith

Dana has been interested in biology since high school. In college, however, she was torn between majoring in dance and biology. She finally decided on biology and went on to complete her Master's degree.

Dana is now working in a lab at the University of California San Francisco. For several years, she investigated ways in which to genetically engineer proteins that would interfere with the way other proteins interact. She is currently studying how and when yeast cells divide.



Life of a Scientist Projects

We need very much a name to describe a cultivator of science in general. I should incline to call him a scientist.

—William Whewell (First written use of the term "Scientist," 1840)

Project 1: Depicting the Life of a Scientist

Before viewing the video, have students create a comic strip or play depicting a day or week in the life of an imaginary scientist. Suggest that students include events that they think might occur during both working hours and leisure hours.

Project 2: Making Discoveries

Ask students to make journal entries about a discovery they have made. Suggest that they answer questions such as: What was the discovery? How was it made? What are the students going to do with that discovery? Is the discovery useful in everyday life or does it apply only to special situations? What is the impact of the discovery?

Project 3: Sharing Information

Have students model the process of presenting scientific information at conferences or through articles that are published in science journals. Suggest that students look through articles in different science journals to see what type of information is included, such as hypotheses, research, and conclusions. Then ask groups of students to present to the class a discovery they have made or the results of an investigation.

Project 4: Identifying Solutions

Brainstorm with the class to identify different problems that society faces today. Then have teams of students choose one problem from the list. Have each team identify the knowledge (science) and application of that knowledge (technology) which might have contributed to the problem and which is being, or could be, used to solve the problem.

Project 5: Perceiving Stereotypes

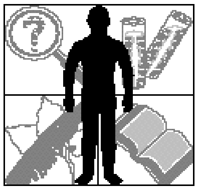
Before viewing the video, brainstorm with the class to create a master list of stereotypes about scientists (such as, they all wear white coats, are nerds, play with beakers and bubbling concoctions, or are men). Then have students view the video and/or interview scientists from the community. Ask students to compare and contrast their findings with the list of stereotypes. Have students discuss the origin of and the reasons for the stereotypes.

Project 6: Changing Opportunities

Assign small groups of students to do research to answer the following questions: How many women and minorities are represented in various scientific fields? Compare the ages and the percentages of women and minorities in science before 1960 and after 1985. What do these comparisons show? Compare and contrast the trends in hiring women and minorities before and after affirmative action policies began.

Project 7: Applying Science

To explore the impact of science and technology on everyday life, have students keep a journal for a day that lists everything they use, consume, or encounter that has been influenced by science and technology. Then have students use their lists to write a story or put on a play that shows what society might be like without science and technology.



Science Career Projects

Science and technology, and the various forms of art, all unite humanity in a single and interconnected system.

—Zhores Aleksandrovich Medvedev

Project 1: Investigating Careers

Have students read through the career descriptions in the Careers in Life Science section on pages 18-21, and ask them to choose one field that interests them. Then have students do further research on the field by looking in job directories or by contacting the organization(s) listed in the For Additional Information sections (pp. 18-21). Ask students to collect information concerning the skills needed for the position, the salary range they could expect, the level of education needed, and the types of positions available within the field. Have students present their findings as a written or oral report.

Project 2: Investigating Jobs

To give students a feeling for the number of different types of careers available in biology, have them search through the classified sections of newspapers and science magazines. Ask students to list the different fields and positions that require a background in the life sciences. Then have students create their own classified section that contains all the different types of ads they find.

Project 3: Identifying Opportunities

Divide the class into small groups. Ask each group to research science career opportunities in their community. Then have each group create a pamphlet that would attract other people to a selected career.

Project 4: Choosing a Field

Have students read through the career descriptions in the Careers in Life Science section on pages 18-21. Then ask them to choose one field that interests them. Have students develop a plan for a career in that field. The plan should include the type of preparation required, the steps the student would take to enter the field, and the advantages and disadvantages of such a job.

Project 5: Interviewing Scientists

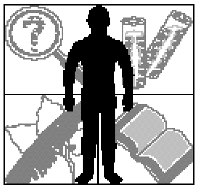
Have teams of students interview a person who uses science in his or her job. Before the interview, have students brainstorm potential interview questions. Ask students to select the best questions and to decide on the best ways to ask the questions. Then have each group write a summary report about the occupation that includes information on the person’s schooling, job responsibilities, and experience.

Project 6: Understanding the Team

Explain to students that there are many different positions available in scientific research. Divide the class into small groups, and have each group research one of the following positions: lab assistant, lab technician, research associate, postdoctoral research scientist, scientist, associate scientific director, scientific director, and project manager. Ask each group to write a description of the position and present it to the class. Then have the class compare and contrast the different positions, including the advantages and disadvantages of each, and discuss how individuals in each position support individuals in the other positions.

Project 7: Working Outside the Lab

Have students investigate the types of jobs people interested in science can pursue outside the laboratory. Suggest that they contact places such as museums, libraries, newspapers, health facilities, farms, national parks, and so forth, to find out what sorts of roles life scientists can have in those areas.



Thinking Like a Scientist Activity 1

The most beautiful thing we can experience is the mysterious. It is the source of all true art and science.

—Albert Einstein

Why Ask Why?

Objective

Students will experience the importance of curiosity in science.

About the Activity

One of the most fundamental characteristics of a scientist is curiosity. Most scientists, regardless of discipline, constantly question the world around them—Why is the sky blue? What happens if I mix these two ingredients? How do people move? Will bacteria grow if the air is heated? How can this disease be cured? These types of questions and the search for their answers form the basis of all science.

In this activity, students will learn to ask questions about items that they probably take for granted—pencils, leaves, fingers, hair, light bulbs, and so forth. Then they will use their creative thinking to ask even more questions about the first questions.

Materials

For each group

- Familiar object, such as a pencil or pen, a piece of hair, a leaf, light bulb, etc.

For each student:

- Pencil or pen
- Paper

Instructions

1. Divide the class into groups of three or four. Give each group an object to examine.
2. Ask the students to study the object closely and to think of at least twenty questions about the object. For example, if students are looking at a pencil, possible questions might include “Why does a pencil have six straight sides?”, “What is the black material inside the pencil?”, “Where does the material come from?”, and “How is it placed inside the pencil?” Have each student write his or her questions on a piece of paper. You may want to remind students that there are no “right answers” to this exercise—instead, they should write down any question that comes to mind.
3. After students have completed their questions, ask the students in each group to compare their lists. Working together, the students should choose one or two questions from the lists that particularly interest the group. Then they should brainstorm to come up with secondary questions that might help them answer the primary question or questions they chose. For example, suppose students choose the question “Why does a pencil have six straight sides?” as their primary question. Secondary questions might include “What would happen if the pencil had five sides or four sides?”, “What would happen if a pencil had rounded sides?”, “What would happen if the pencil were a cube instead of a cylinder?”, or “How would the pencil be sharpened if it were another shape?” Again, encourage students to be as creative as possible with their questions.
4. Have students brainstorm a possible answer for each secondary question.
5. Have each group select two or three primary and secondary questions and answers to share with the rest of the class.

Discussion Questions

1. When you compared your list of questions with others in the group, did all the lists have the same types of questions? What could account for the similarities and differences between the lists?
2. Why do you think you were asked to create two sets of questions? What is the purpose of the secondary questions?
3. Think about one question from your list that you would like to answer. What steps could you take to answer that question? Do you think there is more than one “right” way in which to find the answer? Why or why not?
4. The physicist Albert Einstein wrote “The most beautiful thing we can experience is the mysterious. It is the source of all true art and science.” What do you think he might have meant?

Thinking Like a Scientist Activity 2

The world is full of magic things waiting patiently for our senses to sharpen.

—John Keats

Under Observation

Objective

Students will investigate the importance of observation in science.

About the Activity

One of the most valuable skills for a scientist is the ability to observe—to really see what others might miss. In many cases, observation is not just a matter of seeing an object or phenomenon, but experiencing it using as many of the senses as possible—hearing, touching, smelling, even tasting. Instruments, such as microscopes or magnetic imaging, allow scientists to increase both the accuracy and depth of their perceptions. Once a situation, object, or behavior is observed, it is important to record that observation, either in writing or in pictures or both.

In this activity, students will examine part of a living object, both with the unaided eye and through hand lenses, to gain an understanding of how changing the tools humans use for observation can change our perceptions of an object. Students will also practice recording their observations by drawing sketches.

Materials

For each pair

- 2 hand lenses
- Object to examine such as a plant, feather, soil, wool, insect, etc.
- Paper
- Pencil
- Ruler
- Colored pencils (optional)

Preparation

Before class, obtain several different objects for students to examine.

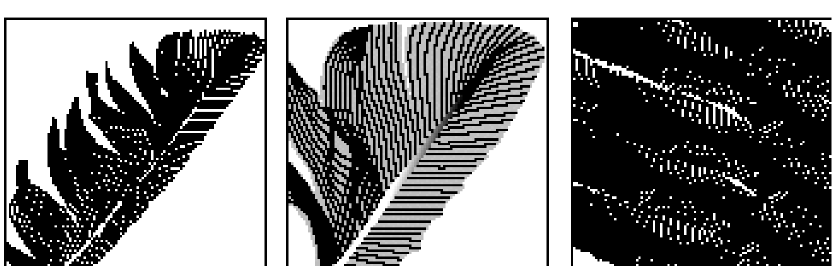
Instructions

1. Divide the class into pairs and pass out the materials. Ask each group to draw three 4" x 4" boxes, each on a separate sheet of paper. Explain that they will be recording their observations of their object within these boxes, and that the boxes represent the students' field of vision.
2. Ask the groups to carefully examine their object. Have them look closely at the shape, color, and texture of the object. Then ask the students to draw what they see in one of the boxes. Have them note any special details in their drawings, and write a brief description of what they see below the box.
3. Next, have students view the object using a single hand lens. Have them draw what they see in the box on the second sheet of paper. Have students write a brief description of what they see below the box. Ask them to indicate the lens magnification in the description. Then, ask them to compare what they see through the hand lens to what they saw without the help of the lens.
4. Now have students place two hand lenses together, to increase the magnification. Have them view the object through the combined lenses. Ask students to draw what they see within the box on the third sheet of paper, and have them write a description of what they see below the box. Be sure to remind them to include the total magnification in the description. (The total magnification equals the magnification of lens 1 multiplied by the magnification of lens 2. For example, 5x times 3x = 15x total magnification.)
5. Ask students to write three (or more) questions about the object they are observing that might be answered if they observed the object with a more powerful microscope.

Discussion Questions

1. How does the appearance of your object differ when viewed by the naked eye, under a single lens, and under two lenses? How would you describe what you saw at each level?
2. What types of information can you get by looking at an object in different ways? Why would this be important to scientists?
3. Why is it important to record your observations?
4. Why do questions change as additional information is gathered?

Sample drawings for the Under Observation exercise



Thinking Like a Scientist Activity 3

Scientists themselves believe, at heart, that behind the diversity lies a unity.

—Horace Freeland Judson

Order from Disorder

Objective

Students will investigate the importance of comparison and classification in science.

About the Activity

When scientists describe and classify objects or events, they do so in order to compare and communicate information about the objects or events. By comparing different groups or classifications, scientists can begin to recognize patterns. These patterns help scientists draw conclusions about the properties and relationships between the objects or events.

In this activity, students will create a karyotype—an ordered display of chromosomes—to see one of the patterns that occurs in living organisms.

Background Information

To study a person’s chromosomes, scientists take a photograph of a sample of white blood cells under a microscope. Water and fixatives are added to the cell during the metaphase cycle of mitosis, when the chromosomes are spread out. This allows the scientists to clearly see each chromosome as well as the location of the centromere of each chromosome. The chromosomes are often treated with a chemical stain, which stains some segments more darkly than others. This results in a distinct banding pattern. Scientists then cut up the photograph and make a chart called a karyotype that shows the individual chromosomes grouped in pairs. The chart helps scientists see defects in the chromosomes and/or any missing or extra chromosomes.

Materials

For each group

- Handout 1, page 12
- Scissors
- Tape or glue stick
- Paper

Preparation

Duplicate the handout to distribute to the students. You may also want to provide a second copy, or make an overhead transparency, of the handout so that students have a completed karyotype to examine.

Instructions

1. Have students begin by cutting out the individual chromosomes on the handout. They should then place all the cutout chromosomes in a pile, and mix them up.
2. Have students create the karyotype by regrouping the chromosomes into pairs based on length, banding pattern, and position of centromere. Ask them to tape or glue each pair onto the sheet of paper. Then have them label the pairs with the names of the chromosomes.

Discussion Questions

1. What is the normal number of chromosomes in a human body cell? How do you think scientists could have determined this?
2. How might scientists be able to identify possible genetic defects by creating a karyotype?
3. Is this a karyotype for a male or a female? How can you tell?
4. There are normally 23 chromosomes in human sperm and egg cells. Why is the number of chromosomes in these cells different from those in human body cells?

Thinking Like a Scientist Activity 4

Inventing hypotheses or theories to imagine how the world works and then figuring out how they can be put to the test of reality is as creative as writing poetry, composing music, or designing skyscrapers.

—F. James Rutherford and Andrew Ahlgren

Seeking Solutions

Objective

Students will experience the importance of forming and testing hypotheses.

About the Activity

The process for producing knowledge in science is to first observe a phenomenon, and then to construct a hypothesis to explain those observations. The hypothesis is based on both previous and current knowledge and research. It is possible that more than one hypothesis will explain a set of observations. It is also just as possible that another hypothesis explains the phenomenon better. To be useful, a hypothesis must be testable—that is, scientists must be able to create and conduct experiments that test the underlying assumptions of the hypothesis. Testing the hypothesis through research and experimentation helps a scientist gather evidence that his or her hypothesis is valid.

In this activity, students will be given information about several phenomena. Students will choose one phenomenon, and form hypotheses to explain the situation. They will then design an experiment to test one or more of their hypotheses.

Materials

For the class

- Reference materials

For each student

- Handout 2, page 13
- Pencil
- Paper

Preparation

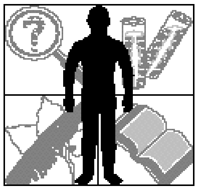
Duplicate the handout to distribute to students. Collect reference materials about the subjects listed on the handout.

Instructions

1. Distribute the handout to the students. Explain that the students should read through the observations on the handout and then choose one scenario that interests them.
2. Ask students to use the reference materials to collect as much information about the problem as possible. They might also research any previous experiments that have studied the problem. Remind students that they can use the library or perform on-line searches.
3. Why must a hypothesis be testable? Why is it important to clearly outline the materials and procedures you would use to test your hypothesis?
3. Next have students brainstorm possible explanations for the observations, and use the explanations to form several possible hypotheses. Have students record their hypotheses and then have them select one from the list to test.
4. Have students research information on ways to test their hypothesis. Then have them write one or more test procedures. Tell students that although they do not actually have to perform the experiment at this time, at least one of the experiments they design should use materials that are readily available at school or at home. Remind students to indicate the materials they would use, the step-by-step procedures they would follow, and the type of data they would collect and record.

Discussion Questions

1. Compare the hypotheses that were proposed for each problem. Were all the hypotheses for a problem the same? Why or why not? Did one hypothesis seem more likely to fit the observations than another?
2. Compare the experiments that were designed to test each hypothesis. Are there any similarities between the experiments? If so, what are they?
3. Why must a hypothesis be testable? Why is it important to clearly outline the materials and procedures you would use to test your hypothesis?
4. Suppose that you performed the experiment you outlined and the results turned out to be the opposite of what you expected. How could this information be helpful? What would you do next?



Thinking Like a Scientist Activity 5

Science is built up with facts, as a house is with stones. But a collection of facts is no more a science than a heap of stones is a house.

—Jules-Henri Poincaré

Just the Facts

Objective

Students will investigate the importance of data collection and analysis.

About the Activity

There are three major parts to an experiment. The first part involves designing and setting up the investigation. The second part includes performing the investigation, making observations, and collecting data. The third part involves analysis, which is essential to understanding the implications of the observations, including whether or not the hypothesis is supported. The purpose of an experiment is to test a hypothesis, not to substantiate it. Thus, it is just as valid to prove that a hypothesis is wrong, as it is to prove the hypothesis is valid.

In this activity, students investigate how food additives affect growth of microorganisms.

Background Material

Bacteria and other microbes grow rapidly under optimal conditions. These organisms feed on many of the same substances as humans do, and can bring about undesirable chemical and physical changes in food. To prevent the growth of these organisms in food, people use processes such as canning, heating, irradiating, freezing, and pasteurizing. In addition, preservatives are often added to the food.

Materials

For each group

- 2 chicken bouillon cubes
- Hot water
- Measuring cup
- Large beaker or glass jar
- 7 clear baby-food jars or cups with lids
- Salt
- Sugar
- Vinegar
- Teaspoon and tablespoon measures
- Masking tape
- Pen
- Paper

Instructions

1. Have students put a strip of masking tape on each of the seven jars. On each piece of tape they should write their names, class period, and jar number.
2. Explain to students that they will be testing the effectiveness of sugar, salt, and vinegar on inhibiting bacterial growth. Have students dissolve the bouillon cubes in 2 cups of hot water. The resulting solution should then be divided evenly between the baby-food jars or cups.
3. Have students add 1 teaspoon of salt to Jar 1, 1 teaspoon of vinegar to Jar 2, and 1 teaspoon of sugar to Jar 3. In Jars 4, 5, and 6, students should place 1 tablespoon of each material. Jar 7 is the control and should not have any additives. Remind students to label each jar to indicate the material and amount of material.
4. Ask students to place the containers in a warm place overnight. Then have them carefully cover each container loosely with a lid, or other material.
5. Have students develop a code based on the cloudiness of the liquid for recording observations. (For example, 0 = clear liquid, 1 = slightly cloudy (can see detail through the liquid), 10 = very cloudy (can't see anything through the liquid).) Have students check the containers each day for a week and record their observations in a chart.
5. Have students draw conclusions about the effectiveness of each material as a food preservative and present their findings to the class.

Discussion Questions

1. How can you tell if bacteria are growing in the solution? Record which containers show bacterial growth and which do not. Of those which show growth, did all the growth begin at the same time? How can you tell?
2. Does the amount of preservative change the results? Do you think the results would be different if you added more preservative to each container? Why or why not?
3. Why was it important to check the containers over a period of a week, rather than just one or two days? Do you think the results would be different if you checked the containers over a longer period of time? Why or why not?
4. What conclusions can you draw from this experiment? Explain your reasons.
5. What questions do you have about this experiment? Describe an experiment you might do next to help answer your questions.

Thinking Like a Scientist Activity 6

The greatest discoveries have come from people who have looked at a standard situation and seen it differently.

—Ira Erwin

Let's Get Together

Objective

Students will experience the importance of scientific collaboration and communication.

About the Activity

New scientific knowledge is often based on scientists bringing information from different areas and putting it together in new ways. Many of today's discoveries have come about because scientists have pooled their efforts. The collaboration can be based on past research or on continuing investigations. The value of communicating and exchanging ideas is emphasized by the fact that scientists present their ideas at conferences, through papers in journals, and over computer networks.

In this activity, students will model the discovery of recombinant DNA technology to discover how collaboration can help create new knowledge.

Background Information

Two scientists, Herbert Boyer and Stanley Cohen, worked together to lay the groundwork for creating recombinant DNA technology. Boyer's research focused on how particular sequences of nucleotides could be cut from a strand of DNA using chemicals called restriction enzymes. These enzymes recognize short, specific nucleotide sequences in DNA molecules, and cut the bonds of the molecules at those sequences. The result is a set of double-stranded DNA fragments with single-stranded ends, called sticky-ends, that can be used to join DNA pieces originating from different sources.

Cohen's research focused on plasmids—small circular units of DNA that can carry genetic material from one bacterium to another. When a plasmid is taken up by a bacterial cell, the cell will reproduce using the new genetic information from the plasmid. Cohen discovered a method for introducing new plasmids into the bacteria. Working together, Boyer and Cohen discovered that they could modify plasmid DNA using restriction enzymes, and then introduce the plasmids into bacterial cells. As the bacteria reproduce, so does the recombinant plasmid. The result is a bacterial colony in which a modified plasmid containing a desired gene has been cloned.

Materials

For each group

- Handouts 3 (parts A and B) and 4 (parts A and B), pages 14-17.
- Scissors
- Tape
- Pencil
- Paper

Preparation

Duplicate the handouts to distribute to students.

Instructions

1. Divide the students into groups of four. Explain that two of each group will represent Science Team A, while the other half of each group will represent Science Team B. Choose one student in each team to be the Lab Technician, and one to be the Researcher. Distribute part A of Handouts 3 and 4 to the A subgroup, and part B of Handouts 3 and 4 to the B subgroup.
2. Tell the students that they will use the information on the handouts to find a way to create and reproduce recombinant DNA. Explain that the Lab Technician in each group should prepare the DNA or plasmid strips as described on the handouts. Next, have the Lab Technicians compare the sequence of base pairs on an enzyme card with the sequences of the DNA or plasmid base pairs. If they find the same sequence of pairs on both the enzyme card and the DNA or plasmid strip, they should mark the location on the strip with a pencil, and write the enzyme name in the marked area. They should do this for each enzyme card.
3. Once the Lab Technicians have identified all corresponding enzyme sequences on the plasmid, have the Team A Researchers identify those enzymes which make two cuts in the DNA, on either side of the shaded gene sequence. Have the Team B Researchers find those enzymes which cut the plasmid once and only once. They should discard any enzymes that cut the plasmid in the shaded plasmid replication sequence.
4. Next, have the Researchers from both teams work together to identify the enzymes that make the appropriate cuts in both the DNA and the plasmid. Then ask the teams to work together to model a method for inserting a segment of DNA into the plasmid. Ask the combined teams to present their results to the class, as if they were presenting a paper at a conference.

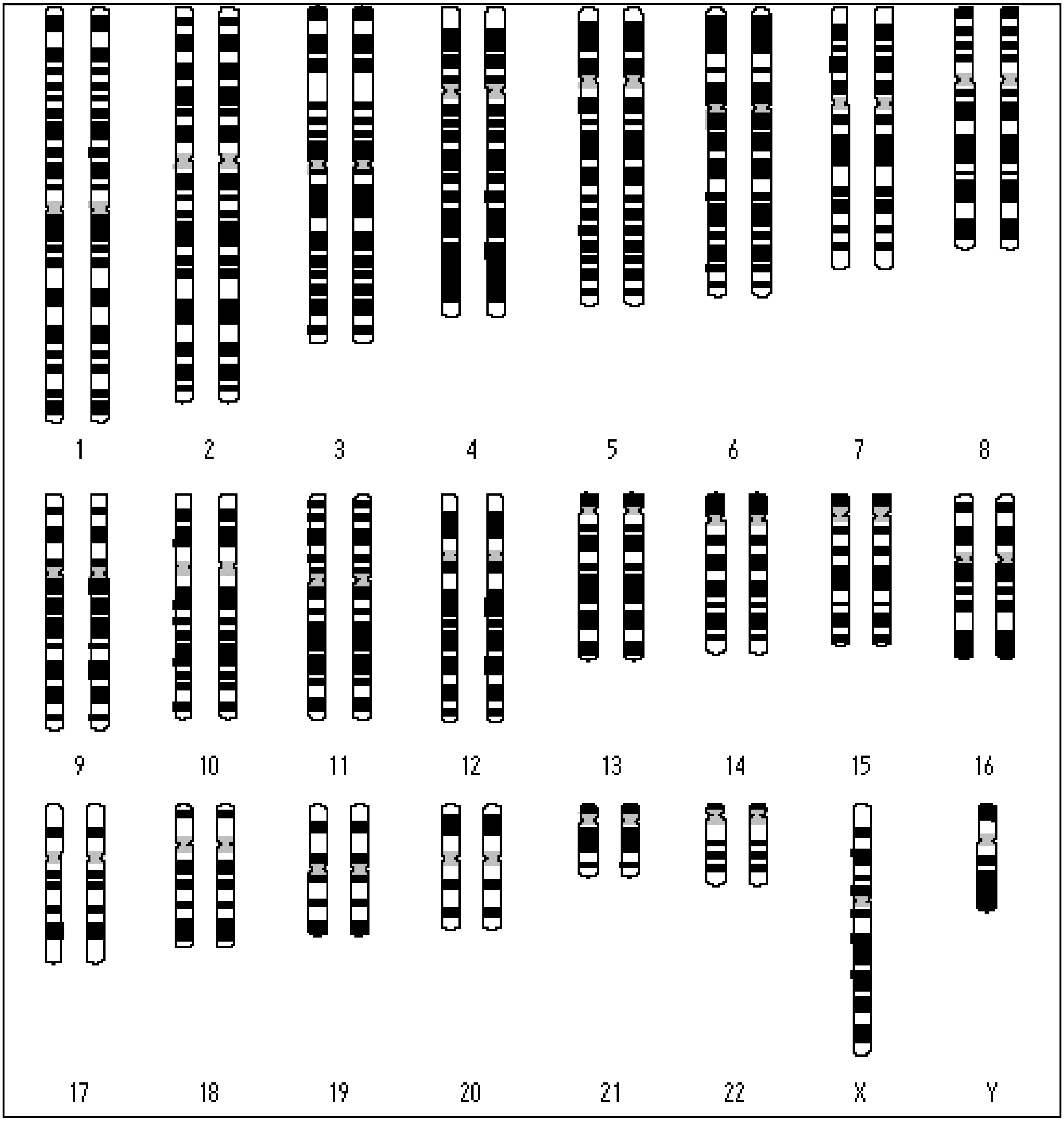
Discussion Questions

1. Describe the process you used to create and reproduce recombinant DNA.
2. Was the information from both scientists necessary to model the process? Why or why not? How did the information about restriction enzymes help you? How did the information about plasmids help you?
3. What was difficult about this process? What was easy? What did you enjoy most and least? Why?

Thinking Like a Scientist Handout 1

Human Chromosones

Cut out each individual chromosome below. Then place the chromosomes in a pile and mix them up. Create the karotype by regrouping the chromosomes into pairs. Tape or glue the pairs onto a sheet of paper.



Thinking Like a Scientist Handout 2

Seeking Solutions Scenerios

Read through the observations below and choose one scenario that interests you. Brainstorm explanations for the observations and use the explanations to form several possible hypotheses. Then develop one or more experiments to test your hypotheses.

Scenario 1

You have often noticed that ants follow one another in a trail to food. How do they know to follow each other in the trail? Do they have a form of communication that we can't hear or see? Or do they follow the trail because they see other ants following the trail?

Make several hypotheses that could explain why ants follow one another in a trail to food. Then design an experiment to test one of your hypotheses. What results would you observe if your hypothesis is true? What results would you observe if your hypothesis is false?

Scenario 2

When opening a container of cranberry juice, you noticed the label "refrigerate after opening." You also notice this label on a variety of other food containers, such as mayonnaise bottles and tuna cans. Why does the food have to be refrigerated once the can or bottle is opened, but not before? What would happen if the food were not refrigerated after opening? What does refrigeration do?

Make several hypotheses that could explain why certain foods can remain unrefrigerated before opening, but not after opening. Then design an experiment to test one of your hypotheses. What results would you observe if your hypothesis is true? What results would you observe if your hypothesis is false?

Scenario 3

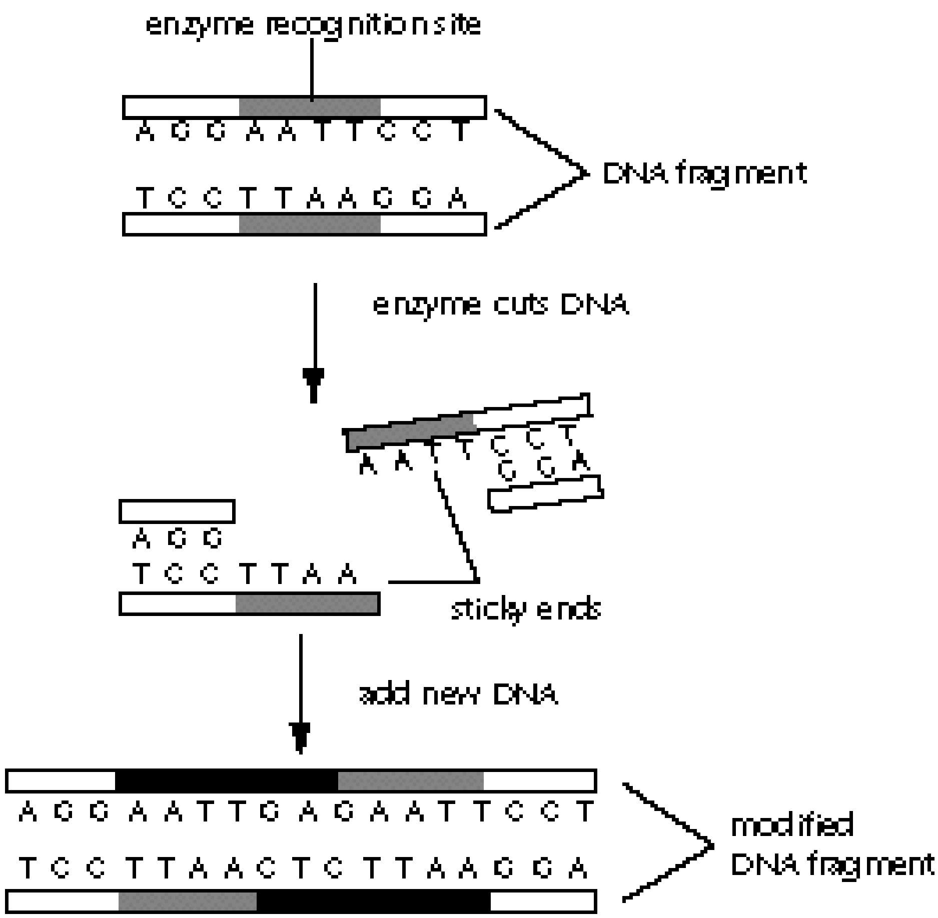
You are at the top of Mt. Haleakala, a dormant volcano that rises over 10,000 feet above the island of Maui in Hawaii. You noticed that a person nearby is talking about starting to feel dizzy, while someone else is complaining about a sudden headache. You feel fine. Why are some people feeling sick when others are not? Is it the air around the volcano? Is it the altitude? Or are the problems completely unrelated to the location?

Make several hypotheses that could explain why certain people feel sick at the top of Mt. Haleakala while others do not. Then design an experiment to test one of your hypotheses. What results would you observe if your hypothesis is true? What results would you observe if your hypothesis is false?

Thinking Like a Scientist Handout 3A

DNA and Restriction Enzyme Scenario

Congratulations! Through careful research your team has discovered a procedure for joining two pieces of DNA from different organisms. First you use a restriction enzyme to cut apart a fragment of DNA. This enzyme recognizes a specific sequence of bases in the DNA molecule, and cuts the molecule within that sequence. The result is a set of double-stranded DNA fragments with single-stranded ends called sticky ends. The sticky ends will form base pairs with complementary single-stranded stretches on other molecules. By combining cut DNA from different sources that have complementary sticky ends, modified DNA fragments are formed.

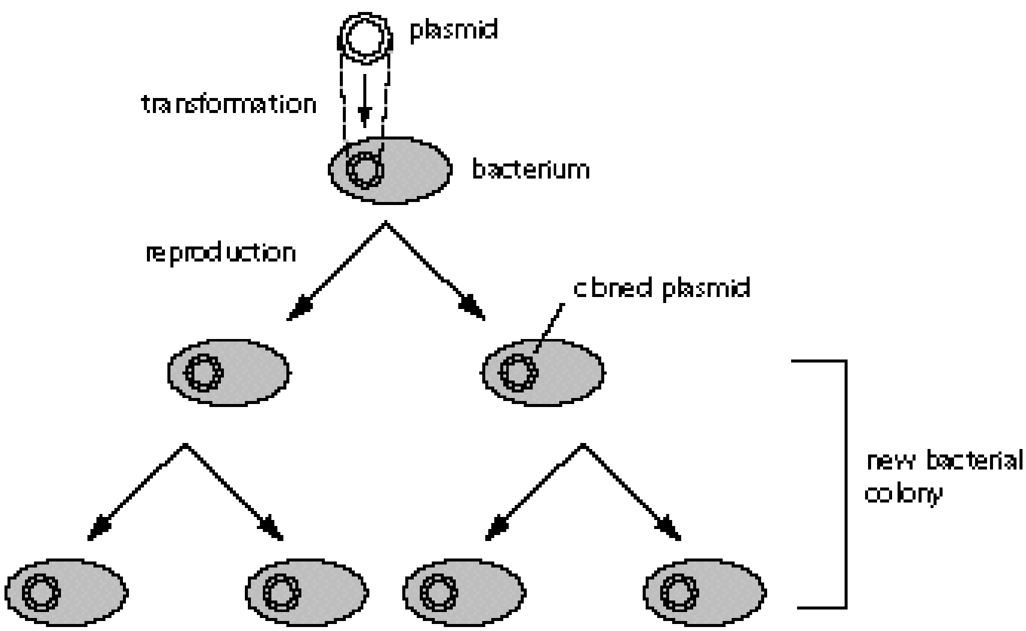


Even though you can make new DNA, you’re not sure that the molecule will function in the same way as normal DNA. Your modified DNA molecules are not useful unless they can be made to replicate and function within a cell.

Thinking Like a Scientist Handout 3B

Plasmid and Bacteria Scenario

Congratulations! Through careful research your team has discovered a procedure for introducing small DNA fragments into a bacterial cell. This procedure, called transformation, involves inserting plasmids—a circular, self-replicating form of DNA found in many species of bacteria—into bacterial cells. To do this you add the plasmid DNA to a bacterial culture. Under the right conditions, the bacteria will take up the plasmid DNA from solution. As the bacterium reproduces, so does the recombinant plasmid. The final result is a bacterial colony in which the foreign plasmid has been cloned, creating genetically identical cells.



You have developed a way to insert foreign DNA into a cell so that it replicates and functions normally to create genetically identical clones. However, you still need a way to change the type of genetic information that the plasmids carry into the cell.

Thinking Like a Scientist Handout 4A

DNA and Enzyme Patterns

Cut out the DNA base sequence strips along the dotted lines, and tape them, end to end, together to form one long strip. The pieces must be taped together so the numbers on the left and right sides of the strips match. Cut out the enzyme cards.

DNA Base Sequence Strips

T G G G C C T A G G C A C A G G G C C C G
1
A C C C G G A T C C G T G T C C C G G G C

T T C G A A G G T A C A T A A C G T C T C
1 2
A A G C T T C C A T G T A T T G C A G A G

T T C G T C A T G T G C C T T T T A A A T
2 3
A A G C A G T A C A C G G A A A A T T T A

G T A A T A T T C C T C C T T A A G A A T
3 4
C A T T A T A A G G A G G A A T T C T T A

T T C G A A C G G G G C C C T A G G A C C
4
A A G C T T G C C C C G G G A T C C T G G

Enzyme Cards

C C T G G G G A C C **AVA II**	C T C G A G G A G C T C **SAC I**	T T C G A A A A G C T T **HIN DIII**
G G C C C C G G **HPA II**	C C T A G G G G A T C C **BAM HI**	C T T A A G G A A T T C **ECO RI**

Thinking Like a Scientist Handout 4B

Plasmid and Enzyme Patterns

Cut out the plasmid strips along the dotted lines. Then shuffle the strips and tape them together, end to end, to form a single long strip. The two ends of the strip should then be taped together with the genetic code facing out to form a circular plasmid. Cut out the enzyme cards.

Plasmid Strips

G	C	C	C	A	G	A	G	T	T	T	C	T	T	A	A	G	G	T	C	T
C	G	G	G	T	C	T	C	A	A	A	G	A	A	T	T	C	C	A	G	A

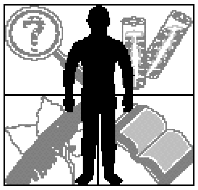
C	G	A	G	T	T	A	A	C	C	T	A	G	G	A	G	G	G	C	C	C
G	C	T	C	A	A	T	T	G	G	A	T	C	C	T	C	C	C	G	G	G

T	G	G	T	G	G	G	G	G	C	A	A	G	G	T	T	A	T	A	C	T
A	C	C	A	C	C	C	C	C	G	T	T	C	C	A	A	T	A	T	G	A

T	A	A	G	C	C	G	T	A	G	G	T	T	C	G	A	A	C	G	C	C
A	T	T	C	G	G	C	A	T	C	C	A	A	G	C	T	T	G	C	G	G

Enzyme Cards

C C T G G G G A C C **AVA II**	C T C G A G G A G C T C **SAC I**	T T C G A A A A G C T T **HIN DIII**
G G C C C C G G **HPA II**	C C T A G G G G A T C C **BAM HI**	C T T A A G G A A T T C **ECO RI**



Careers in Life Science

There is a wide variety of different specialized fields in the biological sciences, and the list is growing rapidly. You can choose to work with a particular type or group of organisms, such as birds, viruses, or trees. You can work with a particular system within an organism, such as cells, tissues, or whole organs. You can focus on the interaction between organisms and their environment in a particular area, such as the ocean, desert, or forest. Or you could focus on the chemical, physical, or medical aspects of living things.

Although many life scientists are primarily involved in research and development, and work in the laboratory or field, you may decide you want to work in another area within the science. There are many jobs available in such areas as management, administration, service work, sales, teaching, financial support, legal support, writing, illustrating, or photography. You do not have to work in a laboratory for scientific training or thinking to be useful. Some life scientists are employed by zoos, museums, aquariums, botanical gardens, schools, libraries, farms, health clubs, parks, the government, and research foundations.

The following is a small sample of some of the different fields and jobs available in biology.

Agronomist

Agronomists work to improve the quality and production of field crops. They apply scientific methods to develop new growing methods and to make crops more resistant to diseases and pests. They also plan and conduct experiments that relate to the planting, cultivating, and harvesting of crops.

For Additional Information
American Society of Agronomy
677 South Segoe Road
Madison, WI 53711

Anatomist

Anatomists study the form and structure of animal bodies. They determine the ability of animal bodies to regenerate destroyed or injured parts, and investigate the possibility of transplanting whole organs or tissues fragments, such as skin.

For Additional Information
American Association of Anatomists
9650 Rockville Pike
Bethesda, MD 20814

Animal Scientist

Animal scientists conduct research in selecting, breeding, feeding, managing, and marketing of domesticated animals.

For Additional Information
American Society of Animal Science
309 West Clark Street
Champaign, IL 61820

Biochemist

Biochemists specialize in the chemical composition and behavior of living things. Their work is vital for understanding of reproduction, growth, and heredity. Biochemists may investigate such things as causes and cures of diseases, or transferring characteristics of one kind of plant to another. Some study the effects of food, hormones, or other substances on various organisms.

For Additional Information
American Society of Biological Chemists
9650 Rockville Pike
Bethesda, MD 20814

Biomedical Engineer

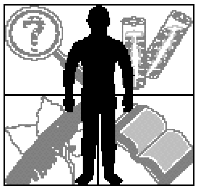
Biomedical engineers research and develop new ways to help people who are handicapped because of the malfunction of some organ of the body. Biomedical engineers have created such devices as artificial hearts, kidneys, limbs, and joints.

For Additional Information
Biomedical Engineering Society
P.O. Box 2399
Culver City, CA 90230

Biophysicist

Biophysicists study the physical principles within living cells and organisms. These scientists specialize in such things as how the eye converts the energy of light into a signal to the brain, how plant or animals respond to gravity, and how radiation affects living matter.

For Additional Information
Biophysical Society
9650 Rockville Pike
Bethesda, MD 20814



Careers in Life Science

Botanist

Botanists study plants and the environment. Some study all aspects of plant life, while others specialize in areas such as identification and classification of plants, the structure of plants, or the causes and cures of plant diseases.

For Additional Information
American Society of Horticultural Science
701 North Asaph Street
Alexandria, VA 22314

Developmental Biologist

Developmental biologists study the development of an animal from a fertilized egg through the hatching process or birth. They also study causes of healthy and abnormal development.

For Additional Information
Society for Developmental Biology
9650 Rockville Pike
Bethesda, MD 20814

Ecologist

Ecologists study the relationship between organisms and their environment. They particularly look at the effects of such things as soil conservation, pollutants, rainfall, temperature, or altitude on all the organisms in an environment.

For Additional Information
American Institute of Biological Sciences
1401 Wilson Boulevard
Arlington, VA 22209

Epidemiologist

Epidemiologists study the patterns of disease within a population. They are also concerned with determining how diseases are caused and how they spread.

For Additional Information
Epidemiology Program Office
Centers for Disease Control and Prevention
Atlanta, GA 30333

Food Scientist

Food scientists study the chemical, physical, and biological nature of food to learn how to safely produce, preserve, package, distribute, and store it. They also work to make food nutritious, flavorful, and wholesome.

For Additional Information
Institute of Food Technologies
221 North LaSalle Street, Suite 2120
Chicago, IL 60601

Forester

Foresters manage, develop, and protect forest areas and their resources. Foresters map forest areas, estimate timber amounts, calculate future forest growth, and manage timber sales. They determine which areas need special care or treatment, such as reseeding. They also help protect trees from fire, disease, and harmful insects.

For Additional Information
American Forest Institute
1619 Massachusetts Avenue, N.W.
Washington, DC 20036

Geneticist

Geneticists study the process of inheritance. They perform experiments to determine what causes different traits and inherited disorders, and investigate how these traits are passed on from one generation to the next. They may also devise methods for altering or producing new traits.

For Additional Information
Genetics Society of America
9650 Rockville Pike
Bethesda, MD 20814

Health Inspector

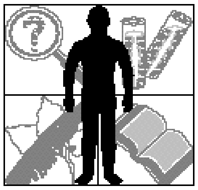
Health inspectors make sure that laws dealing with foods, drugs, cosmetics, and other consumer products are followed. They inspect companies that produce, store, and market such products, and check for bacteria or harmful chemicals.

For Additional Information
Federal Job Information Centers
U.S. Office of Personnel Management
Washington, DC 20003

Horticulturist

Horticulturists work with orchard and garden plants such as fruit and nut trees, vegetables, and flowers. They try to improve plant culture methods for communities, homes, parks, and other areas, as well as for increasing crop quality and yields.

For Additional Information
American Society of Horticultural Science
701 North Asaph Street
Alexandria, VA 22314



Careers in Life Science

Immunologist

Immunologists study the way in which the body protects itself against foreign invaders such as parasites, viruses, and replacement organs. These scientists research ways to develop vaccines to protect against disease and medicines to cure or prevent allergic reactions. They also investigate ways to help control reactions to blood transfusions and transplants.

For Additional Information
American Association of Immunologists
9650 Rockville Pike
Bethesda, MD 20814

Marine Biologist

Marine biologists study the development, function, and environment of plant and animal life in the ocean. They investigate such things as how to improve and control fishing and determine the effects of pollution on marine life. They also may search for new food and drug sources from the ocean and experiment to find ways of raising crops in underwater farms.

For Additional Information
American Society of Limnology and Oceanography
Great Lakes Research Division
University of Michigan
Ann Arbor, MI 48109

Medical Illustrator

Medical illustrators specialize in drawing parts of the human body. Their work is used in medical textbooks and other publications, for research purposes, and in lectures and other presentations.

For Additional Information
Association of Medical Illustrators
2692 Huguenot Springs Road
Midlothian, VA 23113

Medical Laboratory Technician

Medical laboratory technicians perform tests in medical laboratories and hospitals. They prepare tissue samples and perform laboratory tests to screen for the presence of disease and to help diagnose medical problems.

For Additional Information
American Medical Technologists
710 Higgins Road
Park Ridge, IL 60008

Microbiologist

Microbiologists investigate microscopic organisms such as bacteria, viruses, algae, yeasts, and molds. These scientists try to discover how these organisms affect animals, plants, and the environment. Some microbiologists specialize in medicine or agriculture, while others focus on particular organisms.

For Additional Information
American Society for Microbiology
1913 I Street, N.W.
Washington, DC 20006

Mycologist

Mycologists perform experiments on fungi to discover those which may be harmful to humans or are useful to medicine, agriculture, and industry for the development of drugs, medicines, molds, and yeasts.

For Additional Information
The Mycological Society of America
Department of Botany
University of Toronto, Erindale Campus
Mississuaga, Ontario L5L IC6, Canada

Nutritionist

Nutritionists counsel individuals or groups on sound nutritional practices to maintain and improve health. They may develop special diets, plan and prepare meals, and budget and purchase food. They may also be responsible for the nutritional aspects of preventive health and medical care services.

For Additional Information
American Dietetic Association
430 North Michigan Avenue
Chicago, IL 60611

Paleontologist

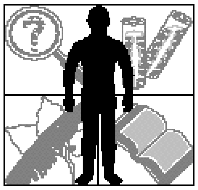
Paleontologists study the fossil remains of plants and animals. These scientists look for evidence of change in the plants and animals to trace the evolution and development of past life. They use fossils to reconstruct prehistoric environments and geography, as well as to make models of animals that have become extinct, such as dinosaurs.

For Additional Information
Paleontological Research Institution
1259 Trumansberg Road
Ithaca, NY 14850

Pathologist

Pathologists study the nature, cause, and development of diseases and the changes to animals and plants caused by the diseases. They make diagnoses from body tissues, fluids, and other specimens. And they perform autopsies to determine the nature and extent of disease as well as the cause of death.

For Additional Information
American Association of Pathologists
9650 Rockville Pike
Bethesda, MD 20814



Careers in Life Science

Pharmacologist

Pharmacologists develop new or improved drugs or medicines. They also conduct tests to determine the effect of drugs and their possible shortcomings or undesirable side effects. Some pharmacologists work with other doctors to study how disease can alter the effects of drugs.

For Additional Information
American Society for Pharmacology and Experimental Therapeutics
9650 Rockville Pike
Bethesda, MD 20814

Physiologist

Physiologists study the functions of plants and animals under normal and abnormal conditions. These scientists are concerned with questions such as: What makes a plant or animal grow? What regulates the rate at which they grow? How is food digested? Why do we need blood? And how do plants breathe? They perform experiments to determine the effects of internal and external environmental factors on life processes.

For Additional Information
American Physiological Association
1200 17th Street, N.W.
Washington, DC 20036

Science Teacher

Science teachers help students learn about different aspects of science. Some science teachers work in elementary schools; others work in middle schools, high schools, colleges, and universities. Some may teach only a particular topic, such as cell biology or anatomy, while others cover many different topics in their classrooms or laboratories.

For Additional Information
National Science Teachers Association
1840 Wilson Blvd.
Arlington, VA 22201

Science Writer

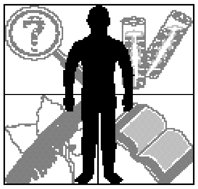
Science writers write about scientific issues, new information, or trends for newspapers, magazines, books, television, and radio. Some science writers specialize in a particular topic, such as medicine or environmental issues, while others cover many different topics. An important part of science writing is making technical information clear and understandable.

For Additional Information
National Association of Science Writers
P.O. Box 294
Greenlawn, NY 11740

Zoologist

Zoologists study the origin, behavior, diseases, and life processes of animals. Some work with live animals, while others dissect dead animals to study the structure of their parts. There are several different branches of zoology, classified by the animal group studied, including ornithology (birds), entomology (insects), mammalogy (mammals), herpetology (reptiles), and ichthyology (fish).

For Additional Information
American Society of Zoologists
California Lutheran University
Box 2739
Thousand Oaks, CA 91360



References

Level indicators:

1 = suitable for general public

2 = suitable for high school students

3 = useful for faculty

4 = useful for advanced faculty

General Reading

Andrews, Lori B., et al., eds. *Assessing Genetic Risks: Implications for Health and Social Policy.* Washington, DC: National Academy Press, 1994. This report by the Committee on Assessing Genetic Risks addresses the many phases of genetic testing and its impact on patients, providers, and laboratories. (1)

Bains, William. *Genetic Engineering for Almost Everybody.* New York, NY: Viking Penguin, 1990. Provides accessible information about the development of genetics, molecular biology, and decoding DNA. (1)

Balkwill, Fran. *Amazing Schemes Within Your Genes.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1993.

——————. *Cells Are Us.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1990.

——————. *Cell Wars.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1990.

——————. *DNA is Here to Stay.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1992.

Cartoon illustrations in all four books support explanations of scientific concepts; suitable for reading aloud to students, as well as for students' use. (1, 2)

Bishop, Jerry E. and Waldholz, Michael. *Genome: The Story of the Most Astonishing Scientific Adventure of Our Time–The Attempt to Map All the Genes in the Human Body.* New York, NY: Simon and Schuster, 1990. Highlights major events leading up to our present state of genetic exploration and biotechnology. Includes examples of personal challenge and achievement as well as a good feeling for the personal and professional challenges involved in scientific research. (1-3)

Cavalieri, Liebe F. *The Double-Edged Helix: Science in the Real World.* New York, NY: Columbia University Press, 1981. A biochemist's critical view of the long-range consequences of recombinant DNA technology, and, more generally, of what he sees as the growing subservience of science to technology. (1)

Cook-Deegan, Robert. *The Gene Wars: Science, Politics, and the Human Genome.* New York, NY: W.W. Norton, 1994. A firsthand look at the politics and science behind the Human Genome project. (1)

Davis, Bernard D., ed. *The Genetic Revolution: Scientific Prospects and Public Perceptions.* Baltimore, MD: Johns Hopkins University Press, 1991. This collection of essays examines molecular genetics, the practical applications of biotechnology, its legal implications, benefits, and harmful consequences. (1)

Duster, Troy. *Backdoor to Eugenics.* New York, NY: Routledge, 1990. This book focuses on ethical and social issues. (1-4)

Edey, Maitland A. and Johanson, Donald C. *Blueprints: Solving the Mystery of Evolution.* New York, NY: Viking Penguin, 1990. A history of genetic and evolutionary theory. (1-4)

Gonick, Larry and Wheelis, Mark. *The Cartoon Guide to Genetics. rev. ed.* New York, NY: HarperCollins Perennial, 1991. Cartoons for all ages. Some illustrations are helpful for class explanations of concepts. (1-3)

Grobstein, Clifford. *A Double Image of the Double Helix: The Recombinant-DNA Debate.* New York, NY: W.H. Freeman, 1979. Recounts the background and significance of the controversy over recombinant DNA research. Illustrates the scientific and social issues generated and how they were addressed early in the history of recombinant DNA. (1-4)

Hall, Stephen S. *Invisible Frontiers; The Race to Synthesize a Human Gene.* Redmond, WA: Microsoft Press, 1988. An inside view for the average reader on the science, politics, and pitfalls of the race to clone the gene for insulin. This well-researched account describes molecular biology in action, scientific competition, the development of NIH's recombinant DNA committee, and the birth of the first biotechnology company, Genentech, Inc. (1)

Herskowitz, Joel and Herskowitz, Ira. *Double Talking Helix Blues.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1993. This tape-book package, illustrated by Judy Cuddihy, provides a unique way of learning about DNA and genes and how they work. Interesting and fun for young people and adults who are curious about how they and their relatives became the unique individuals they are. (1, 2)

Judson, Horace F. *The Eighth Day of Creation: The Makers of the Revolution in Biology.* New York, NY: Simon & Schuster, 1979. A science writer's comprehensive and accessible history of the research leading to the elucidation of the structure of DNA, the deciphering of the genetic code, and the structure and function of proteins. (1-4)

Kevles, Daniel J. and Hood, Leroy, eds. *The Code of Codes: Scientific and Social Issues in the Human Genome Project.* Cambridge, MA: Harvard University Press, 1992. An anthology of essays on the potential scientific and medical triumphs and social and ethical implications of the Human Genome Project. (2, 3)

Levine, Joseph and Suzuki, David. *The Secret of Life: Redesigning the Living World.* Boston, MA: WGBH Educational Foundation, 1993. In this companion book to the PBS series of the same name, the authors expound upon the most important areas of the growing field of molecular biology. (1)

References

Los Alamos National Laboratory. *The Human Genome Project. Los Alamos Science. Vol. 20, 1992.* This is a nicely illustrated overview of The Human Genome Project from the perspective of Los Alamos National Laboratory. It provides an excellent review of genetics and molecular genetics as well as a very thorough overview of genome mapping. The typography and illustrations make this accessible to high school students. (2-3).

McCarty, Maclyn. *The Transforming Principle: Discovering that Genes are Made of DNA.* New York, NY: W.W. Norton, 1985. An engaging description of the crucial experiments that established DNA as the genetic material. (1)

Neubauer, Peter B. *Nature's Thumbprint: The New Genetics of Personality.* Reading, MA: Addison-Wesley, 1990. A look at the nature-nurture-behavior-personality controversy. (1-3)

Recombinant DNA: Readings from Scientific American. New York, NY: W.H. Freeman, 1978. Thirteen articles from *Scientific American* that describe major scientific discoveries basic to recombinant DNA. Includes the 1975 article by Stanley Cohen describing how recombinant molecules were first produced. Includes bibliography. (3, 4)

Shapiro, Robert. *The Human Blueprint: The Race to Unlock the Secrets of Our Genetic Code.* New York, NY: Bantam Books, 1992. A "reader-friendly" account by a professor of chemistry of the historical background, scope, and social meaning of the Human Genome Project. (1)

Suzuki, David and Knudtson, Peter. *Genethics: The Clash Between the New Genetics and Human Values.* Cambridge, MA: Harvard University Press, 1989. (1-4)

Watson, James D. and Crick, Francis H.C. *"Molecular Structure of Nucleic Acids: A Structure of Deoxyribose Nucleic Acid." Nature 171 (1953).* This is the article that set the foundation for all of molecular genetics. Probably the single most important page in the history of biology. (2-4)

Watson, James D. and Tooze, John. *The DNA Story: A Documentary History of Gene Cloning.* New York, NY: W.H. Freeman, 1981. A history of gene cloning told through scientific papers, correspondence, newspaper articles, cartoons, and so on. (1-3)

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Watson, James D. *The Double Helix.* New York, NY: Penguin Books, 1969. A popular and highly personal account of the science and personalities involved in the discovery of the structure of DNA. (1-3)

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Kantrowitz, Mark and DiGennaro, Joann P. *Prentice Hall Guide to Scholarships and Fellowships for Math and Science Students.* Englewood Cliffs, NJ: Prentice Hall, 1993. A directory of financial aid resources and job opportunities that also provides the basic information needed for obtaining facts about and applying for more than 200 scholarships, fellowships, competitions, internships, and summer jobs geared almost exclusively to students interested in the sciences. (1-3)

Lasky, Barry, ed. *The New Careers Directory: Internships and Professional Opportunities in Technology and Social Change.* Student Pugwash USA, 1993. This reference includes data on 300 organizations that offer paid and unpaid internships and entry-level jobs in scientific and technological fields. The directory emphasizes programs that target women and minorities. (1-3)

Schiebinger, Linda. *The Mind Has No Sex. Women in the Origins of Modern Science.* Cambridge, MA: Harvard University Press, 1991. An analytical discussion of the lives and contributions of many woman scientists and the conditions under which they worked. (1-4)

Tobias, Sheila. *They're Not Dumb, They're Different: Stalking the Second Tier.* Washington, DC: Science News Books, 1990. Tobias, a noted authority on making science and mathematics more accessible to students, provides new ways to interest talented students in pursuing college courses that lead to careers in science and technology. (3-4)

Yentsch, Clarice M. and Sindermann, Carl J. *The Woman Scientist: Meeting the Challenges for a Successful Career.* New York, NY: Plenum, 1992. Science teachers and others who may influence students' attitudes about the roles of women scientists should be encouraged to read this book. Chapters deal with status, career goals, early education, and training; a time-line approach to women's lifestyles as career scientists; employment and unemployment; positions of power and influence; support roles, mentors, and role models; participation in science societies; subtle forms of gender-based differential treatment; and career phases. (3-4)

Teacher Resources and Textbooks

Addison-Wesley Biotechnology Manual. Menlo Park, CA: Addison-Wesley, 1996. This manual for teaching a special unit on biotechnology was developed by high-school teachers and university scientists. It includes background essays, lab investigations, issues and decision-making essays, and teacher's instructions. (3-4)

Alberts, Bruce, et al. *Molecular Biology of the Cell. 3rd ed.* New York, NY: Garland, 1994. A veritable encyclopedia of molecular biology and cell biology. (3-4)

American Association for the Advancement of Science. *Project 2061: Benchmarks for Science Literacy.* New York, NY: Oxford University Press, 1993. Project 2061 has been working since 1985 to produce a set of tools that will help reform education in science, mathematics, and technology—including both the design of local curricula and the educational system in which curricula unfolds. (3)

Berg, Paul and Singer, Maxine. *Dealing With Genes: The Language of Heredity.* Mill Valley, CA: University Science Books, 1992. A thorough, advanced textbook intended for non-science majors. (2-3)

Biological Sciences Curriculum Study. *Basic Genetics: A Human Approach.* Dubuque, IA: Kendall Hunt Publishing Company, 1991. A helpful introduction to basic genetics. (3)

——————. *Mapping and Sequencing The Human Genome: Science, Ethics and Public Policy.* Colorado Springs, CO: BSCS and American Medical Association, 1992. Addresses ethical issues and explains the Human Genome Project. (3)

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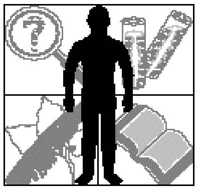

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——————. *National Science Education Standards: An Enhanced Sampler.* Washington, DC: National Research Council, February 1993. A working paper of the National Committee on Science Education Standards and Assessment. (1, 3)

Reforms in Science Education, K-12. School of Education Review: Special Issue. San Francisco, CA: San Francisco State University, Spring 1993. Includes a number of useful articles on incorporating biotechnology into the curriculum. (3-4)

Singer, Maxine and Berg, Paul. *Genes & Genomes.* Mill Valley, CA: University Science Books, 1991. Thorough and comprehensive advanced college text. (4)

Speaker, Susan L. and Lindee, M. Susan, with Hanson, Elizabeth. *A Guide to the Human Genome Project: Technologies, People, and Institutions.* Philadelphia, PA: Chemical Heritage Foundation, 1993. A publication of the Biomolecular Sciences Initiative of the Beckman Center for the History of Chemistry. (3-4)

Watson, J. D., et al. *Molecular Biology of the Gene. 4th ed.* Redwood City, CA: Benjamin/Cummings, 1987. The source on molecular genetics. Superb, readable, comprehensive college-level textbook of molecular biology. (4)

Watson, J.D., et al. *Recombinant DNA. 2nd ed.* New York, NY: W.H. Freeman, 1992. A clearly written text covering both the fundamentals and some of the most exciting current work in molecular biology. (2-4)

Woodrow Wilson 1992 Biology Institute. *Bioethics.* Princeton, NJ: Woodrow Wilson National Fellowship Foundation, 1992. This sourcebook contains useful activities on bioethics. (3)

Movies and Videos

Howard Hughes Medical Institute. *Not So Wild a Dream.* Chevy Chase, MD: Howard Hughes Medical Institute. (Free copies available from the Howard Hughes Medical Institute.) Minority scientists talk about how they chose scientific careers and the paths they took to achieve them. (1-4)

Mastervision, Inc. *Building Blocks of Life.* New York, NY: Mastervision, Inc. Examines the booming science and industry of genetics and how the “building blocks of life” have become the basis of genetic engineering. (2,3)

University of California San Francisco. *Winding your way through DNA Symposium.* Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1992. Designed to educate the public and to encourage a dialogue about the scientific possibilities and social puzzles of recombinant DNA technology. This unique adventure in public education brought together some of the major figures in the development of the science and technology. (1-4) *Contact Pyramid Media directly for broadcast rights.*

University of California San Francisco. *Winding your way through DNA: Stories from the Scientists.* Pyramid Media, 1994. This documentary tells the story of two partnerships in biology—between Francis Crick and James Watson, who discovered the structure of DNA, and between Herbert Boyer and Stanley Cohen, who pioneered the recombinant DNA techniques that revolutionized modern science. This 30-minute videotape weaves together interviews, animation, re-enactments, and historical footage to illustrate the participant’s scientific achievements, personalities, and individual struggles with the challenge of discovery. (1-4) *Contact Pyramid Media directly for broadcast rights.*

University of California San Francisco. *Winding your way through DNA: The Promise & Perils of Biotechnology: Genetic Testing.* Pyramid Media, 1996. Biotechnology has many wonderful applications in medicine—testing for genetic disorders, curing and preventing disease—at the same time it raises ethical, legal and social issues. This moving documentary profiles a young woman being tested for Huntington Disease and a family treated for Familial Hyper-cholesterolemia, providing a framework for the discussion of these issues. It also explores the impact these inherited disorders will have on their lives. (1-4) *Contact Pyramid Media directly for broadcast rights.*

WGBH. *Discovering Women. Boston, MA: WGBH, 1995.* This six-part series presents the professional and personal stories of six notable women scientists, and confronts issues such as stereotypes, gender inequality, and the challenges of balancing a career and family. (1-4)

WGBH. *The Making of a Doctor, Part 2.* Boston, MA: WGBH, 1993. This two-hour video examines the lives of seven doctors as they work their way through medical school, internships, and residencies. (1-4)

WGBH. *The Secret of Life. Boston, MA: WGBH, 1993.* This eight-part series gives an in-depth look at the scientific revolution involving DNA and its impact on our daily lives. (1-4)

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