Biotechnology Curriculum
Acknowledgments

The Biotechnology Curriculum was adapted and written by:

Dennis Bowman, Crops Educator
Greg Clark, Crops Educator
Cathy Deppe, Youth Development Educator
Aaron Dufelmeier, Unit Leader
April Eddinger, Youth Development Educator
Sean Evans, Crops Educator
Pete Fandel, Crops Educator
Marion Shier, Crops Educator
Lisa Woessner, Youth Development Educator

With Special Assistance Provided by:

Janis Burkhardt, Secretary III, Rockford Extension Center

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Introduction

This Biotechnology Curriculum Kit provides teachers with educational, hands-on materials that can enhance a lesson plan and give students a fun way to learn. There is no charge to utilize the materials. Home-school parents also find these kits valuable to enhance the curriculum used with their children.

The curriculum is written specifically for 6th grade, however it can be used with other grade levels with some adaptation.

The kit includes a curriculum designed by Extension Educators and difficult to find, expensive or time-consuming to collect items needed to conduct the activities. The goal of the curriculum kit is to expose youth to the complex scientific and technical issues related to the field of biotechnology. Youth will also have an opportunity to explore biotechnology related careers.

DNA is present in the cells of all living organisms. The curriculum kit will have participants extracting DNA from a banana or other soft fruit in sufficient quantity to be seen and spooled. The process of extracting DNA from a cell is the first step for many laboratory procedures in biotechnology.

The curriculum is divided into six chapters: The Cell, What is DNA?, Inherited Traits, Biotechnology and Gene Splicing, DNA Extraction, and Next Steps in Biotechnology. Teachers utilizing the kits will be asked to complete an evaluation and provide demographic information on the students reached through the project.
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Glossary
Chapter 1: The Cell

Chapter Overview

In this first chapter, students will learn that the cell is the basic building block of all organisms. Included is a review of the parts of the cell (organelles) and the role that each plays in cell function. Similarities and differences between plant and animal cells are also outlined.

Objectives

Students will:
1. Describe the basic function and structure of cells and cellular organelles.
2. Demonstrate their understanding of cell structure by making a model of a plant or animal cell.
3. Explain how groups of specialized cells work together to form larger functional units, such as tissues and organs.

Activities

Cell Pizza
Cell Pudding
Specialized Cells Role Play
Function of Cells and Organelles

During this lesson, students will learn about the basic function and structure of cells and cellular organelles. This information serves as an introduction to several fun activities on cells.

Science Content

- To learn that all organisms are composed of cells

Science Process Skills

- Observing, comparing, categorizing

Life Skills

- Learning to learn

Time

Prep: 10-15 minutes

1. Duplicate student handouts/overheads.
   1-A...“What is a Cell?” on page 5
   1-B...“What’s Inside a Cell?” on page 6
   1-C...“Cell Comparisons” on page 7

Activity: 10-15 minutes

Materials

1. Student handouts/overheads 1-A, 1-B and 1-C

Educator Background Information

Cells serve as the basic unit of life. The most important property of all living cells is their ability to reproduce. In general, cells vary in size from 1 um (10^{-6} meters) in bacteria to 10 um (10^{-5} meters) for most animal and plant cells.

All living organisms (bacteria, plants, animals) are composed of cells. Eukaryotic cells (from plants and animals) contain organelles that provide different functions. Prokaryotic cells (bacteria) do not contain organelles. Eukaryotic cells have three main zones or areas.

- **Nucleus** — “The brain of the cell” provides instructions that “tell the cell what to do.” These instructions are coded in a molecule called DNA (deoxyribonucleic acid). Each chromosome is made of one long DNA molecule. Cells read the genes on DNA to learn about their functions throughout life.

Every organism has a different number of chromosomes located in the nucleus of every cell. Organisms of the same species, however, have the same number of chromosomes. For example, humans have 46 chromosomes, 23 from each parent. Genes are located along the chromosomes; each has a specific instruction, like one step in a recipe.
• **Cell membrane** — The cell membrane surrounds the cell and allows the cell to communicate with its surroundings. In addition to a membrane, plant cells have a rigid wall around them.

• **Cytoplasm** — Cytoplasm is the gel-like fluid inside most organelles. The organelles are specialized structures in the cytoplasm which include the following:
  - Ribosomes — tiny structures where protein molecules are formed.
  - Lysosomes — organelles that contain digestive chemicals.
  - Golgi apparatus — a membrane composed of cytoplasm that packages and sorts protein molecules as they prepare to leave the cell.
  - Mitochondria — rod-shaped organelles that release energy in the cell.
  - Endoplasmic reticulum — they include a network of tubes and flattened sacs connected to the nucleus that store, separate, and transport substances within the cell. Some are rough because they are dotted with ribosomes.

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**Lesson Plan**

**Doing the Activity**

1. Lead a discussion to see what the students know about cells. Ask them the following questions:
   - What is a cell? *Cells are the tiny living units that make up all living things.*
   - Where can you find cells? *Cells are found in all living things.*
   - Can you name different types of cells? *Red blood cells, skin cells, etc.*
   - What size are cells? *Cells vary in size from 1 um in bacteria to 10 um for most animal and plant cells.*
   - Can you see them? *Cells can not be seen without the help of a microscope.*
   - What can you use to see a cell? *Microscope*

2. Give each student a copy of handouts 1-A, 1-B, and 1-C. Tell the students to keep the handouts available for later hands-on activities.

3. Briefly review the three handouts.
Reflecting and Applying

- Name some things a cell can do on the inside. Match each organelle to a cell function.
  - Absorb—cell membrane
  - Excrete—golgi apparatus, cell membrane
  - Metabolize—lysosomes
  - Synthesize—ribosomes
  - Grow—mitochondria
  - Reproduce—nucleus (Note: The nucleus (DNA) is in charge of all of these functions.)

- What are the three main areas of a cell?
  - The cell membrane, cytoplasm, and nucleus.

- Define each of the following in your own words: organelle, nucleus, cytoplasm, mitochondria, golgi apparatus, lysosome, ribosome, and endoplasmic reticulum.
  - Organelle—specialized structures inside a cell that absorb, excrete, metabolize, synthesize and grow.
  - Nucleus—the round mass that contains long strings of DNA.
  - Cytoplasm—the inside fluid and most of the organelles of the cell.
  - Mitochondria—small oval shaped organelles that produce energy.
  - Golgi Apparatus—flattened structure with many layers that are a workstation for the cell. They sort proteins.
  - Lysosome—tiny round organelles that contain chemicals that break things down in the cell.
  - Ribosome—tiny round structures that synthesize proteins.
  - Endoplasmic Reticulum—long folded web of tubes that help transport things inside the cell.

- How do plant and animal cells differ?
  - Plant cells have rigid cell walls and soft cell membranes. Plant cells also have chloroplasts that convert sunlight to food. Animal cells have only soft cell membranes and can not make their own food.

- Why is it important to know about cells and organelles?
  - Cells serve as the basic unit of life. Genes located on the chromosomes are the set of inherited instructions for making and controlling proteins.
What is a Cell?

Cells are the tiny living units that make up all plants and animals.

You can think of a cell as a “package of life”. Each cell has a membrane that keeps the insides in and the outsides out.

Some of the things that a cell can do on the inside are:

- **Absorb**
  - Bring things in from the outside

- **Excrete**
  - Squirt things out from the inside

- **Metabolize**
  - Break down large molecules into smaller bits, to use them for nutrition energy

- **Synthesize**
  - Combine small molecules together to make specific larger molecules
  - Plant cells can actually build their own food, with help from the sun!

- **Grow**
  - Get bigger in size by absorbing and synthesizing

- **Reproduce**
  - Make copies of everything inside, and then divide into two separate cells

To help accomplish these functions, cells contain some very specialized structures inside their membranes. These structures are called **organelles**.
What's Inside a Cell?

Cells have three main zones:
The Cell Membrane defines the inside and outside of a cell. (In addition to the membrane, plant cells also have a rigid cell wall all around them)

The Cytoplasm (SYE-toe-plaz-em) is the name for the inside fluid and most of the organelles.

The Nucleus (NOO-klee-us) is a round blob in the cytoplasm. It’s sort of a library for the cell, carrying chemical instructions about how to make things.

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**Ribosomes** are tiny round things floating in the cytoplasm. They are used as work benches that produce proteins from information in genes.

**Cell Membranes** are selectively permeable. That just means that some things can pass through them and some things can’t. In summertime, the screen door to your house is selectively permeable too! Air can pass through it, but flies and bugs can’t! The cell membrane also allows the cell to communicate with other cells.

**Endoplasmic Reticulum** is a long folded web of tubes that runs through a cell. Lots of ribosomes are attracted to it, and sometimes attach themselves to it. The endoplasmic reticulum transports things such as proteins around inside the cell. The ER works with the Golgi.

**Lysosomes** are tiny round structures that contain corrosive chemicals (chemicals that break things down). If bacteria or viruses invade the cell, lysosomes burst open and melt the invaders! But if too many lysosomes accidentally burst, the cell itself could get eaten away.

**The Nucleus** of a cell contains long strings of chemicals called DNA. The chemicals are strung together in a specific order, just as letters of the alphabet are put together in certain orders to spell words. The “words” in the DNA strings provide the information to build just about everything in your body! Each chromosome is made of one DNA molecule.

**Mitochondria** are small oval shaped blobs with many folds inside them. They help make stored energy available to a cell so that it can absorb, excrete, and synthesize.

**The Golgi Apparatus** is a flattened structure with many layers. It seems to be a kind of work-station where things that the cell is building get their finishing touches. Cells that do a lot of excreting tend to have more! These structures work with the endoplasmic reticulum.
Cell Comparisons

Plant and Animal Cells

Both plant and animal cells have soft cell membranes.

Plant cells differ from animal cells in that they have a rigid cell wall and chloroplasts. These chloroplasts allow plant cells to convert sunlight to food.

Cells in General

Can reproduce by multiplying and dividing themselves.

Viruses enter the cells and are able to duplicate by using the cell’s internal chemicals.

Bacteria are simple cells that do not contain organelles. Their DNA is found directly in the cytoplasm (not in a nucleus).

Single-Celled Vs. Many-Celled Animals

Single-celled animals are freely mobile and have the ability to catch their own food, whereas many-celled animals have limited movement, are considered specialized, and often cared for by other cells.
Cell Pizza

During this activity, students will reinforce their understanding of cell and organelle structure and function. Students will make an edible model of an animal or plant cell. Each part of the pizza will represent a part of the cell. When finished, the students will label and/or color animal and plant cell diagrams as a final review.

Science Content

- To reinforce students’ understanding of cell and organelle structure and function
- To compare and contrast the function of organelles
- To learn where DNA is located

Science Process Skills

- Communicating, comparing, ordering, relating, inferring

Life Skills

- Learning to learn, communicating

Time

Prep: Varies

1. Duplicate student handouts/overheads.  
   1-D...“Cell Pizza” on page 10
   1-E...“Animal Cell” on page 11
   1-F...“Plant Cell” on page 12

2. Gather the pizza ingredients.  
   (Optional) Send a note home asking parents to donate items.

3. Gather the utensils and plan how you will cook the pizza.

Activity: 45-60 minutes

Materials

1. Student handouts/overheads 1-D, 1-E, and 1-F
3. Pizza ingredients:
   - Crust (cell membrane)
   - Pizza sauce (cytoplasm)
   - One slice salami or pepperoni per pizza (nucleus)
   - Mushrooms (lysosomes)
   - Black olives (ribosomes)
   - Onion slices (golgi apparatus)
   - Sausage bits (mitochondria)
   - Cheese (endoplasmic reticulum)

4. Utensils — plates, napkins, pizza server

5. Oven or microwave

For the crust:
Use frozen bread dough, a prepared crust, tortillas, English muffins, or make your own from scratch. Students could make their own individual cells by using biscuit dough or English muffins.
**For plant cells:**
- Tell the students the pizza pan or plate serves as the cell wall.
- Use green pepper slices to represent chloroplasts.

**Alternative:** Visit a local pizza parlor. See if the manager will let your students make their own pizzas. Or you can make the pizza in one class session, freeze it, and eat it the next time class meets.

**Educator Background Information**

*(See “Function of Cells and Organelles” on page 2 for information.)*

**Lesson Plan**

**Doing the Activity**

1. Tell the students you are going to make a cell pizza.

2. Ask them to refer to the handouts as you work. As you make the pizza, review each structure’s name and function.

3. Cook or save pizza.

4. Eat pizza. Discuss cell parts while you eat.

**Reflecting and Applying**

- Ask students to talk about their cell pizza and explain it to the class.

- Quiz the students. Ask them to identify the organelles on their slices. Ask them what each organelle does.

- If a student doesn’t have an organelle on his or her slice, ask the student what might happen if a real cell lacked an organelle.

- As review or homework, ask the students to label and/or color student handouts 1-E and 1-F.

**Alternative Idea**

If you don’t have an oven or microwave available, try the “Cell Pudding” activity on page 14.
Cell Pizza

During this activity, students will make an edible cell model using pudding and candy.

Adapted by University of Illinois Extension from Iowa State University Extension and Iowa State University Office of Biotechnology
Animal Cell

Fill in the lines with the corresponding names and functions at the bottom of the page.
Plant Cell

Fill in the lines with the corresponding names and functions at the bottom of the page.

1. Nucleus
2. Vacuole
3. Cell wall
4. Cytoplasm
5. Mitochondria
6. Ribosomes
7. Chloroplast
8. Endoplasmic reticulum

Nucleus  Vacuole   Cell wall   Cytoplasm
Mitochondria Ribosomes Chloroplast Endoplasmic reticulum
Plant Cell

1. cell wall
2. chloroplast
3. mitochondria
4. cytoplasm
5. vacuole
6. endoplasmic reticulum
7. nucleus
8. ribosomes

Animal Cell

1. lysosome
2. nucleus
3. cell membrane
4. mitochondria
5. ribosomes
6. endoplasmic reticulum
7. cytoplasm
Science Content

- To reinforce the names and functions of the cellular organelles

Science Process Skills

- Communicating, comparing, ordering, relating, inferring

Life Skills

- Learning to learn, communicating

Time

Prep: Varies

1. Duplicate student handouts/overheads.
   1-E..."Animal Cell" on page 11
   1-F..."Plant Cell" on page 12

2. Gather the ingredients.
   (Optional) Send a note home asking parents to donate items.

3. Gather the utensils. One spoon per student is needed.

Activity: 20 minutes

Materials

1. Overheads/student handouts 1-E and 1-F

Educator Background

Information

(See "Function of Cells and Organelles" on page 2 for information.)

Lesson Plan

Doing the Activity

1. Tell the students you are going to make cell pudding.

For animal cells:

- One individual graham cracker mini-pie crust per student, or a clear plastic cup or bowl (cell membrane)
- Vanilla pudding or light-colored gelatin (cytoplasm)
- Large round candy or cherry (nucleus)
- Mike-N-Ike® candy (mitochondria)
- Tiny Tarts® candy or decorative sprinkles (ribosomes)
- String licorice, red (endoplasmic reticulum)

For plant cells:

- Clear plastic cup or bowl (cell wall)
- Green Mike-N-Ike® candy (chloroplast)
2. If the materials are not set up, ask the students to help get the ingredients ready.

3. Structure the set-up so students can make their cells cafeteria style.

**Reflecting and Applying**

- Quiz the students. Ask them to identify the organelles in their cell pudding. Ask them what each organelle does.

- If a student doesn’t have an organelle in his or her pudding, ask the student what might happen if a real cell lacked an organelle.

- As review or homework, ask the students to label and/or color student handouts 1-E and 1-F.
Specialized Cells

During this activity, students will perform a role play about the specialized cells found in the human body.

Science Content

- To introduce students to the concept of cell specialization and diversity
- To explain how groups of specialized cells work together to form larger functional units, such as tissues and organs
- To describe how these functional units, called organs, serve the organism as a whole
- To show that living systems have different levels of organization, each with a separate structure and function

Science Process Skills

- Communicating, ordering, relating

Life Skills

- Learning to learn, communicating

Time

Prep: None

Activity: 15 minutes

Materials


Educator Background Information

(See “Function of Cells and Organelles” on page 2 for information.)

Lesson Plan

Doing the Activity

1. Have students work in pairs, forming 12 groups. Assign each an identity from the following list:

   - Lung cells
   - Brain cells
   - Skin cells
   - Stomach cells
   - Arm muscle cells
   - Taste bud cells
   - Appendix cells
   - Bone marrow cells
   - Heart cells
   - Kidney cells
   - Liver cells
   - White blood cells

2. Have the students pretend that the classroom is a giant body. Position the students according to cell type (skin cells around the wall, brain cells at the front, heart cells at the center, etc.).
3. Ask each group the following questions:

- Where are you found in the body?
- What is your function?
- Could the body survive if a few of you were lost?
- Could the body survive if all of you were lost?

Reflecting and Applying

- Ask the students if they see any trends. Write their responses on the board. Explain that most cells are expendable in small numbers but not in large numbers. Exceptions include muscle, taste bud, and appendix cells, but their loss would impair normal body functions. Some cells, such as liver and skin cells, can easily regenerate.

- Ask the students to describe the advantage of specialization.

  Function efficiency

- Ask the students to describe the advantage of having more cells than needed for survival.

  Reserves

- Ask the students to compare cell specialization to the specialization of people in society.

  Police officers, doctors, teachers
Cell Functions

Type: Lung
Location: chest
Function: oxygen exchange
Some gone? impaired but OK
All gone? FATAL

Type: Brain
Location: skull
Function: perception, reaction
Some gone? impaired but OK
All gone? FATAL

Type: Skin
Location: body surface
Function: protection (radiation, drying)
Some gone? minor impaired
All gone? FATAL

Type: Stomach
Location: abdomen
Function: digestion (secretion, contraction)
Some gone? minor impaired
All gone? FATAL

Type: Muscle
Location: arm
Function: movement
Some gone? impaired
All gone? loss of function

Type: Taste
Location: tongue
Function: sensation
Some gone? impaired
All gone? loss of function

Type: Bone marrow
Location: in bones, all over body
Function: make blood cells
Some gone? impaired
All gone? FATAL

Type: Lymphocyte
Location: all over body
Function: protect against invaders
Some gone? impaired
All gone? FATAL (AIDS)

Type: Kidney
Location: lower back
Function: absorbs/filters water
Some gone? impaired
All gone? FATAL

Type: Liver
Location: abdomen
Function: absorbs/filters poisons
Some gone? minor impaired
All gone? FATAL

Type: Heart
Location: chest
Function: blood circulation
Some gone? serious impairment
All gone? FATAL

Type: Appendix
Location: lower abdomen
Function: none in humans
Some gone? no change
All gone? no change
Chapter 2: What is DNA?

Chapter Overview

In this chapter students will learn about DNA. What it is, why it is important, and how it can affect our lives.

Every living thing has a set of genetic characteristics or traits. These characteristics are passed from parent to offspring. These characteristics are controlled by genes. Genes are the sets of inherited instructions for making and controlling proteins. These instructions, which are coded in a molecule called deoxyribonucleic acid (DNA), determine an organism's traits, how it should look, and behave. Every living thing has DNA in its cells.

DNA, or deoxyribonucleic acid, consists of two strands of nucleotides (G,A,T,C) that spiral around each other. The two strands are called a double helix and are held together by hydrogen bonds. Each chromosome consists of one very long strand of DNA. Genes are encoded by the order of nucleotides in the DNA. The Human Genome Project has determined that we have over 3 billion nucleotides in the DNA cell of our bodies and over 30,000 genes.

We can extract and analyze the structure of DNA. DNA fingerprinting can be used to identify the source of a sample of DNA material. DNA fingerprinting can be used in some cases, to confirm or refute the guilt or innocence of a crime suspect.

Objectives

Students will

1. Demonstrate their understanding of what DNA is and its importance in cells.

Activities

Building DNA
Design Your Own DNA Molecule
Do the DNA Line Dance
What is DNA?

During this activity, students will learn about the chemical and physical structure of DNA (deoxyribonucleic acid).

Science Content

- To teach students the knowledge needed to describe the basic structure and components of DNA

Science Process Skills

- Observing, comparing

Life Skills

- Learning to learn, communicating

Time

Prep: 5-10 minutes

1. Duplicate student handouts/overheads.
   2-A..."What is DNA?" on page 22
   2-B..."The Copycats!" on page 23
   2-C..."Instructions for Building You!" on page 24

Activity: 10-15 minutes

Materials

1. Student handouts/overheads 2-A, 2-B and 2-C

Educator Background Information

DNA is the sub-microscopic material in your cells that tell your body how it should operate and look. DNA is found in the cells of nearly every living thing, and even in many viruses. Each chromosome is made of one extremely long DNA molecule. If we stretched out all the DNA of the 46 chromosomes in one of your cells, it would be about six feet long, but would not be visible because it is so thin.

DNA contains the instructions for building a multitude of proteins. Proteins are the chemical building blocks of living materials. DNA (genes) makes proteins, proteins build cells, and cells make up people.

To understand the shape of the DNA molecule, imagine taking both ends of a long ladder and twisting them around and around. Eventually, it wouldn't look like a ladder at all. Instead, it would look like a long spiral shape called a helix.

There are six types of chemicals that make up DNA. Each strand, or side of the ladder, is composed of alternating sugar and phosphates. The rungs of the ladder are made up of the other four chemicals: adenine, thymine, cytosine, and guanine (abbreviated A, T, C, & G).

Each rung is always made up of two chemicals. Adenine always joins thymine to make a rung; cytosine always joins guanine to make another rung. All 46 DNA molecules in one of your cells contain a total of over 3 billion rungs!
Lesson Plan

Doing the Activity

1. Talk your students through the three handouts using the following discussion questions:

   - Where is DNA found?
     
     Nucleus of every cell

   - How long is all of the DNA from one human cell?
     
     If we placed the human chromosome DNA end-to-end, it would be about six feet long.

   - What does a strand of DNA look like?
     
     Like a twisted ladder

   - What kinds of chemicals are found in DNA? Is there anything special about the arrangement of the chemicals?
     
     Phosphates, sugars, and the four bases are represented by the letters A, T, C, and G. The special arrangement is that A can only go with T, and C can only go with G.

   - How big is a strand of DNA?
     
     It is so tiny it can be seen only with special microscopes.

   - How does a strand of DNA copy itself? What is this process called?
     
     When a cell divides to make a new cell, it needs a copy of the DNA. This copy is made by unzipping the DNA strand down the middle. The DNA building blocks float in the nucleus and will match up to the correct pair on each strand. This is called replication.

Reflecting and Applying

- What do you know about DNA? What do you still need to learn?

- Can you think of examples of other things in life that specifically match up?
  
  A key that unlocks a lock.

Source

Biotechnology Resources for Teachers, Massachusetts Biotechnology Institute

Adapted by University of Illinois Extension from Iowa State University Extension and Iowa State University Office of Biotechnology
What is DNA?

The nucleus of each cell in your body contains many small threads of chemicals, called DNA. Every cell in your body has about 6 feet of DNA coiled up inside it!

If you magnified a string of DNA, you'd see that it looked like a ladder that was twisted around on itself.

If you looked even closer, you'd see that each "crosspiece" on the ladder was made up of two chemicals attached in the middle.

There are four different chemicals that a cell uses to build these crosspieces.

The four chemicals pair up with each other in a specific way, like keys in locks.

A and T fit together to form a crosspiece and C and G fit together, but A or T won't fit with C or G.

SO
If you know half of the crosspiece, you can figure out what the other half is, because only one chemical can match it!

A matches to T
T matches to A
C matches to G
G matches to C
The Copycats!

When a string of DNA needs to copy itself, it UNZIPS itself down the middle! Each crosspiece splits into two pieces.

Each half of the ladder then begins to match up the right chemicals to "rebuild" its missing half.

Since the chemicals fit together in specific ways (C with G and A with T), it's sort of like doing a microscopic jigsaw puzzle.

Eventually, each half has completed itself, and you have two copies instead of one!

The process of copying DNA by rebuilding the missing halves is known as REPLICATION.

Replication occurs when cells divide and multiply. Each new cell needs a complete copy of the "instructions" that the DNA carries.
Instructions for Building You!

The order of G, A, T & C in the DNA ladder is like a secret code, giving instructions for building complex molecules that your body needs. These segments of DNA are called genes.

Genes on the DNA ladder are unzipped in order for the code to be read. Once again, chemicals are matched up to those exposed in the unzipped ladder.

Three of the chemicals are the same as before (A, C, and G). The fourth one, U, takes the place of T and matches up to A.

On the ribosomes, the transfer RNAs match themselves up to the messenger RNA in specific ways and weld their amino acids together.

Strings of connected amino acids are called PROTEINS. Almost all parts of your body are made up of proteins. Some proteins need to be transported to different parts of the cell by the endoplasmic reticulum and golgi.

Some proteins are called Structural. Others, called Enzymes act to speed up chemical reactions in your body. Protein called Hormones cause slow, long lasting changes in cells. This simple process is how genes produce all traits in organisms!

The new string of chemicals that is created is called messenger RNA (mRNA). It detaches itself from the DNA and floats away. The DNA zips itself back up as if nothing happened.

The messenger RNA carries the information out of the nucleus into the cytoplasm. These mRNA's bind to ribosomes.

There are chemicals called transfer RNA already outside of the nucleus. They tow chemicals called amino acids.
Building DNA

During this activity, students will assemble themselves into a giant DNA (deoxyribonucleic acid) molecule and act out replication (making a copy of the DNA strand).

Science Content

- To teach students about the actual structure of DNA

Science Process Skills

- Observing, communicating, ordering, relating

Life Skills

- Learning to learn, communicating

Time

Prep: 5-10 minutes

1. Duplicate student handout/overhead 2-A and 2-D

2. Scissors

3. Crayons

Materials

Educator Background Information

(See the "What is DNA?" activity on page 22 for information.)

Lesson Plan

Doing the Activity

1. Give the students the first page of handout 2-A. Review the DNA structure. Remind them that DNA consists of chemicals that are put together in the shape of a twisted ladder. The four building blocks that make up the ladder rungs match up to each other only in certain ways. Write these on the board: A-T, G-C.

2. Give the students the two pages of handout 2-D. Have them color each of the four letters a different color: for example, A=red, T=yellow, G=blue, C=green.

3. Have the students cut out the base pieces on the thick black lines. Collect the pieces.
4. Divide the class into four equal groups. Have Group 1 line up single file, each person placing his or her left hand onto the shoulder of the person in front. (This is one side of the ladder of a DNA strand.) Give each student in Group 1 a paper base at random; have the students hold the bases out to the right.

5. Have Group 2 stand parallel to Group 1, on the right side. Group 2 students should place their right hands on the shoulder of the person in front of them. They should extend their left hands out to meet Group 1.

6. Give each member of Group 2 a paper base pair to match the Group 1 base he or she is by. When everyone has a base, have each matched pair in Groups 1 and 2 hold their paper pieces together to form a ladder.

7. You now have a DNA molecule! Have the students tell you the sequence of the pairs and copy it down on the board.

8. To replicate: Have Groups 1 and 2 separate down the middle, keeping the sides together. Have Group 2 move a few feet away.

9. Call Groups 3 and 4 up. Give each student a paper base at random. Each student is a free-floating base. Have Groups 3 and 4 mingle around Groups 1 and 2. When the students from Groups 3 or 4 finds a match in Groups 1 or 2, they should stop there.

Some of the students in Groups 3 and 4 may not find a match. If that happens, exchange the base for one that matches an open spot.

10. When everyone has a match, have the two groups link to form ladders. Ask them to call out their base pairs in order; write them on the board. You should have two identical copies of the original DNA.

11. Show the students that the genes are located on the DNA strand. For example:
   - A-T, G-C, A-T
   (This sequence might be one of the genes that gives the information for blond hair. However, most genes are over 3,000 nucleotides long.)

Reflecting and Applying

- How did you like this way of learning about the DNA molecule? Why?
- How did you feel being part of a DNA chain?
  
  Was it fun? Did it help show how A’s and Ts fit together while G’s and C’s fit together?
- Why do you think DNA has parts that have special matches like a puzzle?
  
  So they fit together correctly.
- What happens when DNA replicates or makes a new strand?
  
  The free floating A’s and Ts match up and so do the G’s and C’s.
- Have you ever seen other things in life that have special matches like DNA?
  Specific keys to specific locks.
Design Your Own DNA Molecule

Supplies Needed (per model)*

- 2 white 12" chenille stems (aka "pipecleaners")
- 2 colored 12" chenille stems
- 12 aqua 6mm (pony) beads (A)
- 12 purple 6mm beads (G)
- 6 red 6mm beads (T)
- 6 yellow 6mm beads (C)
- scissors
- ruler

*NOTE: You may use different colors of beads than what is specified. Packages of 100 chenille stems cost approx. $1.50; Packages of 300 pony beads cost approx. $1.50; An entire classroom set can be purchased for under $10

Directions:

1. Cut each white chenille stem into six 2 inch sections.
2. The pony beads represent the 4 different bases:
   - Adenine (A) - aqua
   - Thymine (T) - red
   - Guanine (G) - purple
   - Cytosine (C) - yellow
3. Because A and G molecules have 2 rings, you will use 2 beads for each of these molecules. Use one bead for T and C molecules, which have only one ring.
4. Thread beads representing an Adenine and Thymine base pair onto one of the 2-inch white chenille stems. (Remember to use 2 beads for A and one bead for T). Prepare 6 of these segments.
5. Next prepare 6 Guanine and Cytosine base pairs, using 2 purple beads for G and 1 yellow bead for C.
6. Connect one white chenille segment to the colored chenille stem approximately 1 cm from the top. Wrap the end of the white stem around the colored stem. Connect the other end to the second colored chenille stem (see photo). This is where you can be creative with the genetic code - you can choose to make your own DNA sequence!
7. Follow the same procedure for the remaining white segments and beads. Add each consecutive base pair (white chenille segment) approximately 1 cm from the previous base pair.
8. When all 12 base pair segments have been added to the DNA molecule, you should have a molecule that looks like a ladder.
9. To make your double helix, twist your model slightly so the molecule forms a spiral. DNA molecules have a right-handed helix shape that winds in one direction (see diagram on next page). You can figure out the direction by sliding the fingers of your right hand along backbone. If it is right-handed, your thumb should be moving forward while you do this.

10. CONGRATULATIONS! You have created your own unique DNA molecule. The sequence of the base pairs in the DNA ladder is what makes different DNA molecules unique, and is what the Human Genome Project and other genome sequencing projects are all about. Compare your DNA molecule with other DNA molecules. How are they similar? How are they different?

**Background Information: DNA**

**DNA = Deoxyribonucleic Acid**

DNA is made of **nucleotides**

Nucleotides contain a **base (A, T, G, or C)** + deoxyribose **sugar + phosphate**

The 4 different bases form base pairs:
- **Adenine** binds with **Thymine**
- **Guanine** binds with **Cytosine**

The shape of DNA is a double helix with a right-handed spiral turn (like a twisted ladder) with the steps representing the base pairs and the sugar+phosphate backbone as the hand rails. In our model, the colored chenille stems represent the phosphate (P) groups and the white portion that wraps around the colored stems represents the sugar groups (S) (see diagram below).
DNA Dance

**Supplies Needed**
- Different colors of paper labeled "G, A, T, or C" to be taped to the chest (or different colors) - make sure 4 different colors (A,T,G,C) are evenly divided between the group
- Large scissors (or paper model of scissors)
- Chairs or other obstacles set up in a long hallway or room

**Directions:**

1. Divide the students in 4 groups: A, T, G, and C. Add people as needed – adding one of each complementary base (eg. A and T or G and C). Any extra people (especially physically challenged kids) can act as the restriction enzyme (molecular scissors) at the end of the activity.

2. Assign the rule that A’s go to T’s and vice versa; and G’s go to C’s and vice versa. (Matching rules or bonding rules or Chargaff’s rules).

3. Assign configurations for the RIGHT hand: THIS IS VERY IMPORTANT!

   - C curve their hands partly open.
   - G makes a fist
   - T makes a hook by extending curved index finger
   - A makes an “OK” sign by touching their index finger to their thumb

   *Note that these are designed so As and Ts can match or interlock, and so can Gs and Cs. Other combinations are more awkward.*

4. Assign the position so each person’s left arm is extended to the front, and right arm is extended to the side (in a top view, the arms form an L: the "L" position).
5. Demonstrate how the nucleotides will join together into one strand (see figure below). Their left hand will grab the shoulder of the nucleotide next to them. Their right hand will be kept free at this point (this hand will hydrogen bond with the complementary nucleotide on the opposite strand later).

6. Make the following sequence of DNA. You may add a nucleotide to the end depending on numbers of kids. Be sure to use the same number of complementary base pairs (eg. 4 As, 4 Ts, 5 Gs, 5 Cs) and distribute them evenly in the first chain (eg. 2 As, 2 Ts, 3 Gs, 2 Cs) or you will come up short in the end.

   G A A T T C G C etc...

7. Once the first chain has been made, you will make the complementary DNA strand using this original strand as a template (see figure below). These nucleotides will join the other strand by linking their right hand with their complement on the original strand. The new strand will also join with itself by linking their left hand to the shoulder of their neighbor. (See proper “L” position in Step 4.)

Carolyn A. Zanta, UIUC-Hughes Biotechnology Education and Outreach Program (www.life.uiuc.edu/hughes/footlocker)
(activity modified from UWisconsin Biotechnology Center)
8. Note that the final DNA molecule is **double-stranded**, with the **complementary** nucleotides joined at the middle (these represent **Hydrogen bonds** in a DNA molecule). This model is only 2-dimensional, like a ladder. In reality, the DNA molecule would be twisted into a **3-D double helix**. Note that this second line will face in the direction opposite of the original. This demonstrates the **antiparallel structure** (3' to 5' on one strand and 5' to 3' on the complementary strand) of the DNA molecule.

**EXTENSIONS**

9. Biotechnologists use special tools to study DNA. Some of these tools are **restriction enzymes**, which are molecules that **cut specific sequences of DNA**. Since these are "**molecular scissors**", we can use big scissors to simulate this.

The restriction enzyme that we will use cuts DNA with the sequence: **G A A T T C** (note that this is at the beginning of the strand - underlined). You can have any additional child take the scissors and "cut" the DNA strand at the point noted. The scissors will cut the DNA at that sequence on both strands - so the cut should go through both strands. You should have one short strand of 5 nucleotide pairs and one of 19 or 20 pairs.

\[
\begin{array}{cccccc}
G & A & A & T & T & C \\
C & T & T & A & A & G \\
\end{array}
\]

10. Another biotechnology tool used to study DNA is **agarose gel electrophoresis**. You can mention that electrophoresis is used in many different fields, including by forensic scientists who study DNA from crime scenes.

Depending on time and facilities, you can simulate the movement of these human DNA molecules through agarose during electrophoresis. You will need a fairly long room or hallway with chairs (and/or other things) scattered around as obstacles. The obstacles represent the meshwork of agarose that makes up the gel.

From the last activity, you will have the two DNA fragments that were created by the scissors start at the same location and make their way through the obstacle course. (In order to keep kids safe, it might be a good idea to set a "NO RUNNING" rule and make each group WALK through the obstacle course). The small DNA fragment should get to the end faster than the longer fragment. This is what occurs during agarose gel electrophoresis.
Summary of concepts covered in this activity:

- DNA (deoxyribonucleic acid) is composed of 4 nucleotides, or building blocks: A, T, G and C (Adenine, Thymine, Guanine, and Cytosine)

- These building blocks are strung together to carry a message

- A single DNA chain can be paired with another chain (its "complement"), to make double-stranded DNA molecule which is twisted into a double helix

- A matches with T and G matches with C (Chargaff’s Rule)

- The order of nucleotides in one strand (the “DNA sequence”) determines the order of the other strand.

- The two DNA strands have an antiparallel arrangement (with one strand in the opposite direction of the other).

- Biotechnologists use different tools to study DNA, including restriction enzymes (molecular scissors) and agarose gel electrophoresis.

- Restriction enzymes are molecular scissors that cut DNA at specific DNA sequences. The one we are using cuts at the sequence: GAATTC

- Scientists can measure the length of a DNA molecule by using electrophoresis. Different sized pieces of DNA are separated by agarose gel electrophoresis. Shorter DNA pieces travel faster than longer pieces.

Additional concepts not covered in this activity (possibly use as extension activities):

- The order of the building blocks can be used to make three-letter words that can code a message

- DNA can be copied by "unzipping" the original double strand and filling in the two separated strings or strands with spare building blocks

- A new piece of DNA can be spliced into another piece of DNA to give new messages
Chapter 3: Inherited Traits

Chapter Overview

A gene is the basic building block of heredity which determines traits. Genes are made of DNA, Deoxyribonucleic Acid. Each cell of a human body consists of 23 pairs of chromosomes, one of each pair from each parent. These 23 pairs constitute how the body will develop. Each chromosome is made of genes composed of DNA.

An inherited trait is a particular genetically determined characteristic that distinguishes each individual. However some evidence demonstrates that certain traits such as personality may be determined by conditions that occur after a person's birth. Inherited traits are what make our physical appearances similar to our mother or father. This is why we often hear, "She looks just like her mom," or "He has is father's eyes." The probability of this type of situation in which a daughter looks like her mother and a son has similar characteristics as his father is very similar to the probability of flipping a coin. Each trait is either dominant or recessive. A dominant trait is characterized by a capital letter and is only required from one parent to be expressed. Whereas a recessive trait is a trait that is characterized by a lower case letter and must be inherited from both parents in order to be expressed.

Traits are transmitted from generation to generation. The transmission of these traits is through the genes that we receive from each parent. However the combination of these genes leads to the uniqueness of each individual person.

Objectives

Students will:
1. Understand heredity and discover why they inherit certain characteristics from their parents.
2. Identify variations of traits within a population as well as why certain traits are more dominant than others.
3. Define the importance of accurate information transfer, as a DNA replication or reproduction.

Activities

Trading Traits
Do Your Ears Hang Down?
Jelly Genes
Reebops
Inherited Traits

During this activity, students will learn about genetics. They will learn about traits found among humans and how genes are inherited from our ancestors.

Science Content

- To introduce the concept of genetics and heredity
- To observe variation of traits within a population
- To record data on specific traits
- To teach students about the actual structure of DNA

Science Process Skills

- Observing, communicating, comparing, categorizing

Life Skills

- Learning to learn, communicating

Time

Prep: 10-15 minutes

1. Duplicate student handouts/overheads 3-A and 3-B

Activity: 15-20 minutes

Materials

1. Student handouts/overheads 3-A and 3-B
2. Pencils
3. Package of PTC paper (optional)

Phenylthiocarbamide (PTC) paper may be ordered by contacting Frey Scientific at (888) 222-1332, order # F77681. Cost is $8.95. You will receive 12 packages with 100 strips per package.

Lesson Plan

Doing the Activity

1. Tell the class that you are taking a survey on who can roll their tongues and who can’t. Part of the survey is to observe the actual tongue rolling, record the observations, and come to a conclusion about the percentage of students that can roll their tongues. Tell the students you are not sure about the best way to do this. Discuss the best way to accomplish the survey.

2. Once the class has decided on a system, implement it. After the students have figured out the percentage, tell them that 70-90 percent of humans can roll their tongues.

3. Give the students handout 3-A. Have them circulate around the room to complete the handout.
4. Bring the students back together and discuss the handout. Ask how many students have each particular trait. Look for any obvious patterns. Are there any traits that no one had?

5. Give the students handout 3-B.

6. Give the students the following information before they begin the activity.

- **Ear Lobes** — “Hang down” means to have free-hanging ear lobes where some skin hangs from the point where the ear is joined to the face. “Attached” means to have attached ear lobes where the ear is joined to the face.

- **Tongue Rolling** — “Can” means that they can roll their tongues in the shape of a “U.” “Cannot” means they can’t roll their tongues in the shape of a “U.”

- **PTC Tasting** — Avoid telling your students anything about this until after they have all tasted the paper. “Can” means that when the PTC paper is placed on the tongue of a “taster,” a bitter taste results. “Cannot” means the student can’t taste anything on the paper other than a paper taste.

- **Handed** — “Right” means the right hand is used for most fine motor activities. “Left” means that the left hand is preferred for most fine motor activities.

7. Divide the students into groups of four. The surveyor questions the students in his or her group only. The recorder records the results on a scrap piece of paper. Don’t use the handout yet.

8. When the groups are finished, ask the recorder from each group to write the results on the board. Compile the class results. Fill in the class results on the handout.

9. Each group should calculate the percentages for each trait.

**Reflecting and Applying**

- How else are surveys used? What do they teach us?

- Which traits occurred more frequently? Which occurred less frequently?

- Which traits are the most common?

- Would you expect to find these traits common in other population groups?

- Were you surprised by the frequency of any trait?

- What do you think that you will find if you go home and survey your family?

- Could you figure out which traits are dominant and which are recessive?
**Trading Traits**

How many of these human traits can you find among your classmates? Find someone in your class who has each of these traits. Ask each person to sign his/her name next to the trait that he/she has. Try to get each person to sign the sheet only once.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Brown eyes</td>
</tr>
<tr>
<td>2.</td>
<td>Blue eyes</td>
</tr>
<tr>
<td>3.</td>
<td>Green eyes</td>
</tr>
<tr>
<td>4.</td>
<td>Brown hair</td>
</tr>
<tr>
<td>5.</td>
<td>Blond hair</td>
</tr>
<tr>
<td>6.</td>
<td>Red hair</td>
</tr>
<tr>
<td>7.</td>
<td>Many freckles</td>
</tr>
<tr>
<td>8.</td>
<td>Some freckles</td>
</tr>
<tr>
<td>9.</td>
<td>No freckles</td>
</tr>
<tr>
<td>10.</td>
<td>Curly hair</td>
</tr>
<tr>
<td>11.</td>
<td>Straight hair</td>
</tr>
<tr>
<td>12.</td>
<td>Dimpled cheeks</td>
</tr>
<tr>
<td>13.</td>
<td>No dimples in cheeks</td>
</tr>
<tr>
<td>14.</td>
<td>Dimpled chin</td>
</tr>
<tr>
<td>15.</td>
<td>No dimpled chin</td>
</tr>
<tr>
<td>16.</td>
<td>Left handed</td>
</tr>
<tr>
<td>17.</td>
<td>Right handed</td>
</tr>
<tr>
<td>18.</td>
<td>Ambidextrous (can write with both hands)</td>
</tr>
<tr>
<td>19.</td>
<td>Has a gap between front teeth</td>
</tr>
<tr>
<td>20.</td>
<td>No gap between front teeth</td>
</tr>
<tr>
<td>21.</td>
<td>The second toe is longer than the big toe</td>
</tr>
<tr>
<td>22.</td>
<td>The second toe is shorter than the big toe</td>
</tr>
<tr>
<td>23.</td>
<td>Ring finger is longer than index finger</td>
</tr>
<tr>
<td>24.</td>
<td>Index finger is longer than ring finger</td>
</tr>
<tr>
<td>25.</td>
<td>Little finger is bent in toward ring finger</td>
</tr>
<tr>
<td>26.</td>
<td>Hair on second segment of fingers</td>
</tr>
<tr>
<td>27.</td>
<td>Color-blind (has trouble distinguishing red)</td>
</tr>
<tr>
<td>28.</td>
<td>No color-blindness</td>
</tr>
<tr>
<td>29.</td>
<td>When hands are clasped together, left thumb is on top of the right thumb</td>
</tr>
<tr>
<td>30.</td>
<td>When hands are clasped together, right thumb is on top of left thumb</td>
</tr>
</tbody>
</table>
Do Your Ears Hang Down?

After your teacher explains the 4 traits listed here, decide which traits you do or do not have. As the teacher records the number by the show of raised hands fill in the information on your chart.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Ear Lobes</th>
<th>Tongue Roll</th>
<th>Taste P.T.C.</th>
<th>Handedness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hang Down</td>
<td>Attached</td>
<td>Can</td>
<td>Cannot</td>
</tr>
<tr>
<td>Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surveyed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*To determine percentage: \( \frac{\text{number with trait}}{\text{total number surveyed}} \times 100 = \) ______ %
Jelly Genes

During this activity, students will explore what happens when a change occurs in the DNA (deoxyribonucleic acid) sequence.

Science Content

- To illustrate the importance of accurate information transfer from genes to proteins (see “Instructions for Building You”)

Science Process Skills

- Comparing, organizing, relating, inferring

Life Skills

- Learning to learn, communicating

Time

Prep: Varies

1. Duplicate student handout/overhead. 3-C... “Jelly Genes” on page 45

2. Collect supplies.

Activity: 20-30 minutes

Materials

1. The following supplies are needed per group:
   - Jar of peanut butter
   - Jar of jelly
   - Locking plastic bag with six to eight crackers inside
   - Table knife
   - Napkins or paper towels

Educator Background Information

Mutations occur in the sequence of DNA bases (G,A,T,C). These mutations cause changes in the amino acids of a protein as you saw in the unit “Instructions for Building You.” Mutations can occur naturally. They also can be induced or caused artificially. Agents that cause mutations are called mutagens.

Mutations occur all the time. Most mutations in living organisms are not obvious. They occur in body cells and are not transmitted to offspring. Other mutations in the DNA of sex cells remain hidden or unexpressed in offspring. If a mutation is harmful, it usually results in the death of an organism. Some mutations benefit the organism and whole generations.

For example, scientists know that sickle cell anemia results from a mutation. People afflicted with this disease have blood cells shaped like sickles. These red blood cells are unable to carry the normal
oxygen supply. The disease is caused by an unusual form of hemoglobin, the protein molecule that carries oxygen in the blood.

Researchers know this unusual hemoglobin differs by only one amino acid from normal hemoglobin. Instead of glutamic acid, the abnormal hemoglobin contains valine in one of its chains. This is caused by a mutation in the DNA. Mutations cause problems when genes are made into mRNA and then proteins.

The chance for a particular human gene to mutate in one generation is between 1-to-10,000 and 1-to-1,000,000. Since humans have at least 30,000 genes, each person probably carries at least one mutation. Thus, you may have genetic information that is not present in the genes of either of your parents.

**Lesson Plan**

**Doing the Activity**

The class mission is to construct peanut butter sandwiches (proteins) using three sets of instructions (genes). One set is normal; the others are slightly altered (mutated genes).

1. Select one student to serve as narrator. It is this student's job to read the list of instructions.

2. Have the remaining students line up. As the narrator reads each numbered instruction, the next student in line should come to the table, perform the function exactly as directed (no more, no less), and return to the end of the line.

3. **Case 1: Normal**
   Have the narrator read the list labeled normal. The result is a fairly standard sandwich.

4. **Case 2: Deletion Mutation**
   Next, have the narrator read the list labeled deletion. In this list, two steps are missing. If there is not a step telling the student to pick up a knife, then the student has to make do with, for instance, his or her fingers! The resulting sandwich will look normal, but students should be more reluctant to eat it.

5. **Case 3: Substitution Mutation**
   Finally, have the narrator read the list labeled mutation. In this list, the information in step six has been altered. (The student that does step six should stay at the table.) The resulting sandwich should be very different in appearance from the first two.

**Reflecting and Applying**

Case 1 represents information on a normal strand of DNA — normal sandwich = normal protein. Case 2 represents a DNA strand that is missing key information = abnormal protein. Case 3 represents a DNA strand in which new information is substituted for original information = abnormal protein.
• What does this activity have to do with genes?

*It represents the instructions in genes of a DNA strand being used to form proteins.*

• What would happen to a cell containing changed DNA? What could happen to a person whose DNA has been changed?

• Can you think of other things in life where you have to follow a set of instructions?

**Alternative Idea**

Have the students generate their own list of activities (fixing a flat tire, baking a cake, wrapping a present, providing directions, etc.) that require a procedure. Then have them delete or mutate key steps to produce bizarre results.


**Jelly Genes**

**Case 1: Normal**

1. Open the bag of crackers.
2. Remove two crackers.
3. Close the bag of crackers.
4. Open the jar of jelly.
5. Pick up a knife to use as a spreader.
7. Wipe your spreader with a napkin.
8. Put your spreader down.
9. Close the jelly jar.
10. Open the jar of peanut butter.
11. Spread peanut butter over the jelly you just spread.
12. Wipe your spreader with a napkin.
13. Put your spreader down.
14. Close the peanut butter jar.
15. Pick up a clean cracker.
16. Put it on the peanut butter.
17. Enjoy your sandwich!

**Case 2: Deletion Mutation**

1. Open the bag of crackers.
2. Remove two crackers.
3. Close the bag of crackers.
4. Open the jar of jelly.
5. Spread jelly on the cracker.
6. Wipe your spreader with a napkin.
7. Put your spreader down.
8. Close the jelly jar.
9. Open the jar of peanut butter.
10. Spread peanut butter over the jelly you just spread.
11. Wipe your spreader with a napkin.
12. Put your spreader down.
13. Close the peanut butter jar.
14. Pick up a clean cracker.
15. Put it on the peanut butter.
16. Enjoy your sandwich!

**Case 3: Substitution Mutation**

1. Open the bag of crackers.
2. Remove two crackers.
3. Close the bag of crackers.
4. Open the jar of jelly.
5. Pick up a knife to use as a spreader.
6. Spread jelly on your hand.
7. Wipe your spreader with a napkin.
8. Put your spreader down.
9. Close the jelly jar.
10. Open the jar of peanut butter.
11. Spread peanut butter over the jelly you just spread.
12. Wipe your spreader with a napkin.
13. Put your spreader down.
14. Close the peanut butter jar.
15. Pick up a clean cracker.
16. Put it on the peanut butter.
17. Enjoy your sandwich!

Adapted by University of Illinois Extension from Iowa State University Extension and Iowa State University Office of Biotechnology
Reebops
(a model "organism" for teaching genetics concepts)
Developed by Patti Soderberg
Center of Biology Education
University of Wisconsin

Reebops helps illustrate how meiosis is an important reason for the tremendous variation that exists in every species. Reebops are imaginary organisms made out of marshmallows and other inexpensive materials. Reebops tend to live in discarded pop (that’s "soda" for you non-Midwesterners) cans. However, they are rarely seen in the wild as they are extremely fast. Once you have a male and a female in captivity, your room will soon be filled with Reebops. They are very prolific and require minimal care. Reebops live quite comfortably in a covered shoebox with small holes punched in the sides for ventilation.

Science Content
• To introduce genetics and how traits are passed within families
• To observe variations that can occur even within a family
• To be introduced to terminology related to genetics and heredity

Life Skills
• Decision making, communicating, learning to learn

Time
Prep: 45-60 minutes
1. Creating Reebop Parents
2. Assemble needed materials for students’ Baby Reebops
3. Copy and cut strips representing Reebop chromosomes

Activity: 45-60 minutes

Materials
Per student:
2 small nails
2 thumbtacks
4 large marshmallows (slightly stale works best!)
2 toothpicks
1 orange miniature marshmallow
2 green miniature marshmallows
4 blue push pins
1 pipe cleaner

Copies of Teachers Guide 3-D ("Mom" page on red paper and "Dad" page on green paper).

Adapted by University of Illinois Extension from the Center for Biology Education, University of Wisconsin
Each cell in all living organisms contains hereditary information that is encoded by a chemical called DNA (deoxyribonucleic acid). DNA is an extremely long molecule. When this long, skinny DNA molecule is all coiled up and bunched together it is called a chromosome. Each chromosome is a separate piece of DNA, so a cell with 8 chromosomes has 8 long pieces of DNA. A gene is a segment of the long DNA molecule. Different genes may be different lengths. Each gene is a code for how a certain molecule can be made. The molecules produced by the genes can generally be sorted into two different types: ones that run the chemical reactions in your body, and ones that will be the structural components of your body. How an organism looks and functions is a result of the cumulative effect of all the molecules.

Chromosomes can be seen if one looks through a microscope at a cell stained with dye. The DNA in a cell will coil up to form chromosomes right before the cell is about to divide. Therefore, you need to look at cells that are in the process of dividing to see chromosomes. Otherwise, the DNA will be uncoiled and strung out all over the nucleus of the cell.

Any organism that has "parents" has an even number of chromosomes, because half of the chromosomes come from the "father" and the other half from the "mother." For example, in plants, a pollen grain is the "father's" contribution and an ovule is the "mother's" contribution. These two cells combine to make a single cell which will grow into a seed (the offspring). Humans have 46 chromosomes. The chromosomes sort into 23 pairs. One chromosome in each of the 23 pairs is from the person's father, the other from the person's mother.

Since chromosomes come in pairs, genes do too. One gene is located on one member of the chromosome pair, the other gene is in the same location on the opposite chromosome. The location where the gene can be found on the chromosome is referred to as the gene locus. The gene "pair" is technically referred to as a gene, as both members of the pair code for the same trait. A gene can consist of a variety of different forms, but only two forms are ever present per gene (one from the mother, the other from the father). The two different gene forms on the pair of chromosomes may be identical or different. For example, in the Reebops activity, the gene for tail shape has a "T" form and a "t" form. These forms are arbitrarily represented by capital and lower case letters. If both chromosomes have a "T" form, or both have a "t" form, the gene is said to be homzygous (two of the same form). If one chromosome has a "T" form and the other has a "t" form, the gene is said to be heterozygous (two different forms). The different forms that comprise a gene are called alleles. Therefore, "T" and "t" are alleles for the tail shape gene.

If you look at the Key to Reebop Traits found on page 50, you will notice that two "T"s (TT) or a "T" and a "t" (Tt) code for the same thing: a curly tail. If the Reebop has a small "t" on each chromosome, he or she will have a straight tail. Because both

Adapted by University of Illinois Extension from the Center for Biology Education, University of Wisconsin
the heterozygous (Tt) and one of the homozygous (TT) forms happen to code for the same variation of tail shape, curly tail is said to be the dominant variation and straight tail is the recessive. (Most people like to assign the capital letter to the dominant allele. This is purely an arbitrary designation.)

Now look at the decoder symbols for the nose color gene. Notice that in this case, the heterozygous condition (Qq) codes for a different nose color variation (orange) than either of the homozygous states (QQ=red, qq=yellow). This is an example of codominance. Many people mistakenly believe that a dominant allele (“T” in the tail shape example) is the most prevalent form or that the dominant allele can switch off or mask the recessive allele. Actually, all dominance refers to is what the heterozygous combination codes for. If it codes for one of the homozygotes, that variation is dominant. If it codes for a variation that is different than either homozygous state, then that variation is codominant.

If an expectant mother chooses to have an amniocentesis, she will learn some information about her baby's chromosomes, but not about the baby's genes. Chromosomes are large enough to be seen with a microscope, genes are not. Specialized tests are required to look for a particular gene that can cause a genetic disorder. Typically, an amniocentesis is used to see if the baby has the correct number of chromosomes. The chromosomes of fetal cells taken from the amniotic fluid are examined in the procedure. The baby's chromosomes are photographed through a microscope. Each pair of chromosomes differs in length. The chromosomes are cut out of the photo and arranged by length into 23 pairs. The pairs are numbered longest to shortest, with the longest pair labeled as number one. This chromosomal picture is called a karyotype. If a mistake occurs when cells are dividing to produce egg or sperm cells, the baby may end up with an incorrect number of chromosomes. This error would show up in the karyotype. Non-disjunction is the general term for errors in chromosome division. For example, a pre-sperm cell with 46 chromosomes could divide into one sperm cell with 22 chromosomes and another with 24. If the sperm cell with 24 chromosomes fertilizes an egg with 23 chromosomes, the baby will now have 47 chromosomes. A child with Down Syndrome has an extra number 21 chromosome. The extra chromosome can come from either the father or the mother, depending on if the non-disjunction occurred during the production of either the sperm or egg cell.

Lesson Plan

Doing the Activity

During the Reebop activity, your students will have the opportunity to observe all of the offspring produced by one set of Reebop parents. Your students will sort Mom and Dad Reebop's chromosomes, select the new baby Reebop's chromosomes, decode the "secret code" found on the baby's chromosomes, and construct the baby Reebop according to the code. In
other words, your students will be modeling the processes of meiosis, fertilization, development and birth. After all of the babies are "born," the Reebop family will be assembled so the offspring can be compared to one another.

Assembling Mom and Dad Reebop

Prior to class, you need to assemble Mom and Dad Reebop. Mom and Dad each have two antennae (small nails), a head (white large marshmallow), a neck (two toothpicks), two eyes (thumbtacks), an orange nose (an orange miniature marshmallow), three body segments (white large marshmallows), two green humps (green miniature marshmallows), four blue legs (blue push pins), and a curly tail (a pipe cleaner). Assembly works best if you let the marshmallows sit out over night to firm up. The Reebops tend to be too floppy to stand properly if fresh marshmallows are used.

Constructing Chromosomes

Next, you will have to construct identical sets of Mom and Dad Reebop's chromosomes for the students to sort. Place each set in a large envelope. Chromosomal analysis has revealed that Reebops have 7 pairs, or 14 total chromosomes. Cut strips of red and green construction paper to create the chromosomes (Teacher's Guide 3-D). Each envelope should contain two different colored subsets of 14 chromosomes (a total of 28). Each parental set consists of pairs of chromosomes of 7 different lengths. The 14 red chromosomes are Mom's chromosomes and the 14 green ones are Dad's. Write the "secret code" symbols (the alleles) on the chromosomes with a magic marker. I set it up so that the parents are heterozygous at all loci and each gene locus is on a different chromosome (7 traits, 7 pairs of chromosomes). More traits, such as sex, can be easily added if you wish. Create enough sets so each pair of students will have their own set to work with.

Seven pairs of chromosomes seems to be a large enough number to insure that no two offspring produced by a class will appear identical. However, if you are working with a large group of students, you may want to increase the chromosome number to insure the certainty of variation among all offspring. There are 128 chromosome combinations possible from an organism that has 7 pairs of chromosomes (2 to the 7th power). Or, in other words, there are 128 possible genotype combinations from this arrangement. However, the actual number of phenotype combinations is less than this number as some of the allele
combinations code for the same phenotype, such as blue legs = LL or Ll. If each gene locus exhibited codominance, then the number of genotype combinations would be the same as the number of phenotype combination.

**Breeding Reebops**

Introduce your students to Mom and Dad Reebop and distribute the chromosome sets, one to each pair of students. Ask one member of each pair to take the red chromosomes, and the other the green. Have them turn the chromosomes face down on the table so that no letters are visible, and ask each student to sort them by length. At this point you may want to ask the students to hypothesize why chromosomes come in pairs. Then have each pair of students arbitrarily take one chromosome of each length and place it in a separate “baby pile.” This will be their Reebop baby’s chromosomes. The remaining chromosomes can be returned to the envelope. Each Reebop baby will have 14 chromosomes, half red and half green. If you happen to have a pair of students who sort their chromosomes improperly and end up with either the wrong number of chromosomes or 14 chromosomes without each of the seven lengths, resist pointing this out to them. Their Reebop baby will be a wonderful example of the need for both the correct number and kinds of chromosomes given to the baby by Mom and Dad.

The students can discover what their baby will look like by turning over their baby’s chromosomes and decoding them, referring to the Key to Reebop Traits. Each pair of students will construct their baby according to their “secret code.” Have the proud parents place the completed Reebop babies in a designated nursery. Each Reebop baby should look different than all the other Reebop babies. If none of the groups of students missorted their chromosomes, you may wish to have a pre-constructed baby that has extra parts and is missing others. This baby will be a perfect lead-in to talking about non-disjunction.

**Key to Reebop Traits**

1 antenna = AA  
2 antennae = Aa  
No antennae = aa  

1 green hump = MM  
2 green humps = Mm  
3 green humps = mm  

Red nose = QQ  
Orange nose = Qq  
Yellow nose = qq  

Curly tail = TT or Tt  
Straight tail = tt  

2 eyes = EE or Ee  
3 eyes = ee  

Blue legs = LL or Ll  
Red legs = Ll  

2 body segments = dd  
3 body segments = DD or Dd

Adapted by University of Illinois Extension from the Center for Biology Education, University of Wisconsin
The Advantage of Using Reebops

The advantage of the Reebops is its suitability to a wide range of ages. We have found that elementary teachers as well as college instructors are enthusiastic about the lessons they have taught with Reebops. Of course, the goals of the Reebop activity will vary depending on the grade level of the students. For example, with young children, the goal of the activity may be simply to understand what generations are. With older students, the goals may be to understand that each parent contributes the same amount of genetic information to a child, why siblings in a given family look similar yet are all different, and why identical twins are “identical.” The Reebops can be used with advanced students to teach concepts such as linkage and multiple alleles. They can even be used to teach population genetics, as Reebop offspring can interbreed to produce numerous generations. Multiple generations of Reebops can also be used to introduce a genetics unit. You can have students construct Reebop pedigrees, look for patterns of inheritance of the different traits, and subsequently infer models that account for these patterns.

The Reebop activity generates numerous questions from students, especially when we the effect of non-disjunctional events in humans is discussed. There are very few viable forms of aneuploidy (extra or missing chromosomes) in humans. One example is Down Syndrome. Most adolescents are familiar with Down Syndrome, particularly if they have seen the weekly television show “Life Goes On.” Fetuses with either trisomy 13 or 18 who survive to birth will usually die shortly after. There are living individuals who have a variety of sex chromosome aneuploidies. However in most cases, aneuploidy in humans will not result in viable offspring and a miscarriage will occur. A conservative estimate calculates that at least sixty percent of all miscarriages that occur before the twelfth week of gestation are due to an incorrect chromosome number in the developing fetus.

Conclusion

The strength of the Reebop breeding activity is that it helps students to understand that the function of meiosis is not only to reduce the number of chromosomes, it is an important mechanism to insure the variation which is vital to all species. Variation is the “raw material” for the process of natural selection, the driving force of evolution. After breeding Reebops, students are more apt to recognize and understand both functions of meiosis, because they are not getting bogged down in the jargon of phase names or genetics phenomena. Finally, the best part about Reebops: You can eat the leftovers!
Glossary

**Allele**—A form of a gene. A gene actually consists of two forms, one on the chromosome that came from the father, the other on the chromosome given by the mother.

**Aneuploidy**—Having extra or missing chromosomes.

**Chromosome**—A very long piece of DNA coiled around some proteins. Each chromosome is a separate strand of DNA.

**DNA**—A very long chemical that can coil up to form a structure known as a chromosome.

**Gene**—A segment of a strand of DNA that codes for how to make a particular molecule. The molecules it produces will result in a particular trait. Different genes have different lengths.

**Heterozygous**—Having two alleles (forms of the gene) that are different.

**Homozygous**—Having two alleles (forms of the gene) that are identical.

**Locus**—the location of the chromosome where the gene can be found. The plural of locus is *loci*.

**Meiosis**—The type of cell division that produces cells with half the number of chromosomes than the original cell. This is the process that creates sperm and egg cells.

**Non-disjunction**—An error in the process of chromosome sorting during cell division.

**Trisomy**—Having three chromosomes of one size instead of the normal pair.
Mom Reebop
Chromosomes
(red)
Dad Reebop
Chromosomes
(green)
Reebops

Key to Reebop traits

1 antenna = AA
2 antennae = Aa
No antennae = aa

1 green hump = MM
2 green humps = Mm
3 green humps = mm

Red nose = QQ
Orange nose = Qq
Yellow nose = qq

Curly tail = TT or Tt
Straight tail = tt

2 eyes = EE or Ee
3 eyes = ee

Blue legs = LL or Ll
Red legs = ll

2 body segments = dd
3 body segments = DD or Dd

The gross anatomy of a Reebop

- Small nails
- White large marshmallow
- Thumbtacks
- Green miniature marshmallow
- Orange miniature marshmallow
- 2 Toothpicks
- White large marshmallows
- Pipe cleaner
- Push-pins

Toothpicks function as the unseen ligaments and tendons
Chapter 4: Biotechnology and Gene Splicing

Chapter Overview

Biotechnology is part of our daily lives. It is used in making foods we eat, the medicines we take, and the plants we grow. Biotechnology is used in a wide range of activities of social and economic importance such as: agriculture, chemical industry, environment, food industry, and medicine.

The activities in this lesson will allow students to comprehend that biotechnology is the use of living organisms to improve existing products or to make new ones. Today, the term “biotechnology” has come to mean the use of genetic engineering and its associated technique to produce a useful product, method and service. These organisms are found in a variety of applications, from medicine to agriculture.

This section will also allow students to demonstrate the principles of gene splicing, which is an essential part of biotechnology. Scientist found out that simple organisms like bacteria or viruses often have DNA that is useful because they can be joined or “spliced” with genes. Accomplishing these tasks could give the plant special new abilities like resisting diseases.

By using the techniques of gene splicing and recombinant DNA technology, we can now actually combine the genetic elements of two or more living organisms. From this technology we can develop crop plants that are resistant to diseases and insects along with producing important proteins for animal health and developing foods that stay fresher.

Objectives:

Students will:

1. Define and describe the concepts associated with biotechnology.

2. Demonstrate that biotechnology is part of everyday life.

3. Understand the basic concept of gene splicing.

4. Demonstrate correct use of terminology and functions of the elements involved in gene splicing (i.e. plasmid, restriction enzymes, ligase, “gene of interest”).
Included Activities:
Did You or Will You Ever?
Paper Gene Splicing
Chromosome DNA (from humans)
Plasmid DNA (from E. coli bacteria)
The Technique of Gene Splicing
Transformation—Inserting Recombinant DNA Into Host Cells
Biotechnology and Foods: Is It an Issue?
What is Biotechnology?  
Or Did You Ever?  
Will You Ever?

During this activity, students will be introduced to the concept of biotechnology. They will fill out a survey that asks about their participation in everyday activities, for example, washing dishes or doing laundry. Then, the teacher will lead a discussion on how biotechnology influences daily activities.

Science Content

• To introduce students to the concept of biotechnology

• To make students aware of how biotechnology affects everyday activities

Science Process Skills

• Communicating, categorizing

Life Skills

• Learning to learn, communicating

Time

Prep: 5-10 minutes

Activity: 20 minutes

Materials

1. Student handout/overhead 4-A


Educator Background

Information

(See Appendix B on pages 90-95 for additional information.)

Biotechnology is the use of living organisms and their products and processes to make our lives easier or better. Bio means “living” in Latin. The use of biotechnology is not new. Humans have practiced biotechnology since the beginning of recorded history. It is evident in activities such as raising food crops, breeding domestic animals, and making bread, wine, beer, and cheese.

Today, we understand the scientific principles behind many of these refined processes. Biotechnology affects our lives in many ways that we are unaware exist. Biotechnology often involves the direct manipulation of an organisms’ DNA (deoxyribonucleic acid) molecules. Scientists have developed laboratory techniques such as DNA fingerprinting and genetic engineering as tools for numerous new applications. This technology has produced new companies and many new
Scientists use genetic engineering in pharmaceuticals, gene therapy, and transgenic plant and animal development.

- **Pharmaceuticals** — Drugs such as insulin are produced by inserting the human gene for this molecule into bacteria. The drug is mass produced by growing bacteria through fermentation. This process makes medicine production more efficient and cost effective. Before this was done, insulin was isolated from slaughtered pigs.

- **Gene therapy** — The first clinical gene therapy is underway to correct an enzyme deficiency (called ADA) in children. Bone marrow cells are removed, defective DNA is supplemented with a copy of normal DNA, and the repaired cells are returned to the patient’s body.

- **Transgenic plants** — Scientists have grown and tested transgenic plants since 1987. These plants are more tolerant of herbicides, resistant to insect or viral pests, and express modified versions of fruit or flowers. Scientists are now developing a vaccine in banana plants.

- **Transgenic animals** — Transgenic animals help researchers diagnose and treat human disease. Products such as insulin and growth hormones produced by fermenting transgenic bacteria may soon be obtained by milking transgenic cows, sheep, or goats.

It is possible to use DNA fingerprinting for many applications including producing “a fingerprint” to identify individual humans, plants, or animals. Criminalists use DNA fingerprinting to solve crimes and identify who’s responsible. DNA fingerprinting also helps identify human remains and determine paternity. In agriculture, it is used to control quality and mark crop hybrids developed for patenting.

Public education in biotechnology is needed in view of the great influence that it has on everyday life. Society’s challenge is to make decisions about how these new technologies and products are used.

**Lesson Plan**

**Doing the Activity**

1. Ask the students to define biotechnology. (Discuss and provide students with the definition listed below.)

   Biotechnology employs living organisms (or part of organisms) to make or modify products, improve plants or animals, or develop microorganisms for specific uses to make our lives easier or better.

2. Give each student a copy of handout 4-A.

3. Have the students fill out the survey. Remind them that the question is “Did you or will you ever?” They should answer “yes” if they are likely to perform the activity in the future.
4. Go over the survey one question at a time. Ask for a show of hands for “yes” and “no” responses. You also may use an overhead of the question sheet to tally the responses. Before moving on to the next question, refer to the teacher’s guide handout.

5. Move on to the next question.

6. Have the students tally their “yes” answers. Relate their score to the scale below.

   20-23... We’re inseparable!
   18-22... I’m very affected!
   12-17... I could take it or leave it.
   7-11... I wouldn’t miss it.
   6 or less... Bio-what?

Reflecting and Applying

- Before taking this survey, how much did you think biotechnology affected your life? After taking the survey?
  
  Answers may vary. Promote students involvement.

- How do you feel about biotechnology now?

  Answers may vary. Promote students involvement.

- Do you think biotechnology will be part of your future?

  Answers may vary. Promote students involvement.

Alternative Ideas

1. Have the students keep a scrapbook or bulletin board of newspaper and magazine articles on technology (biotechnology).

2. Look for biotechnology web sites on the Internet.

3. Arrange to visit a site that uses or makes biotechnology-related products. Have someone from one of these companies come and visit your class.

Sites to contact:
- Corn and Soybean Seed Companies/Dealers
- Law Enforcement Agencies (Crime Scene Investigation Unit or Forensic Unit)
- Greenhouses
- Hospitals

Other Resources

- UIUC Biotechnology Education & Outreach Program (www.life.uiuc.edu/hughes/footlocker)
Did You or Will You Ever?

Ride in a car?
Drink tap water?
Go to the bathroom?
Use an extension cord?
Wash dishes or do laundry?
Have a dog or cat?
Fertilize your lawn?
Pull weeds around the garden?
Eat oranges, peaches, or potatoes?
Eat tomatoes?
Eat hamburgers?
Eat bacon or veal?
Drink milk?
Eat eggs?
Get bitten by mosquitoes or black flies?
Take out the trash?
Eat beans, peas or cereal?
Take vitamins?
Use krazy glue?
Wear brightly colored clothes?
Drink fruit juice?
Eat Chinese food?
Eat cheese?
Did You or Will You Ever?
Teacher’s Guide

Ride in a car? Genetically engineered organisms will someday be used to extract oil from rocks. Micro-organisms that break down oil spills are already in use.

Drink tap water? Genetically engineered micro-organisms will someday be used to attract and filter out harmful substances from drinking water.

Go to the bathroom? Micro-organisms are already an important part of sewage treatment; genetic engineering will produce bacteria that are more efficient at breaking down wastes.

Use an extension cord? 10% of the copper mined in the USA is drawn from rock by microscopic organisms. Genetic engineering will make them more efficient at it.

Wash dishes or do laundry? Commercial detergents have enzymes such as protease and amylase that break down protein stains on dishes or clothes. Genetic engineering will produce more efficient enzymes.

Have a dog or cat? Vaccines for a number of pet diseases such as rabies will be improved by genetic engineering.

Fertilize your lawn? Genetic engineering has already produced bacteria that helps plants “fix” nitrogen from the air so they can grow faster. This means farmers don’t have to spend time and money adding fertilizer to their crops!

Pull weeds around the garden? Genetic engineering can produce bacteria that only attack weeds, but leave other plants alone! It is also possible to use genetic engineering to make your garden plants immune to pesticides, then spray everything and kill only the weeds!

Eat oranges, peaches, or potatoes? These crops are very vulnerable to frost. With genetic engineering we can produce bacteria that prevent ice from forming on the plants, so that even if the temperature dips below freezing, the plants don’t die.

Eat tomatoes? Advances in biotechnology make it possible to actually insert new DNA in some plants, such as tomatoes, which make them immune to certain insect pests.

Eat hamburgers? Vaccines for cattle diseases such as hoof-and-mouth disease have been improved with genetic engineering.
Did You or Will You Ever?
Teacher's Guide

Eat bacon or veal? A vaccine for “scours”, a disease that kills piglets and calves, was made possible by genetic engineering.

Drink milk? Using new biotechnology, it is possible to purify large amounts of growth hormone. Cows given injections of growth hormone produce 40% more milk!

Eat eggs? Vaccines for a number of chicken diseases (no, not chicken pox!) have been improved thanks to genetic engineering.

Get bitten by mosquitoes or black flies? Genetic engineering will be able to someday produce micro-organisms that are lethal to mosquitoes or flies but leave other animals alone.

Take out the trash? Some animals (such as termites) can digest wood and paper because they have special bacteria in their stomachs; genetically engineering similar bacteria for cows or pigs would allow them to digest wood or paper, and could not only be a cheap source of feed, but might also solve some of our growing trash disposal problems.

Eat beans, peas, or cereal? These seeds are naturally high in protein, but not as high as they could be. Genetic engineering could make them even more nutritious, which is important for third world countries where malnutrition is a big problem.

Take vitamins? Vitamins can be made more potent and less expensively with biotechnology.

Use krazy glue? Certain kinds of adhesives can be made stronger on a molecular level with biotechnology.

Wear brightly colored clothes? Many clothing dyes can be made less expensively with biotechnology, and will last longer.

Drink fruit juice? Enzymes are used to convert starches into fructose, a sweetener in many juices. Genetic engineering will make the enzyme easier to obtain in pure form.

Eat Chinese food? Many food additives, such as mono-sodium-glutamate (MSG) can be made less expensively with biotechnology.

Eat cheese? Most cheese is already made with an enzyme, chymosin, produced by genetically engineered bacteria.
Paper Gene Splicing in E. coli

During this activity, students will create a large scale model of a very tiny molecular event — gene splicing. Students will transform the plasmid of a bacterial cell by inserting a foreign piece of chromosomal DNA (deoxyribonucleic acid), which contains a special gene of interest (healthy human hemoglobin A). The bacterial cell will be represented by a plastic sandwich bag; the chromosome and plasmid will be represented by colored paper strips.

To accomplish this task, the students will use a “restriction enzyme” (represented by a pair of scissors) to cut open the plasmid. The same “restriction enzyme” scissors will then be used to remove the desired section of DNA from the chromosome. This DNA is then inserted into the plasmid by joining the “sticky ends” of both pieces. The DNA is kept in place by the addition of ligase enzymes, represented by self-adhesive dots.

Science Content

- To teach students how to construct a paper model of a spliced gene
- To help students identify the elements involved in gene splicing: plasmid, “gene of interest,” restriction enzymes, ligase
- To help students define the function of each of the four elements involved in gene splicing
- To help students correctly order the basic steps involved in gene splicing

Science Process Skills

- Observing, ordering, inferring, applying

Life Skills

- Making decisions, organizing

Time

Prep: 30 minutes

1. Duplicate student handouts/overheads.
   4-C...“Paper Gene Splicing” on pages 70-71
   4-D...“Chromosome DNA” on page 72
   4-E...“Plasmid DNA” on page 73
   4-F...“The Technique of Gene Splicing” on page 74
   4-G...“Transformation—Inserting Recombinant DNA Into Host Cells” on page 75

2. Duplicate handouts/overheads 4-D and 4-E on different colors of paper so the students recognize that these types of DNA come from different organisms. The chromosome DNA is from a human. The plasmid DNA is from E. coli bacteria.

3. Give each student a set of scissors and tell them the scissors represent a “restriction enzyme.”
4. Each student also will need several pieces of clear tape to construct the chromosome and plasmid. Each student will need two plastic bags containing four colored self-adhesive red dots to represent the ligase enzyme.

5. Prepare a sign for the classroom door, such as "Recombinant DNA Factory" or "Welcome to the Hemoglobin Factory."

Activity: 45 minutes

Materials

1. Student handouts/overheads 4-C, 4-D, 4-E and 4-F
2. One pair of scissors labeled "restriction enzyme" per student
3. Four red half-inch self-adhesive dots (ligase)
4. Two locking sandwich bags per student
5. Clear tape for every 2-3 students
6. (Optional) Lab coat and safety goggles
7. The teacher/leader will need overheads 4-F and 4-G. These transparencies can be used to visually review the process of gene splicing. The instructor also could conduct a discussion of other ways in which genetic engineering/biotechnology can benefit human health care.

Educator Background Information

The purpose of this activity is to allow the students to demonstrate the principles of gene splicing. This technique is the backbone of current biotechnology. It is also referred to as "recombinant DNA." It allows for the massive production of proteins, human hormones, drugs, vaccines, and enzymes, as well as engineering agricultural plants with resistance to disease and immunity from certain insects.

Gene splicing is a major instrument of biotechnology. Its methods and techniques are used to remove DNA from one organism and combine it with the DNA of another organism. Following the instructions on the foreign DNA, organisms such as bacteria are able to produce substances that they are normally unable to make. In a sense, the bacteria are "tricked" into making large amounts of proteins for which they have no use. Scientists also can use gene splicing to transfer a desirable characteristic to another organism. For example, certain plants can be given genes for pest resistance and/or resistance to drought.

To splice a gene, the scientist must first locate it on the chromosomal DNA strand. He or she then selects a restriction enzyme that will cut the plasmid and allow for the insertion of the gene of interest. The same restriction enzyme will cut the gene from the chromosomal DNA. The gene of interest is placed into the plasmid and secured with ligase, an enzyme that

Adapted by University of Illinois Extension from Iowa State University Extension and Iowa State University Office of Biotechnology
allows the DNA to seal. The inserted gene will then become part of the original plasmid and will be reproduced each time the plasmid replicates. The organism now possesses the desired trait as part of its genetic material.

There are four principal terms to understand in gene splicing: plasmid, restriction enzyme, ligase, and "gene of interest."

- **Plasmid** — Plasmids are rings of DNA found in bacteria that are separate from the single chromosome. Plasmids contain genetic information, such as resistance to antibiotics.

- **Restriction enzyme** — These also occur naturally in bacteria. The bacteria use them to destroy any foreign DNA that may get into the bacterial cell. These enzymes protect bacteria from viruses.

  Each restriction enzyme cuts only at a very specific sequence of DNA. For example, EcoRI cuts only at

  \[
  \begin{align*}
  &G \quad A \quad T \quad T \quad T \quad C \\
  &C \quad T \quad T \quad A \quad A \quad G
  \end{align*}
  \]

  There are more than 800 known restriction enzymes; each will cut a specific sequence of base pairs in the DNA. If this sequence occurs in more than one DNA location, the restriction enzyme will cut all of these sites. For a scientist wishing to insert a fragment of DNA into a plasmid, the restriction enzyme is carefully chosen so there will be only one site for it to cut.

- **Ligase** — This is a cellular enzyme that creates a strong bond between the cut ends found on the DNA after the restriction enzymes have done their work. The rough ends of cut DNA are referred to as "sticky ends." Ligase serves as a type of glue to link the DNA fragments together.

- **"Gene of Interest"** — This is found on a piece of chromosome DNA. It carries a trait that the scientist would like to transfer to another organism. The gene may be inserted into an organism to improve its quality (e.g. Roundup® resistance to tomatoes) or to "trick" bacteria and yeasts into producing useful human proteins (e.g. vaccines) or hormones (e.g. insulin and growth hormone).

The process of inserting recombinant DNA into host cells is called transformation. Recombination of genetic material occurs constantly in nature, but transformation or gene splicing makes it possible for scientists to carry it out in a controlled laboratory. For this reason, the result is frequently called "genetic engineering."

*Adapted by University of Illinois Extension from Iowa State University Extension and Iowa State University Office of Biotechnology*
Lesson Plan

Introducing the Activity

“Welcome to the Hemoglobin Factory” or “Recombinant DNA Factory.” These are suggestions for signs to hang on the classroom door. The teacher can review human dwarfism and ask the students how science might help children with this disease. Perhaps they will come up with the idea to produce a human growth hormone to give these children by injection.

Doing the Activity

This lesson can be done in class, or be used as a homework assignment. The directions are self-explanatory; little teacher guidance is required.

1. The students should follow the instructions from handout 4-C to assemble human chromosomal DNA and an E. coli cell and to complete the gene splicing or recombinant DNA strategy.

2. The students should complete the analysis questions.

Reflecting and Applying

Gene splicing resulted from molecular biological research. Its application has developed into the science of biotechnology. Today, scientists use gene-splicing, also called recombinant DNA, to enhance the traits of an organism. It use to take years and years of selective breeding to accomplish these same goals. There are three primary discoveries that were necessary for the development of the science of gene-splicing:

1. The discovery of certain naturally-occurring restriction enzymes that cut DNA at specific predictable sites.

2. The discovery of plasmids, tiny DNA rings, in bacteria. These plasmids were then cut open at specific sites using the same restriction enzymes that cut chromosomal DNA.

3. The discovery of enzymes called ligases. Ligases attach the ends of the new genes (from chromosomal DNA of another organism) to the ends of the plasmid DNA to reform the plasmid circle. This produces a bacteria carrying a new gene or several new genes — a transformed cell with recombinant DNA.

Conduct a group discussion of the analysis questions from handout 4-C.

Alternative Idea

“Jelly Genes” activity, Student Handout 3-C on page 45. (If not used in a previous class session.)
Paper Gene Splicing

1. Were you able to complete the construction of a spliced gene in E. coli?
   Yes

2. In this activity, what did the following things represent?
   - Four sticky dots
     *Ligase enzymes; actually, the bonds formed by ligase enzymes. The actual enzymes will detach after the bond has formed and be used again.*
   - Scissors
     *Restriction enzyme*
   - Locking plastic bag
     *All of it represents an E. coli bacteria cell; the bag itself represents a cell membrane.

3. Number the following statements so that they show the correct sequence of steps in gene splicing (also called genetic engineering):
   1 Plasmid DNA is removed from an E. coli cell
   2 Restriction enzymes are added, cutting the DNA at a specific location.
   4 The human hemoglobin gene is inserted into the plasmid using ligase, forming recombinant DNA.
   3 A hemoglobin "gene of interest" from a human cell is cut out with the same enzymes.
   5 The recombinant DNA plasmid is put into a new E. coli cell and more copies of hemoglobin are made as the E. coli bacteria multiplies.
   Alternative correct answer: 3, 1, 2, 4, 5

4. If E. coli in a culture doubles every 20 minutes, what would happen to the amount of hemoglobin that the culture could produce?
   The amount of hemoglobin produced would also probably double. This results in an exponential increase 1→2→4→8→16

5. How would you feel about using a product that was produced using recombinant DNA technology?
   Answers may vary. Promote students involvement.

6. What are possible benefits of recombinant DNA technology?
   It allows for the massive production of proteins, human hormones, vaccines, and enzymes, as well as engineering agricultural plants with resistance to disease and immunity from certain insects.
7. Are there any possible hazards associated with recombinant DNA technology?

- **Scientists use genes for antibiotic resistance when they manipulate genes in the laboratory. These genes end up in the genetically engineered organisms. In some cases, resistance may end up in bacteria, making the bacteria resistant to antibiotic treatment and thus endangering human health.**

- **The ultimate consequences of introducing genetic engineered organisms into the environment (as opposed to maintaining control of them in the laboratory) are unknown. Some people think that until we are able to ensure that the benefits of genetically engineered organisms outweigh the risks, we should not use genetically engineered organisms in our food supply. Scientists are studying these potential problems.**
Paper Gene Splicing

In this activity you will learn the basic operation by which scientists are able to transform (change) a normal *E. coli* bacterium into one with an unusual characteristic. This is done by removing a "gene of interest" from a piece of human DNA and inserting it into a bacteria cell.

You will need the following materials:
- 1 chromosome DNA sheet (copy on colored paper)
- 1 plasmid DNA sheet
- 1 pair of scissors labeled "restriction enzyme"
- 4 colored sticky dots
- 2 Ziploc™ sandwich bags
- Scotch tape

Assembly of human chromosomal DNA and the *E. coli* cell:

1. Cut out the 2 strips of plasmid DNA along with solid lines. Tape the ends together, matching the marks.
2. Form the plasmid into a circle and seal with another piece of tape.
3. Place the plasmid DNA into a Ziploc™ bag. The bag represents the cell body of the bacteria. Your *E. coli* cell is now complete.
4. Construct a segment of human chromosomal DNA by cutting out the 4 strips along the solid lines.
5. Tape the ends together, matching the marks. You now have a section of human DNA with the gene for healthy human hemoglobin A. This gene is found on the segment carrying the following code sequence. Highlight this gene sequence on your chromosomal DNA molecule.

   GTA—CTA—TTT—ACT—CCT—GAA—GAA—AAA
   CAT—GAT—AAA—TGA—GGA—CTT—CTT—TTT

Now it is time for you to put on your lab coat and safety goggles. Prepare your laboratory workshop for the operation of the day: Gene Splicing or Recombinant DNA Techniques of Biotechnology.

**Gene Splicing or Recombinant DNA Strategy:**

1. Open the "baggie" *E. coli* bacterial cell and remove the plasmid.
2. Use the scissors, which represent a restriction enzyme called Eco RI, to cut the plasmid DNA at its marked site. Do this by cutting along the dotted line.

3. Use the same scissors, which represent the restriction enzyme Eco RI, to cut out the "gene of interest" (healthy human hemoglobin) from the chromosomal DNA. Do this by cutting along the dotted lines. (You can throw away the short pieces of the DNA chromosome.) Note that the code sequence for healthy hemoglobin A is included in the segment to be inserted into the *E. coli* plasmid.

4. The 4 red dots represent ligase, an enzyme that strengthens the bonds which hold the nucleotides together. Use the 4 ligase enzymes to connect the "gene of interest" to the plasmid.

5. Place the plasmid into a new Ziploc\textsuperscript{TM} bag. The plasmid is also called "recombinant DNA" now. This bag represents a new "transformed" bacterial cell. The previous *E. coli* cell was destroyed when you removed its plasmid.

6. The model now represents an *E. coli* cell with a new gene. The cell now contains the instructions to produce healthy human hemoglobin.

7. The bacteria can be grown in huge vats and large amounts of hemoglobin can be collected. Although this process is still being perfected by scientists (they are working out some problems still!), researchers have already developed sources of insulin, interferon, human growth hormone and hepatitis B vaccine using this technique.

**ANALYSIS:**

1. Were you able to complete the construction of a spliced gene in *E. coli*? _____

2. In this activity, what did the following things represent?
   - The 4 sticky dots: ______________________
   - The scissors: ______________________
   - The Ziploc\textsuperscript{TM} bag: _______________________

3. Number the following statements so that they show the correct sequence of steps in gene splicing (also called GENETIC ENGINEERING):
   - Restriction enzymes are added, cutting the DNA at a specific location.
   - The human hemoglobin gene is inserted into the plasmid using ligase, forming recombinant DNA.
   - Plasmid DNA is removed from an *E. coli* cell.
   - A hemoglobin "gene of interest" from a human cell is cut out with the same enzymes.
   - The recombinant DNA plasmid is put into a new *E. coli* cell and more copies of hemoglobin are made as the *E. coli* bacteria multiplies.

4. If *E. coli* in a culture double every 20 minutes, what would happen to the amount of hemoglobin that the culture could produce? ______________________
Chromosome DNA
(from humans)
Plasmid DNA
(from E. coli bacteria)
The Technique of Gene Splicing

Plasmid removed from E. coli bacterium and a small section is cut

Plasmid reintroduced into Bacterium

Hemoglobin gene inserted in plasmid

Hemoglobin is injected into patients

Hemoglobin is extracted for medical use in humans

Bacteria multiply in fermentation tank—hemoglobin is produced by E. coli bacteria

Hemoglobin Gene from Chromosomal DNA

Human Cell

Plasmid

Cell DNA

E. coli Bacterium

Cell

Adapted by University of Illinois Extension from Iowa State University Extension and Iowa State University Office of Biotechnology
Transformation—Inserting recombinant DNA into host cells

As cells continue to divide, many recombinant plasmids are produced. Each contains a copy of the foreign gene.
Biotechnology and Foods: Is It an Issue?

Students will have the opportunity to explore issues surrounding foods produced through biotechnology techniques.

Science Content

- To introduce concepts related to food production influenced by biotechnology
- To gain multiple perspectives related to biotechnology and food

Science Process Skills

- Communicating, relating, applying

Life Skills

- Decision making, communicating

Time

Prep: 5-10 minutes

Duplicate student handouts 4-H, 4-I, 4-J and create overheads 4-K and 4-L.

Activity: 1 class period

Materials

- Student Handout 4-H
- Student Handouts 4-I and 4-J
- Overheads 4-K and 4-L

Procedure

Optional: Have the students read Student Handout 4-I "LoSatSoy™: The Story of a New Soybean Oil" as a homework assignment prior to doing this activity.

1. Inform the students that today they will play the role of a team of research scientists who are using biotechnology techniques to produce a new food product. As research scientists, they must first ask themselves the following three questions:
   - What type of modified food would the consumer want?
   - Are the genes for the modification available? (in nature, by plant breeding, or by genetic engineering)
   - Is it possible to develop a product with this modification that will be economically feasible? (Will consumers buy the product? Can my company make money?)

2. Divide the students into groups of 3-5.

3. Using Student Handout 4-H, the groups should discuss and record their views/input on each of the questions. Optional: You can use the list of "real" current or proposed food products provided in Overhead 4-K or join with the students to determine their own future product lists. Their lists might include such...
things as "bubble-gum-flavored spinach" or other creative options they invent.

Reflecting and Applying

After the students complete their team discussions, lead a large group discussion using the following questions:

- Which product would you produce? Why did you choose that product?
- What are the concerns or issues that this product might bring up? Who are the players involved in this issue?
- Who will do the testing for your product? What type of testing needs to be done?
- Will you label your food product? Why or why not?
- How will you promote your product to consumers?
- As a consumer, how would you make a decision about whether to purchase this product?

Source

_Iowa State University Extension and ISU Office of Biotechnology_
Biotechnology and Foods: Is It an Issue?

1. You are a team of food science researchers that works for Future Foods, Inc. The company has asked your team to use biotechnology techniques to produce a new food product. Your team must consider the following three questions as you plan for the new food product.

   A. What type of modification or change would consumers want in their food?

   B. Are the genes for making that modification available? You might need to look in nature or use plant breeding techniques or genetic engineering.

   C. Would it be possible to make an economically feasible product with this modification? Will consumers buy the product? Will the changes make the food too expensive?

2. Read _LoSatSoy™: The Story of a New Soybean Oil_ (Student Handout 4-I) to see how one food product was created.

3. Attached is a list of possible new food products (Student Handout 4-H) that your company could produce. Look over the list and decide which product your research team would like to produce. Write your choice below.

4. Now that you have selected your product, what issues or concerns in producing this product can your team foresee? List below.

5. Who will do the safety testing for your product? What type of testing will need to be done?
6. Will your product be labeled as a special biotechnology product? Why or why not?

7. How will you promote and advertise your product to consumers? Give a brief description of your marketing plan.

8. Would you as a consumer buy or use this product? Why or why not? How would you make this decision?

**Enrichment**
Search the Internet to discover views by different companies and consumer groups about biotechnology and foods. Your teacher can supply you with a list of sites to begin your search.
LoSatSoy™
The Story of a New Soybean Oil

Introduction

You are about to become part of the continuing story of a new biotechnology product, LoSatSoy™ soybean oil. Developed in Iowa, LoSatSoy™ is the world’s first low-saturated-fat soybean oil. In fact, that’s what the "LoSat" part of LoSatSoy™ stands for.

Eating too much saturated fat has been associated with the development of heart disease, some cancers, and other health problems. You may have read articles from health-related organizations like the American Heart Association about the dangers of too much saturated fat. You’ll learn more about that later.

LoSatSoy™ is so new that all the ways to use it in foods have yet to be discovered. Food scientists, nutritionists, school food service managers, and consumers like you are experimenting with how to use LoSatSoy™ in recipes to help them lower the saturated fat in their meals.

Even companies and the U.S. government are getting into the act. One Iowa company already has modified its recipes for spreadable salad dressing and mayonnaise to include LoSatSoy™ oil. If you live in Iowa, you may have heard their radio and television ads about their new lower-fat products.

Schools in 10 states have tested the new low-saturated-fat soybean oil for use in the U.S. Department of Agriculture’s National School Lunch Program. In fact, your school food service already may be serving meals made with the new low-saturated-fat soybean oil.

As part of this unit, you’ll learn a lot about the science behind the development of LoSatSoy™. You’ll also have the opportunity to design your own food science experiments using the new oil in your favorite recipes or new ones that you create.

But first, the story of LoSatSoy™ . . .
What's All the Fuss About Soybeans?

During the past few years, you’ve probably heard about the health benefits attributed to soybeans. Doctors and scientists are working to sort out which health claims are true and which are not. There are, however, some basic facts about soybeans on which most people can agree:

Facts About Soybeans

Fact 1: Soybeans are an excellent source of protein.

Fact 2: Soy products such as tofu, soymilk, or soy flour are consumed by millions of people around the world, especially in Asia.

Fact 3: Soybean oil is the major vegetable oil produced and consumed in the United States.

And that brings us to LoSatSoy™ oil. The scientists who developed LoSatSoy™ were looking for a soybean oil with less saturated fat. Eating too much saturated fat has been associated with high levels of blood cholesterol which, in turn, have been linked to heart disease. Because soybean oil is the major vegetable oil consumed in the United States, lowering its saturated fat could help reduce heart disease in this country.

Elevated Cholesterol and Heart Disease

Heart disease is the number one cause of death for both men and women in the United States. Doctors measure serum (blood) cholesterol to determine a person’s risk of developing heart disease.

Cholesterol is a waxy substance that circulates in the blood. Although some cholesterol is essential to make your body’s cell membranes, hormones, and bile digestive acids, too much cholesterol is associated with heart disease. The fat you eat can raise your blood cholesterol level. The higher your blood cholesterol level, the greater your risk of developing heart disease.

The following chart will give you an idea of how blood cholesterol levels are associated with heart disease.
In addition to monitoring total blood cholesterol, doctors also watch the blood levels of LDL and HDL cholesterol. HDL stands for "high density lipoproteins." LDL is the abbreviation given to "low density lipoproteins." Because cholesterol does not mix with water, it needs help circulating through blood, which is mostly water. Lipoproteins transport cholesterol throughout the body. LDLs carry cholesterol from the liver to the body and leave deposits on artery walls. HDLs carry cholesterol back to the liver for elimination.

If the ratio of LDLs to HDLs becomes too much in favor of the LDLs, it is likely that more cholesterol is being deposited in the arteries than is being removed. Some scientists use the LDL/HDL ratio to predict a person's chances of developing heart disease. A ratio greater than 3 to 1 can indicate above average risk.
The Saturated Fat Connection

Saturated fat is one of two types of fat in your diet. The other type is unsaturated fat. There is strong evidence that saturated fat raises blood cholesterol. The reason why too much saturated fat elevates blood cholesterol is probably linked to the chemical structure of saturated fat.

If the carbon atoms (C’s) in a fat have all the hydrogen atoms (H’s) that they can hold, the fat is saturated. In the average American diet, animal products are a major source of saturated fat. These products include fatty meat, butter, cheese, cream, and whole milk.

Some vegetable oils also are high in saturated fat. These oils include palm or palm kernel oil and coconut oil. These oils are listed as ingredients in many store-bought baked goods and snack foods, such as cookies, candy bars, and crackers.

Unsaturated fats are classified as either monounsaturated or polyunsaturated. As you might guess from the prefix “mono-” meaning one, a monounsaturated fat has one site where hydrogen atoms can be added. A polyunsaturated fat has two or more sites where hydrogen atoms can be added. The prefix “poly-” means more than one.

Unsaturated fats commonly are found in plant products. They can help lower the cholesterol levels in your blood when you substitute them for saturated fats. Sources of monounsaturated fat include nuts, olive oil, and canola oil. Sources of polyunsaturated fat include corn, safflower, sesame, soybean, and sunflower oils.

Adapted by University of Illinois Extension from Iowa State University Extension and Iowa State University Office of Biotechnology
Searching for Low-Saturated-Fat Soybeans

Now that you know about saturated fat and its role in increasing the risk of heart disease, you can understand why soybean scientists want to produce a soybean oil as low in saturated fat as possible. The seed of soybeans and other oilseed crops are crushed to obtain oil. The fatty acids in the seed determine the fat characteristics of the oil.

Soybeans contain two different saturated fatty acids, palmitic (rhymes with arthritic) and stearic (rhymes with derrick) acids. Palmitic acid is responsible for about 70 percent of the total saturated fat in soybean oil. That fact told the developers of LoSatSoy™ that palmitic acid was their target. They began the search for a soybean with genes that tell it to produce less palmitic acid.

The Right Genes

There are three ways that plant breeders obtain the genes they need to change crop plants.

1. Search the world’s collection of the crop plant for an existing plant that has the desired gene.
2. Increase the natural mutation rate of the crop plant and hope the right gene appears.
3. Remove a gene from another organism and artificially put the gene into the crop plant through genetic engineering.

A mutation is a genetic change in an organism. The organism’s DNA is changed by any one of a number of factors that include ultraviolet radiation, exposure to some chemicals, and radioactivity. Mutations are a natural process that constantly produce variations in a species. A mutation can be helpful, harmful, or make no difference to an organism.

Strike One

The developers of LoSatSoy™ examined the different variations of soybeans throughout the world and did not find one whose genes produced the low amount of palmitic acid that they wanted.

You're going to miss me!
Strike Two
Removing the DNA of a gene from another plant and placing it into a soybean was not possible in this case. No one had isolated the DNA of the gene(s) that regulate palmitic acid production in soybeans and other plants.

A Hit
That left the mutation method. The Iowa State University scientists who developed LoSatSoy™ treated soybean seeds with a chemical to increase the natural rate of mutations. They hoped that at least one of the genetically changed plants would produce less palmitic acid. It was a long process.

1. Seeds of an existing soybean variety were soaked for several hours in a chemical solution.
2. The seeds were planted, and seeds from the resulting plants were harvested and planted again. Then those seeds were harvested and analyzed for fatty acid content. The palmitic acid content had dropped considerably. But still the scientists weren’t satisfied. Their goal was to lower the saturated fat in soybean oil to the same level as canola oil, a competing product.
3. The scientists decided to cross their new mutant soybean line with another mutant soybean line developed by the U.S. Department of Agriculture and Purdue University. The USDA/Purdue soybean line also had reduced palmitic acid content. When the genes from the two mutant lines came together, the scientists had what they wanted---a soybean that produced oil with half the saturated fat of conventional soybean oil.
Playing the Rest of the Innings

The LoSatSoy™ game was far from over. After the Iowa State University scientists had the new soybean line they wanted, someone had to make the new soybeans field-worthy. Growing in a carefully tended test plot is one thing, and growing in a real field is something else! The soybeans had to have characteristics to help them yield well when grown by farmers.

The new low-saturate soybean was crossed to other varieties of high-yielding soybeans already being grown by farmers. Some of the low-saturate offspring from those crosses yielded well enough under field conditions to be grown by farmers. A company contracted with farmers to grow the new soybean seed from which LoSatSoy™ oil would be extracted. Because the LoSatSoy™ seed was different from all other seed, the farmers had to agree to keep the seed separate from regular soybean seed at all stages of planting and harvesting, a process called identity preservation.

Is This the End of the Story?

If you think that this is the end of the LoSatSoy™ story, you're wrong. In fact, it's just
Possible New Food Products

**Tomato Number One**—This tomato has its flavor enhanced by a gene that makes it slow to ripen. Your tomatoes would not need to be picked green and could stay on the grocery shelf longer.

**Tomato Number Two**—The tomato resists insects so chemical insecticides would not need to be used. You could make this product by crossbreeding your plants with a poisonous wild tomato plant that is found in South America.

**Corn**—The corn is resistant to insects so that chemical insecticides would not need to be used.

**Potato**—This potato is higher in starch and absorbs less oil during frying.

**Rice**—The rice has more nutrients.

**Soybean Number One**—These soybeans produce cooking oil that is lower in saturated fat.

**Soybean Number Two**—These soybeans have a milder flavor and are easier to digest.

**Nutriceuticals**—Plants such as bananas would contain vaccines to prevent disease.

**Vegetable Oil**—The cooking oil adds no calories or fat.

**Sugar Substitutes**—The product uses a microbe to produce amino acids for aspartame sweetener.

**Hormones**—These can be given to pigs to produce leaner meat or to cows to produce more milk.

**Mystery Product**—Use your imagination and determine your own potential food product. How does bubble-gum-flavored spinach sound?
Possible New Food Products for Future Foods, Inc.

**Tomato Number One**—This tomato has its flavor enhanced by a gene that makes it slow to ripen. Your tomatoes would not need to be picked green and could stay on the grocery shelf longer.

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**Hormones**—These can be given to pigs to produce leaner meat or to cows to produce more milk.

**Mystery Product**—Use your imagination and determine your own potential food product.
Research Team Questions for Future Foods, Inc.

1. What type of modification or change would consumers want in their food?

2. Are the genes for making the modification available?

3. Will consumers buy the product? Will the changes make the food too expensive?
Biotechnology Defined

Biotechnology can be broadly defined as “using living organisms or their products for commercial purposes.” As such, biotechnology has been practiced by human society since the beginning of recorded history in such activities as baking bread, brewing alcoholic beverages, or breeding food crops or domestic animals.

A narrower and more specific definition of biotechnology is “the commercial application of living organisms or their products, which involves the deliberate manipulation of their DNA molecules” (see glossary for definitions of bold-print words). This definition implies a set of laboratory techniques developed within the last 20 years that have been responsible for the tremendous scientific and commercial interest in biotechnology, the founding of many new companies, and the redirection of research efforts and financial resources among established companies and universities.

These laboratory techniques provide scientists with a spectacular vision of the design and function of living organisms, and provide technologists in many fields with the tools to implement exciting commercial applications.

Principles of Biology

All living organisms are composed of cells that contain a substance called DNA (deoxyribonucleic acid) in the chromosomes. (See Fig. 1.) The structure of DNA molecules contains information that is used by cells as a “recipe” for the organism; that is, the characteristics of any living thing essentially are determined by the information in DNA. The “words” for the DNA recipe, called genes, are derived from a 4-letter alphabet (A, C, G, T) and usually contain between 1,000 and 100,000 letters. The entire recipe, called the genome, may contain between 4 million (simple bacteria) and 3 billion (human) letters or more.

Except for the sequence and number of letters in each recipe, DNA from any organism is chemically and physically the same. One of the great scientific discoveries of biotechnology is that DNA from any organism will function if it is transferred into any other organism!

Using Biotechnology to Modify Plants and Animals

Combining DNA from different existing organisms (plants, animals, insects, bacteria, etc.) results in modified organisms with a combination of traits from the parents. The sharing of DNA information takes place naturally through sexual reproduction and has been exploited in plant and animal breeding programs for many years.

However, sexual reproduction can occur only between individuals of the same species. A Holstein cow can be mated with a Hereford bull because the two animals are different breeds of the same species, cattle. But trying to mate a cow with a horse, a different species of animal, would not be successful.

Figure 1

All life is composed of cells that contain DNA.
Production of Human Growth Hormone

What's new since 1972 is that scientists have been able to identify the specific DNA genes for many desirable traits and transfer only those genes, usually carried on a plasmid or virus, into another organism. This process is called genetic engineering and the transfer of DNA is accomplished using either direct injection or the Agrobacterium, electroporation, or particle gun transformation techniques. It provides a method to transfer DNA between any living cells—plant, animal, insect, bacterial, etc. Virtually any desirable trait found in nature can, in principle, be transferred into any chosen organism. An organism modified by genetic engineering is called transgenic.

Figure 2

Products of Genetic Engineering

Specific applications of genetic engineering are abundant and increasing rapidly in number. Genetic engineering is being used in the production of pharmaceuticals, gene therapy, and the development of transgenic plants and animals.

1) Pharmaceuticals
Human drugs such as insulin for diabetics, growth hormone for individuals with pituitary dwarfism, and tissue plasminogen activator for heart attack victims, as well as animal drugs like the growth hormones, bovine or porcine somatotropin, are being produced by the fermentation of transgenic bacteria that have received the appropriate human, cow, or pig gene. (See Fig. 2.)

2) Gene Therapy
The first clinical gene therapy is underway to correct an enzyme deficiency called ADA in children. Bone marrow cells are removed, defective DNA in bone marrow cells is supplemented with a copy of normal DNA, and the repaired cells are then returned to the patient's body.

3) Transgenic Plants
Transgenic plants that are more tolerant of herbicides, resistant to insect or viral pests, or express modified versions of fruit or flowers have been grown and tested in outdoor test plots since 1987. The genes for these traits have been delivered to the
plants from other unrelated plants, bacteria, or viruses by genetic engineering techniques. (See Fig. 3.)

4) Transgenic Animals
Presently, most transgenic animals are designed to assist researchers in the diagnosis and treatment of human diseases. Several companies have designed and are testing transgenic mammals that produce important pharmaceuticals in the animal’s milk. Products such as insulin, growth hormone, and tissue plasminogen activator that are currently produced by fermentation of transgenic bacteria may soon be obtained by milking transgenic cows, sheep, or goats.

Using Biotechnology in Diagnostic Applications

Since each living creature is unique, each has a unique DNA recipe. Individuals within any given species, breed, or hybrid line can usually be identified by minor differences in their DNA sequences—as few as one difference in a million letters can be detected! Using the techniques of DNA fingerprinting and PCR (polymerase chain reaction) scientists can diagnose viral, bacterial, or fungal infections, distinguish between closely related individuals, or map the locations of specific genes along the vast length of the DNA molecules in the cells.

Identifying Organisms
By using RFLP technology (restriction fragment length polymorphism), DNA fingerprints can be generated. Any individual organism can be uniquely identified by its DNA fingerprint. Consequently, this fingerprint can be used to determine family relationships in paternity litigation, match organ donors with recipients in transplant programs, connect suspects with DNA evidence left at the scene of a crime (in the form of hair or body fluids), or serve as a pedigree for seed or livestock breeds. (See Fig. 4.)

Identifying Genes
One important aspect of genetic engineering projects is to identify the DNA gene that controls a particular trait. In the same way that a visitor might use

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**Production of Transgenic Plants**

**Agrobacterium + Ti Vector**

**Natural Plant Gene**

**Gene Insertion**

**Particle Gun Transformation**

**Transgenic Plant**

**Tissue Culture**

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Adapted by University of Illinois Extension from Iowa State University Extension and Iowa State University Office of Biotechnology
the state, city, street, and house number to locate a friend’s house, genetic engineers use genetic “maps” to locate genes. The genetic maps are generated by statistical analyses, PCR, RFLP, and DNA sequencing. Maps are being developed for humans, mice, swine, cattle, corn, wheat, and other plants or animals with commercial or research importance.

**Diagnosing Infectious Diseases and Genetic Disorders**

Diagnosis of infectious diseases is a profound application of the new DNA technology. Tuberculosis, AIDS, papillomavirus, and many other infectious diseases, in addition to the inherited disorders like cystic fibrosis or sickle cell anemia, are diagnosed within hours by the PCR technique rather than days or weeks by traditional methods. The greatly increased sensitivity and speed of the PCR technique, as compared with traditional methods, allows earlier intervention and treatment. PCR assays will soon be available to diagnose diseases of crops and livestock.

**Summary**

1) All living organisms are composed of cells that contain the molecule DNA. The chemical structure of DNA contains information, based on a 4-letter genetic code, that cells use as a “recipe for life.” The functional units of information, the “words” of the recipe, are called genes.

2) DNA from all living organisms is the same, except for the sequence and number of letters in the “recipe.” Therefore, traits can be transferred from one organism into another by transferring the DNA genes for those traits. This transfer process is called “genetic engineering” and the organisms that are produced are called “transgenic.”

---

**THE PROCESS OF DNA FINGERPRINTING**

1. The process begins with a blood or cell sample from which the DNA is extracted.

2. The DNA is cut into fragments using a restriction enzyme. The fragments are then separated into bands by electrophoresis through an agarose gel.

3. The DNA band pattern is transferred to a nylon membrane.

4. A radioactive DNA probe is introduced. The DNA probe binds to specific DNA sequences on the nylon membrane.

5. The excess probe material is washed away leaving the unique DNA band pattern.

6. The radioactive DNA pattern is transferred to X-ray film by direct exposure. When developed, the resultant visible pattern is the DNA FINGERPRINT.

---

**Figure 4**

3) Organisms can be uniquely identified by their DNA sequences. Though the DNA of all organisms is chemically and physically the same, the DNA “recipe” (sequence and number of letters) is unique to each individual. These different sequences account for the diversity of life observed in nature and are the basis for using DNA “fingerprints” to distinguish between any two individuals, breeds, hybrids, species, etc. They are also the basis of diagnosis of viral, bacterial, or fungal diseases using PCR technology.
Glossary

Agrobacterium—a natural bacterium that can be used to transfer DNA genes into broadleaf plants, such as tobacco, tomato, or soybean.

Chromosome—a cellular structure comprised of a long, folded DNA molecule and protein.

DNA—deoxyribonucleic acid, the substance within cells that carries the “recipe” for the organism and is inherited by offspring from parents.

DNA fingerprinting—cutting a DNA chromosome with restriction enzymes and separating the pieces by electrophoresis to generate a unique pattern, the “fingerprint” for each species, breed, hybrid, or individual, depending on which enzymes and probes are used.

Electrophoresis—a lab technique for determining DNA fragment sizes by separating them in a gel placed in an electric field.

Electroporation—using an electric shock to transfer DNA into the cells of an organism; one of several procedures called transformation.

Gene—a functional unit of DNA, one “word” in the DNA recipe.

Genetic code—the information contained in DNA molecules that scientists describe on the basis of a 4-letter alphabet (A, C, G, and T).

Genetic engineering—the process of transferring DNA from one organism into another that results in a genetic modification; the production of a transgenic organism.

Genetic map—the locations of specific genes along a chromosome marked with probes.

Genome—the entire DNA “recipe” for an organism, found in every cell of that organism.

Mutation—a change of one of the “letters” in the DNA “recipe” caused by chemicals, ultraviolet light, X-rays, or natural processes.

Particle gun—a gun that shoots DNA into the cells of an organism; the most versatile of a series of procedures called transformation.

PCR—polymerase chain reaction, which rapidly duplicates specific DNA molecules in response to temperature changes in a computer-controlled heater.

Plasmid—a small, circular DNA that is used to transfer genes from one organism into another.

Probe—a very short piece of DNA used to find a specific sequence of “letters” in a very long piece of DNA from a chromosome or genome.

Recombinant DNA—DNA formed by joining pieces of DNA from two or more organisms.

RFLP—restriction fragment length polymorphism, which describes the patterns of different (polymorphism) sizes of DNA (fragment length) that result from cutting with restriction enzymes (restriction). See DNA fingerprinting above.

Sequence—the order of “letters” in the DNA “recipe.” The DNA sequence is the chemical structure that contains information.

Transformation—a procedure to transfer DNA into the cells of an organism. Can be done with Agrobacterium (most dicots), calcium chloride (bacteria), electroporation (any organism), or the particle gun (any organism).

Transgenic—an organism that has been modified by genetic engineering to contain DNA from an external source.

Vector—any DNA structure that is used to transfer DNA into an organism; most commonly used are plasmid DNA vectors or viruses.

For Further Reading

Bio/Technology. A monthly journal devoted specifically to scientific, economic, and public policy issues in biotechnology. For subscription information, phone 1-800-524-0328.


Written by David F. Betsch, Ph.D., Biotechnology Training Programs, Inc. Edited by Glenda D. Webber, Iowa State University Office of Biotechnology.
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In cooperation with NCR Educational Materials Project


March, 1994
Chapter 5: DNA Extraction

Chapter Overview

The activities in this chapter will help students internalize the fact that DNA is in all living things. This is accomplished by providing them the opportunity to extract DNA from common materials in the world around them.

DNA is discussed as being sub-microscopic, but if you get enough of it together in one place in the right environment, it becomes visible. Actually seeing the mass of DNA created as the end result of these activities brings home the lesson that DNA is real and in every living organism.

In general, the process of DNA extraction from the nucleus of a cell requires the following:
1. Breaking cell and nuclear membranes mechanically (blending, mixing) and chemically (with detergents).
2. Separation of cellular debris from DNA (filtration—optional in some procedures).
3. Precipitation and clumping of thousands of DNA molecules using alcohol.

These activities are similar to the work that is practiced in biotechnology and genetics laboratories around the world. DNA extraction is also the first step in genetic engineering. The final activity, "Solve a DNA Mystery," illustrates how extracted DNA is used for DNA fingerprinting.

Objectives:
Students will:
1. Perform simple DNA isolation while learning basic lab skills.
2. Explore the nature of DNA while isolating the DNA from different biological materials.

Activities
DNA Extraction Lab
Wind Your Way Around Your Own DNA! - Human Cheek Cell DNA Extraction
Solve a DNA Mystery (Dog Mystery)
DNA Extraction Laboratory

During this laboratory procedure students will learn how to extract DNA (deoxyribonucleic acid) from cells. Students will also use this technique to extract DNA from a fruit. This is very similar to the first steps that a biotechnology laboratory use so that the DNA might be studied or changed.

Science Content

• Students will learn the importance of following proper laboratory procedures.

Science Process Skills

• Observing, comparing, organizing, relating

Life Skills

• Learning to learn, communicating

Time

Prep: Varies by teacher
Activity: 30-45 minutes

Materials

1. DNA Extraction Kit — make sure all of the following items are in the kit.
   - Blender
   - Pipets
   - Vials (clear film canisters work well)
   - Denatured ethyl alcohol (ethanol)
   - Distilled Water
   - Paper Cups
   - Spoons
   - Coffee Filters
   - Shampoo
   - Salt
   - Measuring Cups
   - DNA Model
   - Toothpicks

2. Additional Items — you need to supply
   - Soft fruit such as bananas or kiwis
   - Ice
   - Ice Cooler

Educator Background Information

The cells of all living organisms contain DNA. Extracting DNA is the first step in many biotechnology laboratory procedures. Scientists attempt to separate the unbroken DNA strands from any unwanted substances. This technique is important to any scientist working with DNA, whether making recombinant DNA or mapping the human genome.
Fruits such as strawberries, kiwi, or bananas allow the students to clearly see DNA at the end of this activity.

The shampoo causes the cell and nuclear membranes to break down by dissolving their lipids (fats) and disrupting the bonds that hold the membranes together. Filtering separates the DNA from cellular debris. The salt shields the DNA’s negative phosphate sides, which enables them to clump together so that the DNA can precipitate out of the cold alcohol solution.

Introducing the Activity

After explaining that they’re going to extract DNA from fruit, ask your students the following questions:

- What does it mean to extract?
  
  To extract means to draw out by effort, to take out or to remove.

- Where is DNA found?
  
  In the nuclei of plant and animal cells.

- Why would we want to extract DNA from fruit?
  
  Soft fruits work best for this experiment because the cell membranes are easily broken down.

- Why would scientists want to extract DNA from an organism?
  
  Extracting DNA is the first step in many biotechnology laboratory procedures used to study or change the DNA.

Lab Instructions: Teacher

1. Put several inches of ice in the bottom of a shallow pan or cooler. Fill vials 3/4 full of alcohol and place upright in ice. One vial for each student/group.

2. Give each student/group the following:
   - 2-5 oz. cups
   - 1 plastic spoon
   - 1 coffee filter
   - 1 pipet

3. Have distilled water, salt, shampoo, and measuring cups in a central location.

4. In blender add fruit (2 bananas or 4 kiwi) and one cup (250 ml) of distilled water. Blend for 15-20 seconds, until the solution is a slurry.

5. Have each student/group mix, in one 5 oz. cup, 1 spoonful of shampoo and two pinches of salt, and 20 ml (four spoons) of distilled water. Dissolve the salt and shampoo by stirring slowly with a spoon to avoid foaming.

6. Have each student/group add 2 spoonfuls of banana slurry to the solution in the cup from previous step. Stir solution for 5-10 minutes. The shampoo dissolves the lipids that hold the cell membrane together, which releases the DNA into the solution. The salt enables the DNA molecules to come together.
7. Have each student/group place the coffee filter inside the other 5 oz. cup. Fold the coffee filter over the edge of the cup so that the filter does not touch the bottom of the cup.

8. Have each student/group pour the solution from steps 5/6 into the coffee filter and let it stand for several minutes until there is at least 5 ml (covers bottom of cup) of filtrate to test. The DNA is in this liquid, but is not visible at this point.

9. Have each student/group fill a pipet with filtrate and add it to one of the vials of alcohol.

10. Let vials sit for 2-3 minutes without disturbing it. It is important not to shake the vials. You can watch while the DNA precipitates out into the alcohol. The DNA will appear as white, stringy mucus. This is thousands of DNA molecules clumped together. You may have the students spool out the DNA using a toothpick or coffee stirrer. Have them touch the DNA they eat in every meal!

11. All materials except the alcohol may be thrown away in the trash.
WIND YOUR WAY AROUND YOUR OWN DNA!!!

DNA contains the instructions for making an organism, including YOU! Your DNA determines how you look, what blood type you have, even your tendency to get some diseases. Almost every cell in your body contains the same DNA and same genes (some cells such as gametes have half as much DNA and mature red blood cells don’t have any DNA). Each chromosome is made of a single, long strand of DNA. If the DNA from the 46 chromosomes in one cell of your body could be laid out end-to-end, it would measure 6 feet!!!

In this activity, you will isolate your very own DNA from your cheek cells. First, you will break away the membranes surrounding the cells and nuclei, and then you will precipitate the DNA so you will be able to see your DNA!

MATERIALS NEEDED:
- clear Gatorade OR 0.9% salt water (NaCl) (approximately 1/2 teaspoon in 8 oz. water)
- small cup (4-8 oz.)
- 30 - 50 ml test tube or other small container (such as a clear film canister)
- 25% soap solution (1 teaspoon dish soap or shampoo + 3 teaspoons water)
- ice cold alcohol (95% ethanol/ethyl alcohol is best; 91% isopropanol/rubbing alcohol also works) - keep in freezer or on ice until use
- teaspoons for measuring

PROCEDURE:
1. Swish 2 teaspoons (10 ml) of the salt water from the small cup in your mouth vigorously for 30 seconds. Your goal is to slough off as many cheek cells as possible. Your instructor will time you to make sure you have swished long enough.

2. Spit the water with cheek cells back into the small cup.

3. Pour this solution into a tube containing 1 teaspoon (5 ml) of soap solution.

4. Gently mix this solution for 2-3 minutes. Try to avoid creating too many bubbles. The soap solution breaks the cell membranes that are made up of fats – just like soap breaks down grease on your dishes!

5. Tilt the tube of soap solution/cells. Pour 2-3 teaspoons (10-15 ml) of ice cold alcohol (EtOH) down the side of the tube so that it forms a layer on top of your soapy solution. DO NOT MIX THIS!!

6. Let the tube stand for 1 or 2 minutes.

7. The white clump that you see is YOUR DNA!!!!! Research laboratories use a similar procedure to isolate and study DNA from different organisms.

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Carolyn A. Zanta, UIUC-Hughes Biotechnology Education and Outreach Program (www.life.uiuc.edu/hughes/footlocker)
This activity is a modification of a procedure developed by the Museum of Science and Industry, Chicago
Solve a DNA Mystery

During this activity, students are presented with a display board that sets up a crime in which a farm dog has chewed his owner’s boots. Fortunately, the dog left some hair behind. The display has pictures of the possible culprits and vials with hair from each dog, as well as hair collected from the crime scene.

The teacher leads a discussion on solving the crime with the evidence available. There is a discussion on DNA (deoxyribonucleic acid) and how individuals have their own unique set of genes.

Also in this activity, students are introduced to DNA fingerprinting. Students will see a DNA fingerprint made from the dog hair samples to help solve the crime.

Science Content

- To introduce students to DNA, the fact that each organism has its own distinct DNA, and that DNA is found in every living cell

- To familiarize students with the concept of DNA fingerprinting and its similarities to fingertip fingerprinting

- To show students how DNA’s uniqueness can be used to identify who is responsible for a crime

Science Process Skills

- Observing, communicating, comparing, relating, inferring, applying

Life Skills

- Learning to learn, communicating, making decisions

Time

Prep: 5-10 minutes

1. Request the Dog Mystery Display from your local county Extension office.

Activity: 15 minutes

Materials

1. Dog Mystery Display
Educator Background Information

Because each living creature is unique, each has a unique DNA recipe. Scientists can use DNA fingerprinting to diagnose viral, bacterial, or fungal infections; distinguish between closely related individuals; and map the locations of specific genes along DNA molecules.

By using the DNA fingerprinting process, any individual organism can be uniquely identified. The process of DNA fingerprinting includes the following steps:

1. DNA is extracted from a cell sample.

2. The DNA is cut into different-sized fragments using a restriction enzyme. The fragments are then separated by a process called electrophoresis. This process occurs in a gel box that is connected to electricity, which causes the fragments to move across the gel. The smaller fragments move quickly, while the larger ones move more slowly. This causes a distinct banding pattern to appear.

3. The DNA banding pattern is transferred to a nylon membrane.

4. A radioactive DNA probe is introduced. The DNA probe binds to specific DNA sequences on the nylon membrane.

5. The excess probe material is washed away, leaving the unique DNA banding pattern.

6. The radioactive DNA pattern is transferred to X-ray film by direct exposure. When developed, the visible pattern is the DNA fingerprint.

Lesson Plan

Doing the Activity

1. Set up the Dog Mystery Display in the front of the classroom. It is large enough for most students to see it from their desks.

2. Ask the students what DNA is or what genes are. (Make sure they don’t describe the ones they wear!) They should know about DNA from the lessons on the cell. Ask leading questions to get them to tell you the following:

   • DNA is located in the nucleus of every cell.
   • DNA contains the information that tells the cell what to do.
   • DNA carries the genes that tell a person’s eyes to be blue or hair to be brown.

   Ask the students if every cell in their bodies has DNA. The answer is “yes.” Ask them if the DNA in their hair follicle cells is the same as the DNA in their skin cells. Again, the answer is “yes;” this is an important point to which they often say “no.” Explain or ask someone else to explain why all cells of an organism have the same DNA. (Explain that skin cell genes are turned on in skin cells and turned off in hair follicle cells.)
3. Introduce the dog crime: Scientists use DNA to solve crimes.

Tell the students the dog crime scenario: A farmer has three dogs. One day he comes home and finds one of his shoes has been chewed on. He’s not sure which dog did it, but there is dog hair with attached follicle on the shoe.

4. Ask the students what other evidence from the crime scene could be used for DNA fingerprinting. (This evidence must have cells, from skin, saliva, or blood on it.)

5. Show the picture of the DNA fingerprints. Explain to the students that the scientist used biotechnology techniques to apply the DNA samples from the dogs to an electrophoresis gel (looks like clear gelatin). He or she obtained a print for each sample.

Row one shows the DNA fingerprint from the hair found at the scene. Row two shows the DNA fingerprint from dog one. Row three shows the DNA fingerprint from dog two, and so on. Ask the students to compare each dog’s fingerprint to that of the culprit. Which dog did it? Students are usually able to solve the crime right away.

Reflecting and Applying

- How did you feel about solving the mystery?
- What information did you use to make your decision about which dog did it?
- When solving a mystery, is it important just to consider the facts when making your decision?
- Have you ever solved a mystery before? What steps did you take to solve it?

Alternative Ideas

1. Discuss evidence collection and how it is used in court. More than one piece of evidence is needed to convict a person.

2. Ask a police officer to come and talk to the class about how legal authorities use DNA fingerprinting.
Chapter 6: Next Steps in Biotechnology

Chapter Overview

In this chapter students will learn about the wide range of careers available in the field of biotechnology. This range includes relatively low-skill jobs, all the way to very specialized, highly skilled jobs.

Students, through their research will also begin to understand how education is a very important part of many careers. Hopefully they will also see that education is a life-long process, one that people in the field of biotechnology (and in other areas!) have to keep working at to stay up to date.

Finally, students will begin to see the wide range of information available to them through the Internet and other sources. There is an excellent resource page included at the end of this section that you will find helpful.

Objectives

Students will:
1. Discover the wide range of careers available in the field of biotechnology.
2. Chart how the information they have gained from this curriculum is used by scientists each and every day.

Activities

Biotechnology Want Ads
Next Steps in Biotechnology Career Exploration and Beyond

During this activity, students will learn about biotechnology related careers including some of the academic preparation and skills required.

Life Skills

- Communication, decision making, critical thinking

Time

30-40 minute class period with time to research and write outside of class.

Materials

Copies of Handout 6-A, Biotechnology Want Ads

Educator Background Information

Biotechnology is an important part of many different jobs. In order to best prepare for a career in biotechnology, a person should learn as much as possible about biology, chemistry and other life sciences, as well as computer science.

There are many career fields that utilize biotechnology. Some of these include:

- Biotechnology Research
- Biotechnology in Human Health & Medicine
- Biotechnology in Veterinary Medicine and Animal Science
- Biotechnology in Plant Sciences
- Biotechnology in Teaching
- Biotechnology in Law Enforcement
- Biotechnology in Waste Management

Biotechnology Research - Individuals working in the research area of biotechnology are unraveling genetic codes that govern biological processes. Their work often provides beginning steps toward genetically engineered products such as vaccines, drugs, or plant varieties.

A new field called Bioinformatics utilizes computers to analyze DNA. This is a field used in the Human Genome Project and other areas of research.

These individuals often work for universities, but may also be found in government agencies or working for private companies. They focus their work on animals, bacteria, humans, plants, viruses or other organisms that they have a special interest in.

Biotechnology in Human Health - The creation of human insulin for the treatment of diabetes was one of the first genetically engineered products to become commercially available. Since then individuals in the field of biotechnology have been working with health care professionals to detect and fight other diseases. Some areas they are working on include: heart disease, AIDS, and cancer.
Biotechnology in Veterinary Medicine and Animal Science - Animal science professionals including veterinarians are using biotechnology discoveries to improve the health of animals as well as their production value. Their work has been in the areas of: vaccines, monoclonal antibodies (which can be used in the development of vaccines, and to detect illness), and growth hormones.

Biotechnology in Plant Sciences - Scientists in the field of plant sciences have been working to explore the genetic modification of food crops to achieve desirable characteristics like high yield, increased nutrient, protein, or oil production, and disease or pest resistance.

Biotechnology in Teaching - As the impact of biotechnology becomes more widespread, it is becoming increasingly important that students be exposed to this field early on in their academic career. Because of that, there is beginning to be an increased demand for science teachers who have a background in biotechnology.

Biotechnology in Law Enforcement - Examining a crime scene for traces of tissue, hair, blood, and other body fluids can link a suspect to a particular crime. Scientists in this area also use a technique called DNA fingerprinting. This science is based on the fact that each individual’s DNA is unique.

Biotechnology in Waste Management - Biotechnology is also helping the area of waste management. Research has found that there are bacteria, which can be introduced to solid waste sites to actually speed up the break down of waste. Biotechnology can also be used to improve the enzymes and microorganisms that are used in the treatment of wastewater.

Lesson Plan

Doing the Activity

1. Share with your students some of the information from the Background Information section of this lesson. Ask them these questions:
   - Are you surprised to find out how many career areas are using biotechnology?
   - Are you interested in any of the career areas that we have talked about? If so, which areas are you interested in?
   - Think about what career you would most like to have when you grow up. Do you think that biotechnology will have any impact on what your job is or how you do your job? If so, what impact do you think that it will have?

2. Today, we are going to consider some biotechnology jobs. In fact, we are going to create our own want ad section based on: job qualifications, salary, responsibilities, and work location. (Give each student a copy of handout 6-4.) Tell the students to use the worksheet as a starting point for their want ad. Encourage creativity.
3. Assign each student a biotechnology related career. (Use the list provided, Teacher Guide, 6-B as your guide.) Encourage students to research their assigned career and create an interesting job want ad that would entice people to apply for the job they are advertising.

4. When students submit their want ads post them to a wall or bulletin board. Encourage the other students to review the other jobs listed there.

Reflecting and Applying

- Name five jobs in the field of biotechnology.
- Which career would you be most interested in learning more about?
- How much education is required for the job that you are most interested in?
- Where do you think you could find out more about this job?

Note to Teachers

Please note that included with this section is a resource list. This listing includes information about websites and books that may be of interest to you and your students.
Biotechnology Want Ads

Imagine that you are working for a newspaper in a large city. Your job is to write up want ads for people to read when they are looking for a job. Use the job title that your teacher gives you. Based on that, research the other information that you need to complete the top part of this worksheet. On the bottom of the page, write an ad that you could place in your newspaper. Remember to make the ad exciting, so that people will want to apply!

Job Title (From your teacher): ________________________________

Education Required (How much school does this person need to complete? What type of classes do they need to take?) ________________________________

Job Responsibilities (What does this person do each day at work?): ________________

Location of Work (Is this a job that can only be done in a large town?): ________________

Salary (What does this person make each year as a starting salary?): ________________

Here’s the Ad! In the space below use the information that you have collected to write a want ad for your newspaper!

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Biotechnology Want Ads
Job List

Here is a list of jobs that can be found in the field of biotechnology. Assign one career to each student, or if you would prefer, you can have students work in pairs or small groups. Feel free to add other careers to the list you provide your students.

Research and Development

**Glasswasher** – A glasswasher is responsible for washing and drying glassware and distributing it to appropriate locations within the laboratories.

**Laboratory Assistant** – Laboratory assistants are responsible for performing a wide variety of research laboratory tasks and experiments. They also make detailed observations, analyze data and interpret results.

**Greenhouse Assistant** – A greenhouse assistant performs a variety of greenhouse research tasks and experiments on plants.

**Plant Breeder** – A plant breeder is responsible for plant breeding research projects.

Quality Control

**Environmental Health and Safety Specialist** – An environmental health and safety specialist is responsible for making sure that the company is a safe place to work.

**Quality Assurance Auditor** – A quality assurance auditor is responsible for checking on production to make sure the products are good.

Clinical Research

**Clinical Programmer** – A clinical programmer is responsible for coordinating and monitoring data that is going into computer databases. He or she also analyzes that data to make sure there aren’t any mistakes being made.

**Biostatistician** – A biostatistician works with others to define and analyze data that is then printed in publications and shared in presentations.

**Clinical Research Associate** – A clinical research associate is responsible for the design, planning, implementation, and overall direction of clinical research projects.

**Animal Handler** – An animal handler is responsible for the daily care of research animals.

**Technical Writer** – A technical writer is responsible for writing and editing standard operating procedures, laboratory procedure manuals, and other related documents.
Manufacturing and Production

Product Development Engineer – A product development engineer is responsible for the design, and development of existing products and processes.

Packaging Operator – A packaging operator is responsible for packaging, labeling and inspecting finished products.

Manufacturing Research Associate – A manufacturing research associate is responsible for deciding how to best manufacture the product the company is making.

Instrument Technician – An instrument technician is responsible for taking care of equipment that is used in manufacturing and in research.

Regulatory Affairs

Regulatory Affairs Specialists – A regulatory affairs specialist prepares documents that are submitted to the government agencies that regulate biotechnology products.

Documentation Coordinator – A documentation coordinator provides clerical and administrative support related to a company's documentation when they are submitting papers to the government about new products.

Information Systems

Library Assistant – A library assistant locates and orders articles and books on topics that will help the researchers.

Scientific Programmer Analyst – Scientific programmer analysts design, develop, and modify computer programs to solve scientific or engineering problems. This helps the researchers do their job.

Marketing and Sales

Market Research Analyst – A market research analyst is responsible for finding out what the company can manufacture that people (or other companies) will want to buy.

System Analyst – A systems analyst is responsible for making sure that the computer software and the computer network are working well. They also help people who use computers to make sure that they can do their job efficiently.

Sales Representative – A sales representative is responsible for selling the company’s products or services.
**Customer Service Representative** – Customer service representatives are responsible for making sure that products get delivered to the people who order them. That means working with the customers as well as the factory to make sure that demands for products can be met.

**Administration**

**Technical Recruiter** – A technical recruiter is responsible for finding and hiring people to work in technical jobs.

**Buyer** – A buyer is responsible for buying materials, scientific equipment and services.

**Patent Agent** – A patent agent is responsible for preparing, filing, and processing patent applications for the company. Patents help make sure that other companies don't use your company's idea.
Biotechnology Resource Guide

Biotech Books for Kids:


FREE Resources for Biotech Education

**Online resources**
There are many super online resources that you can use in your classroom or for background information to share with your students. See our program website for Biotech NEWS and links. (http://www.life.uiuc.edu/hughes/footlocker) Below is a list of printed biotech educational materials that you can request for free (as of Fall 2002). See website for updates.

**Booklets/Magazines**
NIH (National Institutes of Health) Office of Science Education
Publishes a magazine twice each year entitled "Snapshots of Science and Medicine”. This magazine is focused on modern biology for the high school classroom. The online materials include a teachers guide and student handouts. In the future, this magazine may exclusively be available online. [http://science-education.nih.gov/snapshots](http://science-education.nih.gov/snapshots)

San Diego Center for Molecular Agriculture (SDCMA) publishes two brochures on GMOs: “Foods from Genetically Modified Crops” and “Foods from Genetically Improved Crops in Africa”. You can request additional copies of this publication by contacting: milda@ucsd.edu or website [http://www.sdcma.org](http://www.sdcma.org)

Carolyn A. Zanta, UIUC-Hughes Biotechnology Education and Outreach Program (www.life.uiuc.edu/hughes/footlocker)
**Education Kits/Curricula/Teacher's Guides**

The National Institute of Health offers free curriculum supplement kits on "Cell Biology and Cancer", "Infectious Diseases", "Human Genetic Variation", and soon to be published, "The Brain: Understanding Neurobiology Through the Study of Addiction". They also have a video on poster series entitled "Women Are Scientists". You can sign up for these kits (including CD-ROMs) at: [http://science-education.nih.gov/hs](http://science-education.nih.gov/hs)

The Howard Hughes Medical Institute (HHMI), which funds our outreach program, offers a variety of print publications for high school classrooms on topics such as "The Immune System", "Evolution and the Fossil Record", "Exploring the Biomedical Revolution", and "The Genes We Share with Yeast, Flies, Worms, and Mice". These can be ordered online at: [http://www.hhmi.org/home/publication/order.html](http://www.hhmi.org/home/publication/order.html) (You can order class sets of up to 30 by mailing your request.)

BSCS offers the following curriculum modules free to download or print versions for $5. You can order these at: [http://www.bscs.org/cp_hs.html](http://www.bscs.org/cp_hs.html) or 719-531-5550, email: info@bscs.org. Topics include: "Basic Genetics: A Human Approach, 3rd Ed.", "Mapping and Sequencing the Human Genome: Science, Ethics, and Public Policy", "The Human Genome Project: Biology, Computers, and Privacy", "The Puzzle of Inheritance: Genetics and the Methods of Science", and "Genes, Environment, and Human Behavior".

**Posters**

Receive a FREE colorful human genome poster from The US Department of Energy Human Genome Program and Qiagen Inc. at: [public.ornl.gov/hgmis/external/poster_request.cfm](http://public.ornl.gov/hgmis/external/poster_request.cfm) (you can also view an interactive online version of the poster).

Request a human genome poster by sending a written request on school letterhead to: Wright Center, Department W, Room 267 C, Science & Technology Center, Tufts University, 4 Colby Street, Medford, MA 02155. You can view the available posters at: [http://www.tufts.edu/as/wright_center/svl/posters/posts.html](http://www.tufts.edu/as/wright_center/svl/posters/posts.html)

**Interactive CD-ROMs**

The Howard Hughes Medical Institute (HHMI) also offers free interactive CD-ROMs on a variety of topics including Infectious Diseases, Cardiovascular Genetics, Neurobiology, and Immunology, as well as videos on "Biological Clocks and "Infectious Disease". Many of these CD-ROMs include interactive laboratories that are super! You can order these online at: [http://www.hhmi.org/grants/lectures/video/](http://www.hhmi.org/grants/lectures/video/)

**Videos**

At the same link ([http://www.hhmi.org/home/publication/order.html](http://www.hhmi.org/home/publication/order.html)), you can order HHMI Videos. *Not So Wild a Dream* explores the views and experiences of young people from several minorities as they pursue their dreams to become scientists and doctors. They tell of their determination and how they deal with barriers. Scientists, teachers, and students share the excitement of turning dreams into opportunities. VHS, 21 mins. An online version is available at: [http://www.hhmi.org/dream](http://www.hhmi.org/dream)

*Life in Motion* tells how one group of teachers came together to revitalize their classrooms. Short and inspirational, this video shows how teachers from diverse backgrounds can work with scientists — and each other — to help students discover the excitement of today’s biology. VHS 6.5 mins.

Carolyn A. Zanta, UIUC-Hughes Biotechnology Education and Outreach Program (www.life.uiuc.edu/hughes/footlocker)
Free publications to help you learn more about biotechnology breakthroughs

Human Genome News (Sponsored by the US Department of Energy Human Genome Program)
This publication is geared toward researchers and policy makers. However, it has succinct articles and facts on the human genome project. They also offer education kits for teachers. Subscribe online at: http://public.ornl.gov/hgmis/external/insert_name.cfm (If you need bulk quantities of these publications, contact Laura Yust at 865-574-7582 or by e-mail at yustln@ornl.gov)

NOT FREE, BUT GREAT RESOURCES FOR YOUR CLASSROOM:
Your World: Biotechnology and You (published by the Biotechnology Institute)
Your World/Our World is a magazine of biotechnology fundamentals and applications in healthcare, agriculture, the environment, and industry, written for 7th to 10th grade students. They have recently begun to charge a subscription fee ($46/year for 2 issues, including classroom sets of 30 of each issue + poster + teacher guide), but some issues can be viewed online, as well as the teacher guides. Contact them at 800-796-5806 or order from the website http://www.BiotechInstitute.org/publications.html

**Please let me know if you find additional classroom resources (Carolyn Zanta; 217-265-0816; czanta@life.uiuc.edu)
Appendix
Illinois Learning Standards Biotechnology

Goals

The activities in this curriculum address the following Illinois Learning Standards for late elementary and middle/junior high school students.

State Goal 3: Write to communicate for a variety of purposes.

3.B.4a Produce documents that exhibit a range of writing techniques appropriate to purpose and audience, with clarity of focus, logic of organization, appropriate elaboration and support of overall coherence.

3.B.4c Evaluate written work for its effectiveness and make recommendations for its improvement.

3.C.3a Compose narrative, informative, and persuasive writings for a specified audience.

3.C.4a Write for real or potentially real situations in academic, professional, and civic contexts.

3.C.5b Write for real or potentially real situations in academic, professional, and civic contexts.

State Goal 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

11.A.2c Construct charts and visualizations to display data.

11.A.2e Report and display the results of individual and group investigations.

11.A.3a Formulate hypotheses that can be tested by collecting data.

11.A.4a Formulate hypotheses referencing prior research and knowledge.

11.A.4c Collect, organize and analyze data accurately and precisely.

11.A.4d Apply statistical methods to the data to reach and support conclusions.
11.A.4f Using available technology, report, display and defend to an audience conclusions drawn from investigations.

**State Goal 12**: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

12.A.2b Categorize features as either inherited or learned (e.g., flower color or eye color is inherited; language is learned).

12.A.3a Explain how cells function as “building blocks” of organisms and describe the requirements for cells to live.

12.A.3c Compare and contrast how different forms and structures reflect different functions (e.g., similarities and differences among animals that fly, walk or swim; structures of plant cells and animal cells).

12.A.4a Explain how genetic combinations produce visible effects and variations among physical features and cellular functions of organisms.

12.A.4b Describe the structures and organization of cells and tissues that underlie basic life functions including nutrition, respiration, cellular transport, biosynthesis and reproduction.

12.A.5a Explain changes within cells and organisms in response to stimuli and changing environmental conditions (e.g., homeostasis, dormancy).

12.A.5b Analyze the transmission of genetic traits, diseases and defects.

**State Goal 13**: Understand the relationships among science, technology, and society in historical and contemporary contexts.

13.B.2b Describe the effects on society of scientific and technological innovations (e.g., antibiotics, steam engine, digital computer).

13.B.2c Identify and explain ways that science and technology influence the lives and careers of people.

13.B.3b Identify important contributions to science and technology that have been made by individuals and groups from various cultures.

13.B.3c Describe how occupations use scientific and technological knowledge and skills.
13.B.4a Compare and contrast scientific inquiry and technological design as pure and applied sciences.

13.B.4b Analyze a particular occupation to identify decisions that may be influenced by a knowledge of science.
Glossary
Amino acid
The building blocks of protein molecules that make up living things

Bioethics
Discussion of social and ethical issues raised by the introduction of new technology

Biotechnology
The use of living organisms to make commercial products; simply a collection of old and new technologies or tools that allow scientists to rearrange the genetic makeup of organisms

BST (bovine somatotropin)
Increases milk production in dairy cows

Cell
The basic unit of living systems

Cell membrane
The other boundary of a cell; encloses all the cell organelles

Cell wall
The outer cellulose wall secreted around plant cells

Chloroplast
The organelle of plant cells that contains chlorophyll and produces food from sunlight

Chromosomes
The tiny rod-shaped bodies in a cell’s nucleus that carry the hereditary information; humans have 23 pairs of chromosomes. Each chromosome is a single long, thin DNA molecule

Clone
An exact copy of a gene, a cell, a bacterium, etc.

Codon
A specific sequence of three consecutive nucleotides that is part of the genetic code and that specifies a particular amino acid in a protein or starts or stops protein synthesis

Cytoplasm
In a cell, the clear fluid between the nuclear membrane and the cell membrane; contains all the organelles and aids in transporting materials within a cell.

DNA (deoxyribonucleic acid)
Molecule that contains genetic information and is located in the nucleus of every cell inside an organism

DNA code
The sequence of nucleotide bases on a DNA molecule

DNA extraction
The separation of DNA from the unwanted substances of the cell

DNA fingerprinting
Cutting DNA with restriction enzymes and separating the pieces by electrophoresis to generate a unique pattern, the “fingerprint” for each species, breed hybrid, or individual, depending on which enzymes and probes are used
**E. coli**
A bacterium commonly found in the intestinal tracts of most vertebrates

**Electrophoresis**
The movement of suspended particles through a fluid or gel under the action of an electromotive force applied to electrodes in contact with the suspension

**Endoplasmic reticulum**
The network of tubes and flattened sacs connected to the nuclear membrane that stores, separates, and transports proteins within the cell.

**Gene**
The basic unit of heredity that serves as a “blueprint” for each protein product produced in the human body; humans have over 30,000 genes

**Gene of interest**
This is found on a piece of chromosome DNA. It carries a trait that the scientist would like to transfer to another organism.

The gene may be inserted into an organism to improve its quality (e.g. Roundup® resistance to tomatoes) or to “trick” bacteria and yeasts into producing useful human proteins (e.g. vaccines) or hormones (e.g. insulin and growth hormone).

**Gene splicing**
Any of various techniques by which recombinant DNA is produced and made to function in an organism

**Gene therapy**
The addition of genetic material to an individual so that a defect or disease can be corrected

**Genetic engineering**
The directed alteration of genetic material by intervention in genetic processes

**Golgi apparatus**
Cytoplasmic membranes that package proteins to be secreted from the cell; Golgi body

**Helix**
A coiled structure

**Human dwarfism**
The state of being a dwarf; underdevelopment of the body

**Human genome**
A complete set of human hereditary factors — all of the DNA in the 23 pairs of chromosomes of a single cell

**Ligase**
An enzyme that splices (glues) pieces of DNA together

**Lysosome**
A cellular organelle that contains digestive enzymes

**Microliters (µl)**
A unit of measurement in which 1,000 microliters equals 1 ml (1,000,000 µl = 1 liter)
**Micropipettor**
An instrument designed to accurately measure and transfer precise volumes of a given liquid

**Mitochondria**
Rod-shaped organelles that are the principal sites of energy release in the cell

**Molecule**
The smallest particle of a substance that retains all the properties of the substance and is composed of one or more atoms

**Mutation**
A change in the DNA of a gene that results in a new trait

**Nucleotides**
Building blocks of DNA (G,A,T,C) also called "bases"

**Nucleus**
A cellular organelle that contains the chromosomes and that directs all cellular activities

**Oncogenic**
Relating to tumor formation

**Organs**
A differentiated structure (such as a heart, kidney, leaf, or stem) consisting of cells and tissues and performing some specific function in an organism

**Plasmid**
A small, self-replicating circle of DNA found in bacteria that may be used as a carrier for a foreign gene

**Procedure**
A series of steps followed in a regular order

**Protein**
Molecule composed of amino acids joined together by chemical bonds; proteins make up cell structure and control cell function

**PST (porcine somatotropin)**
A hormone that increases protein and decreases fat content of pork products

**Replication**
Process of copying DNA by rebuilding the missing halves

**Restriction enzyme**
A protein that cuts DNA at one or a particular base sequence

**Ribosome**
A tiny structure in a cell upon which protein molecules are formed

**Technology**
An applied science; a technical method of achieving a practical purpose.

**Tissue**
A group of similar cells that perform a particular function, such as muscular tissue

**Transgenic animals**
Animals that have been genetically engineered to contain the gene of another organism

**Viruses**
The causative agent of an infectious disease
Appendix A

A Crime, a Clue, and Biotechnology

Participant Evaluation
Please circle the best answer.

My age is: eleven  twelve  thirteen fourteen Other: __________
My sex is: male  female

1. Learning about fingerprinting was:
   Great!  O.K.  Boring

2. Viewing the crime scene and collecting evidence was:
   Great!  O.K.  Boring

3. Finding out about DNA and doing the DNA Extraction Lab was:
   Great!  O.K.  Boring

4. Finding out about heredity/genes and building a baby was:
   Great!  O.K.  Boring

5. Doing the DNA Fingerprinting Lab was:
   Great!  O.K.  Boring

6. Learning about biotech products while making (circle one) ice cream, bread, or cheese was:
   Great!  O.K.  Boring

7. Having a discussion about bioethics was:
   Great!  O.K.  Boring

8. Preparing for and taking part in the trial was:
   Great!  O.K.  Boring

9. The camp over all was:
   Great!  O.K.  Boring

10. My knowledge about biotechnology:
    Before the camp
    Lots  A little  None
    After the camp
    Lots  A little  None

A Crime, a Clue and Biotechnology, Iowa State Cooperative Extension Service and Iowa State Biotechnology

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