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ABSTRACT

This guide is designed to foster an understanding of the basic concepts underlying biotechnology through simple activities that are fun and creative for students in grades 3-5. It contains four units that will lead young students to an appreciation of how biotechnology is possible and some of its applications. The process of learning is intended to build awareness of how biotechnology can affect us without the fear that often arises with the subject. Each unit contains a number of activities which can stand alone or be used in sequence. The activities are designed to help students learn through a discovery process rather than be told what to think. Units are as follows: (1) The Basis and Basics of Life; (2) Genetic Changes and Old Biotechnology; (3) Biological Processes and Old Biotechnology; and (4) Biotechnology Today and Tomorrow. Also contains a selected list of references. (JRH)

Of Apples and Animals

An Introduction to Biotechnology

THE OHIO STATE UNIVERSITY

A Project of the
College of Food, Agricultural, and Environmental Sciences
The Ohio State University

Of Apples and Animals

An Introduction to Biotechnology

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Introduction

This guide is designed to foster an understanding of the basic concepts underlying biotechnology through simple activities that are fun and creative for third to fifth graders. It contains 4 units that will lead young students to an appreciation of how biotechnology is possible and some of its applications. The process of learning is intended to build awareness of how biotechnology can affect us without the fear that often arises with the subject.

How to Use This Guide

Each unit contains a number of activities which can stand alone or be used in sequence. The lessons vary in preparation and class time, so you may select those activities that suit your circumstances. However, we recommend that you begin the subject with the first activity, "Abundance of Apples," as an introductory piece.

When preparing each lesson, review the objectives of the unit, the background material, the purpose of the activity, and the activity outlines. All the materials you will need for each activity are listed. Practice the activities beforehand and feel free to use substitutes if suggested materials are unavailable.

Familiarize yourself thoroughly with the discussion guidelines and the processing sections. The activities are designed to help students learn using a discovery process rather than be told what to think. Thus, it is important to maintain the element of surprise or mystery while using many of these activities. Then, use the discussion guidelines to help students understand and make sense of what they observe. The processing section, together with the background information and the activity outline will help you highlight the main points of the activity. Since most of the questions are "open-ended," it is best to treat all answers as possible solutions. Then, help students to see why some solutions may be more appropriate.

Lessons may last one hour using about two or three activities. Allow sufficient time for discussion after the activity so that students can process the lesson before moving on to another activity.

Selected List of References

General Information

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   Medicine and the New Biotechnology (revised 1994)
   Protecting our Environment (1992).
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   Available from Biotechnology Industry Organization, 1623 K Street, N.W., Suite 1100, Washington, DC 20006; phone: (202) 857-0244
2. Kieffer, George H. (1987). *Biotechnology, Genetic Engineering and Society.* Monograph Series III. Reston, VA: National Association of Biology Teachers. Provides an overview of the history and tools of biotechnology; discusses the applications and impacts of biotechnology. Also contains a list of biotechnology companies, regulation guidelines, and a glossary.
   Available from National Association of Biology Teachers, 11250 Roger Bacon Drive #19, Reston, VA 22090; phone: (703) 471-1134.
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Curriculum Activity Guides

1. Oughton, Marie (Ed.) (1990). *An Introduction to Biotechnology: The Nature of Change. Unit For Sixth Grade Students.* St. Louis, MO: St. Louis Mathematics and Science Education Center. Looks at plant development; cellular design and DNA; inherited traits; variation; Available from Mathematics and Science Education Center, 8001 Natural Bridge Road, St. Louis, MO; phone: (314) 553-5560; fax: (314) 553-5342.
2. Kormos, J., Nichols, S., Upfield, E., & Whatley, G. (1993). *Biotechnology for a healthier world: An introduction to Biotechnology and Immunology for Senior Elementary Science.* Ontario, Canada: Connaught Laboratories Ltd. Looks at the immune system and the role of bacteria and viruses in disease and immunization. Contains worksheets; ideas for integration into existing curricula, and assessment; and a glossary.
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3. Cobb, Vicki. (1979). *More Science Experiments You Can Eat*. J. B. Lippincott, New York, NY.
4. *Life Changes Through Time.* (1993). MacMillan/McGraw-Hill School Publishing Co. New York, NY. Includes activities on genetic change.
5. *Living Things Grow and Change*. 1993. MacMillan/McGraw-Hill Publishing Co. New York, NY. Includes an activity on cells.
6. Mebane, Robert C. and Thomas R. Rybolt. 1991. *Adventures with Atoms and Molecules Book III: Chemistry Experiments for Young People*. Enslow Publishers, Inc., Hillside, NJ.
7. Noad, Susan Strand. 1979. *Recipes for Science Fun*. Franklin Watts. New York, NY.

Unit I

The Basis and Basics of Life

What's the Secret Behind Biotechnology?

Take a look at your hands, your hair, your eyes. Examine the roots of an onion, the leaf and branches of a maple, the mold growing on bread. Observe the colorful plumage of a cardinal or a mallard, the nose of your pet dog, the gills and fins of a fish. All of these are made up of amazing **cells** — the foundation of life and the key to biotechnology.

Tiny, inconspicuous units, cells do all the work an organism needs to survive, like breathing (or metabolism), giving protection against foreign microscopic bodies, and growing. Some organisms are just one-celled, like yeast or bacteria. Most organisms are much more complex — made up of billions of cells joined together like lace or a honeycomb.

Cells are usually specialized, just as some people are teachers, others farmers and others, scientists. Cells in different parts of the organism may have different jobs and may contain different substances.

Organisms grow by adding more cells. For instance, the trunk of a tree becomes wider as new layers of cells form new rings each year.

Unit 1 Objectives

The students will learn:

- ✔ living things are made of cells,
- ✔ cells perform different jobs directed by a molecule called DNA,
- ✔ cells of all organisms contain DNA, the basic genetic molecule,
- ✔ a gene is the smallest segment of DNA which is inherited,
- ✔ genes determine the traits of an organism, and
- ✔ genetic information is different in every individual.

What's Cooking or What Do Recipes Have to Do With Biotechnology?

Clearly, there are a tremendous number of cells that constitute most types of organisms. However, constituting an organism is not simply a random act of mixing up different cells. Just as preparing a dish is not simply an ad hoc affair, but a careful combination of certain ingredients according to a recipe, so organisms are constituted out of elaborate recipes: which elements to produce, in what amounts, when to introduce them, etc.

Every cell within an organism contains the complete recipe book with all of the instructions required to assemble and sustain life in that organism. However, any individual cell within the organism will only read the recipes necessary for the functioning of that particular cell. For instance, there are genes in a Red Delicious apple that instruct the cells in the skin to produce its bright red color. Each organism has its own unique book of instructions which leads to the great diversity of life on earth. These instructions (or genes) are passed on from generation to generation.

Suppose we have one apple that is sweet but green and another that is red but sour. It is possible to combine the two and produce a variety of apple which is red and sweet. For that matter, we can produce one that is green and sour. We have created new varieties of apple by trading genetic information.

Another way of thinking about this is that we often use ingredients of one recipe in another. Of course, the result is not always tasty or what we might expect. In the same way, we cannot be sure of the results when we combine genes except after much trial and error. We will look at this process more closely in the next unit.

Activity 1: Abundance of Apples

Before beginning the unit, make enough copies of the characteristics of the apple for each student to receive one trait.

Introduce students to the idea that organisms are made of cells by opening up a discussion with the following questions:

- ✔ What makes up a leaf?
- ✔ How many of you have heard of cells?
- ✔ What is a cell?
- ✔ Is a cell alive?
- ✔ Are there dead cells?
- ✔ Do we have cells inside of us?

Give each student a leaf. Ask the students to look at it and guess how many cells thick it is. Then, project the transparency of the cross-section of the leaf. The leaf is about 9 cells thick.

Explain that we are going to understand cells by looking at how things grow. Ask the students how a tree grows. Have them imagine a nail in a tree. Where would it be in 20 years?

Demonstrate how a tree grows from the terminal bud using shaving cream. The can represents the bud and the cream that falls is the tree the bud "leaves behind." Thus, the tree grows upwards and the nail does not move.

Next, have students form teams of three and give each team a branch. Tell them to feel for the bud. Ask the students what they think the bud does? Slice open the head of cabbage to reveal the "world's largest bud." Explain that the bud is where the cells are manufactured.

Next, ask the students:

- ✔ how the tree grows wide? From center out? Or from bark out?

Peel off a piece of bark from a branch. Explain that the bark is like a bud that covers the tree. The bark lays down the new tree. Use the roll of paper towels to represent a tree, where new rings are added each year. Use the shaving cream to make the rings around the roll of paper towels.

Tell the children the story of how we come to have the red big apples of today.

> When the pioneers arrived in this country, the only apples in North America were crab apples. They tasted so sour that the Native Peoples never ate them. Eventually, the pioneers brought seeds of edible apples, seedlings, and even small trees from their home countries. In fact, most pioneers had at least one apple tree in their yard. However, these apples were small, green, and coarse tasting compared to today's modern apples.

Materials

- ✔ Leaves for each student
- ✔ A can of shaving cream
- ✔ Enough branches with terminal buds for teams of threes
- ✔ A head of cabbage
- ✔ A roll of paper towels
- ✔ A knife
- ✔ 3 or 4 apples
- ✔ Slips of paper with apple characteristics
- ✔ Transparency of a cross section of leaf
- ✔ Paper and colored pens or crayons for drawing

Purpose of Activity

Use this activity to introduce students to the cellular nature of organisms and to the idea that cells contain information that instruct their work.

The only things they were good for was cider, applesauce, and baking.

It wasn't until 1810-1811, when John McIntosh discovered some young apple seedlings on his land in Ontario, Canada. Being a lover of apples, he carefully uprooted the seedlings and planted them in the garden beside his house. Eventually, the trees flourished and bore fruit in their new location. Oddly enough, one of the trees began producing the juiciest, sweetest, reddest apples that John McIntosh had ever seen. All of his neighbors wanted to taste it. Soon word of his apple spread throughout Canada and even New York. The apple became known as the McIntosh Red.

Now, divide the class into two groups. Have one group sit down. Ask them to imagine their "ideal" apple. It can be something different from what is available in the supermarket. Have them draw and color their "ideal" apple.

Meanwhile, take the second group aside. Give each student one apple characteristic that has been cut out from the first page. Set aside the taste traits for now. Tell the students that they are cells and that the pieces of paper are "instructions" so the cells know what to do. Have the students rehearse a movement that may be associated with the characteristic.

Then, prepare a table, placing chairs leaning on the table on both sides. Tell the whole class that the table is an apple bud and the children in the first group are cells. Have the children crawl through and as they emerge at the other end, shout out their characteristic and make the movement.

Now, have the first group of apple cells sit down. Repeat the activity with the other group using the remaining characteristics.

Go through the discussion questions and then offer real apples sliced to the students as a demonstration of the new apple with combined traits.

Discussion

- ✔ What did the first apple (the first group) taste like?
- ✔ How can we make the first apple tasty?
- ✔ How is this possible?
- ✔ What was your "ideal" apple like?
- ✔ Why do you want apples to have those characteristics?

Explain that the first apple did not have any taste characteristics. But we can make a big, round, red, crunchy, juicy, and sweet apple by joining the cells of the two. This is possible because cells have instructions that can be understood by other cells.

Tell the students that as we move on, we will explore how to obtain their "ideal" apples.

Characteristics of an Apple

Cut along the dotted lines.

red	red	red
smooth	smooth	smooth
big	big	big
round	round	round
firm	firm	firm
sweet	sweet	sweet
juicy	juicy	juicy

Activity 2: Moth Miracles

Materials

- ✔ construction paper cut into 1" square pieces, according to the instructions
- ✔ 11" X 14" sheets of white art paper to glue the parts of the moth on for each pair
- ✔ a large sheet of paper to mount the parts together into one whole moth. One sheet per moth created.
- ✔ glue sticks, for each pair
- ✔ scissors
- ✔ plastic sandwich bags

Purpose of Activity

Use this activity to illustrate that cells have information, or genes, that make them grow into different parts of an organism.

This activity can be done in conjunction with the "A Tale of Two Moths" activity in Unit II.

Before the activity, prepare the 1" squares of construction paper according to the instructions and place them in plastic bags. These are the cells. Be sure each bag contains one set of instructions and the appropriate cells. The students will work in pairs to make 5 parts of a moth separately, so there should be as many parts to make enough whole moths as pairs. Have all moths look the same except one, e.g. 10 pairs of students will form 2 different colored moths; 15 pairs of students will make 2 moths of the same color and the third a different color and so forth.

Tell the students that they are about to witness a "miracle": they will help to form an organism. In order to find out what that organism is, they will have to work with cells. Show the students the squares of construction paper.

Explain that just as the apple contains cells which make it sweet and red, etc., all organisms are made up of cells that make them what they are.

Recall that students were given papers with information on what type of cell they would be (red, sweet, etc.). In the bags, there is also a piece of paper that will tell them what the cells will be.

Have students work in pairs. Give each pair a bag with the cells and the instructions, the glue stick, and a sheet of 11" x 14" art paper.

When the students are done, ask them to figure out what has emerged. Cut out the shape of the parts and paste them together as moths on the large sheet of paper. Hang it on the wall.

Discussion

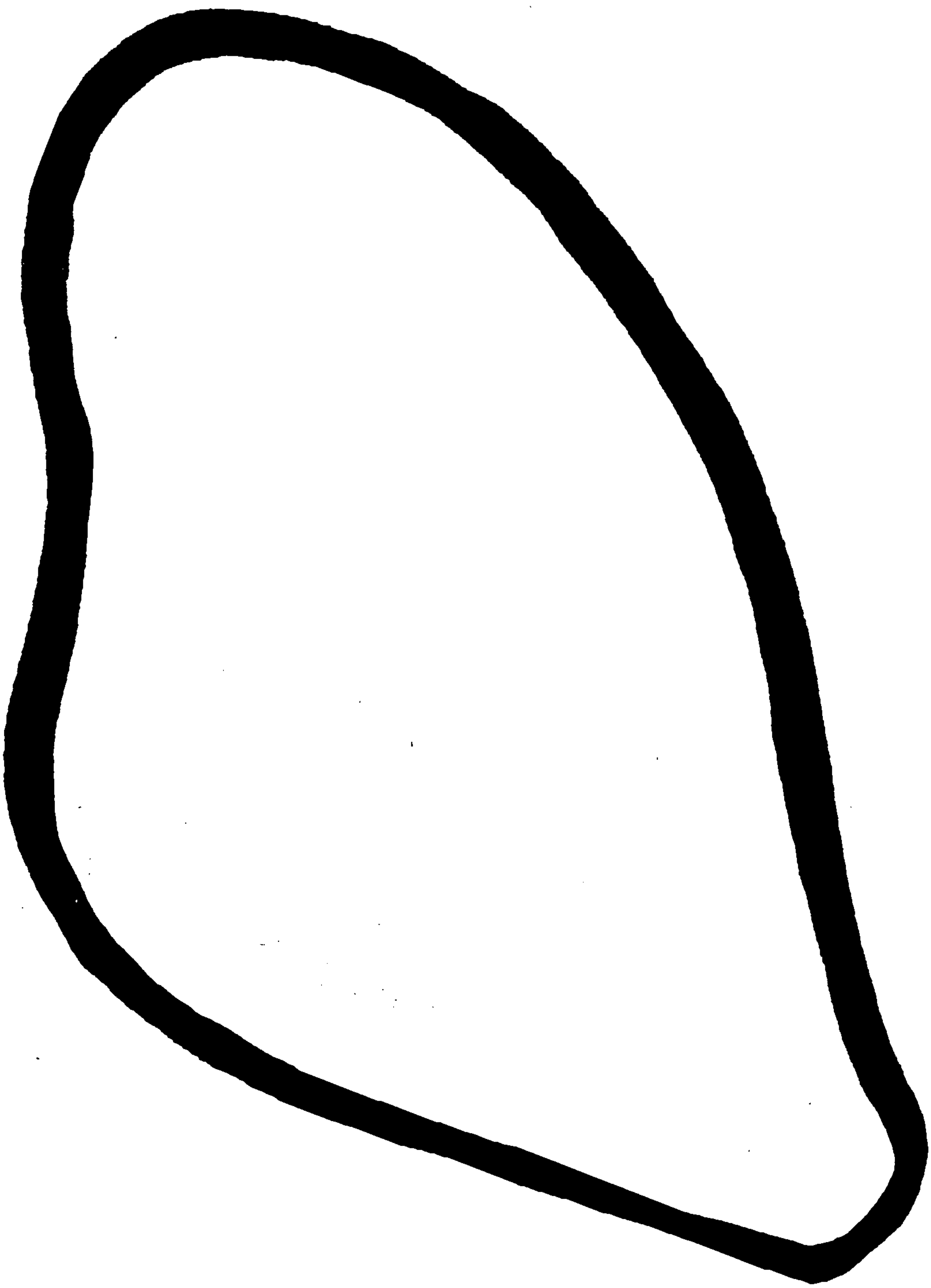
- ✔ What organism did we help to form?
- ✔ How did the cells know to make the wings, the body or the eyes, etc?
- ✔ Why was one moth different?

Explain that the cells had instructions which told them what they would become. One moth was different because it had a different instruction for color. These instructions are known as genes. Apples and moths both have genes in their cells. They have different genes but all genes are made up of the same thing, DNA.

Moth Miracles Instruction Sheets

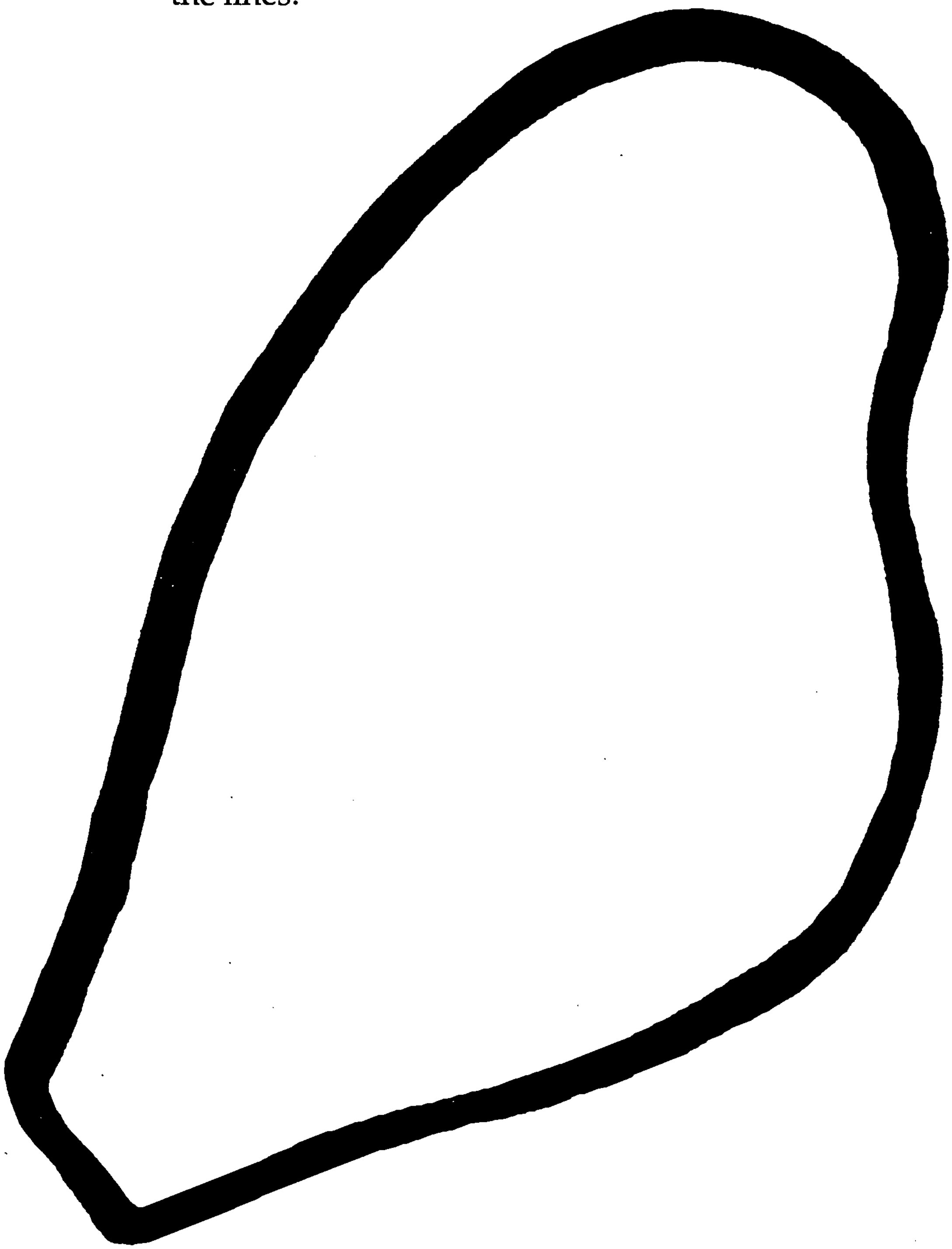
Here are your instructions:

There are about 75 brown cells in this bag. Copy this figure on your art paper. Glue all the cells in the figure you have drawn. Cells may overlap to stay within the lines.



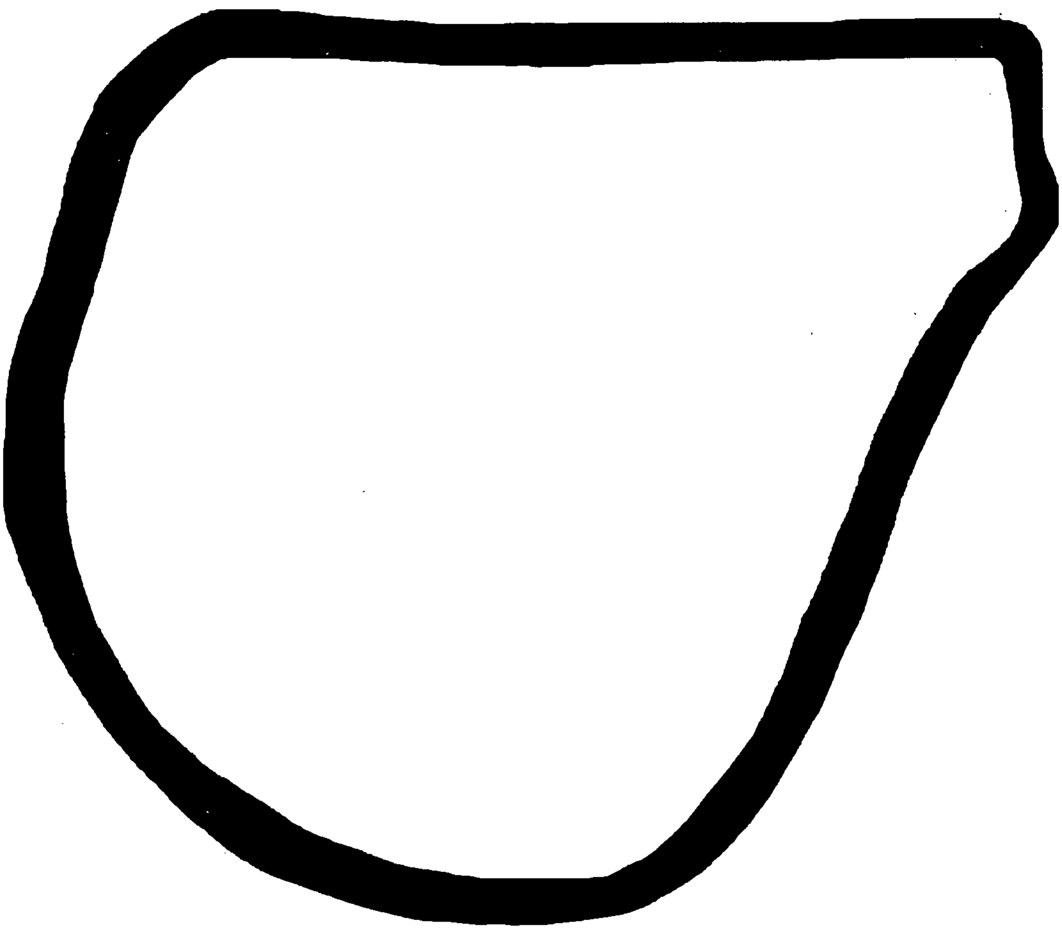
Here are your instructions:

There are about 75 brown cells in this bag. Copy this figure on your art paper. Glue all the cells in the figure you have drawn. Cells may overlap to stay within the lines.



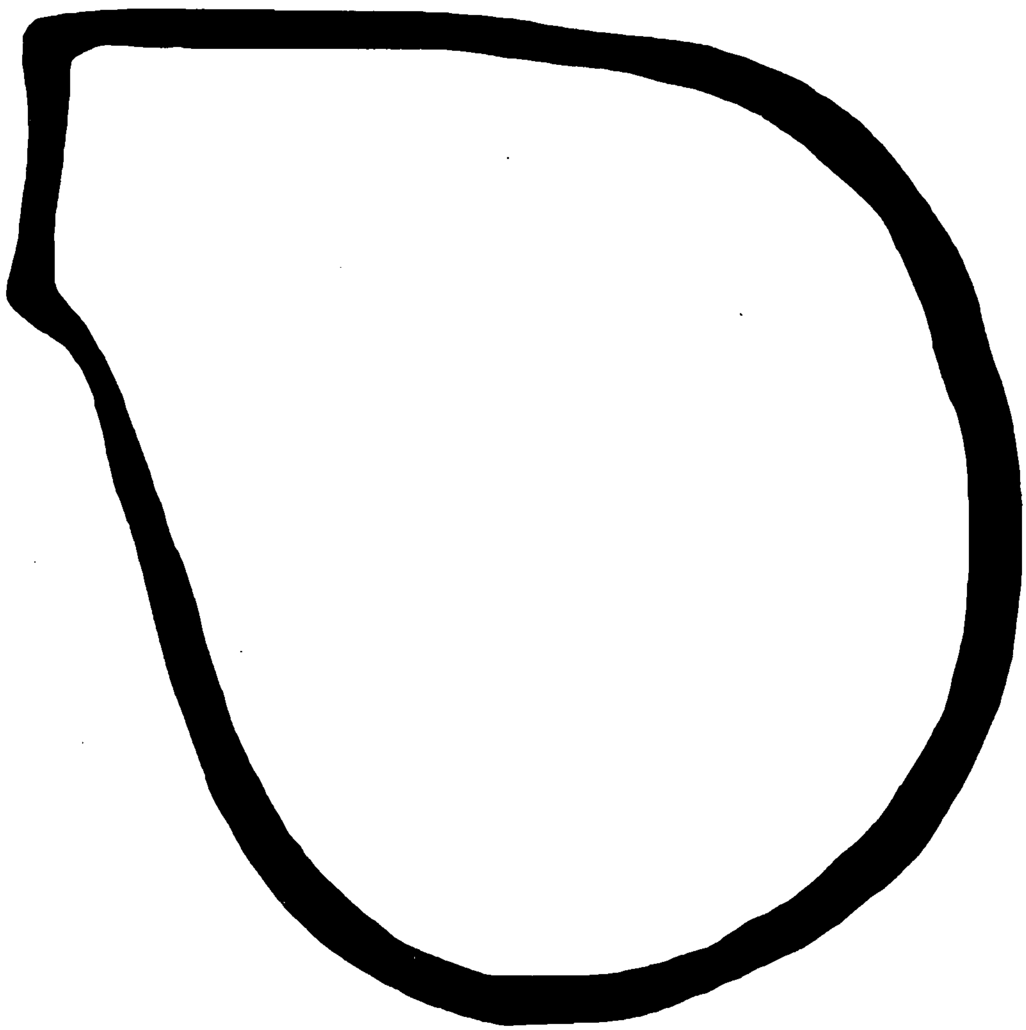
Here are your instructions:

There are about 75 white and brown cells in this bag. Copy this figure on your art paper. Glue all the cells in the figure you have drawn. Cells may overlap to stay within the lines.



Here are your instructions:

There are about 75 white and brown cells in this bag. Copy this figure on your art paper. Glue all the cells in the figure you have drawn. Cells may overlap to stay within the lines.



Cut out these instructions:

Here are your instructions:

There are 20 pink cells in this bag. On your art paper, draw two curved lines in the shape of a V, 1 inch thick and about 4 inches long. Glue the cells on the line you have drawn. Use 10 cells for each curve. Cells may overlap.

Here are your instructions:

There are 10 blue cells in this bag. On your art paper, draw a circle 2 inches wide. Glue all the cells in the circle you have drawn. Cells may overlap.

Here are your instructions:

There are 30 black cells in this bag. On your art paper, draw a rectangle that is 7 inches long and 1 and 1/2 inches wide. Make the ends curved so you get a long oval shape. Paste all 50 cells to fill the oval. Cells may overlap.

Activity 3: The Amazing Marble Moving Machine

Materials
- ✔ Marbles or pebbles
- ✔ 2 buckets (or pans, or bowls)

Purpose of Activity
Use this activity to show that different cells perform different tasks. In every organism, all the cells contain a substance called DNA which "instructs" the cells on what to do. DNA is like a common language for all organisms.

Explain that we are going to learn about how cells work together so that an organism can survive.

Before the activity, place 2 sets of marbles, pebbles, or some small object of equal number, at one end of the room. At the other end of the room, place the 2 buckets.

Divide the group into 2 equally-numbered teams.

Instruct the group that the goal is for each team to create the most amazing marble moving machine possible. Each person will be responsible for one *movement* and one *sound*. No two team members should use the same movement and sound.

Explain that each student is like a cell. The movement and sound represent the traits expressed by the cell. In order to survive, the organism has to do certain things (e.g. breathe), represented by the passing of the marbles. The cell knows what to do (which traits to express) because it has understood the "instructions."

Students may need individual instructions written out on pieces of paper to perform the movement and sound, such as:

"Stretch out your left hand in front of you and raise your right hand. Move up and down by bending your knees. Receive the marble in your left hand and make the sound of a duck."

These will need to be prepared before class. Verbal or written instructions represent genes.

Have one member from each team stand next to a set of marbles. Have the student create their movement and sound. When they are each ready with a movement and a sound, have them pick up a marble and attempt to pass it on. The student should not walk toward the bucket.

Point out that the first students are ready to pass on the marbles. Call for another student from each team to join in to receive the marble. The second student should stand at least one arm's length away from the first student and work out a unique movement and sound.

When they are ready, have a third person from each team join the line. Add a fourth, fifth, etc., until all children are in line with a gesture and sound.

Have each team practice their machine for a few minutes. Then, have each team watch the other team.

Return all the marbles to the start of the line. Have a race to see which team can pass the marbles on more quickly.

Repeat the activity but tell the students that the objective this time is not to pass the marble quickly but smoothly so that the machines work very well.

Discussion
In the machines,
- ✔ How are we, the students, different?
- ✔ How are we alike (human traits)?

- ✔ How are the two teams different?
- ✔ How are the two teams alike?
- ✔ How is each student like a cell?
- ✔ How did the machine know what to do?

Lead the discussion about how each student in the machine is like a cell. The cells are connected and form one organism—the machine. Although each cell (child) has different genes (instructions) operating, and do different jobs (movements and sounds), they share common structures—heads, arms, legs, knees, etc.

In a similar way, every cell in all living things comes equipped with a master coding device: DNA. This coding device is a molecule which cells depend on for information to go about its work. DNA is like a universal language that is understood by all cells.

Recall the "Abundance of Apples" activity. The information in the cells of organisms can be exchanged so that a new organism can be formed.

Activity 4: Busy Bees

Materials
- ✔ construction paper
- ✔ scissors
- ✔ rubber cement/tape
- ✔ containers or bottles of various shapes and sizes
- ✔ honey (optional)
- ✔ honeycomb (optional)

Purpose of Activity
Use this activity to reinforce the understanding that organisms are made up of cells. Cells are unique and separate but they are all linked together like a honeycomb to make one organism.

Inform the students that they are "worker bees" in a hive. Their task is to design a hive to contain the honey. Show students several types of containers and discuss their features. For example, some bottles have long necks, other containers are shallow and square.

If you are using honey, have the students describe the honey.

- ✔ What are the characteristics that might make a container difficult to create?
- ✔ What will make the task easy?

Inform the "worker bees" that they will design containers for honey in teams of two. They can use the paper, scissors, and rubber cement or tape.

When the containers are finished, use rubber cement or tape to hold them together to form a "honeycomb."

Discussion
- ✔ How are the containers similar?
- ✔ How are the containers different?
- ✔ What would make the "honeycomb" more effective in its use of space?
- ✔ Project the transparency of cells on the wall. Compare the structure of cells to the "honeycomb."

Optional
- ✔ Show the students a real honeycomb. Compare it with the "honeycomb" designed by the students.

Explain that the containers, like the cells of the honeycomb, are like cells in a organism. Each cell is unique and separate, but are linked together to form the organism. Thus, changing the way cells work may affect the organism, for better or for worse.

Activity 5: Investigating the Secrets of *Ingot Theobroma Cacao*

Divide the group into teams. Inform the group that they are about to uncover the secrets of the *Ingot Theobroma Cacao** (pronounced Kah Kay-O). Have students guess what it means.

**Ingot* = bar, *Theobroma Cacao* = the cacao tree from which cocoa or chocolate is derived (In Latin, the noun is before the adjective).

Distribute one candy bar, one plastic knife, and one paper plate to each team.

Have each team unwrap the bar and place it on the paper plate.

With adult present, have each team cut a piece at least 1/4 to 1/2 inch wide from the middle of the bar. Analyze the *Ingot Theobroma Cacao* using the Observation guidelines.

After studying the bars, mount the cross section on a piece of cardboard and cover with plastic wrap. Observations and comparisons can be attached (Optional).

Materials
- ✔ 12-14 different candy bars, enough for the number of pairs of students in the class
- ✔ paper plates
- ✔ plastic knives
- ✔ gloves (optional)
- ✔ plastic wrap (optional)
- ✔ glue (optional)
- ✔ mounting board (optional)
- ✔ paper and pencils (optional)

Purpose of Activity
Use this activity to illustrate how genes combine to produce variations in traits

Observation Guidelines
- ✔ What is present in your *Ingot Theobroma Cacao*?
- ✔ What are all the items that can be seen with the naked eye?
- ✔ What other items may be present in your *Ingot Theobroma Cacao* that cannot be seen? Check the list of ingredients on the wrapper.

Compare your *Ingot Theobroma Cacao* with the others.
- ✔ What are the common elements in both bars?
- ✔ Are the elements used in the same manner?
- ✔ Are there different variations of the same element?
- ✔ What elements are present in one but not the other?

Discussion
- ✔ Did you find that many of the *Ingot Theobroma Cacao* had the same elements?
- ✔ What were the common elements?
- ✔ Did variations of an element affect the appearance of the *Ingot Theobroma Cacao*?

For example,
- ✔ Using peanuts will make the bar appear lumpy versus using peanut butter for a filling;
- ✔ Dark chocolate vs. milk chocolate;
- ✔ Chocolate with no filling made the bar flat vs having a fluffed chocolate filling;
- ✔ Wafers of different colors give different visual appearance;
- ✔ Some bars are flat, some have rounded tops, most are long and square;
- ✔ The weight of the bars varies, depending on the content.

Explain that the ingredients in the chocolate bars are like the genes in the cells of organisms. Different combinations of genes will produce variations. For example, human beings are made up of water, minerals, elements, etc., but genetic variation produce differences in our appearance. Some of us have blond hair, some of us have green eyes, some of us have brown skin, etc. Sometimes, the differences are subtle (a daughter that is slightly taller than her mother when full grown) and sometimes they are very obvious (a son that stands 6' 7" when both parents are 5' 6" or less).

Data Chart — The Secrets of *Ingot Theobroma Cacao*

Ingredients

You Can See	You Cannot See

Unit II

Genetic Changes and Old Biotechnology

In Unit I, we looked at how organisms are made up of cells. In those cells are combinations of instructions or recipes guiding their work. As succeeding generations of organisms are produced, new combinations are formed. These are genetic combinations formed naturally. In this unit, we will examine how this genetic change comes about.

Genetic change occurs naturally through a process known as natural selection and mutations. Alternatively, different combinations can also be achieved through human intervention. Did you know that broccoli, cauliflower, cabbage, kale, and Brussels sprouts all came from one species of a wild mustard? This amazing variety would probably not have occurred if not for human intervention.

These interventions are what biotechnology is about. For our purpose, let us define biotechnology as:

the use of biological organisms, systems, or processes to make or modify products.

Biotechnology can be characterized as old and new. What is being referred to as *Old Biotechnology* does not imply that it is out of date. It simply refers to the methods of manipulation that have existed for centuries. On the other hand, *New Biotechnology* refers to the techniques which developed with the discovery of DNA and to applications in new areas that have not been understood previously.

How do we "manipulate" these changes and processes? What are the limitations of our efforts? Why do we do so? What are the benefits and the risks of our interventions? We will consider these questions in this unit and the next.

Unit II Objectives

The students will learn:

- ✔ genetic change occurs naturally,
- ✔ natural genetic change can occur through natural selection and mutations,
- ✔ an understanding of old biotechnology, and
- ✔ genetic changes can be manipulated through selective breeding.

Natural Changes in Genetic Information

How can we tell that genetic changes are natural? Let us take a look at family trees. It is easy to see how a line of similarity runs through our families. At the same time, there are also clear differences.

Changes in genetic information are natural and occur at random. In sexual reproduction, virtually millions of genetic combinations are possible. Thus, it is reasonable that within one family, there can be much genetic variation in terms of physical traits and even preference traits.

Through successive generations, considerable genetic variation can occur naturally. Over time, new varieties or species evolve when there are changes in the genetic code. Nature allows for this through two processes: natural selection and mutation.

Natural Selection: Genetic Changes Taking Their Time

Natural selection is what happens when species which have the traits that help them adapt to the environment survive and reproduce. Their genes get passed on to the next generation.

The "Tale of Two Moths," an activity in this unit, recounts how the light gray, spotted variety used to be in abundance in the English countryside. They were camouflaged when resting against a backdrop of light-colored lichen. In contrast, the dark-winged variety made easy targets for predators. However, with the Industrial Revolution at the turn of the 19th century, factories were built on a large scale, producing unprecedented levels of pollution which killed the lichen on the rocks. As a result, the dark-winged moths were better able to blend in with their surroundings, while their spotted cousins stood out and were driven close to extinction.

This is in fact a classic tale of natural selection among the English Peppered Moth or the *Biston betularia*. Over a long period of time, if the pollution of the Industrial Revolution had not been checked, there might be enough changes in the genetic information that could lead to the evolution of new species of the moth.

Evolutionary changes may occur gradually over millions of years: new generations differ in small details from the previous ones. Evolution may also take giant leaps with dramatic changes occurring in just several hundred or thousand years.

In either case, clearly, we would not be able to observe or gain much genetic variation in our lifetime.

Mutations: Random Changes in Genetic Information

However, we can and do observe genetic variation in nature. This is possible because genes sometimes mutate. Recall from Unit I that every organism has its own unique recipe book of genes that ultimately determines what traits an individual organism has.

Cells divide to make more cells. This is how organisms grow. In this process, DNA is copied. Mutations are the rare mistakes made during copying. Suppose we tried to copy the recipe for cupcakes but by mistake, noted 1 tbsp of salt instead of 1tsp, we would get a different result.

Usually mutations cause little harm. However, sometimes, mutations can cause disease, e.g. cancer. At other times, new traits result that can actually benefit the organism. For instance, some insects are resistant to pesticides because of mutations in their genes. So, they survive and breed a new generation of insects with this resistance.

Or think of why we need to finish a course of antibiotics when we have a throat infection, usually 7 days. If we stopped the treatment after 4-5 days, infection may recur. This time, there is a chance that new bacteria which has mutated may be resistant to the antibiotics, rendering it ineffective.

Mutations happen by chance and at random points of the DNA chain. They can also result from radiation, exposure to certain chemicals like dioxin, tobacco, and UV radiation. Mutations are an important natural source of genetic variation. They can contribute to an increase in the chances of survival for a species.

Selective Breeding: Selected Changes in Genetic Information

Selective breeding involves cross-breeding closely-related species, usually through the normal reproductive means. Just think of the champion horses specially bred for their speed or even our pet dogs.

With plants, it is possible to cross-breed using cuttings and other asexual means. This ancient practice uses the whole or some substantial part of an individual organism.

This practice may also be referred to as artificial selection, as opposed to natural selection. People select the individual animal or plant that has a certain trait useful to human beings, for example, strength or quick growth rate. These individuals form the breeding stock and new generations with these traits can be bred.

We should note that selective breeding is in fact a form of genetic manipulation because we are selecting organisms that have those genes we want, giving them a greater chance of being reproduced. In this way, we modify the original species.

Selective Breeding of Dogs

Type of Dog	History of Origins	Traditional Status	Current Status in the U.S.
Poodle: standard miniature toy	Germany. Popular in France since the 19th century.	water retriever	water retriever, watchdog, pet
Bulldog	Britain	bullbaiting	British mascot, pet
Siberian Husky	Siberia. Imported into Alaska in 20th century.	sled dog, watchdog, pet	pet, sled dog racing
Akita	Japan. Imported into the U.S. in 1937	guard dog, hunting, spiritual symbol	pet

Using Biological Organisms: How Does Selective Breeding Work?

Suppose Farmer Brown owns a field of broccoli, which is part of the cabbage family. With a keen eye, Farmer Brown observes that some of the broccoli grew faster than others. The farmer also found other broccoli that survived a disease called "soft rot." If only Farmer Brown could have broccoli that both grows fast and is disease-resistant. Farmer Brown began to dream ....

And Farmer Brown can! The farmer can collect the seeds from the top 10% fastest growing broccoli and the healthiest plants. These will form the parent plants. If grown side by side the plants can cross-pollinate and form hybrids. Bees are very helpful for this task.

When the new plants mature, Farmer Brown will collect the seeds which display both the desired traits — the hybrids — and repeat the whole breeding process. After many generations of breeding, Farmer Brown is very likely to get the dream crop of broccoli.

Selective breeding is also applied to animals such as sheep, horses, and cattle. The process is much like what Farmer Brown did to achieve his dream crop.

In plants, by very specific and careful cross breeding, it is possible to create new species that look very different from the original. Thus, from the wild mustard, we can have kale, red cabbage, broccoli and cauliflower.

Similarly, the American pioneers we met in Unit I in the activity, "Abundance of Apples," used the same process to cultivate larger, redder, and juicier apples.

Limitations

Selective breeding might sound easy but there are some practical limitations.

1. It is a very slow process, requiring several generations of breeding to obtain results. Depending on the reproductive cycle of the organism, selective breeding may take years.
2. It is a trial and error process. There is no guarantee that desired traits will be obtained.
3. We cannot simply mix and match any organism. Only closely-related species can be cross-bred. When this is possible, often, the next generation is sterile or they do not live very long (non-viable) e.g. the mule — a cross between a female horse and a male donkey.
4. Organisms cross-bred for one desirable trait may also pass on undesirable ones.

Activity 6: Me and My Tree

Have the students take home the handout. They can complete the handout with their families.

Students choose 4 colored markers. With:

- ✔ **Color 1**—circle all the physical traits that are similar from the child to the other family members on the page.
- ✔ **Color 2**—circle all the preference traits (likes) that are similar from the child to others on the page.
- ✔ **Color 3**—put a box around physical traits that are different.
- ✔ **Color 4**—put a box around preference traits that are different.

Materials
- ✔ handout
- ✔ colored pencils or crayons or pens

Purpose of Activity
Use this activity to discuss natural genetic changes over time.

Discussion
- ✔ How are you like your parents and grandparents?
- ✔ How are you like your brothers and sisters?
- ✔ How are you different from your family members?
- ✔ What does this mean?

Explain that over time, there are natural genetic changes. Changes can occur within one generation or more gradually over many generations.

Family Traits

Me and My Tree

Me

What I Look Like:

What I Like:

Brothers

Looks Like:

Likes:

Sisters

Looks Like:

Likes:

Mother

Looks Like:

Likes:

Father

Looks Like:

Likes:

Mother

Looks Like:

Likes:

Father

Looks Like:

Likes:

Mother

Looks Like:

Likes:

Father

Looks Like:

Likes:

Activity 7: Fruitful Choices

At least three days before this session, select some type(s) of fruit: strawberries, grapes, cherries, berries, bananas, etc.

Separate the fruit into four groups.

- ✔ **Group 1**—Store in a bowl and refrigerate.
- ✔ **Group 2**—Wash and while wet, place in a plastic bag and refrigerate.
- ✔ **Group 3**—Wash and place in a bowl on the counter.
- ✔ **Group 4**—Wash and place in a plastic bag on the counter.

Let sit for at least 3 days.

Place each group of fruit into a different bowl. Place the bowls on a table. Have the students examine the four bowls of fruit.

Create a scorecard for the fruits (on next page). Compile the scores and rank the bowls of fruit. After scoring, let the students choose which of the bowls they would prefer to eat.

Let them eat the fruit while discussing the following questions.

Materials

- ✔ some type of fruit, aged as indicated
- ✔ 2 plastic bags
- ✔ 2 bowls

Purpose of Activity

Use this activity to discuss how natural selection works.

Discussion

- ✔ Why did we, as a group, choose one bowl over another?
- ✔ How do we "select" what we think is better fruit?
- ✔ Has anyone ever heard of "survival of the fittest"? How does this relate?

Explain that nature "selects" the better or "fittest" organisms in a species to go on and reproduce. When a fruit is attractive, the chances of it being eaten is higher than less attractive fruits. In the wild, the chances of the seeds (from the attractive fruit) bearing a new plant and surviving is also increased, when animals leave the seeds in places where they can germinate.

Score Card Fruitful Choices

Judge's Name:

Bowl Number	Attractiveness	Smell	Feel	Taste

Activity 8: A Tale of Two Moths

Before the activity, prepare 2 branches or logs. Leave one log as is. Glue bits of newspaper on the other log.

Tell the students that they are going to understand one reason why genetic change occurs naturally. Hold the "moths" that the students made in the previous unit in front of the class. Tell them that the different colors will affect the chances of their survival.

Preface the story with the following questions:
- ✔ How many of you have seen factories?
- ✔ Have you ever seen smokestacks at factories?
- ✔ What color are the smokestacks? Why?
- ✔ Do you know where factories were first built?
- ✔ Do you know when they were first built?

Smokestacks at factories can be rather black because of the soot deposited from burning fossil fuels. The first factories were built in England nearly 200 years ago at the time of the Industrial Revolution. Share with students the following tale:

Now in those days when there were yet no factories, and folks still moved around by a horse and cart, all that could be heard on a hot summer afternoon was an occasional duck calling and the snore of a farmer leaning against a great oak in the shade. Just outside London, there lived two types of moths. One of those moths had light gray wings speckled with dark spots *(hold up the mixed colored moth)*. The other had wings all a dark gray *(hold up the moth with the solid color)*.

The moths loved to dance in the light of the dawn, chasing each other, visiting every tree and rock.

They did not have a care in the world, until at mid-day, it got far too hot and the moths needed to take a nap.

"Nothing like a soft bed to rest on in this heat," said Pepper, one of the speckled kind, as it made itself comfortable on its favorite tree *(show them the spotted moth resting on the log covered with bits of newspaper)*. The tree was covered with a lovely light-colored lichen *(explain that lichens are moss-like growths made up of fungus and algae)*.

"I couldn't agree more," said Bold, its dark-winged cousin *(let the other moth also rest on the newspaper-covered log)*.

Not too far away, a robin flew overhead. "I wonder what I should eat for lunch today," said the robin. It spied a worm crawling on a leaf and very quickly swallowed it. Suddenly, it spotted Bold on the tree. The two moths were oblivious to their danger. With one swoop, the dark gray moth was gone.

(Stop. Ask the children what they think had happened?)

Pepper woke up with a start and seeing what had happened, it quickly flew to a safe place where the robin could not reach it.

Not long after, people began to erect big buildings with tall towers that reached into the sky. The towers puffed out billows

Materials
- ✔ 2 logs or branches for the moths made by the students to rest on
- ✔ bits of newspaper to cover one log
- ✔ glue
- ✔ pictures of factories with smoke stacks (optional)
- ✔ picture of a robin (optional)

Purpose of Activity
Use this activity to illustrate natural selection in action.

of smoke *(Ask the children to guess what these towers are).* Trees were cut down, and the land was cleared to build more tall towers for important people to do important work. Soon, a black cloud hung over the city and the surrounding countryside.

(Ask students what they think the black cloud is?)

This black cloud was a great nuisance. Laundry drying in the wind would be covered with fine black flecks; the beautiful bright days turned bleak and gloomy, as if a thunderstorm were about to break. But worse still, the black smoke was a poison to the soft lichen that covered the tree trunks which Pepper and his friends loved to rest on.

One day, after playing the whole morning, Pepper and its friends, some dark-winged and some speckled, visited their favorite tree at noon time as usual. But to their disappointment, they found the tree all hard and bare *(show them the bare log).* Gone was the soft lichen bed, leaving behind the dark tree trunk. Pepper and its friends flew to another tree but to no avail. All the trees were hard and stiff.

By now they were so tired the moths did not care anymore. One by one, speckled and dark-winged, they dropped off to sleep. *(show the moths resting on the bare log this time.)*

Now, it is in the natural cycle of life that one organism is food for another. So, we are not surprised when another robin appeared as the moths were asleep. *(Ask the children which moth the robin is likely to see more easily?)*

From the top of the tree, the robin discovered the light gray moths and swiftly, it picked up one of the company, but all the dark-winged moths managed to escape.

Discussion

- ✔ Why did the dark-winged moths escape?
- ✔ What happened to the lichen?
- ✔ How did the death of the lichen affect the robin's choice of moth to eat?
- ✔ What would happen if the pollution was reduced?
- ✔ What might happen if the pollution continued?

Explain that pollution was an environmental factor that affected the natural selection process. Those moths that did not blend into their environment would be easily spotted and eaten. As a result, their genes would not be passed on to future generations. So over time, if pollution continued, the speckled moths might disappear because they would stand out against the dark tree trunks. If pollution were reduced, and the lichen were revived, chances are good that the speckled variety would return. This indeed happened in England.

Activity 9: Cupcake "Seeds"

Materials

- ✔ box cake mix and additions
- ✔ cupcake papers
- ✔ peppermint
- ✔ vanilla
- ✔ lemon extract
- ✔ other flavorings
- ✔ food coloring

Purpose of Activity

Use this activity to explore how genes and recipes create change in a species.

Before carrying out this activity, mix one standard box cake mix—white or yellow preferably. Most box mixes make 1 1/2 to 2 dozen cupcakes. Bake 1/2 dozen cupcakes from batter—unaltered. Use these cupcakes for later comparison.

Have the students imagine that they are going to create "seeds" which they will "plant" from the batter.

Students may work individually or in teams. Give each student or team a cup and spoon. Into each cup, place enough batter for 1 cupcake.

Each team may choose 1 ingredient to add to their cupcake seed. Some teams may choose the same ingredient but *different* amounts can be used. For example, 1 cupcake seed may have 2 drops of lemon extract and another may have 1/4 teaspoon of extract. Each team should note the amount of the ingredient used.

Create an "accident." In one of the cupcake seeds, tell students you will pour 1 teaspoon of vanilla. Instead, pour 1 teaspoon of peppermint!

Place cupcake seeds in a muffin tin that has been lined with cupcake papers. Keep track of "seed" pattern. Record the placement of "seeds" (ingredients) on the paper.

Bake at the designated temperature for appropriate time. When finished, remove cupcakes and cool.

Have the teams compare their cupcakes. Explain that the batter is a cupcake "seed" and by baking it, they have planted a cupcake plant.

Compare the unaltered cupcakes to the cupcake plants. Have students taste an unaltered cupcake and the cupcake they "planted." Have the students taste each other's cupcake plants. Have them taste the cupcake you made with the peppermint instead of vanilla.

Discussion

- ✔ Do they appear to be the same color, texture, size? What is similar? What is different?
- ✔ Do they taste the same? What does your cupcake plant taste like?
- ✔ What do these cupcake plants look like? What do they taste like? Are they different from yours? Are they similar to yours?
- ✔ What happened to the cupcake plant the teacher made? Did it taste like vanilla? Was it still good?

Explain that different cupcake plants were produced by introducing different ingredients. These ingredients are like the instructions in cells that tell the organism which traits to produce. Sometimes, changes in these traits can be seen, e.g. food coloring. At other times, changes in traits cannot be seen although the whole plant is affected. One cupcake plant tastes different from another.

Sometimes, changes in ingredients are made by mistake, like the one that you made. Mistakes happen in nature too. Explain that organisms grow by creating more cells. In the process, the instructions or genes are copied. When the instructions are copied incorrectly, a "mutation" is said to have occurred. Sometimes, the mutation does no harm. The cupcake plant is still good. At other times, disease can result.

However, we can also control how genes are combined, and intentionally produce different varieties of plants and animals. Recall how we can combine the different instructions in the "Abundance of Apples" activity to make a large, round, red and juicy, sweet apple. Or, think about the "Secrets of *Ingot Theobroma Cacao*." Sometimes, the same ingredients come together but with a totally different result. Selective breeding is an ancient practice of biotechnology.

Unit III

Biological Processes and Old Biotechnology

So far, we have been talking about cells and how genetic changes occur. But that is not the only thing happening in organisms: different processes take place naturally in organisms in order that they can grow, move, and maintain themselves. Let us turn our attention to a common biological process: fermentation.

As you probably know, this process has been harnessed to produce a number of foods that we enjoy today, e.g. cheese, yogurt, apple cider, etc. Before we study the significance of fermentation in biotechnology, let us first understand how it occurs in natural settings.

Unit III Objectives

The students will learn:

- ✔ how fermentation processes occur naturally,
- ✔ fermentation can be manipulated to produce useful items,
- ✔ limitations of fermentation technology,
- ✔ reasons for the development of biotechnology, and
- ✔ monitoring of biotechnology.

So What is Fermentation?

One of the basic jobs cells do is to produce energy constantly. To do this, cells break down the food taken by the organism. In most organisms, a key component of this process is oxygen. However, there is also a kind of back-up system that will provide energy if oxygen is missing.

This system or process is known as fermentation. Fermentation is one method by which organisms, including human beings, derive their energy for living when oxygen (O_2) is lacking. Normally, when oxygen is plentiful, the cells of most organisms break down sugars and starch from food to release carbon dioxide (CO_2), water (H_2O), and energy.

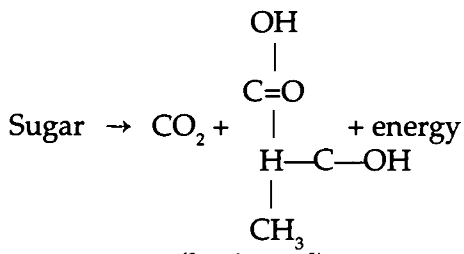
When oxygen is insufficient, cells in organisms switch to the fermentation process to provide that energy. Our body cells are also able to switch to fermentation, e.g., during strenuous exercise, when we cannot take in oxygen quickly enough.

Like the normal process, fermentation also breaks down sugars, releasing carbon dioxide (CO_2) and energy. In addition, depending on the type of fermentation, lactic acid or alcohol is produced. These are the two most common types of fermentation naturally occurring in nature. Our muscle cells produce lactic acid during fermentation. This causes the pain that we feel in our muscles.

Breakdown of Sugar when Oxygen is available.

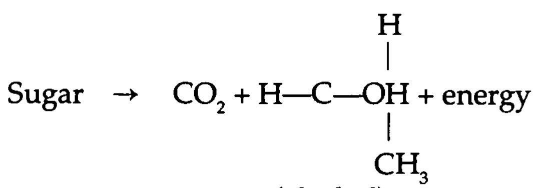
$$\text{Sugar} + O_2 \rightarrow CO_2 + H_2O + \text{energy}$$

Lactic Acid Fermentation



(lactic acid)

Alcohol Fermentation



(alcohol)
(alcohol)

Using Biological Processes: Harnessing Single-celled Organisms to Work

Various foods such as food and fruit juices will ferment when left on their own. Invisible to the eye, single-celled microorganisms such as yeast and bacteria are at work, breaking down the sugar molecules present.

When we deliberately introduce living organisms into our bread, milk, and apple juice, we are applying biotechnology to food production. Indeed, sugars in the dough, juice, and milk are food for these microscopic organisms. The carbon dioxide and lactic acid or alcohol are really waste products for these organisms but are useful for human beings.

How is Fermentation by Microorganisms Useful?

Different types of yeasts or bacteria used will yield different by-products, providing variety to our tastes. We can obtain different wines and beers depending on the type of bacteria or yeast we use. In baking, it is the CO_2 that makes the dough rise.

Fermented products also last longer. The fermentation process preserves foods. This is why fermentation was a popular preservation method in the days before refrigeration.

Limitations

Fermentation technology has its share of limitations, a few of which are listed below.

1. Remember that microbes such as bacteria and yeast are living organisms. Just like other organisms, they require a specific environment in order to survive and function. For instance, the temperature, oxygen levels, acidity levels, amount of nutrients, etc., need to be closely monitored.

2. Toxic by-products may result.
3. Considerable waste may be produced.
4. To obtain pure products, caution is needed to avoid contamination or to ensure that no anti-microbial reactions will occur.

Why Do We Manipulate?

The word *manipulate* or *control* may evoke some fears that human beings are tinkering with nature and life. However, human beings have influenced the course of nature since the dawn of civilization. A long time ago, people used to travel long distances to gather wild grain and fruit and to eat.

Later, they found that the seeds from their food began to grow where they were left behind. Soon, they began to plant the seeds near their dwellings. Thus, began the earliest form of agriculture. In so doing, wild plants were being "domesticated" or tamed.

Similarly, our early ancestors used to hunt animals for meat. However, they found out that some animals could be reared in their villages, and so was born the domestication of wild animals. Soon, they also found that animals could help them in doing work and animals like horses were reared not so much for their meat but for their strength.

Taming the Wild

This domestication of wild plants and animals became the basis for selective breeding. People discovered that new varieties appeared—food could be tastier, easier to cultivate or breed.

People also found that fermented foods were tasty and was a form of preservation e.g. cheese and wines. Without fully understanding what was taking place, our ancestors were making use of natural processes and manipulating genetic traits. This manipulation became a part of everyday life.

Regulating Old Biotechnology

Selective breeding and fermentation techniques were developed over many centuries and were tied to the way of life of the ordinary people: farming, cattle-rearing, baking, weaving, making dairy products, establishing beautiful gardens, brewing beer, etc.

Every family produced their own food and other daily needs on a small scale. They were able to enjoy the fruits of their own labor, the products of biotechnology, in their own homes. In the days when electricity was yet undiscovered and the refrigerator yet uninvented, fermentation contributed greatly to extending the shelf lives of food products.

As such, these ancient practices, even though they were a form of tampering with nature, were widely accepted. In fact, we can say that biotechnology was an integral part of cultural norms.

Today, the scenario is rather different. With increased urbanization, more and more families no longer produce their daily requirements themselves. Instead, they depend on farmers and industry.

Safeguards and Checks

When food and other items are being produced for hundreds of thousands of people at a time, some safeguards need to be in place and somebody has to check that these standards are met.

Setting and checking standards is a way our society regulates what is acceptable. This includes both the process of manipulation and the outcome.

What needs regulating?

There are several concerns which require monitoring:

- ✔ health risks to the public,
- ✔ health risks to employees (those working in the farms and industries),
- ✔ environmental impacts — including waste disposal questions, and
- ✔ quality of the product.

Both the risks and benefits need to be considered, especially as we develop the new biotechnology, which we shall explore in Unit IV.

Activity 10: In A Pickle

Discuss how fermentation is used in food processing. During the discussion, guide students in peeling and slicing the washed cucumbers and onions (or have this prepared).

Lay the cucumber and onion slices in the bowl. Cover with equal amounts of vinegar and water.

Let this sit for a while (perhaps proceed with the next activity, "Then and Now").

Have the students taste the cucumbers and onions.

Discussion

✔ What does adding vinegar do to the cucumber and onions?

✔ Why would we do this?

Explain that the acid in the vinegar stops microorganisms from growing. Thus, the sugars and starch in the cucumber and onions are not broken down. They now taste different and can be preserved for a longer time than when they were fresh. Although this is the opposite action to fermentation of food, the aim is similar: to create a new product that has a longer shelf life and a different taste.

Materials

✔ cucumbers (1 for every 10 students)

✔ onions (1 for every 15 students)

✔ white vinegar

✔ water

✔ plastic knives for every student

✔ paper plates

✔ bowl

Purpose of Activity

Use this activity to discuss food preservation and variety in general and introduce how fermentation biotechnology allows us to achieve a similar aim.

Activity 11: Then and Now

Materials
- ✔ chalk
- ✔ chalkboard (or flipchart and markers)

Purpose of Activity

Use this activity to discuss the usefulness and history of fermentation and other methods of food preservation.

On the board, create a chart that looks like this:

	Then	Now

Talk about the fruits in the activity "Fruitful Choices."
- ✔ What had happened to the fruit that the students did not want to eat?
- ✔ What could have been done so that the fruit would not go "bad" or rot?

Have the students imagine they are living in the mid-1800s. Point out that there is no refrigeration.
- ✔ How would you preserve foods for use when the food is not freshly available?

On the chart, write down the food categories:

"Meats," "Fruits," "Vegetables," and "Dairy." For each, identify ways in which the foods were preserved.

Next, ask the students to think of all the ways in which foods are "preserved" (or their shelf lives extended) now.

Discussion
- ✔ What does our chart tell us about food preservation?
- ✔ Have the methods of the 1800s been replaced by the newer methods?
- ✔ Why not?
- ✔ Which of the methods on the chart involved using organisms?

Explain that despite the enormous increase in new methods since the 1800s, people have not rejected the old methods of fermentation. This is partly because the technique and the tastes of fermented foods have become a part of human culture and life. If you were Chinese, can you imagine going without soy sauce? How would an oil and vinegar salad dressing taste without the vinegar? And what if you never got to eat cheese ever again?

Explain that in making use of organisms and natural processes, people wanted to improve product quality, increase efficiency of production and raise the quality of life.

Introduce the term *biotechnology* as the use of biological organisms, systems, or processes to make or modify products. Explain that selective breeding and fermentation for food are examples of old biotechnology, practiced for thousands of years.

Sample Chart: Then and Now

	Then	Now
Meat	salted pickled dried	salted pickled dried refrigerated frozen irradiated canned
Fruit	preserves—jellies, jams canned pickled dried juiced	preserves—jellies, jams canned pickled dried juiced refrigerated frozen irradiated genetically controlled chemically treated
Vegetables	canned dried pickled	canned dried pickled juiced refrigerated frozen irradiated genetically controlled chemically treated
Dairy	cheese soured	cheese dried/powdered pasteurized aseptically packaged refrigerated chemically treated

Activity 12: Little Helping Hands (optional)

Purpose of Activity
Use this activity to illustrate fermentation biotechnology at work.

There are several simple ways to show fermentation at work. These activities take time to complete, some may require several hours for results to appear.

Refer to the description of the suggested activities.
Here are a few suggestions:

1. Make some bread.

Materials

3 to 3-1/2 cups bread flour
1 package dried baker's yeast
2 Tablespoons sugar
1 teaspoon salt
1-1/2 cups very warm water (110 degrees F)
2 Tablespoon margarine, softened
1-1/2 cups whole wheat flour (bread flour can be substituted for white bread)
1 box large freezer bags with locks, microwaveable
1 conventional or microwave oven
aluminum bread pans, enough for each pair, if using conventional oven
1 can cooking oil spray
1 roll wax paper for lining worktables

Students will work in pairs. They will need guidance. If there is no oven available, it may be necessary to leave this activity toward the last hour of the day. Make sure there is enough time for clean-up too.

Before the activity, grease enough self-locking freezer bags for each pair of students and place the following ingredients in each bag:

1-1/2 cups bread or all-purpose flour
1 package rapid rise yeast
2 Tablespoons sugar
1 teaspoon salt

Also prepare aluminum bread pans for students to place their dough in. You may wish to have their names written on the foil. Students may take the bread dough home in the aluminum pans placed in freezer bags. Do NOT place aluminum pans into microwave ovens.

Line work tables with wax paper.

Have all students wash their hands before the activity. Distribute one bag to each pair. Show students the dried yeast and then place half the yeast in each bag. Tell the students that yeast are single-celled plants which are going to help us make the bread. Pour half the water in each bag. Ask the students to close the bags and mix the ingredients well by hand. Allow the dough to rise.

Remove the dough from the bag and show the students how to knead it. Add a small amount of flour to the dough if necessary.

Divide the dough into two portions, one for each student. If using a conventional oven, place the dough in the aluminum foils that has been lightly sprayed with oil. If using a microwave oven, place in microwaveable plastic bags.

Discussion

✔ What does the yeast do?
✔ Can you think of baked goods that do not use yeast?

If you can bake the bread, ask students to describe the smell or aroma from the oven. Or, ask the students to take note while they are baking their bread at home.

✔ What is the smell?
✔ Where does it come from?

Point out that in order to make the bread rise, we need to add yeast. Yeast is a single-celled plant, the tiniest in the world. Yeast gives off carbon dioxide gas during fermentation. The gas gets trapped in the flour particles, making the bread rise.

The yeast also releases alcohol during fermentation. This produces the sweet aroma. The alcohol is eventually driven off in the process of baking. When the temperature gets too hot, fermentation stops as the yeast cells die.

Like other living organisms, yeast cells go through mutations and those that ferment quickly were found and cultivated. Thus, we can now enjoy the time-saving benefits of the "rapid rise" yeast.

Optional

You may also wish to demonstrate that carbon dioxide gas is in fact produced during fermentation of yeast.

Place about half a pound of grapes in a perforated vegetable bag which can be closed. Carefully squeeze out all the air and then lock it. In a freezer bag without any holes, place 2 tsp of dried baker's yeast. Place the bag of grapes in the freezer bag and close it.

Crush the grapes without opening the bags, allowing the grape juice to seep through the holes and become mixed with the yeast. Place the bags in a warm place and watch what happens in the next hour. There should be foam and gas filling the bag. To test for carbon dioxide, introduce a lighted match into the bag. The fire will be extinguished.

2. *Make some cream or cheese.*

Before the activity, have students taste some commercially available varieties of dairy products: yogurt, milk, heavy cream, sour cream, and various cheeses.

Explain that making these products involve little helpers called bacteria, which are still alive in the finished products.

Details of the procedures and materials needed can be found in *More Science Experiments You Can Eat* by Vicki Cobb (J. B. Lippincott, 1979).

If you wish to try making yogurt, you can look up *Science Fun with Dairy Foods* by Robert L. Horton (Ohio State University Extension Publications, 1989) or *Recipes for Science Fun* by Susan Strand Noad (Franklin Watts, 1979).

Note: To make cheese and yogurt will require cooking utensils and a stove or a burner.

Discussion

✔ How does yogurt, milk, or cream turn sour?
✔ What makes these foods become thick and creamy? Or why does the milk curdle during cheesemaking?
✔ Can we make these foods if the yeast or bacteria are dead?
✔ Can we use just any bacteria or yeast? Or, why do we have to wash our hands and make sure all the containers and spoons are very clean?
✔ In cheesemaking, the curds are used and eaten. What happens to the whey?

Explain that the sour tastes comes from the acid that is produced by the bacteria during fermentation. Not only does it change the taste, it thickens the milk to form a custard-like appearance. Given time, the acid will "curdle" the milk. By separating the solid portion, the *curds*, from the liquid portion, the *whey*, cheese is formed.

Whey is a waste product in cheesemaking. Alternative uses for whey have to be found or it can be a waste disposal problem when cheese is manufactured in a large quantity. This is one limitation of fermentation biotechnology.

Fermentation is a living process. We can only make these foods by using live bacteria and yeasts. Different types of bacteria and yeasts will release different types of acids and alcohols. Thus, we have to ensure that the products contain the pure type and are not contaminated with other bacteria which can spoil the food and make us sick. This is the reason that we have to wash our hands and utensils well. The "active cultures" found in the commercial dairy products are of the appropriate bacteria. Thus, we can use them to make more food.

Unit IV

Biotechnology Today and Tomorrow

Sparked by the understanding of how cells and living processes work, biotechnology presents us with new ideas to:

- ✔ increase efficiency in the production of food and other substances,
- ✔ enhance the quality of products,
- ✔ improve the quality of life, and
- ✔ reduce environmental hazards.

"New" biotechnology began to develop in the 1970s especially with:

1. the advance of DNA research, and
2. learning how microbes are useful in many new applications.

Keep in mind that biotechnology is a broad term for a number of methods which manipulate cells and genes. However, it is beyond the scope of this unit to consider them all. We shall restrict our focus to what is commonly known as genetic engineering or recombinant DNA (rDNA) techniques and also take a second look at fermentation technology.

Unit IV Objectives

The students will learn:

- ✔ genetic changes can be manipulated through recombining selected genes,
- ✔ some applications of genetic engineering,
- ✔ some limitations of genetic engineering,
- ✔ some new applications of fermentation technology,
- ✔ to consider some risks and benefits of genetic engineering, and
- ✔ to consider some ethical issues related to biotechnology.

The Promise of DNA Research

How would you like tastier French fries, low in fat and calories? What about tomatoes that are juicy, red, flavorful and remain firm and fresh as well? If you were a farmer, what would you say about crops resistant to pests, diseases, frost and drought? And gives high yields as well? Suppose you suffered from diabetes, or cancer and you could get a cure?

How can biotechnology do all this? Recall that all organisms, whether bacteria or the extinct dinosaur, use the same molecule — DNA — to store genetic information. Since the genetic language is universal, it is possible to cut and paste pieces of genes. Actually, genes being "cut" and "glued" together again can happen naturally at random, when our cells divide to make more cells and DNA is being produced.

Scientists can also do this intentionally. This is known as **recombinant DNA (rDNA)** technology or **genetic engineering.** The idea is to persuade the original DNA molecule to adopt and integrate a new gene so that it yields a new trait or product.

With recombinant DNA technology, scientists can do what nature has not done:

1. recombine genetic information of *different* species;
2. by-pass the natural reproductive cycle to transfer genetic information, thereby speeding up the process of "cross-breeding"; and

3. unlike traditional cross-breeding or selective breeding, rDNA is very specific—introducing one gene will usually not affect the development or functioning of the rest of the organism.
   Let us look at two ways in which this technology is being used:

First, desired genes can be directly inserted into the cells of host plants or animals.

Inserted genes usually make something happen. For example, a gene can be introduced into a crop which will produce a substance toxic to targeted pests when eaten. The crop is then said to be pest-resistant.

Inserted genes can also stop something from happening, for example, a gene has been introduced into a tomato that prevents it from becoming soft while ripening. This allows the fruit to stay firm, making it easier to transport.

Second, desired genes are introduced via another organism.

Very often, it is difficult or too expensive to directly introduce genes into a complex organism. Scientists have a technique to add these genes to bacterial or viral cells instead, and hope that some of them will adopt the new genes. Bacteria multiply very quickly, so scientists can find those that have adopted the new gene and breed them separately in a *bacteria culture*. The result: the new gene has been **cloned,** i.e. the bacteria create copies of themselves.

Recall from Unit I that genes are like recipes for specific products. So if we are able to clone the gene, we can mass produce desired products. One example of this is the pioneering production of human insulin, a hormone used to treat diabetes. This was the first commercial application of recombinant DNA technology in 1977. Bacteria with the new gene started to produce insulin, which can then be easily extracted and purified.

Today, recombinant DNA technology has many applications, especially in agriculture and medicine.

Limitations

1. Although recombinant DNA technology overcomes some of the limitations of selective breeding, there is no guarantee that the inserted gene will go on to produce the desired product or trait even if it is adopted by the host. We can say that this is an "internal" means of regulating biotechnology.
2. Organisms that have new genes may not be permanent solutions to problems. For instance, we can genetically modify some plants to produce certain toxins against pests. However, these pests can in time develop new varieties that are resistant to these toxins.

Fermentation Revisited

The "New" Fermentation

In biotechnology, the term *fermentation* is actually used to refer to the process of generating large numbers of microbes such as bacteria. The idea is that when these microbes are placed in a suitable environment, or fermenter, where nutrients are kept adequate, they will multiply. This is the process of cloning microbes. Greater numbers of microbes can produce more desired products.

Fermentation may seem rather unsophisticated when we think of baking bread or brewing beer. However, scientists are finding new applications for this age-old technology. One such application is the production of biofuels. These are made from plants.

Fermentation of some plants produce alcohol, just like in wine-making. For example, sugar cane and corn when fermented produce the alcohol called ethanol. Ethanol is a biofuel that can be used as a substitute for gas. In Brazil, all the cars run on ethanol or a petroleum-ethanol mixture.

Another application of fermentation is in the manufacture of bioplastics. Bacteria that make plastics similar to polyester are added to huge fermentation vats where they feed on crops such as sugarcane. The plastics that are created as a by-product can be used to make shampoo bottles and disposable razor holders.

However, sometimes, it is not so much the products of fermentation that is sought, but the microbes themselves. The production of the insulin hormone combines both genetic engineering with the fermentation process.

As discussed earlier, the human gene responsible for insulin production is introduced into bacteria. These bacteria are then allowed to multiply in a vat containing nutrients. As a result, the bacteria containing the gene are cloned and insulin can be produced in large quantities.

Limitations

The limitations of using fermentation biotechnology in these new applications are essentially the same as those in old applications. Despite the variety of products that can be made, fermentation processes depend on the work of those single-celled organisms like bacteria and yeast, which live in specific environments.

Risks and Benefits

Just like in old biotechnology, there are concerns about health risks, environmental impacts, and product quality. New biotechnology does not take away these concerns. Indeed, some people fear new biotechnology while they would not think twice about selective breeding.

New Biotechnology Speeds Change

Perhaps one of the basic reasons for concern is simply the speed of change. Selective breeding also involves the manipulation of nature but the results take several years to show. In the time taken, whole societies can adapt and may even adopt the process as a part of their culture as discussed in Unit II.

Recombinant DNA technology, however, can offer results almost immediately. Thus, there is a sense that we lack control and security. Indeed, with old biotechnology, anyone can apply it and control the process. With new biotechnology, this responsibility lies almost exclusively with scientists, industrialists and policymakers.

Is Biotechnology Safe?

Further, since new biotechnology often involves bacteria and viruses, there is a concern that accidental release may be difficult to deal with since they can multiply very quickly and can be a risk to health.

Scientists are aware of the health risks since they deal with the microbes in their work. Often, they try to make use of microbes which are commonly found and which they know a lot about.

How about genetically modified foods? Rigorous procedures would have to be in place to ensure quality and safety to consumers. In general, biotechnology is a highly controlled process with genetic modifications introduced one at a time and outcomes systematically monitored.

Regulation of quality and safety are conducted by government agencies, corporations, and, among the scientific community. We can say this is an "external" means of regulating biotechnology.

Ethical Issues

But are we treating organisms as simply a bunch of cells to be manipulated? This is an ethical question that has no easy or straightforward answers.

Microorganisms such as yeast and bacteria play a very useful role in our lives. Many bacteria even live in animals and humans, helping in the digestive system. They are fundamental to the ecosystem, breaking down dead plants and animals, to produce useful, rich soil that sustains more growth. Thus, fermentation biotechnology may be regarded as an extension of the role of these microbes in nature.

On the other hand, is it right to alter the genetic makeup of a plant, an animal, or even a bacterium even if it is safe? Should we give these organisms genetic recipes that they never had, especially if they were genes from another species?

There are many factors to consider such as the social and economic impacts. However, one important way of answering these questions is to decide if there is a real need for the product. For instance, suppose we could do it, do we need a tomato that tastes like chicken? Probably not. But what if altering a plant or bacterium genetically can produce new medicines which were unavailable? Or what if there is a chance that new biotechnology can offer environmentally more friendly resources like biofuels and biodegradable plastics? Are these worth the long term impacts that are often unknown?

Biotechnology — old and new — is a very dynamic concept that can have as many applications as the mind can imagine. Already, many products are on the market. In understanding what biotechnology means, we can make better decisions for ourselves and all that is in our environment.

In the Market: Biotech Old and New

Today	Tomorrow
Baby whole carrots	Seedless mini-melon
Tomatoes that stay fresh up to two weeks	Sweeter peas and peppers
High-Laurate Oil *a raw material used in soaps, detergents and cocoa butter replacement fats*	Low-Saturate Oil *a healthier salad and cooking oil from rapeseed plants*
Bst-stimulated Milk *A growth hormone called Bst has been introduced in cows to stimulate milk production. A gene with the recipe for Bst was inserted in bacteria.*	Colored Cotton *color-producing genes from bacteria are introduced in cotton genes. This will mean fewer dyes are needed, reducing environmental pollution.*
Eggs *vaccinated while still in the shell against a common virus*	Salmon *faster-growing salmon*
Insulin *a hormone for diabetics, who are unable to produce the hormone to break down sugar. Produced by genetically-engineering bacteria.*	Tissue Plasminogen Activator (TPA) *a natural human protein that dissolves blood clots, used when a heart attack occurs, allowing blood to flow. Used currently in hospitals but patients may be able to use it themselves one day.*
Hepatitis B Vaccine	AIDS Vaccine
Aspire™ *a biofungicide used on citrus fruits, berries, and grapes to prevent postharvest rot. It is a naturally occurring yeast, harmless to non-targeted organisms.*	Insect-protected corn and potato *genetically improved plants to control the European corn borer and the Colorado potato beetle*
Methane gas *a biogas that can be obtained from microbial fermentation of domestic, agricultural, and industrial wastes*	WHAT DO YOU THINK?

Task Table

Habitat Task	Food Task	Transportation Task
Lives in marsh or swampy areas	Hunts at night from the ground	Has no feet or paws—moves by slithering
Builds nests of grasses	Scavenges for food from what animals have left behind	Moves very slow—eats only small insects that come close
Lives in deep, open water; feeds on small fish	Eats insects but lives on the ground	Moves from place to place by flying short distances
Lives on the open plain	Eats small plants close to the ground	Moves from place to place by hopping
Lives in rocky areas with little vegetation	Lives in treetops, eats only insects	Moves from place to place only at night
Lives in high altitudes	Lives underground, eats plant roots	Wings to travel between home and food
Lives in very cold climates	Hunts in daylight from the air	Uses fins to move around
Lives in forests on the ground	Hunts only small rodents that live on the high plains	Spends a lot of time in water, but lives on land

Activity 15: Biotech Me (A Summative Activity)

Have each student choose a specific plant or animal. Students may also work in pairs of small groups.

Have students decide on one trait they would like to change or adapt in the plant or animal. Using any of the art supplies, have students report on the change of this trait in the plant or animal.

Tell the students that their report:

- ✔ should illustrate the plant or animal before and after the genetic change,
- ✔ explain why this change would be beneficial,
- ✔ who would benefit from it, and
- ✔ what possible problems may result from making the change.

Have each student present their project to the full group.

This activity can serve as an evaluation of the unit. Evaluation can be based on how thoroughly each student or team addresses the considerations you emphasized in the course of the unit.

This activity is highly variable to your specific instructions through the unit, and the directions to the students can and should reflect the focus you had.

Materials

✔ art supplies

Purpose of Activity

Use this activity to sum up the unit and for evaluation.

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