UNIT G
INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGY

	Unit/Competency/Objective	Cognitive	Performance
G	**INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGY**		
EB07.	**Analyze the use of biotechnology applications in industry and the environment.**	**7%**	**2%**
EB07.01	*Discuss industrial and environmental biotechnology.*	*2%*	
EB07.02	*Analyze components of industrial biotechnology.*	*2%*	*1%*
EB07.03	*Evaluate environmental biotechnology applications.*	*3%*	*1%*

Unit Materials

EB07.01	Activity	◆ Introduction to Industrial and Environmental Biotechnology
	PowerPoint	◆ Introduction to Industrial and Environmental Biotechnology
	Content	◆ Terminology – Industrial and Environmental Biotechnology
EB07.02	PDF File	◆ *Your World*, Industrial Biotechnology Issue
	Activity	◆ Fermentation: Putting Microorganisms to Work and Scaling Up Questions
	Content	◆ Biomining
EB07.03	Teacher Information	◆ Observation of Enzyme Activity
	Teacher Information	◆ The Biodegradation of Oil by Aerobic Bacteria
	Content	◆ Dr. Jason Shih, NC State University
	PDF File	◆ *Your World*, Environmental Biotechnology Issue

Recommended Resources

Biotechnology INSTITUTE

http://www.biotechinstitute.org/

Your World Magazine is the premier biotechnology publication for 7th-12th grade students. Each issue provides an in-depth exploration of a particular biotechnology topic by looking at the science and its practical applications.
A subscription offers 30 copies of each issue of the magazine for one year. Teachers will also find an array of invaluable resources available on our Teacher Resources page.

Supplemental Resources

http://compost.css.cornell.edu/schools.html

It's Gotten Rotten is a 20-minute video designed to introduce high school students to the science of composting. It focuses primarily on the biology of the invertebrates and microorganisms that decompose organic matter.

Students are shown designing and using both indoor and outdoor composting systems, observing living organisms, and using finished compost to grow plants.

Available from:

Bullfrog Films
Box 149, Oley PA 19547
E-Mail: bullfrog@igc.apc.org
Phone: (800) 543-3764
Fax: (610) 370-1978

Lesson Plan

EB07.01 DISCUSS INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGY.

Activity	Steps	Comments
Introduction to Industrial and Environmental Biotechnology **(Activity pages and PowerPoint)**	1. Provide each student with a copy of the activity "Introduction to Industrial and Environmental Biotechnology." 2. Instruct students to read the activity carefully and answer the questions to best of their ability, using common sense and prior learning to come up with the answers. 3. Discuss the activity and allow students to share their answers. 4. Show the PowerPoint of the same name.	▪ The activity is a "pre-learning" assignment to prepare them for the PowerPoint.
Terminology – Industrial and Environmental Biotechnology	1. Give students a copy of the terminology list, colored pencils and 8 1/2 x 11""paper. 2. Have students carefully read the terms and definitions, then secretly select one of the terms on the list. 3. Students should be given 5-10 minutes to illustrate the word they chose, using pictures only and no words. 4. Have students write the term they illustrated on the back of the paper and turn them in. 5. The teacher should show each picture and have the class guess what has been illustrated. Throughout the process, the teacher should point out important facts and components of the terms identified.	▪ This could be done as a homework assignment. ▪ Be aware that some students may be embarrassed by their lack of artistic ability. The teacher should show the pictures in such a way that protects each student's identity.

EB07.02 ANALYZE COMPONENTS OF INDUSTRIAL BIOTECHNOLOGY.

Activity	Steps	Comments
***Your World* Industrial Biotechnology Issue** **Fermentation Questions**	1. Access the full Industrial Biotechnology issue of *Your World* magazine. 2. Have students read pages 4 & 5 of the issue which contains the article "Fermentation: Putting Microorganisms to Work" and "Scaling Up" and answer the questions on the activity page from this guide.	▪ Teachers may download and print the entire magazine for their students. ▪ Another option is to have the students access the issue in a computer lab. ▪ The Industrial Biotechnology issue can be found at www.biotechinstitute.org ▪ Answering these questions will draw on prior knowledge and serve as an introduction to the experiment.
Fermentation Experiment	1. Give students a copy of the experiment "The Process of Fermentation" from page 15 of *Our World,* the Industrial Biotechnology issue. 2. Gather materials necessary for completing this assignment. 3. Allow students to read the instructions and follow the directions for the activity.	▪ Students may write their answers to the experiment analysis questions on a sheet of notebook paper.
Biomining	1. Have students read the Biomining information in this curriculum guide.	▪ Briefly have students verbally summarize the article. ▪ As a critical thinking question, ask them to speculate if there is any "biomining" going on in North Carolina, and as an optional homework assignment, ask them to research the topic and report back what they find.
Composting		▪ Optional Assignment: If time permits, visit the Composting in the Classroom website at http://compost.css.cornell.edu/schools.html for a video and instructional suggestions to teach the concept of composting.

EB07.03 EVALUATE ENVIRONMENTAL BIOTECHNOLOGY APPLICATIONS.

Activity	Steps	Comments
Bioremediation	1. Give students a copy of the article "Bioremediation: Bacteria's Top Job" from *Our World* magazine. 2. Lead a brief class discussion on "What is an enzyme and how do they work?"	• The PDF file for the Environmental edition of Our World magazine is on the course CD or can be accessed from www.biotechinstitute.org • This assignment should prepare students for the Observation of Enzyme activity.
Observation of Enzyme Activity	1. Gather materials necessary for completing this assignment. 2. Allow students to read the instructions and follow the directions for the activity.	• Assign students to work in pairs or groups of 4 for this lab activity,
Biodegradation of Oil by Aerobic Bacteria (Optional)	1. Follow the instructions given for this lab experiment.	▪ Use if time permits to extend understanding of bioremediation.
Patents: A "Quid Pro Quo" **Dr. Jason Shih**	1. Have students read the article "Patents: A "Quid Pro Quo." 2. Then have students read the article in this curriculum guide about Dr. Jason Shih. 3. After reading the information, have students answer the following questions: ▪ Do you think Dr. Shih has a patent for any of his discoveries? If yes, what and why?	▪ The PDF file for the Environmental edition of Our World magazine is on the course CD or can be accessed from www.biotechinstitute.org ▪ The answer to the patent question is yes – see http://www.lib.ncsu.edu/archives/exhibits/patents/CALS.htm
Biosensors **Biotech Musical Chairs**	1. Have students read the Biosensors article from *Our World* magazine. 2. Have the class carry out the Biotech Musical Careers activity.	▪ The PDF file for the Environmental edition of Our World magazine is on the course CD or can be accessed from www.biotechinstitute.org – Biosensors is on pages 10-11 and Biotech Musical Chairs is on page 12.

Activity

INTRODUCTION TO INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGY

As you have noticed in previous units, “bio” anything refers to living cells. Usually, this means the use of microorganisms such as bacteria, fungi and yeasts, or the products they produce, such as enzymes.

Given this definition, what do you think the following terms describe?

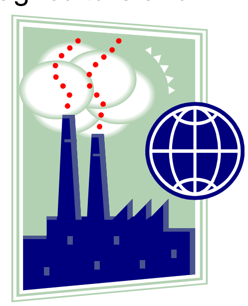
Biobased energy:

Biobased products:

As you proceed in this unit you are going to notice a lot of those “bio” words. Some you will be able to figure out while others are a little more difficult.

Try this one. What do you think “bioprocessing” means? It means using ___________________________________ to manufacture products.

We have already learned about how biotechnology is used in medicine, agriculture and food production. Now, it’s time to learn more about how biotechnology can benefit industry and the environment.



An early example of environmental biotechnology was the use of microbes (oil-eating bacteria) to clean up an oil spill. In what year would you guess that happened? _______

Environmental biotechnology involves the use of science to clean up pollution.

List three examples of pollution in your community:

1. ____
2. ____
3. ____

Wouldn’t it be wonderful if advances in biotechnology could clean up the environment in your community?

There are many advantages to the use of biotechnology in industry. The use of biotechnology can reduce the energy required for industrial processes. Why is that important? ____

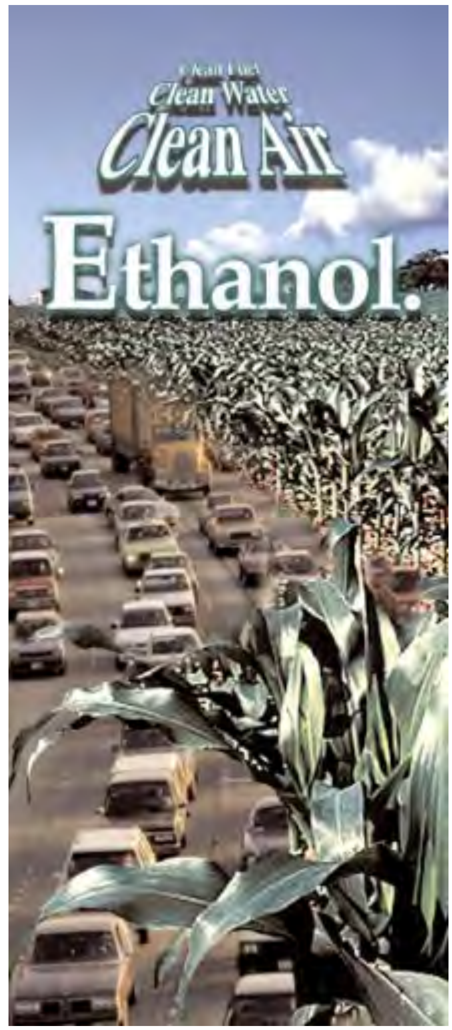
____

Do you remember learning about fossil fuels in your science class? What is a fossil fuel? ____

Biobased energy companies want to replace fossil fuels with renewable, raw materials. The “raw materials” they are using are sugars.

One product that can be made from sugars is Ethanol.

After looking at the picture on the right, what conclusions can you draw about Ethanol?



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One of the advantages of using biobased products is that they are often biodegradable. What does it mean when something is biodegradable?

____

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Based on what you have learned so far, on a scale of 1 – 10, how important is industrial and environmental biotechnology research, and why?

Importance _______

Why? ____

____

TERMINOLOGY – INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGY

Biocatalysts – Enzymes used in manufacturing processes. Enzymes are proteins produced by living organisms that break down other proteins, cellulose, fat and starch.

Biomaterials – Products made using bioprocessing. Developments in biomaterials have led to products that reduce their environmental impact. Next time you are at your local grocery store, look at the plastic bag you carry out to your car. Chances are, if the bag is recyclable, that the bag was made from potatoes using new biomaterials.

Bioprocessing - Using complete living cells or their counterparts (e.g., enzymes, chloroplasts, etc.) to create desired physical or chemical changes. Examples of industrial products created by bioprocess technology include: polymers, plastics, chemicals, fuels, lubricants, newsprint ink, pharmaceuticals, cosmetics, and construction materials.

Bioremediation – The use of living microorganisms to clean up environmental pollutants. A famous example of this was the cleaning of the beaches along the Prince William Sound after the Exxon Valdez disaster that occurred in the 1990s. Workers noticed that petroleum was removed more quickly from beaches that received an application of fertilizer than from beaches that were steam-cleaned. The fertilizer stimulated the oil-eating microbes and quickened the removal of oil.

Bioreporters – Living microbial cells that have been genetically engineered to produce a measurable signal in response to specific chemical or physical agent in the environment. Used in the detection of environmental contaminants.

Biosensors – Detecting devices (microelectronic) that can detect specific substances in cells. When the substance we are looking for combines with the biological component, the transducer produces a signal. Biosensors can locate and measure environmental pollutants.

Composting – The earliest example of environmental biotechnology, the process of using bacteria, fungi, and other organisms to break down organic matter and return nutrients to the soil.

Microbe (microorganism) – The "life" forms used in industrial biotechnology, usually yeasts, bacteria and fungi. They are used to produce industrial enzymes or as whole cells.

Activity

Name________________________________ Period______

FERMENTATION: PUTTING MICROORGANISMS TO WORK AND SCALING UP QUESTIONS

Directions: Use the article on page 4 & 5 of *Your World*, to answer the following questions in ***complete sentences.***

1. Describe the process of fermentation and how it has been used in food production since ancient times.

2. Describe the actions of the microorganism yeast in the bread making process.

3. Name 4 new industrial products made by fermentation,

4. Describe ethanol and how it is used in fuels.

5. Besides corn, name 3 other things needed to produce industrial ethanol.

6. What is found in "stillage" and what can it be used for?

7. In a bioprocessing factory, describe the importance of the following items in the steps of production:

   A: Nutrient Broth:

   B. Sterility:

   C. Oxygen:

   D. Temperature:

   E. Recovery & Purification:

Answer Key

FERMENTATION: PUTTING MICROORGANISMS TO WORK QUESTIONS

1. Fermentation is when microorganisms are purposely allowed to grow in food and reproduce. Micobes eat certain nutrients found in their food, chemically changing those nutrients and giving off other substances as waste. Fermentation has been used since prehistoric times to make wine, bread and cheese.
2. In bread making, yeast eats the sugar in bread dough and gives off carbon dioxide gas and alcohol. The carbon dioxide is what makes dough rise and alcohol evaporates during baking and gives bread its distinct smell.
3. Four industrial products made by fermentation are: vitamins, antibiotics, industrial solvents, acids, dyes, fabrics, glues and more.
4. Ethanol is a fermented alcohol made from the sugar found in corn. Ethanol can be mixed with gasoline to produce a cleaner burning fuel that reduces carbon monoxide emissions by 25%.
5. To produce industrial ethanol you need: water, enzymes and yeast.
6. Stillage contains protein, oil and water and it can be used as animal feed.
7. A. The nutrient broth gives the microorganisms the food they need to grow.
   B. Sterility means you keep the equipment and tanks free from unwanted bacterial growth that could contaminate your product.
   C. Oxygen is needed for the microbes to live.
   D. The temperature for the proper growth of microorganisms fluctuates throughout the fermentation process.
   E. During recovery and purification, the cells must be removed from the broth. Then, the broth should be distilled to capture the product.

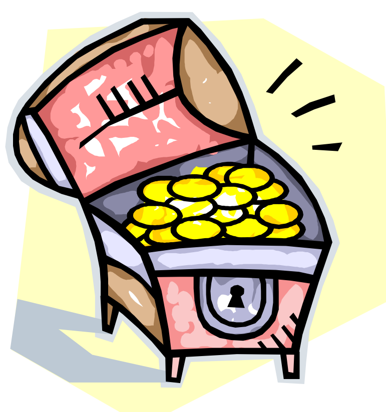
Content

BIOMINING

Mankind has been using precious metals for jewelry, coins, and other finery since the beginning of time. In tombs traced to ancient civilizations such as the Incas, Mayans, and ancient Egyptians, we find many examples of gold and silver ornaments. Most of these metals were obtained by mining; and obviously, the first metals mined were the easiest to get. The techniques used to extract minerals from the earth have not changed significantly over the past few centuries. Ore containing the mineral is dug up from the earth. Then, the ore is crushed and the precious minerals are extracted either by extreme heat or by using toxic chemicals such as cyanide.

Over the past few years, mining techniques have been changing and this change can be attributed to the use of new **biomining** techniques. These techniques rely upon the behavior of certain bacteria that, at very high acidity levels, can eat away any unwanted iron and minerals leaving the valuable mineral (silver, copper, or gold) behind.

The process of **bioleaching** is used widely in the extraction of copper with approximately 25% of all copper worldwide, worth more than $1 billion dollars annually, being produced through **bioprocessing**. This technique is particularly successful with lower quality copper ore. After removal from the mine, the ore is treated with sulfuric acid—the acid stimulates the growth of Thiobacillus ferooxidans bacteria which literally eats up the ore. As the ore is eaten, the copper is released and collected in solution. To make the process even more environmentally sound, the sulfuric acid can be recycled.



Integral to this use of biotechnology are bacteria and microbes that assist in mineral processing. There is a need to find bacteria that can resist heat because the **bioprocessing** of ore releases a tremendous amount of heat. Biotech researchers are now searching for new bacteria under the ocean near volcanic vents and geysers. The goal is to find bacteria that can be used for **biomining** temperatures up to 1000 degrees Celsius. One mine, Gold Mines of Australia, is using high-temperature (thermophilic) bacteria in their processes. The mine was able to process 98% of the available gold because of the efficiency of the thermophilic bacteria. This compared to a gold recovery rate of only 40-60% with traditional cyanide processing.

Teacher Information

OBSERVATION OF ENZYME ACTIVITY

The procedure outlined below offers a simple way to let your students observe enzyme activity.

Students often do not realize that nearly identical genes are found in a wide variety of organisms. The proteins encoded by these genes perform similar tasks whether they are in bacteria, plants or people. Using the simple procedure below you can demonstrate that amylase is made by creatures across the biological spectrum.

Detection of starch. The presence of starch can be detected with iodine. Because of the bond angles between glucose residues in starch, starch molecules nestle inside the turns of the helix, forming a complex that appears navy blue. However, it takes at least 6 turns of the starch helix (requiring 36 glucose units) to give the blue color with iodine. When amylase has cleaved the starch molecule into shorter dextrins, the color change will not longer occur.

Materials Needed:

- Cornstarch
- Unflavored gelatin or plain agar powder
- Clear dishes – Petri dishes or glass dishes (a casserole would be fine)
- Q-tips
- Commercial tincture of iodine, diluted 1:4 with water

Procedure:

1. Make starch plates with agar or gelatin. Use agar if you have it; it makes a stiffer gel that is easier to write on.

   Recipe: 2 g (about 1 tsp) cornstarch
   450 ml (2 cups) water
   4 envelopes unflavored gelatin
   OR
   6.5g plain agar

   Combine ingredients. Heat to boiling. Pour into Petri dishes or other clear containers. Let sit at room temperature or refrigerator until solid (overnight on the counter works fine). If moisture has accumulated in the lids of the dishes, wipe it away before use. This recipe does not make sterile plates, nor does it make a nutrient agar suitable for culturing microorganisms.

2. Add amylase to plates.
    a. For human amylase, put the end of a Q-tip in your mouth, then use that tip to write a message on a starch plate.
    b. Gelatin plates are very soft compared to agar plates; be gentle with them.
    c. If you have other amylase samples, use fresh Q-tips to dip into them and write other messages.
    d. Let the plates sit for 10-15 minutes at room temperature.

3. Perform iodine test for starch.
    a. Flood the test plates with iodine diluted as described.
    b. You should see your written message appear clear against a blue background.
    c. The clear area shows that the amylase enzyme broke down the starch molecules where you touched plate.
    d. The blue background shows the presence of starch in the rest of the plate.

This activity was used with permission from the North Carolina Biotechnology Center, www.ncbiotech.org.

Teacher Information

THE BIODEGRADATION OF OIL BY AEROBIC BACTERIA   BY JON WILLIAMS

As a seventh grade student, Jon Williams presented an award-winning project demonstrating biodegradation of oil at the North Carolina Student Academy of Science competition. Jon had used inexpensive, readily available materials in a simple but effective procedure. His experiment uses Mason jars, aquarium pumps, and tubing to set up small bioreactors for microbial digestion of oil.

Introduction

Oil released into the environment is a well-recognized problem in today's world. Oil spills affect many species of plants and animals in the environment, as well as humans. The search for effective and efficient methods of oil removal from contaminated sites has intensified in recent years, in part, due to the enormous publicity of the Exxon Valdese spill. One promising method that has been researched is the biological degradation of oil by bacteria. The bacteria metabolize the oil in much the same way as humans convert food into energy. Like food, oil is a compound rich in carbon. The following experiment can be used to demonstrate the some types of bacteria can degrade oil. Also, other variables can be selected and incorporated into the lesson plan to allow additional experimentation.

Materials

- 8 1-pint Mason jars
- Aquarium pumps and tubing
- Inorganic nutrients: ammonium phosphate, magnesium sulfate, potassium phosphate, and non-iodinated sodium chloride
- Lightweight machine oil (not motor oil; available at hardware stores)
- Pipettes that can deliver drops or reproducible small volumes
- Distilled water
- Brown paper bags
- Laboratory balance
- Soil sample (preferably collected from and oil-contaminated site); will contain soil bacteria

Procedure

1. This experiment includes 4 treatments, each done in duplicate. Therefore, label the jars 1A, 1B, 2A, 2B, etc, up to 4B. The jars with the same numerical markings (for example 1A and 1B) will contain identical treatments. The jars should be clean.

2. Put 150 ml distilled water and 2 grams of machine oil into each of the 8 jars.

3. The first set of 2 jars (1A and 1B) will contain only distilled water and oil and serve as controls. Set them aside.

4. Add into the second set of jars the following mixture of inorganic nutrients: 0.25g ammonium phosphate; 0.05g magnesium sulfate; 0.25g potassium phosphate; 1.25g non-iodinated sodium chloride. The inorganic nutrients provide nitrogen and minerals to t organisms.

5. Add into the third set of jars the soil sample. The best place to collect soil is from an area already contaminated with oil. That way it is likely that the surviving bacteria in the sample may be representative of oil-degrading species. One suggestion is to collect bacteria from where engine oil has repeatedly leaked on the ground for several years (service stations, dirt parking lots, etc.) If you don't have access to such a place, soil taken from an organically rich area may be substituted, since oil-degrading bacteria are generally present in most soils. Approximately 5g of the soil from your chosen area should be added to each of the two jars for treatment.

6. Into the fourth and final set of two jars add both the inorganic nutrients and the soil sample as described in steps 4 and 5.

7. Cover the top of the jars loosely with inverted Petri dish halves in order to reduce evaporation of the water and oil in the treatments (aluminum foil can be substituted). The dish halves should have a hole drilled in them to allow a piece of tubing to reach into the water and bubble up air from a small aquarium pump. (If you use 4-way splitters, only 2 pumps will be needed for the 8 jars.)

8. Results may be recorded from each jar every 3 days or weekly for up to 30 days. Take results by performing a "greasy spot" test. To perform this test, cut a brown paper bag into a 16 x 16 inch square. Then, with a ruler, divide the large square into 8 2 x 2 inch squares. In the corner of each small square, put the number (1A, 1B, etc.) of each different treatment jar, one per square. This way, there should be one 2 x 2 inch square for each jar. Using a pipette or dropper, draw a small quantity of liquid from just under the top of the water level of one jar. Deposit three drops of his liquid onto the center of the correct square of paper (if the sample was from jar 1A, place the three drops on the square for 1A, etc.). Take samples from the same place in each jar each time (just under the surface of the water). After a few hours, the water will evaporate, leaving a greasy spot on each small square. Circle the circumference of each greasy spot with a pencil and measure and record the diameter of each spot. Average the results from jars containing identical treatments. During the course of the experiment, the spots from the treatments containing the bacterial and inorganic nutrients should be smaller since the oil is being degraded.

9. Place your cumulative data into graphs and compare. What trends do you find, if any? Where did activity plateau? Why were the soil sample, inorganic nutrients, oxygen, etc. necessary for the oil concentration to be decreased?

Discussion

As previously stated, the soil sample provides bacteria to digest the oil. However, oil is composed only of hydrogen and carbon, and the bacteria need additional nutrients to grow. The inorganic nutrient mixture provides nitrogen and several essential minerals. The bacteria also require oxygen, provided by air from the aquarium pumps.

This activity was used with permission from the North Carolina Biotechnology Center, www.ncbiotech.org.

Content

DR. JASON SHIH, NC STATE UNIVERSITY

Professor
Agriculture & Life Science
NC State University

Advances in environmental biotechnology are happening in our own backyard. Read about a North Carolina State University scientist who is making important discoveries for the future.

Keratinase Technology

Two different technologies were invented from Dr. Jason Shih's laboratory. One derived from the discovery of a feather-degrading bacterium, which can break down chicken feathers. This discovery is significant, because feathers, like hair, are made of keratin protein that is resistant to common digestive enzymes. Because keratin is difficult to digest, feathers and hair have never been used as dietary protein. During a series of studies, the enzyme keratinase, which catalyzes the hydrolysis of feathers, was isolated. The gene that encodes keratinase was also isolated and sequenced. Cloning of this gene for hyper-production of this enzyme is now possible. More importantly, it was demonstrated that feathers after treatment with this enzyme were indeed hydrolyzed to peptides and amino acids. Feathers processed with the keratinase, therefore, are convertible to dietary protein used in animal feeds. The poultry industry in the U.S. produces eight billion chickens each year. From processing these chickens, one million tons of feathers are generated each year as a major by-product, mostly wasted or underutilized. If the keratinase technology can be adapted to process feathers, it can create a $400 million market based on the value of digestible protein. The development of the keratinase technology is a good case study in converting the waste into a value-added product.

Figure 1: Dr. Jason Shih and his graduate student (now Dr. Scott Carter) are inspecting the culture of bacteria growing on feathers. These bacteria produce and secrete the keratinase enzyme that hydrolyzes feather keratin.

Thermophilic Anaerobic Digestion

Another technology invented in Dr. Shih's laboratory is called thermophilic anaerobic digestion (TAnD). It is a microbiological process by which organic matter can be degraded and converted to methane and carbon dioxide in the absence of air or oxygen. The same process can be used to manage animal waste that is generated in large amount on a poultry or livestock farm. It was in Dr. Shih's laboratory that the process was found to be very efficient when operated at higher (thermophilic) temperatures, first in the laboratory and then on the university farm. After a successful test with the prototype at NCSU, the full-scale system was tested successfully in Taiwan and China. In North Carolina, a full-scale TAnD and associated Integrated Farming system has been proposed as an alternative method for waste management on farms. The Integrated Farming system is designed to fully use all resources or by-products generated by TAnD.

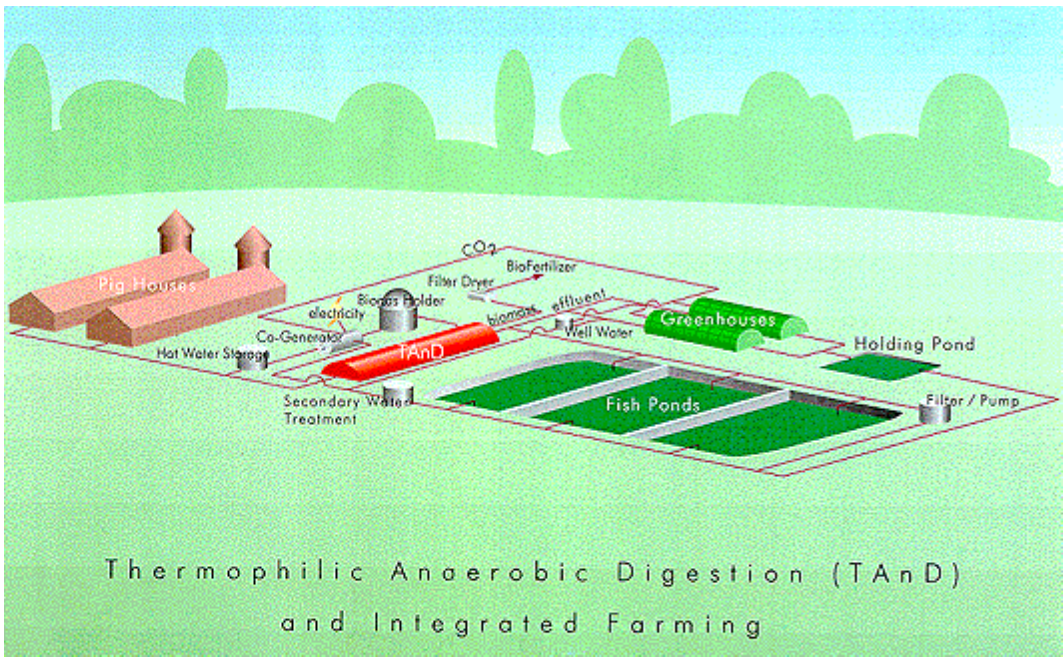


Figure 2: Thermophilic anaerobic digestion (TAnD) and integrated farming is a new agricultural ecosystem. TAnD converts animal waste into useful resources including biogas (65% methane and 35% carbon dioxide) energy, nutrients for aquaculture and bio-fertilizer for horticultural produce.

From North Carolina State University's web site at www.ncsu.edu/

UNIT E
AGRICULTURAL BIOTECHNOLOGY

	Unit/Competency/Objective	Cognitive	Performance
E	**AGRICULTURAL BIOTECHNOLOGY**		
EB05.	**Analyze the science of plants, food and animals in agricultural biotechnology.**	**11%**	**2%**
EB05.01	*Discuss the fundamentals of biotechnology in agriculture.*	*2%*	
EB05.02	*Analyze biotechnology and plants.*	*4%*	*2%*
EB05.03	*Investigate when various techniques of food biotechnology were introduced.*	*1%*	
EB05.04	*Analyze the production and processing of genetically modified foods.*	*3%*	
EB05.05	*Discuss the use of transgenic farm animals.*	*1%*	

Unit Materials

EB05.01	Content	◆ Biotechnology in Agriculture
	Activity	◆ An Introduction to Agricultural Biotechnology
	Video	◆ Super Seeds Video
EB05.02	Activity	◆ Fast Plants
	Activity	◆ The Life Cycle of Fast Plants
	Video	◆ Plants Video – Bill Nye
	Content	◆ Asexual Reproduction in Plants
	Activity	◆ Asexual Reproduction Matching
	Teacher Information	◆ Plant-Made Pharmaceuticals
EB05.03	Activity	◆ Welcome to the World of Biotechnology: It's Time to Eat
EB05.04	Teacher Information	◆ Plant Biotechnology Information
	Activity	◆ Good Ideas are Growing - Brochure
	Activity	◆ Benefits of Plant Biotechnology
	Content	◆ Considering the Nature of Issues of Food Biotechnology
	Activity	◆ Food Biotechnology Poster - Rubric
EB05.05	Overhead Transparencies	◆ Transgenic Farm Animals
	Activity	◆ Transgenic Farm Animals Puzzle

Recommended Resources

AgriScience Explorations, *3rd Edition (2004)*

Authors: Morgan, Lee, and Wilson. This is an updated third edition of a book written for students in grades 7–9. It gives a cursory look at many aspects of agriscience, quite appropriate for a middle-school program. Published by Pearson Prentice Hall.
http://www.phschool.com/career_technical/rave_reviews.html#agriscience

Biotechnology
by Mathematics and Science Education Center
Biotechnology–Grades 5-6   0-7872-1638-0 $51.99

Grades 5-12: Biotechnology is a key part of a natural process, and students are challenged through hands-on activities and analysis

http://www.kendallhunt.com/elhi/paintTemplate

The New Explorers: The Super Seeds (Video)

Vendor: Arts & Entertainment (A&E) Home Video Customer Service
PO Box 2284, South Burlington VT 05407
Go to http://www.aetv.com/

Select “store” from the navigation bar

In the search box, type in Super Seeds

1 Volume Set. 50 Minutes. $24.95

Note: This video is also available at the same price from Amazon.com

Plants (video)
Part of Bill Nye the Science Guy Complete Series
Price: $39.95
Subject Area: Science & Nature   26 minutes
Grade Level: Primary, Intermediate, Junior High, High School
Product ID: 68A53VL00
Science guy Bill Nye branches out and gets to the root of the matter to explain wild things about plants such as how they breathe, make food, defend themselves, and move their seeds around.
http://dep.disney.go.com/educational/store/detail?fromsearch=1&product_id=68A53VL00

Your World Magazine – Plant-Made Pharmaceuticals issue and Transgenic Animals issue

www.biotechinstitute.org

Free download in PDF format.

Recommended Resources (continued)

Fast Plants

Teachers may order "Fast Plants" from Carolina Biological Supply Company as noted below. There are different kits available. The type of kit ordered will depend on the materials the teacher already has in the classroom. Here is one example:

***Wisconsin Fast Plants*™ Plant Light House™ Package**

www.carolina.com

Plant Light House™

Growth and Development Classroom Kit

For a limited time, get both the Plant Light House™ and our most popular Growth and Development Classroom Kit for the special low price of just $99.00.

Welcome to the World of Biotechnology: It's Time to Eat

http://www.accessexcellence.org/AB/BA/DODpub/dodles1a.html

Council for Biotechnology Information

Materials for teaching this unit can be found in the publications section and downloaded:
http://www.whybiotech.com/index.asp?id=publications

- **Explore the Benefits of Biotechnology (PowerPoint)**
- **Good Ideas Are Growing - U.S. (Brochure)**

Supplemental Resources

Council for Biotechnology Information

Materials for teaching this unit can be found in the publications section and ordered at
http://www.whybiotech.com/index.asp?id=publications

- **Information Kit**

This CBI information kit contains a timeline of key biotechnology developments and short profiles of some plant biotech pioneers, as well as plant biotech facts and figures and frequently asked questions.

- **Understanding Biotechnology CD**

This multimedia presentation answers key questions such as what is plant biotechnology, how does it work, what are its benefits and is it safe. The presentation also explores the history of biotechnology and how it is regulated in the United States.

Lesson Plan

EB05.01 DISCUSS THE FUNDAMENTALS OF BIOTECHNOLOGY IN AGRICULTURE.

Activity	Steps	Comments
Biotechnology in Agriculture		• This article is provided as a teacher resource in providing an overview of agricultural biotechnology for students.
An Introduction to Agricultural Biotechnology	1. Provide students a copy of the handout. 2. Help students find classroom or Internet resources to find the answers to the questions in the handout.	• This handout is designed to introduce students to essential concepts about agricultural biotechnology. • The answers will vary depending upon the resource used. The recommended resource is *AgriScience Explorations*, 3rd Edition, by Morgan, Chelewski, Lee and Wilson. • This activity can be done in pairs.
Introduction to Biotechnology	1. Conduct the introductory lesson in Book One: *An Introduction to Biotechnology*.	• This curriculum guide supplement is an essential teacher tool for this course. Ordering information is provided on page E.2.
Super Seeds video	2. Have student watch the Super Seeds video. 3. As they watch the video, have them fill in the blanks on the Super Seeds Video worksheet.	• Ordering information is provided on page E.2. • At press time, the video was readily available from the A&E website. • This video serves as an introduction to the fundamentals of agricultural biotechnology.

EB05.02 ANALYZE BIOTECHNOLOGY AND PLANTS.

Activity	Steps	Comments
Wisconsin Fast Plants – Teacher Information	1. Purchase a kit and follow the directions for growing fast plants in the classroom. 2. While the plants are growing, students may continue with the other activities in this unit.	• Different kits are available for growing Fast Plants. Before beginning this activity, research information on the Carolina Biological Supply website as well as the Fast Plants website. There you will find detailed instructions, student activities, etc. • NOTE: Lesson 1 in Book One: *An Introduction to Biotechnology* includes lesson suggestions.
The Life Cycle of Fast Plants	1. Have students follow the directions as outlined in the activity.	• This activity could be done in a computer lab at school.
Plants Video – Bill Nye	1. Explain to students that they are working in pairs for this activity. 2. Have students take notes during the video. 3. In pairs, have them answer the questions on the activity worksheet.	• Ordering information for this video can be found on page E-2. • When students are told they will be working in pairs and sharing a grade, performance improves because two heads are better than one (in answering the questions) and some students try harder when they work in pairs.
Asexual Reproduction in Plants **Asexual Reproduction Matching**	1. Discuss asexual reproduction in plants. Give students a copy of the two-page handout to use as a guide during the discussion. 2. Have students follow the directions in the Asexual Reproduction Matching worksheet.	▪ Begin this lesson by talking candidly about the science of reproduction – sexual means that both male and female parts (sperm and egg) are needed to create an embryo – asexual means that only one organism is needed. ▪ NOTE: Lesson 3 in Book One: *An Introduction to Biotechnology* includes lesson suggestions.
Inherited Traits and Variation	1. Select activities from Lessons 5 and 6 in *An Introduction to Biotechnology.*	▪ The human trait information is also addressed in EB06.03.
Plant Made Pharmaceuticals	1. Select appropriate learning activities from the teacher information page.	▪ The information on Plant Made Pharmaceuticals is on page E.25.

EB05.03 INVESTIGATE WHEN VARIOUS TECHNIQUES OF FOOD BIOTECHNOLOGY WERE INTRODUCED.

Activity	Steps	Comments
Welcome to the World of Biotechnology: It's Time to Eat http://www.accessexcellence.org/AB/BA/DODpub/dodles1a.html	1. Go the Access Excellence website to print out the instructions and print materials for this activity. 2. Gather the materials needed for the activity. 3. Set up stations around the room for the 5 time periods. 4. Have students answer the questions presented for each time period.	• The website includes an answer key for the student challenge questions and additional information for teachers on the technologies presented in this activity.

EB05.04 ANALYZE THE PRODUCTION AND PROCESSING OF GENETICALLY MODIFIED FOODS.

Activity	Steps	Comments
Plant Biotechnology Information	1. Introduce students to this unit on genetically modified foods by helping them understand the similarities among: a. Plant biotechnology b. Agricultural biotechnology c. Crop biotechnology d. Food biotechnology e. Genetically modified foods	• The Council for Biotechnology Information contains excellent materials for downloading and use in the classroom. The web link is provided on page E.3.
Good Ideas are Growing – Brochure	1. Give students a print copy of the brochure or spend a class period in the computer lab. 2. As students study the brochure they should answer the questions on the worksheet.	• See page E.26 for web access information. • This assignment may be done in pairs. If so, the teacher should encourage students to discuss the questions before formulating their answers.
Benefits of Plant Biotechnology	1. Before showing the PowerPoint presentation from the Council for Biotechnology website, give students a copy of the worksheet and have them answer the first five questions. 2. Have students read the "After the Show" questions, then turn their worksheet over and carefully watch the PowerPoint. 3. After the show, have students complete the worksheet.	• See page E.26 for web access information. • The pre-show questions force the students to think about what they have already learned. • The "After the Show" questions are designed to measure the students' thinking and understanding of plant biotech concepts.
Considering the Nature and Issues of Food Biotechnology	1. Give students a copy of the print article or have them access the information from www.ncbiotech.org 2. Assign different parts of the article and have students create a poster to illustrate the information assigned.	• The student-created posters will illustrate the answers to important questions about plant biotechnology. • School administrators should be asked for permission to display the posters around the school in an effort to educate students and teachers about food biotech.

EB05.05 DISCUSS THE USE OF TRANSGENIC FARM ANIMALS.

Activity	Steps	Comments
Transgenic Farm Animals (Overhead Transparency Masters)	1. Introduce students to transgenic farm animals through the use of the overhead transparencies. 2. Encourage class discussion about the science of genetic engineering, and the benefits vs. the risks.	▪ If preferred, the teacher can convert the transparency masters to PowerPoint and create a slide show.
Transgenic Farm Animals – Puzzle	1. Have students fill in the blanks of the crossword puzzle.	● This can be a homework assignment.
Transgenic Animals – *Your World* magazine	1. Divide students into 6 teams. 2. Provide each team with an article from the Transgenic Animals edition of Your World magzine. 3. Give teams 15 minutes to discuss and analyze the article. 4. Have them “creatively” share the content of their article with the class.	● *Your World* magazine can be downloaded from www.biotechinstitute.org ● This activity should be fun and provide a creative opportunity for students.

RESOURCE INFORMATION: BIOTECHNOLOGY IN AGRICULTURE

Biotechnology
by Mathematics and Science Education Center
Biotechnology–Grades 5-6   0-7872-1638-0 $51.99

Grades 5-12: Biotechnology is a key part of a natural process, and students are challenged through hands-on activities and analysis

http://www.kendallhunt.com/elhi/paintTemplate

The curriculum supplement illustrated above is an important tool for this unit in providing classroom instruction. There are many activities to choose from in helping students experience agricultural biotechnology.

The following lessons from the guide are used in this course. Teachers will pick and choose the amount of the material to use from the guide, based on student needs and the time allotted for this competency.

Introductory Lesson: Used to introduce students to basic agricultural biotechnology.

Lesson 1: Plant Development

Lesson 3: Asexual Reproduction

Lesson 5: Inherited Traits

Lesson 6: Variation

Content

BIOTECHNOLOGY IN AGRICULTURE

The following information is from the Biotechnology Industry Organization at www.bio.org. The complete article, Agricultural Production Applications, can be found at http://www.bio.org/er/agriculture.asp

We have always relied on plants and animals for food, shelter, clothing and fuel, and for thousands of years we have been changing them to better meet our evolving needs. Society's demand for resources provided by plants and animals will increase as the world's population grows. The global population, which numbered approximately 1.6 billion in 1900, has surged to 6 billion and is expected to reach 10 billion by 2030. The United Nations Food and Agriculture Organization estimates world food production will have to double on existing farmland if it is to keep pace with the anticipated population growth.

Biotechnology can help meet the ever-increasing need by increasing yields, decreasing crop inputs such as water and fertilizer, and providing pest control methods that are more compatible with the environment.

Crop Biotechnology

Farmers and plant breeders have relied for centuries on crossbreeding, hybridization and other genetic modification techniques to improve the yield and quality of food and fiber crops and to provide crops with built-in protection against insect pests, disease-causing organisms and harsh environmental conditions. Stone Age farmers selected plants with the best characteristics and saved their seeds for the next year's crops. By selectively sowing seeds from plants with preferred characteristics, the earliest agriculturists performed genetic modification to convert wild plants into domesticated crops long before the science of genetics was understood.

As our knowledge of plant genetics improved, we purposefully crossbred plants with desirable traits (or lacking undesirable characteristics) to produce offspring that combine the best traits of both parents. In today's world, virtually every crop plant grown commercially for food or fiber is a product of crossbreeding, hybridization or both. Unfortunately, these processes are often costly, time consuming, inefficient and subject to significant practical limitations. For example, producing corn with higher yields or natural resistance to certain insects takes dozens of generations of traditional crossbreeding, if it is possible at all.

The tools of biotechnology allow plant breeders to select single genes that produce desired traits and move them from one plant to another. The process is far more precise and selective than traditional breeding in which thousands of genes of unknown function are moved into our crops.

Biotechnology also removes the technical obstacles to moving genetic traits between plants and other organisms. This opens up a world of genetic traits to benefit food production. We can, for example, take a bacterium gene that yields a protein toxic to a disease-causing fungus and transfer it to a plant. The plant then produces the protein and is protected from the disease without the help of externally applied fungicides.

Improving Crop Production

The crop production and protection traits agricultural scientists are incorporating with biotechnology are the same traits they have incorporated through decades of crossbreeding and other genetic modification techniques: increased yields; resistance to diseases caused by bacteria, fungi and viruses; the ability to withstand harsh environmental conditions such as freezes and droughts; and resistance to pests such as insects, weeds and nematodes.

Natural Protection for Plants

Biotechnology will also open up new avenues for working with nature by providing new *biopesticides,* such as microorganisms and fatty acid compounds, that are toxic to targeted crop pests but do not harm humans, animals, fish, birds or beneficial insects. Because biopesticides act in unique ways, they can control pest populations that have developed resistance to conventional pesticides.

Herbicide Tolerance

Using biotechnology, it is possible to make crop plants tolerant of specific herbicides. When the herbicide is sprayed, it will kill the weeds but have no effect on the crop plants. This lets farmers reduce the number of times herbicides have to be applied and reduces the cost of producing crops and damage to the environment.

Increasing Yields

In addition to increasing crop productivity by using built-in protection against diseases, pests, environmental stresses and weeds to minimize losses, scientists use biotechnology to improve crop yields directly. Researchers at Japan's National Institute of Agrobiological Resources added maize photosynthesis genes to rice to increase its efficiency at converting sunlight to plant starch and increased yields by 30 percent. Other scientists are altering plant metabolism by blocking gene action in order to shunt nutrients to certain plant parts. Yields increase as starch accumulates in potato tubers and not leaves, or oil-seed crops, such as canola, allocate most fatty acids to the seeds.

Environmental and Economic Benefits

Beyond agricultural benefits, products of crop biotechnology offer many environmental and economic benefits. Transgenic crops allow us to increase crop yields by providing natural mechanisms of pest control in place of chemical pesticides. These increased yields can occur without clearing additional land, which is especially important in developing countries. In addition, because biotechnology provides pest-specific control, beneficial insects that assist in pest control will not be affected, facilitating the use of integrated pest management. Herbicide-tolerant crops decrease soil erosion by permitting farmers to use conservation tillage.

Forest Biotechnology

Throughout the world, wood provides us with fuel, construction materials and paper, and its supplies are dwindling rapidly

Increasing Productivity

We are using biotechnology to create disease- and insect-resistant trees and to increase their growth rates. Scientists are also learning how to use biotechnology to improve the efficiency with which trees convert solar energy into plant material and to shunt more of that energy into wood production and less into pollen, flowers or seeds. All of these methods of increasing productivity should decrease the pressure on natural forests.

Animal Biotechnology

Animals are playing a growing role in the advancement of biotechnology, as well as increasingly benefiting from biotechnology. Combining animals and biotechnology results in advances in four primary areas:

1. Improved animal health through biotechnology.
2. Advances in human health through biotechnology studies on animals.
3. Enhancements to animal products with biotechnology.
4. Environmental and conservation efforts of biotechnology.

Increasing Livestock Productivity

Livestock producers are always interested in improving the productivity of agricultural animals. Their goal is to obtain the same output (milk, eggs, meat, wool) with less input (food), or increased output with the same input. Increasing muscle mass and decreasing fat in cattle and pigs has long been a goal of livestock breeders.

Using biotechnology to increase the productivity of livestock is a variation of selective breeding. We select individual animals that possess desirable traits, then, instead of breeding the animals, we collect eggs and sperm and allow fertilization to occur in a laboratory dish. This in vitro fertilization is followed by embryo culture, a form of mammalian cell culture in which the fertilized egg develops into an embryo. When the embryo is a few days old, it is taken from the laboratory dish and implanted into a female of the same species — but not necessarily of the same breed. This is known as embryo transplant.

Animal Biotechnology to Enhance Human Medical Applications

Animals are often used as models for research as many of the technologies developed for animals can also be transferred to humans. Some of the work being done with animals that will advance human health:

Xenotransplantation

Extensive research has been done to use animals as blood or organ donors for humans in order to address the worldwide human organ shortage for transplants.

"Pharm" Animals

- Transgenic animals, including cows, goats and sheep, now produce milk that contains therapeutic proteins that may be used to nourish premature infants or to treat emphysema, cystic fibrosis, burns, gastrointestinal infections and immunodeficiency diseases such as AIDS.

Aquaculture

Aquaculture is the growth of aquatic organisms in a controlled environment. The increased public demand for seafood, combined with the relatively small supply of aquaculture products provided by U.S. companies, has encouraged scientists and industry to study ways that marine biotechnology can increase the production of marine food products. By using biotechnology techniques, including molecular and recombinant technology, aquaculture scientists study the growth and development of fish and other aquatic organisms to understand the biological basis of traits such as growth rate, disease resistance or resistance to destructive environmental conditions.

Transgenic Salmon

Salmon enhanced through biotechnology have received much public exposure over the last year. Some of the biotech improvements being made with fish include:

- Some transgenic salmon reach maturity quickly and do not hibernate, which enables year-round availability of salmon.
- Researchers are trying to develop fish that are more resistant to disease, tolerant of low oxygen levels in the water and tolerant to freezing temperatures.
- Some species of fish naturally produce a protein that allows them to survive in the Arctic. This "anti-freeze" gene has been transplanted to other species of fish so they can survive in very cold waters.

Activity

Name_________________________________ Period______

AN INTRODUCTION TO AGRICULTURAL BIOTECHNOLOGY

Directions: Use classroom and Internet resources to find the answers to the following questions.

5. Can plants and animals be improved through the use of biotechnology? Why or why not?

3. In your own words, what is agricultural biotechnology?

4. Fill in the chart by describing the following plant procedures:

Cloning	
Tissue Culture	
Cuttings	
Grafting	

5. How are hormones used to help plants and animals grow better?

6. How is genetic engineering used in agriculture?

7. Describe each of the following benefits of biotechnology, and rank them on a scale of 1-5, how important you think the benefit is the society.

Benefit	**Description**	**Rank**
Reduce Pollution		
Improve Food		
Conserve Resources		
Reduce Hunger		
Improve Health		

Activity

Name________________________________ Period______

SUPER SEEDS VIDEO

Directions: Watch the "Super Seeds" video and answer the following questions.

1. Year after year, the hornworm caused Colombian farmers to lose _______% of their crop.

2. The "magic seed" Dr. Julia Kornegay dreamed of would:

A. ____

B. ____

3. Once the female bean weevil lays her eggs on the bean, it takes ________ days for the offspring to emerge.

4. There are over _______________ different beans preserved at CIAT's bean bank.
5. Hornworms can devour up to ____________% of a plant.
6. In their final stage, the cassava hornworms emerge as a ______________.
7. For over a century, the ______________ weevil has ravaged cotton fields in the South.
8. In 1958, the locust wiped out ________________ tons of grain in Ethiopia; enough to feed ____________________ people for 1 year.
9. More and more pests are developing _________________________ to chemical pesticides.
10. Wasps prey on __________________________ larvae.
11. A family of wasps can kill up to __________ hornworms in one day.
12. How did Dr. Kornegay test 10,000 types of beans for resistance to bean weevils?

____

____

13. The secret of the Arcelin bean's resistance to bean weevils lies in its _________.

14. In hybrid seed, ________% of genes come from the mother and ___________% come from the father.

15. Pollen comes from the __________________.

16. The female part of the plant that receives the pollen is the _________________.

17. Because of the Arcelin variety, bean yields have increased by ________ to _________ percent.

18. The Salicornia plant seeds produce an oil that is used for what? _____________

19. Biotechnologists at CIAT want to record the entire genetic makeup of cassava to identify the genes that could produce resistance to insects and ______________ and yield _______________ ____________________ ____________________.

20. Describe how natural germ warfare was waged against hornworms. __________

____

____

Answer Key

SUPER SEEDS VIDEO – ANSWER KEY

1. 20%
2. A. Expensive

B. Poison Good bacteria in the soil

3. 30
4. 26,000
5. 75
6. moth
7. boll
8. 160,000; 1 million
9. resistance
10. hornworm
11. 100
12. She placed adult bean weevils on the beans to see of they would lay eggs.
13. genes
14. 50; 50

15. stamen
16. stigma
17. 50; 100
18. cooking
19. drought; higher nutritional content
20. Insects with a disease were blended in a blender to make a liquid. The liquid was sprayed on the plants to spread the disease to other insects so they would die.

FAST PLANTS

Teachers may order "Fast Plants" from Carolina Biological Supply Company as noted below.

Wisconsin Fast Plants™ Plant Light House™ Package

https://www3.carolina.com/onlinecatalog/Templates/Default/mainscreen2frame.asp?workspace=home&button=home

Plant Light House™
Ideal for individual or classroom science projects, the Plant Light House™ is a compact growth chamber for Wisconsin Fast Plants™ and other plants up to 20" H. The chamber accommodates up to 64 Wisconsin Fast Plants™. It includes a height-adjustable light fixture with a compact, fluorescent, high-intensity bulb (27 to 39 W) and an adapter. With the addition of the Optional Butterfly Screen (WW-15-8994A), the Plant Light House™ can be converted easily to a butterfly box. The assembled dimensions are 16 1/2 × 16 1/2 × 20 1/2" H.

Growth and Development Classroom Kit
Our basic kit for growth and development, physiology, and tropism studies includes standard Brassica seed. Experiment times vary (40 to 100 days).

For a limited time, get both the Plant Light House™ and our most popular Growth and Development Classroom Kit for the special low price of just $99.00.

Wisconsin Fast Plants™ "Confetti" Kit

https://www3.carolina.com/onlinecatalog/Templates/Default/mainscreen2frame.asp?workspace=home&button=home

Your students will learn to observe, describe, and form hypotheses in this fun-filled, hands-on science kit. Our "confetti" mix of 8 or more different types of Wisconsin Fast Plants™ seed produces plants varying in height, color, and hairiness. Students measure, graph, name, and describe their own unique plants. Sturdy 1 1/2 × 2" plastic pots allow each student (or pair of students) to "own" a confetti garden of 2 to 3 plants. Kit includes detailed growing instructions, age-appropriate activities, and student worksheets. A lighting system is not included (see our WW-15-8998 Plant Lighting System). For 15 students working alone or 30 students working in pairs.

Pack "Confetti Mix"
Soil and Fertilizer
Watering Tray Plant Stakes and Rings
Pollination Materials
Wicks
5 Rulers
Seed (50)
15 Pots and Mat
5 Magnifiers
Plant Labels

WW-15-8692 $34.60 Per kit

Wisconsin Fast Plants Website
http://www.fastplants.org/home_flash.asp

Activity

Name_________________________________ Period______

THE LIFE CYCLE OF FAST PLANTS

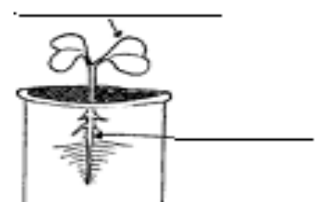
Go to this location: http://www.fastplants.org/resources/life_cycle.html and answer the questions below as you scroll through the Fast Plant Life Cycle.

1. What is the name for the tiny plant inside the seed?

2. What is a synonym for quiescent?

3. During germination, why does the seed coat crack?

4. Label the missing names on this picture:



5. Around day 4, why does the hypocotyl (stem) elongate or get longer?

6. What is another name for the tip of the plant where the leaves and flowers first appear?

7. What part of the plant allows food, water, and minerals to move throughout the plant?

8. Explain how plants breathe:

9. What is the purpose of chlorophyll?

10. CO_2 + LIGHT + WATER =

11. What is the name of the process described in the above equation?

12. What is the name of the part of the plant that protects the bud?

13. The female part of the flower is the _________________________.

14. The male part of the flower is the __________________ and each one is covered with millions of yellow, powdery ___________________ grains.

15. Why are bees and butterflies attracted to flowers?

16. What is another name for the seed pod?

17. What 2 things are needed for a fast plant seed to germinate?

THE LIFE CYCLE OF FAST PLANTS – ANSWER KEY

1. embryo
2. sleeping
3. The water makes it swell and crack.
4. cotyledon and root
5. To reach for light.
6. meristem
7. stems
8. They take up carbon dioxide and expel oxygen.
9. It turns leaves green and captures light.
10. carbohydrates (sugar)
11. photosynthesis
12. sepals
13. pistil
14. stamen; pollen
15. nectar (sugar)
16. fruit
17. water; warmth

Activity

Name________________________________ Period______

PLANTS VIDEO – BILL NYE

1. Plants take energy from the sun and make their own _________________.
2. Different types of plants make different types of ________________.
3. Plants take in carbon dioxide from the air and give off _________________.
4. The process of water + sunlight is ___________________________.
5. As plants grow, they take carbon dioxide from the air, light and water and make food and oxygen for us to _____________________.
6. ______________ is used to get animals to carry the seeds to some new place.
7. Dandelions use the _______________ to move their seeds around.
8. Fruit is the part of the plant where the ______________ are stored.
9. Cacti store water in their stems and pads and use it during periods of ______________.
10. Spines or needles on a plant are a form of _______________ for the plant.
11. Name a plant the grows without roots: ______________________________
12. If you burn yourself, oil from an _______________________ can help soothe the burn.
13. Chamomile tea, cinnamon and lemon help if you have a sore _______________.
14. Medicinal plants are those that contain natural chemicals that might be used in the treatment of __________________.
15. Most plants use light from the ___________, water from the ____________ and nutrients from the ____________ to make their own food.
16. Venus fly traps attract flies and trap them between the middle of their ______________.
17. ______________________ is a green chemical that plants use to trap sunlight.
18. Why do trees change color?

____

____

19. When water and CO_2 react, oxygen and ______________ are had.

PLANTS VIDEO KEY

1. food
2. sugar
3. oxygen
4. photosynthesis
5. breathe
6. fruit
7. wind
8. seeds
9. drought
10. defense or protection
11. algae, kelp, moss
12. aloe vera plant
13. throat
14. disease
15. sun, rain, soil
16. leaves
17. chlorophyll
18. They stop making chlorophyll when the days get shorter. When that happens, other colors come through.
19. food

Content

ASEXUAL REPRODUCTION IN PLANTS

Important points about asexual reproduction in plants:

- Asexual reproduction in seed plants is common.
- Asexual plant reproduction requires only one organism.
- The new plants have the same genetic structure as the parents.
- Seed plants use different methods of asexual reproduction.
- Asexual reproduction is not as complex and requires far less energy.
- Organisms that are genetically identical to their parent are known as **clones**.

Types of Asexual Reproduction

1. **Rhizomes**

Plants such as the grasses, cattails and sedges produce underground stems or rhizomes. Buds produced at the nodes develop into branches that stay underground or develop into aerial shoots. If the rhizome subsequently dies, a new separate plant will have been formed.

2. **Tubers**

Tubers are actually modified rhizomes. They are formed in such plants as Irish potatoes. They develop when specialized stem branches grow down into the ground and swell up with starch containing cells. Buds on the tubers will grow into new plants. Examine the potato tuber and note the buds which are commonly termed "eyes".

3. **Runners**

These are horizontally growing stems that produce few, if any, leaves. The stems, called runners, creep along the ground. The runners can be cut from the parent plant and new plants will grow. Examples: wild strawberry and spider plant

4. **Cuttings**

Cuttings involve vegetative plants that have been removed and rooted in soil or other suitable material. Cuttings are made from stems, roots or leaves. A cutting or piece of carrot root can develop into a new carrot if placed over a container of water. Examples: geranium, coleus, African violet.

5. **Bulbs**

Onions, chives and lilies winter in the form of a bulb. Each bulb has a very short stem which is surrounded by fleshy leaves. In the spring, the shoot apex begins to grow using the nutrients stored in the leaves. Examine the onion bulb and find the storage leaves and stem.

6. **Corms**

This structure is similar to bulbs except that there are no storage leaves. The nutrients are, instead, stored in the swollen stem. Examine the demonstration of the corm and compare it with the bulb. *Gladiolus* sp. and *Crocus* sp. produce corms.

7. **Cell Culture**

Sometimes just one cell can regenerate into an entire plant. One cell from a carrot taproot is put into a tube of water with plant nutrients. The one cell divides and forms a bunch of cells. Under special conditions, roots and leaves develop. The small carrot plant grows into a carrot identical to the carrot from which the one cell came.

8. **Tissue Culture**

Engineered cells of some plants, like petunias, tobacco and tomatoes, can readily be used to regenerate entire plants under sterile conditions. Tissue culture works when the cell culture returns to an undifferentiated state (callus). The process involves placing the engineered cells in an environment with special hormones and nutrients that encourage cell growth. Eventually the tissue culture forms leaves and roots and finally an entire plant.

Activity

Name________________________________ Period______

ASEXUAL REPRODUCTION MATCHING

Instructions: Read the following definitions, and match to the correct word listed below. Put the letter of the correct word in the blank. ONE OF THE WORDS WILL BE USED TWICE.

______ 1. New organism produced by asexual reproduction that is genetically identical (the same) as the parent.

______ 2. An underground stem that creeps and may develop roots at nodes along its length.

______ 3. Underground stems that are short, thickened and fleshy with one or more buds developing into shoots bearing leaves and flowers.

______ 4. Plants grown from stems, roots and or leaves.

______ 5. To make the cell return to an undifferentiated state and then produce a plant.

______ 6. Stems that creep along the ground and develop leaves and roots.

______ 7. The culture that can divide and form a bunch of cells and under special conditions can develop roots and leaves.

______ 8. Thickened portions of rhizomes or underground branches with buds.

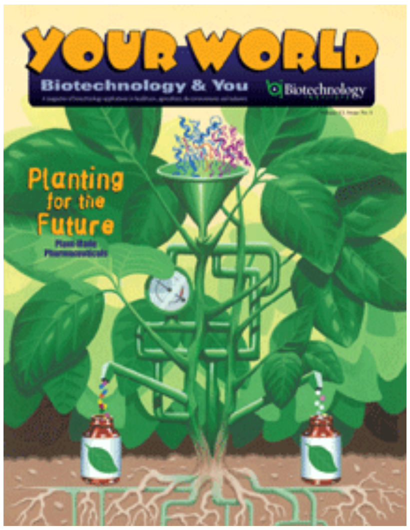
______ 9. A very short stem wrapped in thickened, fleshy bulb scales which can grow into a new plant.

______ 10. The method by which geraniums are asexually reproduced.

A. Tuber
B. Runner
C. Corms
D. Cell Culture
E. Clone
F. Bulb
G. Tissue Culture
H. Rhizome
I. Cuttings

Teacher Information

PLANT–MADE PHARMACEUTICALS



The subject of the fall 2003 issue of *Your World* magazine is Plant-Made Pharmaceuticals. Interest in this field is growing as scientists recognize the tremendous potential of using plants to manufacture useful proteins. It's one of the many aspects of biotechnology – the use of living organisms to benefit humanity.

The issue can be obtained as a free download from the Biotechnology Institute website at:

http://www.biotechinstitute.org/yourworld.html

This issue of *Your World* magazine addresses the following questions:

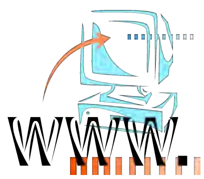
- What is involved in making plant-made pharmaceuticals (PMPs)?
- How are PMPs different from nutraceuticals and edible vaccines?
- Who can benefit from PMPs?
- Are plant-made pharmaceuticals safe and effective?
- How are policymakers dealing with PMPs?

A teacher's guide and activity supplement section are available on the Biotechnology Institute web site. In addition, the magazine itself includes instructions for a lab, "Microbial Bioassay" on page 15.

Activity

WELCOME TO THE WORLD OF BIOTECHNOLOGY: IT'S TIME TO EAT!

This comprehensive activity can be found at the Access Excellence website at
http://www.accessexcellence.org/AB/BA/DODpub/dodles1a.html



You will need to go to the website to print out the pages of the activity. When students complete this activity, they will understand when techniques of Food Biotechnology were introduced. All of the instructions, questions, answer sheets and support information can be found on the website.

Summary:

This activity serves as an introduction to the entire unit on biotechnology and food. Here, students will gain an appreciation for the age and diverse scope of biotechnology by observing applications to food items throughout a long history of humankind's utilization of living systems in food preparation and production. Stations will be set up around the classroom. At each station will be a food of a specific time period which has an associated biotechnology application. A brief description of the food/technology association and related questions for students will also be at each station.

Materials:

- The following are the foods suggested in this activity. However, there are many other appropriate examples.
  - B.C. time period: leavened bread
  - 1 A.D. –900 A.D. : peas
  - 900–1970: corn (hybrids are the focus here)
  - 1970–1996: milk
  - Future: tomatoes, peanuts, potato chips, popcorn (any or all of these may be represented for this time period)
- Additional materials needed are as follows. The Informational cards, Challenge questions, etc. can all be found on the website.
  - Paper plates, cups, bowls, and utensils as needed for each station.
  - Informational 3 x 5 card for each time period
  - Challenge Questions 3 x 5 card for each time period.
  - Student Answer Sheet
  - Teacher Additional Background Information Sheet

PLANT BIOTECHNOLOGY INFORMATION

Council For Biotechnology Information
GOOD IDEAS ARE GROWING

The website of the Council for Biotechnology Information has excellent resources for Plant Biotechnology. Teachers are strongly encouraged to browse this website before beginning to teach this unit.

The home page is http://www.whybiotech.com From there, the "Teachers and Students" like provides current articles on the field of Plant Biotechnology.

Materials for teaching this unit can be found in the publications section at http://www.whybiotech.com/index.asp?id=publications

If you wish to order copies of the publications - The Council for Biotechnology Information may provide up to 50 copies of a publication free of charge to organizations in the continental United States. To order bulk quantities, follow the link provided on the publications page of their website.

All of the publications can be downloaded from the website for classroom use. Those recommended include:

- **Explore the Benefits of Biotechnology (recommended)**

In this 55-slide PowerPoint presentation, learn how plant biotechnology can produce more and better food while helping to preserve the environment.

- **Good Ideas Are Growing - U.S. (recommended)**

This Council for Biotechnology Information brochure addresses the benefits that biotechnology provides to consumers, farmers and people in developing countries. It also contains information on the safety of food biotechnology and a timeline showing how food and agricultural biotechnology has evolved and developed.

- **Information kit (optional)**

This CBI information kit contains a timeline of key biotechnology developments and short profiles of some plant biotech pioneers, as well as plant biotech facts and figures and frequently asked questions.

- **Understanding Biotechnology CD (optional)**

This multimedia presentation answers key questions such as what is plant biotechnology, how does it work, what are its benefits and is it safe. The presentation also explores the history of biotechnology and how it is regulated in the United States.

Activity

Name________________________________ Period______

GOOD IDEAS ARE GROWING - BROCHURE

Directions: Answer the following questions using the information brochure provided.

1. List three benefits of plant biotechnology.
1.
2.
3.

2. Define plant biotechnology:

3. Name the person that was the first to understand genetics.

4. ___________________ carry the code that tell a plant what color it will be or how it will taste.

5. What was the very first commercial biotechnology product?

6. How many biotech crops have been approved for sale in the United States & Canada?

7. Name four ways that biotechnology crops are enhanced:
1.
2.
3.
4.

8. Describe the protein *Bt*:

9. Name 4 reasons farmers have embraced biotech crops:
1.
2.
3.
4.

10. "…six biotech crops planted in the United States…produced an additional ______ billion pounds of food and fiber on the same acreage, improved farm income by $_______ billion and reduced pesticide use by _______ million pounds."

11. When was the word biotechnology first coined and who was the person responsible for it?

12. What is the projected population of world for the year 2030? ______________
How many more acres of land will be needed to feed all these people if farm productivity doesn't increase?

13. Name 3 crops that researchers are currently working to make more hardy:
1.
2.
3.

14. Name 3 ways biotechnology food is better:
1.
2.
3.

15. Bananas are being used to develop a vaccine for what disease?

16. Where is lycopene found and why is it important?

17. In 1982, what biotechnology event happened?

18. Name 2 benefits of using conservation tillage:
1.
2.

19. Before foods developed with biotechnology can be marketed in the United States, there are _______ separate steps in the regulatory process that typically take _____ to _____ years to complete.

20. What is significant about the golden rice developed by German and Swiss scientists in 1999?

21. Name 3 regulatory agencies in the United States:
1.
2.
3.

22. When did the EPA renew regulation for *Bt* corn and cotton and site they do not pose any health or environmental risks?

Answer Key

GOOD IDEAS ARE GROWING - BROCHURE

1. Three benefits of plant biotechnology.
1. Boost yields
2. Improve livelihoods
3. Preserve the environment
2. Plant biotechnology is a process in which genetic information and techniques are used to develop useful and beneficial plants.
3. Gregor Mendel
4. Genes
5. Human insulin
6. 50
7. 1. Herbicide tolerant
   2. Pest resistant
   3. Virus resistant
   4. Stacked trait
8. Bt is a naturally occurring soil bacterium that wards off the European corn borer.
9, 1. Improve yields
   2. Cut costs
   3. Reduce spraying
   4. Save time
10. 4; 1.5; 46
11. 1919; Hungarian immigrant Karl Ereky
12. 8 billion; 4 billion
13. 1. Rice
    2. Sweet potato
    3. Papaya
14. 1. Healthier
    2. More nutritious
    3. Better tasting
15. Hepatitis B
16. Lycopene is found in tomatoes. Lycopene protects human tissue and could prevent breast and prostate cancers as well has heart disease.
17. In 1982 the first biotech plant was produced.
18. 1. Saved nearly 1 billion tons of soil
    2. Lower maintenance costs
    Other possible answers: Better habitats for animals; Saved nearly 306 million gallons of fuel
19. 9; 7; 10
20. Golden rice is fortified with beta carotene and it stimulates Vitamin A that can prevent some forms of blindness.
21. 1. FDA
2. EPA
    3. USDA
22. 2001

Activity

Name________________________________ Period______

BENEFITS OF PLANT BIOTECHNOLOGY

Directions: Before watching the PowerPoint presentation, answer the "Before the Show" questions below. Pay careful attention during the PowerPoint show, and think about the information being presented. When it is over, answer the "After the Show" questions.

Before the Show

1. What is plant biotechnology?

2. When (what year) do you think people started developing hybrid plants and flowers, and why did they do it? (What was their purpose?)

3. Can you list at least 3 biotech food products that you have probably eaten?

4. What country do you believe uses the most biotech crops?

5. Can you name at least one benefit of plant biotechnology?

After the Show

1. Can you list three benefits of plant biotechnology?

2. The National Research Council wrote "No conceptual distinction exists between genetic modification of plants and microorganisms by classical methods or by molecular techniques that modify DNA and transfer genes." If you were explaining this information to a friend, how would you state it in your own words?

3. Can you name at least 6 biotech products that are approved for commercial use in the United States?

4. Can you name at least two other countries that seem to embrace the use of biotech crops?

5. Why is the United Nations so interested in food biotechnology?

6. Can you name at least two examples of foods that are “improved” through biotechnology?

7. Can you name at least two government agencies that regulate the application of food biotechnology?

8. Name one thing you learned from reading the brochure that you understand more clearly after viewing this PowerPoint show.

9. What is one new thing you learned from watching this PowerPoint show?

Answer Key

BENEFITS OF PLANT BIOTECHNOLOGY

Actual answers may vary. The “Before the Show” questions are designed to get students thinking and should not be counted wrong. Give credit for all reasonable responses in the “After the Show” section.

Before the Show (Accept all responses)

1. What is plant biotechnology?

2. When (what year) do you think people started developing hybrid plants and flowers, and why did they do it? (What was their purpose?)

3. Can you list at least 3 biotech food products that you have probably eaten?

4. What country do you believe uses the most biotech crops?

5. Can you name at least one benefit of plant biotechnology?

After the Show

1. Can you list three benefits of plant biotechnology?
More food, better food, better for the environment

2. The National Research Council wrote “No conceptual distinction exists between genetic modification of plants and microorganisms by classical methods or by molecular techniques that modify DNA and transfer genes.” If you were explaining this information to a friend, how would you state it in your own words?
Evaluate individual response for accuracy

3. Can you name at least 6 biotech products that are approved for commercial use in the United States?
Canola, corn, cotton, papaya, potato, soybeans, squash, sugarbeets, sweet corn, tomato, etc.

4. Besides the United States, can you name at least two other countries that seem to embrace the use of biotech crops?
Argentina, Canada, China, Africa, India, etc.

5. Why is the United Nations so interested in food biotechnology?
Population growth in low income areas – more food needed to feed a growing global middle class.

6. Can you name at least two examples of foods that are “improved” through biotechnology?

Tomatos, soybeans, canola and rice = nutrition added
Coffee = decaffeinated

7. Can you name at least two government agencies that regulate the use of food biotechnology?

USDA, FDA, EPA, NIH

8. Name one thing you learned from reading the brochure that you understand more clearly after viewing this PowerPoint show.

Responses will vary

9. What is one new thing you learned from watching this PowerPoint show?

Responses will vary

CONSIDERING THE NATURE AND ISSUES OF FOOD BIOTECHNOLOGY

Reprinted with permission from the North Carolina Biotechnology Center, http://www.ncbiotech.org

North Carolina Biotechnology Center
a non-profit center moving biotechnology from the mind to the marketplace

Ever since humans began cultivating crops instead of hunting and gathering food, we have been genetically modifying our food. Until recently, this meant simply breeding crops with the best characteristics and saving those seeds to plant the next year.

As we've learned more about DNA - the molecule in every cell that gives the instructions for life - we understand better why some corn tastes sweeter and squash and other plants resist viruses. These traits are associated with genes, pieces of DNA that give a plant or animal specific traits. Today we can insert into a plant cell a gene that carries a beneficial trait. That gene can come from the same type of plant, from a different plant or even from an animal. For example, a gene from citrus fruit may allow potatoes to grow in soil with high acid levels.

These advances carry a lot of potential benefits for farmers, food processors, consumers and the environment. These advances also carry a lot of questions, from whether the technology creates new problems to whether it's right to "mess with Mother Nature." This brochure addresses some of these questions and illustrates the advantages that biotechnology brings to one of our most basic needs - food.

Overview of Food Biotechnology

Biotech food, also called genetically modified or genetically engineered, is grown from seeds that carry specific genes to produce desired characteristics. The first biotech food on the market, in the early 1990s, was a tomato that ripened on the vine and could be transported without bruising. Today, the products of agricultural biotechnology include plants that are protected from insects or are tolerant to herbicides. Biotech foods have now made their way onto our tables: more than a third of the corn and more than half of the soybeans in the 1999 U.S. harvest were grown from seeds produced using biotechnology.

As biotechnology crops and foods have proliferated, so have questions and concerns. European consumers - perhaps because of unrelated food scares about diseased beef and contaminated soda - are arguing to label biotech food or keep it out of stores.

U.S. consumers are starting to pay more attention to these issues. Concerns range from food safety to environmental impact. Ethical questions, including whether it is right to change the genetic makeup of a plant, also frame the debate. However, some objections that activists raise also apply to conventional crops grown with modern high-intensity agriculture.

Biotechnology is still the world's best hope for crops that are hardier, have a higher yield and are more nutritious. Individuals, governments, corporations and public interest groups must weigh the benefits and risks. The following facts provide a basis for further discussion.

Questions and Answers

Who benefits from biotech crops and food?

We all benefit from reduced food production costs. Farmers have reduced expenses, reaped higher crop yields, and used less pesticide, which is good for the environment. Future biotech crops will allow farmers to grow food in areas with poor soil or irrigation. New crops will also be more nutritious. Businesses that have developed biotech seeds make a profit. Consumers may soon be able to buy oils with reduced saturated fat, fruits with higher vitamin C and E levels, and rice with more protein and vitamin A to prevent blindness.

Are biotech foods safe to eat?

Yes. Biotech foods have been a safe part of our nation's food supply for nearly a decade. The 40-plus biotech foods reviewed so far by the U.S. Food and Drug Administration have proven to be as safe as conventional foods.

Are biotech foods different from traditional foods?

Biotech foods and crops look and taste the same as traditional foods and crops. The difference between the two is usually one or two genes out of tens of thousands in the entire plant. These few genes yield traits that are beneficial to the grower, the consumer or the environment, but they do not change the basic nature of the plant. By analogy, if a Chrysler owner puts a Toyota carburetor on his car, the Chrysler is still a Chrysler.

Are biotech foods labeled?

No. Some people favor labeling all biotech foods, but that policy would be difficult and costly to implement. Traditional and biotech crops are mixed in the food distribution system. Simple tests often can't distinguish between the two, so routine testing to determine if a food has been modified by biotechnology would be expensive and time consuming. Labeling is required for biotech foods only if a substance known to cause an allergic reaction is present or if a food's composition or nutritional content has been substantially changed.

Can biotech food cause allergic reactions?

A very small percentage of foods, whether traditional or biotech, can potentially cause allergic reactions in some people. The FDA screens for those effects. If a biotech food contains a gene from a food known to cause reactions, the company must label the food, unless it proves the product does not cause a reaction. Foods do not cause allergic reactions just because they are produced using biotechnology.

Will biotech foods create new allergies?

Biotechnology may actually help remove allergy-causing substances from food. Scientists are also working to identify these substances by their structure, so problems can be caught before any reactions occur. The FDA looks for these substances in any new food, whatever its origin. Using biotechnology to alter food may be safer than traditional breeding methods, which could accidentally increase natural toxins or allergens.

How does the government regulate biotech foods?

Three government agencies test and approve food regardless of the method used to breed the crops from which it comes. The FDA looks for harmful substances in food and ensures foods are safe. The U.S. Department of Agriculture and the U.S. Environmental Protection Agency investigate and monitor the potential agricultural and environmental impacts of biotech food crops.

How are the environmental effects of biotech crops regulated?

Companies must conduct extensive field tests to prove their crops won't damage the surrounding soil, water, animals or plants before they can sell biotech seeds to farmers. University and industry researchers continue to study the effects of biotech crops on the surrounding environment. Farmers have planted these crops commercially across the country for four years, including nearly 200 million acres in 1999, with no reports of significant problems.

Will herbicide-tolerant crops and insect-resistant plants lead to more chemicals in the environment?

The most common pesticide made by biotech plants is Bt toxin, a natural substance produced by bacteria found in soil and used by organic farmers for years. (See GM Corn sidebar.) Because the pesticide's repeated application is not practical for large-scale farming, the gene to produce it was incorporated into plants. U.S. farmers planting cotton modified to make Bt toxin used one million pounds less pesticide in 1998 than in previous years. Plants have also been modified to resist a weed-killing chemical that is much less harmful to the environment than older herbicides. For some crops the amount of herbicide can be reduced.

Will these new crops create insects, weeds or viruses that aren't controlled by chemicals?

When humans develop ways to combat pests - bacteria, weeds or insects - then a few pests with resistance to the treatment survive and reproduce. More than 100 weeds have already emerged that can survive the herbicides used liberally around traditional crops since the 1950s. To slow the evolution of bugs resistant to the Bt toxin pesticide, the EPA now requires farmers to plant a certain percentage of traditional crops alongside the biotech variety. Researchers continue searching for new ways to manage pests.

Are biotech foods natural?

Our traditional staple crops, such as corn, wheat, rice and soybeans, have been bred for greater quantity and quality for thousands of years. Today we continue this tradition of genetic modification using both conventional breeding practices and biotechnology techniques to insert specific genes for crop improvement. No food is completely natural except for wild berries, nuts, fish and game harvested from the wild.

Looking to the Future

The world's population is rapidly increasing, while a lower percentage of people farm now than ever before. We must ensure that the U.S. and the world have enough food, and biotechnology is one of several tools we can use. The greatest beneficiaries will be farmers in the Third World, where crops can potentially grow on less land, produce higher yields with less labor and thrive in places where they haven't before. Nutritional levels in food will rise. Risks, which are closely regulated in the U.S., have proven so far to be minimal, especially when measured against these compelling benefits.

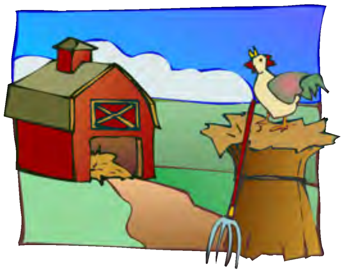
A Biotech a Corn Chip

FOOD BIOTECHNOLOGY POSTER - RUBRIC

Name ______________________________ Period ____________ Date ______________

Items Evaluated	Points Possible					Points Allocated
	Superior	Excellent	Good	Fair	Poor	
Educational Value						
a. The poster's impact on assigned topic (depth of content)	15	12	9	6	3	
b. Interpretation of food biotech issue (creativity)	15	12	9	6	3	
c. Poster contains a relevant message	15	12	9	6	3	
d. Information is clear, understandable and correctly spelled	15	12	9	6	3	
Quality of Work						
e. Imaginative and innovative design	15	12	9	6	3	
f. Arrangement is eye appealing	10	8	6	4	2	
g. Color and accent are used effectively	5	4	3	2	1	
h. Overall appearance is neat and attractive	10	8	6	4	2	
Total Possible Points	100	80	60	40	20	

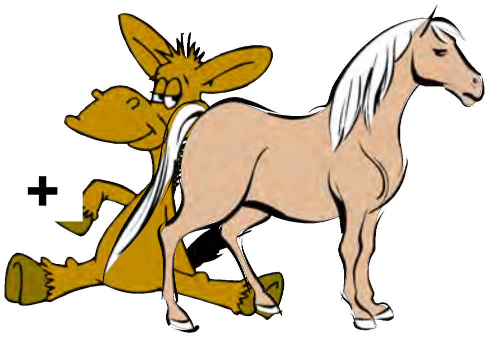
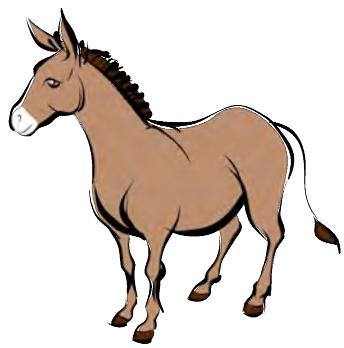
Adapted and used with permission from National HOSA – www.hosa.org



TRANSGENIC FARM ANIMALS

Before transgenic animals – selective breeding.

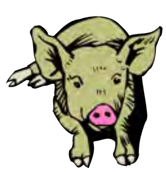
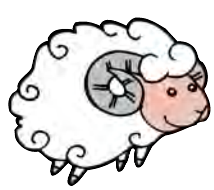
- Donkey + horse = mule

\+  = 

- Farmers have always bred stronger, larger, healthier livestock to produce better offspring

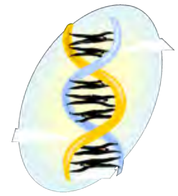
The first successful transgenic animal was a mouse in 1980.

Then came rabbits, pigs, sheep and cattle.

What is a transgenic animal?

An animal whose genome is changed to carry genes from other species.



Benefits of Transgenic Animals

- Larger sheep that grow more wool
- Cows that produce insulin in their milk
- Goats that produce spider silk for materials production
- Faster than selective breeding – larger herds with specific traits
- Cows that produce more milk or milk with less lactose or cholesterol
- Pigs and cattle with more meat

Future Benefits

- Disease resistant livestock
- Transgenic animals whose organs could be used for heart, liver or kidney transplants
- Milk to treat diseases such as phenylketonuria (PKU), hereditary emphysema, and cystic fibrosis.

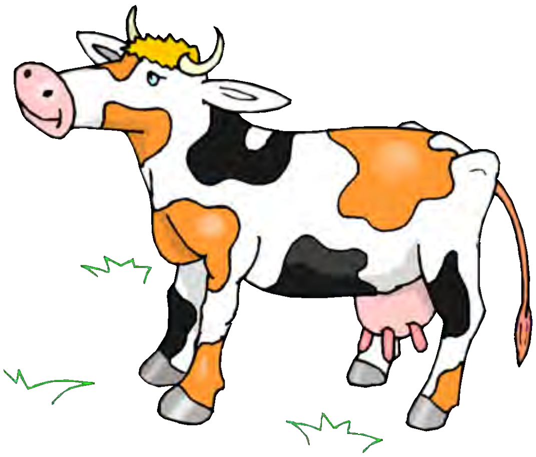
Herman Becomes a Father

"Biotech Notes." U.S. Department of Agriculture (June 1994)

- Herman, the transgenic bull who carries the human gene for lactoferrin, became the father of at least eight calves in 1994, and each one inherited the gene for lactoferrin production.
- Lactoferrin is an iron-containing protein that is essential for infant growth.
- Since cow's milk doesn't contain lactoferrin, infants must be fed from other sources that are rich in iron - formula or mother's milk.
- With the successful breeding of Herman and his progeny, however, a new source of nutritious milk may become available.
- This scientific advancement could have far-reaching effects for children in developing nations.
- Herman was genetically engineered in a laboratory at the early embryo stage.
- Scientists microinjected cells with the gene coding for lactoferrin. The scientists then cultured the cells in vitro to embryo stage and transferred them to recipient cattle.

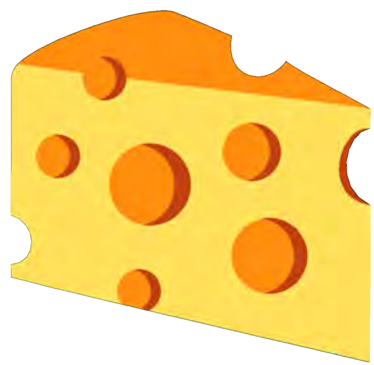
Better Cheese

To make cheese, milk is mixed with a protein called rennin. Rennin makes the milk curdle. It comes from the inside of a calf's stomach.



Biotechnology has changed the art of cheese-making by developing a new source for rennin.

In the near future, transgenics may allow us to genetically engineer cows so they make milk that curdles more easily and consistently. This could lower the price of cheese and improve the quality.

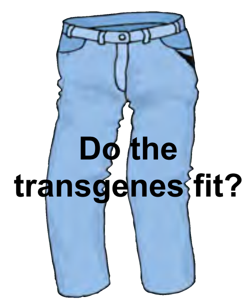


How are transgenic animals produced?

Through genetic engineering. Here are the steps:

1. We can change genes using recombinant DNA technology.

2. "Recombinant" comes from the word recombined – which is what we are doing when we cut a gene out of a strand of DNA and paste it into another strand of DNA.



3. The new, "different" genes are called transgenes.

4. We must then find a way to insert the transgene into an animal's reproductive cells.

5. The process is successful ONLY if the new gene is inherited in the animal's babies.

6. The most popular method is DNA microinjection

○ Eggs are fertilized and removed from the female animal

○ In the laboratory, the transgene is injected into the nucleus of a reproductive cell.

○ Ideally, the transgene will insert itself into a chromosome and become a permanent part of the genome. (Although it only works about 3% of the time.)

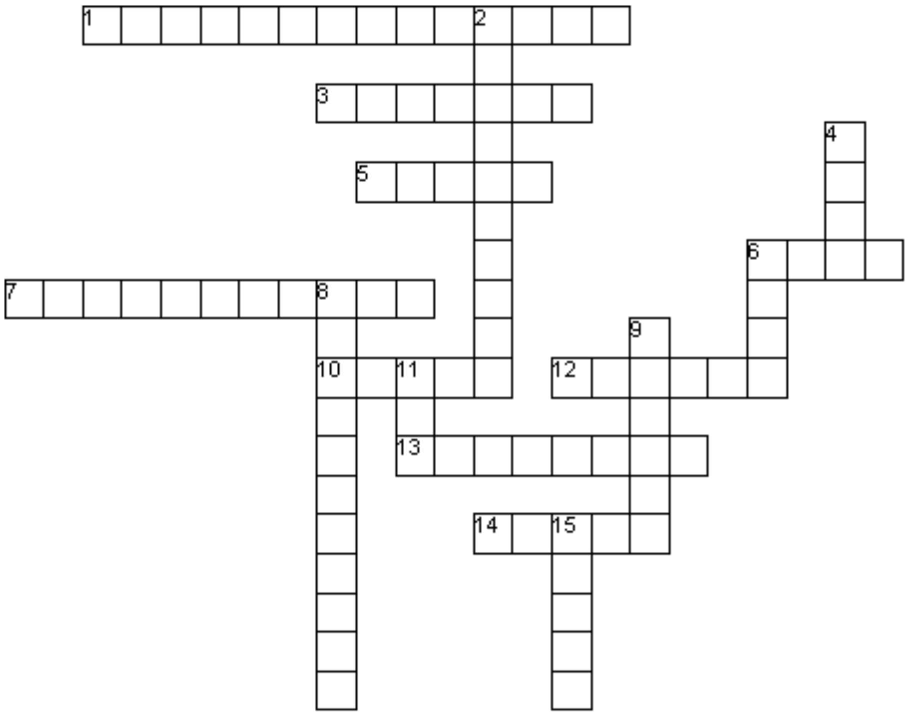
○ When the cell develops to a certain embryonic phase, it is transferred to the female animal where it develops until birth.

7. When we successfully create a transgenic animal, future offspring will inherit the new trait through normal reproduction.

Activity

TRANSGENIC FARM ANIMALS - PUZZLE

Complete the puzzle using the clues shown below.



Across

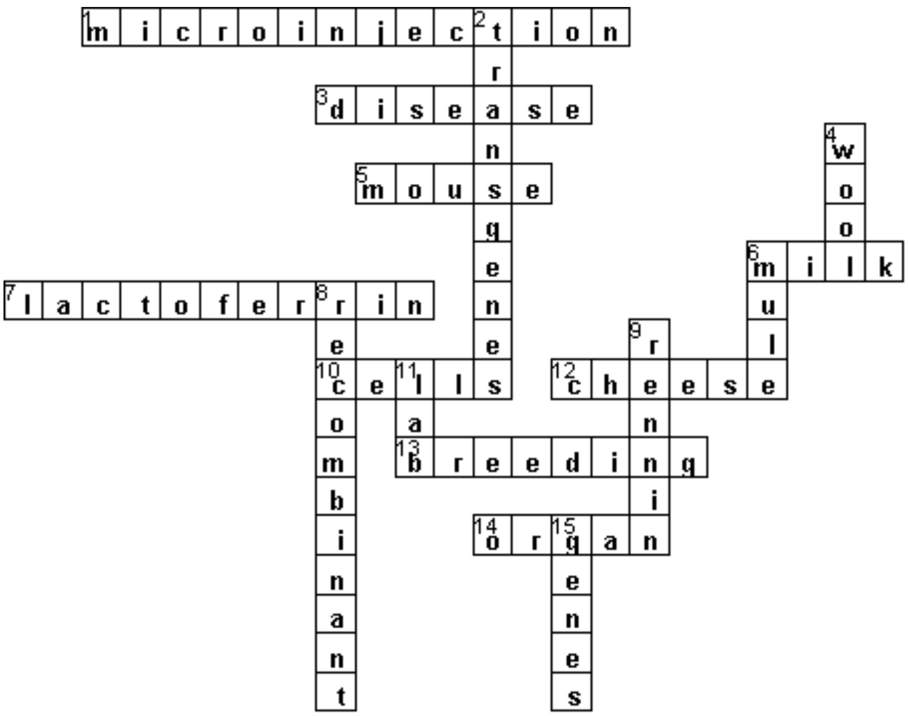
1. A popular method of genetic engineering.
3. In the future, livestock may be produced who are ____-resistant.
5. First transgenic animal.
6. Transgenic cows may be able to produce low cholesterol _____.
7. An iron-containing protein that is essential for infant growth.
10. Transgenes can be inserted into an animal's reproductive _______.
12. Rennin is needed to make this.
13. Before transgenics there was selective ____________.
14. Future transgenic animals may be used for _____ transplants.

Down

2. Different genes.
4. Larger sheep can grow more of this.
6. Bred from a donkey and a horse.
8. We change genes using _________ DNA technology.
9. Makes milk curdle.
11. The place where genetically engineered animals are made.
15. A transgenic animal carries _________ from other species.

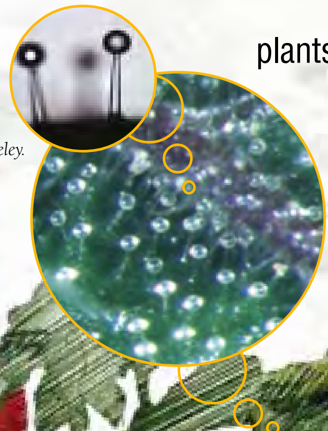
Answer Key

TRANSGENIC FARM ANIMALS - PUZZLE



Creating Better Plants

Plants live in a hostile world. Animals chew them, insects chomp them, pushy plants surround them, and disease withers them. But plants are not helpless. They make oils, smells, and poisons to fight back.

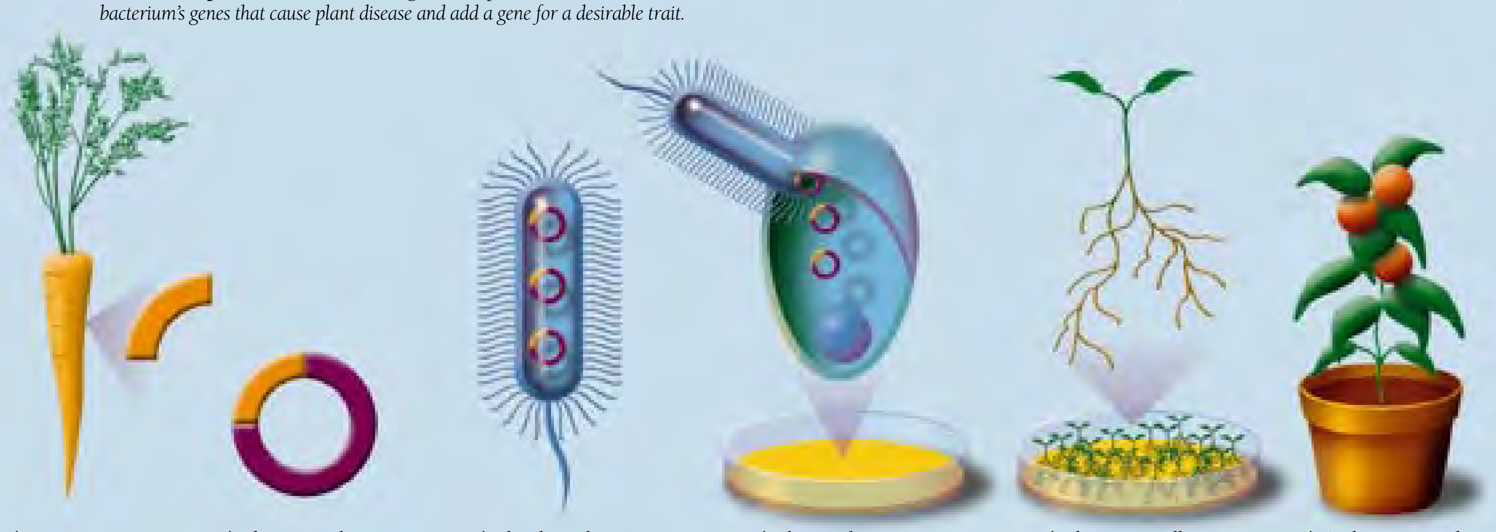


Photos courtesy of Shelia Colby, University of California, Berkeley.

If you look at a leaf of a tomato plant under a microscope, you'll see the leaf is covered with tiny hairs. These hairs emit chemicals that act like flypaper to trap little insects. How did this insect-fighting trait come about?

Creating a Vitamin-Rich Tomato with a Carrot Gene

The bacterium Agrobacterium *naturally infects plants. It carries some genes on a circular piece of DNA called a* **plasmid** *and inserts those genes into plant cells. Scientists are now able to remove the bacterium's genes that cause plant disease and add a gene for a desirable trait.*



1) *Scientists copy a carrot gene that converts a pigment to beta-carotene.*

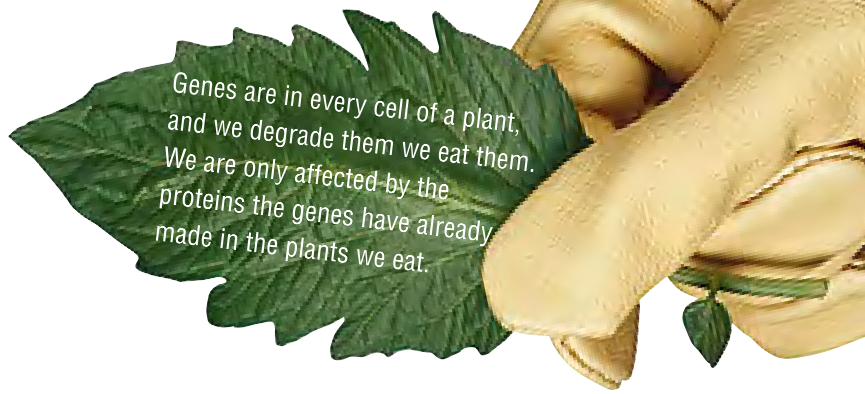
2) *They insert the carrot gene into a plasmid.*

3) *The plasmid is reintroduced into the Agrobacterium.*

4) *The Agrobacterium transfers the carrot gene to the cells of tomato leaves in a petri dish.*

5) *The tomato cells grow and divide in a culture with hormones that encourage the cells to become new shoots and roots.*

6) *As the tiny new plants grow, the carrot gene converts the tomato's pigment into beta-carotene, creating an enhanced tomato.*



Natural Selection

Wild tomatoes may have developed these tricky leaf hairs by chance. To reproduce, plants pollinate each other. In doing so, they exchange ***genes*** – the molecular instructions that produce different traits. The offspring have a different combination from either of their parents. Occasionally, genes undergo ***mutations*** (changes) during this mix. One such change made the leaf hair cells produce the sticky insect-fighting proteins. This mutation gave that plant an edge over others, so it passed its insect-resistance on to new generations.

Selective Breeding

Along came the age of farming, and people noticed the insect-resistant tomato. They selected it to pollinate other tomatoes, such as those with bigger fruits. To understand selective breeding, imagine that a gene is a book in a library. Different tomatoes have different versions of certain books. One plant may have a book for the insect-trapping flypaper. Another plant may have a book that makes big fruits. If a farmer cross-pollinates these two plants, eventually one offspring might combine both traits. But genes don't mix individually; they come "linked" with other books on their shelves. The big fruit book may come linked to a sour fruit book. Getting rid of that sour book might take generations of selective breeding, if it could be done at all.


Photo courtesy of Scott Camazine, Penn State University, Department of Entomology

Selective breeding has given us a huge variety of plants. Over time, cultivated varieties have little similarity to the original wild plant. For example, early Native Americans cultivated corn from a wild grass called teosinte. Carrots were yellow until a mutation created an orange one in the 1700s. Two thousand years ago a single gene mutation in a peach produced a nectarine. Observant farmers selected these pleasing surprises and bred them.

Discoveries Behind Genetic Engineering

The door to genetic engineering opened when scientists realized that all genes are written in the ***universal language of DNA***. Learning to use ***plasmids*** (see illustration) and special "cut and paste" proteins called ***restriction enzymes*** allowed them to "edit" DNA. Now, plant ***genomics*** is cataloging genes that could give plants beneficial traits, as well as genes we could eliminate to make food safer. (See box on page 7.)

Hybridizing Plants

Selective breeding has limitations. You can only breed tomatoes with closely related plants. What if you want a tomato with a trait found in a distant relative? Wild tomatoes, which are like little berries, can fight off a soil bug that attacks the roots, but many wild varieties can't pollinate modern tomatoes. Scientists broke the pollination barrier by combining their germ cells and nurturing them in a laboratory tissue culture. They produced a ***hybrid*** (mixed) tomato with the ability to repel soil bugs.

Inducing Mutations

Cross-pollinating and hybridizing depend on natural variations, and plant breeders search the world for useful traits. To entice more variations than nature provides, scientists zap seeds with radiation and chemicals. Occasionally this method produces a desirable variety, such as a bean that grows as a bush rather than a vine.

Think about it!

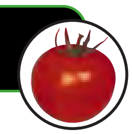
Is genetic engineering a logical continuation of the way farmers have been modifying food for centuries? Or is it an entirely new – and perhaps risky – process?

Genetic Engineering

All these methods give us some control over plant breeding, but they are time-consuming, trial-and-error processes. Since the 1980s, genetic sciences have made plant breeding more quick and precise – and expanded its reach. ***Genomics*** (the study of an organism's entire genetic instructions) is identifying genes that produce specific traits. Before, scientists didn't know which book gave the tomato leaf its sticky compound that traps insects. Now, they can pinpoint the exact book for the flypaper goo. They can pick that book off the shelf, copy it, and put it in other plants. In this way, they make a ***genetically modified*** plant. Scientists can borrow books from unrelated species to get traits like disease resistance, faster growth, better flavor or nutrition, or longer shelf life.

For example, tomatoes have a pigment that gives them their bright red color and special flavor. Carrots produce a protein that could turn that pigment into ***beta-carotene***, which our body turns into vitamin A. The illustration on page 4 shows how scientists used the "natural" genetic engineer, a bacterium called ***Agrobacterium***, to modify a plant. Another method coats a tiny gold pellet with genes and shoots it into plant cells that then grow into plants.

Career Connection: Plant Breeder: *Develop new plant varieties with needed traits.*



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Making the Most of Genetic Engineering

Certainly one of the greatest successes of genetic engineering has been the insertion of genes from a bacterium called *Bacillus thuringiensis* that code for production of insecticidal proteins into the chromosomes of various crops. The resulting transgenic cotton, corn and potato plants contain bacterial genes. These plants produce insecticial proteins from seedling stage until harvest, effectively protecting the crops from specific pests without disrupting beneficial insects or wildlife. Insecticide use on these so-called Bt crops is reduced, which saves farmers money and helps protect the environment. But as is the case with other insecticides, insect pests can evolve resistance to Bt proteins. If that happens, farmers will lose a powerful tool and may have to return to conventional insecticides to protect their crops.


Dr. Fred Gould

For 17 years, Dr. Fred Gould, William Neal Reynolds professor of entomology, has been studying how insects evolve resistance to Bt proteins and looking at ways to decrease the risk of rapid pest adaptation to Bt toxins. Indeed, Gould was among the first to show that insects could adapt to Bt crops. The detailed research findings of the Gould lab have been instrumental in convincing the Environmental Protection Agency and industry that there are ways to get long-term benefits from Bt toxin-producing crops. One of these ways is the planting of what have become known as refuges of non-Bt crops, crops that are susceptible to insect attack. Refuges help prolong the useful life of Bt crops by ensuring that an insect population continues to contain individuals susceptible to the Bt toxin. If these susceptible individuals breed with the initially rare, resistant insects, they can substantially decrease the rate at which the entire pest population becomes resistant. Most recently, Gould was involved in a study that suggested that late in the season, a large percentage of cotton bollworms, a major pest of cotton, are developing on plants like corn rather than on cotton, as had been thought. This work indicates that, at least for the bollworm, there are normally occurring refuges for susceptible individuals, so less cotton acreage needs to be devoted to non-Bt cotton.

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