Agriculture and Related Biotechnologies

Student Guide
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Agriculture and Related Biotechnologies

Preface

This is a nine week unit of study designed to explore agriculture and related biotechnologies. You will explore relationships between these technologies and begin to understand how they may influence your life. You will also use various resources and examine the issues associated with the use of each. As with any technological design, constraints and trade-offs must be considered and potential risks must be evaluated before proceeding to the next step. Finally, you will utilize a variety of technologies throughout this unit.

Key Concepts

- Technological Spinoffs
- Issues about Resources
- Constraints and Trade-offs
- Evaluating Risks
- Technological Utilization

Learning Unit Goal

The Learning Unit Goal provides a target for the Agriculture and Related Biotechnologies Learning Unit. As you complete this unit, you will be able to:

Describe and demonstrate how technology has changed the science of agriculture, particularly the ways in which technology is used to measure and control the yield of crops.
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A Look at the Learning Unit Basics

In this Learning Unit and throughout the ProBase curriculum, you will find graphical keys to help you navigate within the module. Each Learning Unit consists of a Preliminary Challenge, a Primary Challenge, and several learning cycles.

The Preliminary and Primary Challenges

Each Learning Unit consists of a Preliminary Challenge, which readies the student for the learning cycles that follow. The Primary Challenge poses a larger, more robust challenge. Students should be able to solve the Primary Challenge by the end of the Learning Unit.
The Learning Cycle

There are four phases of each learning cycle, each actively engaging technology and yourself.

Explore concepts and principles through hands-on activities.

Answer questions, journalize, and connect concepts from Exploration to the Primary Challenge.

Apply concepts and principles from Exploration through appropriate activities.

Expand concepts to global situations as well as the Primary Challenge. Careers related to the context and the learning cycle may also be explored during this phase.

Take time to return to the Primary Challenge and apply what you have learned during each learning cycle to help you solve the Primary Challenge.
AS A PROBLEM-BASED CURRICULUM, the ProBase Learning Units offer a variety of opportunities to engage in design activities. When asked to solve a design-based problem during the Learning Unit, it is suggested that you use the following design model adapted for the ProBase curriculum from *Standards for Technological Literacy* (International Technology Education Association, 2000/2002).

The design loop is what designers and engineers use to guide their thinking while developing solutions to problems. Although it is used in many different variations, the strategy of using a design model or loop can help reduce the chances of a faulty or inadequate design solution. The “loop” aspect of the design process will assure periodic feedback so that the proposed solution will continually be re-evaluated and designed to meet changing needs. The design loop also helps designers solve problems in a logical and effective way by following a series of steps.

Once a problem becomes apparent, the complete nature of the problem is clarified and understood in order to create a complete solution. After the problem is identified, the parameters involved in solving the problem are established and outlined. Some typical parameters include the availability of resources, the technical expertise needed, and the amount of money available. After the problem and the parameters are clarified, the next step in the design loop is to begin brainstorming and identifying multiple potential solutions to the problem.

The solution that best meets both the problem and the parameters is chosen (or a solution is created from condensed and combined ideas). The selected solution is refined and fully developed and then tested and evaluated to determine if it meets the parameters and solves the problem. If refinements are necessary they are made, then the solution is tested and evaluated again. After the problem is believed to be solved, the solution is presented. If other problems or feedback concerning the solution occur the loop starts over again.
Preliminary and Primary Challenges
BIOTECHNOLOGY IS A TERM THAT HAS DIFFERENT MEANINGS for different people. Some think that biotechnology is about new medicines and vaccines for people. Others think that it means working with DNA. Biotechnology also makes people think of controversial topics such as human cloning, genetically modified foods, or stem-cell research. Which of these concepts do you think is correct? After all, a new vaccine and a cloned sheep are very different things. Or are they?

None of these concepts are wrong. They are just incomplete. The fact is that biotechnology is really all of these things. The field of biotechnology is so large, complex, and fast-changing that it is difficult to accurately define. A simple definition of biotechnology is the application of biological knowledge and techniques to develop products and complete processes. Biotechnology is used in many different fields, including medicine, forensics, and agriculture. Biotechnology involves many different procedures, applications, and techniques such as plant and animal breeding, fermentation and enzyme purification, and recombinant DNA technology; thus, it is difficult to pinpoint one clear definition.

**Key Terms**

**Fermentation:** Process where microorganisms are used to aid in the production of foods such as cheese, bread, beer, wine, and yogurt, as well as other products such as ethanol fuel.

**Enzyme Purification:** Process where a single enzyme (a protein that causes a chemical reaction) is extracted from cells, tissue, etc. which may contain more than 1,000 different enzymes. Each enzyme requires a specific strategy for purification.

**Recombinant DNA Technology:** Techniques for cutting apart and splicing together different pieces of DNA into a foreign cell in order to mass produce the protein encoded by the inserted gene.
Although these applications may seem abstract, biotechnology greatly impacts our daily lives through its ever-growing commercial and industrial use. Biotechnology affects the food we eat, the medicine we take, and the products we buy. The impact of biotechnology on our lives is certain to become even more pronounced in the future. A good understanding of the field is important, not only to be informed consumers, but also potential contributors.

The basis for all scientific research, especially within biotechnology, is the scientific method. The fundamental element for the scientific method is the principle of cause and effect, which asserts that everything has a cause. By determining and understanding the cause, the effect can be changed or manipulated. Scientists learn as much as possible about the issue or problem in order to form a hypothesis about its cause. The hypothesis is then tested through experiments that either support or challenge it. If revision is necessary, the hypothesis is revised and retested until it will withstand the scrutiny of others. A hypothesis that has been accepted by the scientific community is referred to as a theory and is accepted unless new information is uncovered.
In the following Preliminary Challenge activity, you will have the opportunity to use a procedure that is the basis of most biotechnology applications, DNA isolation. You will be working at the same level that most biotechnology researchers work, the cellular level. Much of the research and methods in biotechnology involve the modification of genetic materials of living cells so they will produce new substances or perform new functions. The procedure used to isolate the DNA from a cell, for example, is required to develop new products or procedures within many different fields.

As you may have learned in biology class, cells are the fundamental working units of living organisms. The instructions for each cell are contained within the DNA, which is made up of the same chemical and physical components or amino acids (base pairs of four different nucleotides: adenine, cytosine, guanine, and thymine) as in all organisms. The order and placement of the amino acids on the DNA strand, however, determines the unique traits of each particular organism. Biotechnology has enabled researchers to isolate and identify an organism’s DNA sequence. The Human Genome Project, for example, announced in 2000 that it had completed the first working draft of the entire human genome.
Because technologies have enabled researchers to work at the cellular level, many different products and methods have been developed. Forensic scientists, for example, now use DNA “fingerprinting” to identify criminals. Each individual has a unique DNA sequence that can be recovered from cells found in tissue from blood, hair, or skin samples. Following a set procedure, researchers can extract and analyze the DNA found within the tissue and compare it to another sample to determine a match. In the following activity, you will follow many of the same procedures forensic scientists and other biotechnology researchers use to extract DNA.

In groups of four, obtain the following from your instructor:

- Measuring instruments/cylinders: 6 mL and 30 mL
- Small beaker or test tube
- 10 mL pipette
- (6 mL) ice cold 95% ethanol
- Thin wire (with one end bent into a loop)
- (6 mL) onion, detergent/salt solution

Your instructor will blend the onion and the detergent/salt solution together and, after straining the mixture, will add a meat tenderizer solution. Each group will then receive 6 mL of the mixture in a test tube or beaker.
Each group will need to carefully pour about 6 mL of the ice cold ethanol down the side of the tube to form a layer on top of the onion mixture. Let the mixture sit undisturbed for two to three minutes until the bubbling stops. The DNA should float in the alcohol that is sitting on top of the mixture.

Everyone in the group should examine the DNA and sketch below what the DNA looks like.
Reflection

Answer the following Reflection questions in the Inventor’s Logbook spaces provided.

1. Why did the DNA separate from the onion mixture?

2. What role did each of the following materials play in the experiment:
salt, ethanol, and detergent?

3. Why do you think an onion was used for the experiment?

4. Besides the examples provided, how could DNA isolation be used to
develop a product? How could it be used in a procedure?

5. What benefit could DNA isolation have in the field of agriculture?
Half-Buried Treasure

Imagine going on a modern-day “prospecting” trip in Africa. You land in Nairobi, the capital of Kenya, and then take a small plane out into the wild. After a bumpy landing on a dirt airstrip, you hire a local driver to guide you in your search. You will spend the next several days hunting with a shovel and a pair of binoculars. In one week, the plane will return to pick you up. If you are lucky, you will fly back home with a case full of samples. If not, you will have to try again.

What might justify this sort of searching? Other prospectors have hunted all over the world for such things as minerals, oil, gemstones, and other valuable resources. In this case, you were searching for something potentially much more valuable . . . plants.

That’s right! Plants are far more valuable than many people believe. We eat them, make clothing out of them, and grow them for their beauty. Plants also provide the oxygen that we breathe and raw materials for our houses. Some plants have medicinal properties that can be used to treat illness. Biotechnology aids in the research, identification, and manipulation of plants for multiple uses.

Unfortunately, plants are disappearing from the earth at a very fast rate, largely due to increased urbanization. For example, one-eighth of the world’s plant species are threatened with extinction, including thousands in North America. Botanists are racing to understand more about threatened plant species before it is too late.
The World Conservation Union, for example, has for the past several decades compiled a database known as the Species Survival Commission’s (SSC) Red List Programme. The Red List identifies and documents those species in danger of global extinction. Some plants, however, become extinct before they are placed on the list, and some are extinct before they are discovered by humans. A plant containing a cure for cancer could be disappearing right now as a farmer plows a field or a new subdivision is built on undeveloped land. Once a plant reaches extinction it is too late.

Many species of plants can be easily propagated (reproduced) by traditional methods, but this requires large quantities of plant material. In some cases, plants are so rare that only a small number exist. In those cases, only a small sample can be taken out of the wild. Your challenge is to find a way to reproduce a large number of plants from a small sample of plant material.
Design Challenge

Cloning of Plants

Your team must design techniques and equipment to grow as many new plants as possible from a very small amount of original plant material. You must follow precise scientific methods and standards to guard against contamination and to provide the highest chance of success. Starting new plants requires an extremely sterile environment. Otherwise, the plants will grow mold and die.

You must also develop a way to control the environment in which the plants are grown. The environmental factors that need to be controlled may include light, nutrients, plant hormones, temperature, pH, CO₂, humidity, and most importantly, sterility. Controlling these factors will also enable you to manipulate and test how plants react to different growing conditions.

Constraints/requirements

Your designed solution must:

• Include a technique to produce new whole plants from your small sample of plant material.

• Produce as many healthy plants as possible from your small sample of plant material.

• Include a created environment that will give your plants the greatest chance of replicating. Your created environment must:
  - Include methods to regulate as many environmental variables as possible.
  - Fit on a tabletop, desktop, or other space indicated by your instructor.

• Contain a photo-laboratory journal, which documents the procedures and progress of your plants with photographs.

Key Terms

Callus: Undifferentiated tissue that forms over the surface of a wounded or cut area of a plant or tissue culture.
# Primary Challenge Rubric

Name:  

Date:  

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<th>Element</th>
<th>Criteria</th>
<th>Points</th>
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<tr>
<td><strong>Primary Challenge Completion</strong></td>
<td>Followed all procedures and addressed all criteria, parameters, and equipment specifications set forth in the Primary Challenge.</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Followed all procedures and met most criteria, parameters, and equipment specifications set forth in the Primary Challenge.</td>
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<tr>
<td></td>
<td>Made a serious attempt to solve the Primary Challenge but did not follow procedures and did not address many of the stated criteria, parameters, or specifications.</td>
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<td></td>
<td>Did not complete procedures and did not meet the stated criteria, parameters, or specifications.</td>
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<th>Point Values</th>
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<tr>
<td><strong>Drawings, Diagrams &amp; Sketches</strong></td>
<td>Drawings, diagrams, or sketches clearly illustrate an understanding of all requirements, criteria or specifications, and used proper format.</td>
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<td>Drawings, diagrams, or sketches illustrate needed information, but do not address all stated requirements, specifications, or criteria.</td>
<td>10</td>
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<tr>
<td></td>
<td>Drawings, diagrams, or sketches illustrate needed information, but do not address all stated requirements, specifications, or criteria.</td>
<td>5</td>
<td></td>
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<tr>
<td></td>
<td>Drawings, diagrams, or sketches do not illustrate all needed information. Illustrations are incomplete or poorly presented.</td>
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| **Documentation** | As directed, the team responded to questions and/or maintained comprehensive records, logs, and other notations of activities while completing the Primary Challenge. | 15 |
|                   | Team responded to questions and/or maintained topical records, logs, and other notations of activities while completing the Primary Challenge. | 10 |
|                   | Team responded to most questions and/or maintained some records, logs, and other notations of activities while completing the Primary Challenge. | 5  |
|                   | Team marginally responded to questions and did not maintain records, logs, and other notations of activities while completing the Primary Challenge. | 2  |

**Total Points**
Learning Cycle One

Unnatural Selection
Introduction

Biotechnology is a cutting-edge field that will continue to have a huge impact on your life. Amazing new developments regularly make the news. To a casual observer, biotechnology might seem like a brand new science. However, the foundations for biotechnology go back thousands of years. Certain practices that are now classified as applications of biotechnology have been used by people for centuries. Our ancestors produced cheese and bread using a common biotechnology process known as fermentation thousands of years ago. Fermentation allowed people to manipulate certain conditions and improve the quality and yield of the food and drinks they produced.

Agricultural applications of biotechnology have also been in use for centuries. The cultivation of crops by early farmers was manipulated by the practice of selective planting. Farmers found they could increase the yield and improve the taste of crops if they selected the seed from desirable plants. This practice progressed into the manipulation of plants through breeding for desirable traits.

For example, not many people know that most carrots are naturally white, not orange. Hundreds of years ago, farmers carefully bred carrots to produce the bright orange colors that people thought were more attractive. Today, it would be very difficult to find a white carrot at the supermarket!

Farmers and plant biologists have developed other ways to change the traits of biological organisms, most notably, plants. This section will introduce you to some of the most important tools used to change plant traits: selective breeding, cloning or vegetative propagation, and genetic modification.
Changing the traits of plants requires some basic knowledge of how plants grow. Over long periods of time, plant species will adapt at the cellular level, through a process called natural selection, to enhance survival and reproductive success. Those qualities that are unnecessary or harmful to the plant’s survival are naturally removed from the plant’s genetic make-up over an extended period of time. For example, some desert plants have reduced their leaves to the point that the stem is the primary photosynthetic organ instead of the leaves. An understanding of this process at the basic level allowed for selective breeding to be successful. A more in-depth understanding has also allowed for successful genetic modification procedures.

Some people argue that the recent advances in agricultural biotechnology are just a simple continuation of the fermentation, selective planting, and breeding techniques that humans have been using for generations. Other people claim that recent biotechnology practices have crossed a threshold into radically different, even dangerous, territory. This learning cycle will help you to develop an understanding of some of the practices and methods of agricultural biotechnology and help you develop your own ethical beliefs about issues that are being raised across the world.

**Objectives**

After completing this learning cycle, you will be able to:

1. Identify and describe some of the historical context, issues, and practices involved in agricultural biotechnology.

2. Discuss the role of government in the regulation of biotechnology.

3. Discuss the potential benefits and risks associated with genetic modification.
How have humans altered plants to better suit their own needs in the past?

Selective Breeding for a Dominant Trait

The next time you bite into a juicy ear of sweet corn, take a moment to think about the history of what you are eating. Ten thousand years ago, corn didn’t look or taste anything like it does now. An ear of “corn” had only about twenty hard kernels, each covered by a tough outer shell. The whole ear might be only an inch or two long! This type of corn plant survives today and is called teosinte. Until the 1900s, botanists didn’t even realize that it was related to corn!

So how did corn turn out as we know it now? By human interaction. Farmers over thousands of years selected the best teosinte kernels to plant each successive year. They selected the largest and softest kernels and the ears with the most kernels to plant. That way, next year’s plants would have more of these traits. By selecting the best kernels year after year, farmers gradually changed the traits of the plant to be more useful to humans.
This technique, known as selective breeding, is still used to change plant varieties today. Fortunately, not every selective breeding project takes ten thousand years!

The traits of a corn plant, for example, are controlled by genes within the plant’s DNA. A particular gene might control one trait, such as the relative size of a corn kernel. The plant may have different versions of this gene working together to produce that one trait. Each version is called an allele. There could be an allele for large kernels and another for small kernels.
Selective breeding describes the process of eliminating unwanted alleles from a plant variety by only breeding the plants with the desired alleles. One method of selective breeding works like this:

1. Plants receive two copies of a gene--one from each parent. These may be the same allele, or different.

2. Only one allele can be expressed in an individual plant. If the alleles from both parents are the same, this is not an issue. But if the alleles are different, one will overrule the other. The stronger allele will cause the plants to show the dominant trait. Plants with two of the weaker allele will show the recessive trait.

3. People selectively breed plants by taking only those plants showing the desired trait and cross-breeding them with each other. Plants showing the undesired trait are discarded.

4. In the new generation of plants, more plants will show the dominant trait, but there will still be some plants that show the recessive trait. These are discarded again.

5. Steps 3 and 4 are repeated each season until all plants show the dominant trait.

To simulate this process, your class will use playing cards. Each person will receive two cards to represent the genetic material inherited from each parent. Your instructor will give you instructions as you carry out the simulation.
Reflection

After you have finished the simulation, answer the following questions:

1. During the card game, how many rounds did it take for the recessive traits (hearts, diamonds, and clubs) to stop appearing?

2. Is it possible for a new plant in future generations to show the recessive traits? Why or why not?

3. How long would it take to completely remove a recessive trait?

4. How could you selectively breed for a recessive trait? (In the card simulation, suppose clubs were hidden by all other suits.) How long would it take?
Selective breeding is a very useful and common technique. Unfortunately, it is very slow. Each “round” of breeding takes an entire growing season. Producing a dependable plant variety using selective breeding methods can take many years. Sweet corn is the result of ten thousand years of selective breeding. Even changing one trait, like the color of a fruit, might take decades. It is no wonder that people have looked for a better way to modify the traits of crops.

One such method is cloning or, when plants are involved, vegetative propagation. Cloning involves the creation of a new organism with the exact genetic makeup of the parent through asexual means. While human and animal cloning is a hot topic in the media today, plant cloning has been around as long as there have been plants. Many plants actually clone themselves by sending out a small shoot that roots and grows into a new plant. The new plant has the same traits as the parent plant because it has the same genetic makeup.
Through research and experimentation, humans have developed methods and procedures to control the cloning process. People can successfully clone a plant that has the most desirable traits. Instead of waiting many years for a desirable trait to be displayed through selective breeding, farmers, for example, can plant exact copies of a desired plant.

However, cloning has its own challenges. One of the greatest challenges is that each new plant must be individually cloned and nurtured, often by hand. Since seeds are not involved, farmers have a harder time planting a whole field in the spring. Still, cloning is widely used in research and for other agricultural applications.

Two vegetative propagation methods are commonly used: “cuttings” and micro-propagation. In your Primary Challenge teams, you will have the opportunity to perform the traditional method using cuttings in an upcoming activity. In another learning cycle, you will have the opportunity to perform a more advanced method using micro-propagation. This will give you the chance to compare methods throughout the remainder of the Learning Unit.
In the following activity, you will propagate a plant using the “cutting” method. There are many different ways to perform the cutting method. Often, the type of plant dictates the appropriate method. You will need to make sure the plant can be propagated by the method you are using. Cuttings can be propagated from a stem or just a leaf, and some cuttings can grow in water before being planted in soil. Instructions are listed below for herbaceous stem cuttings. Obtain the following materials and follow the directions below. (Materials may change depending upon the method chosen by your instructor.)

1. After gathering all of the needed materials, examine your plant cutting as a Primary Challenge team. Your cutting should be about three-five inches long and include at least two leaves. The cutting should appear healthy.

2. Fill the container with the rooting medium and moisten lightly with water.

3. Dip or dust the cut end of the cutting with rooting hormone. (Rooting hormone is available in powder and liquid form.)

4. Place the prepared cutting into the medium so it is firmly planted (about an inch of the cutting should be buried).
5. Place the newly potted cutting inside a large plastic bag. Insert a couple of sticks into the soil to keep the bag from collapsing onto the cutting. Tie the bag with a twist tie or rubber band. The bag will act as a miniature greenhouse and provide heat and humidity while roots are developing.

6. Place the cutting in a bright location, but shielded from direct sunlight.

As you complete these steps, keep a photo laboratory journal by documenting the process and your observations throughout the remainder of the Learning Unit. Use space provided in this student guide or a separate notebook. You will also need to take pictures to document your cutting’s progress.

Remove the cutting from the bag after about seven to ten days have passed. You will know that you have successfully cloned the plant when new growth is noticeable. Once you see new growth, transplant the cutting into a container filled with potting soil and water. You now have a successful clone that will mature into a normal, healthy plant that is an exact copy of its parent plant.
Reflection

Answer the following Reflection questions in your Inventor’s Logbook spaces.

1. Are plants bred using vegetative propagation an example of biotechnology? Why or why not?

2. What were some of the factors you controlled while propagating the plant? Why is it important to control these factors?

3. What are some possible reasons why the cutting method would not be the best to use in large-scale agriculture?

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Engagement

Genetic Modification

The newest technique in plant breeding is *genetic modification* or *genetic engineering*. In many ways, genetic modification provides the immediate results of cloning with the practical benefits of selective breeding. More importantly, plants can be given traits that would be impossible to develop using any other method. For example, researchers have created plants that glow in the dark! More common applications include creating plants with better yields, increased shelf-life, or increased disease resistance.

Genetic modification involves humans working directly with the genes in a plant cell. A piece of DNA from the gene of one organism is inserted into the cell of another for the purpose of achieving a desired trait. The glow-in-the-dark plants used a gene that came from fireflies. The cell is allowed to grow into a new plant that has the new traits. Because the new gene is a permanent part of the cell’s DNA, all of its offspring will also have the same traits.
Humans do not fully understand how genes work. Yet we have enough knowledge to be able to make useful modifications to many types of plants. Successful genetic modification can produce plants that are stronger, more adaptable to environmental conditions, and better-yielding. But our incomplete understanding of genes means that genetic modifications can sometimes produce unpredictable results and some of these results may not be entirely positive. Some modifications may actually produce plants that are less successful than the original plants. If these genetic failures get into the wild and mix with native plants, the weakened traits could affect the whole plant population. Or, a successful genetic modification (i.e., drought resistance) might be transferred into a different type of plant – like an undesirable weed.

Some genetic problems in crops might not even show up until long after the plants have been harvested. For example, food products containing a certain type of genetically modified corn were recalled because the corn had the potential to cause allergic reactions in some people. The recall cost millions of dollars and wasted hundreds of tons of corn. As in this case, the actions of a single biotechnology company could have national or global effects. Who should have responsibility for these actions?

Many people would say that it is the government’s job to regulate biotechnology and make the big decisions about ethics in biotechnology. However, the government is simply a group of people much like you and me. For the next few days, your class will have the chance to take on the role of the United States Department of Agriculture (USDA), which has immense control over biotechnology in the United States.
Making Ethical Decisions

Your class will act as the USDA Animal and Plant Health Inspection Service (APHIS). APHIS has authority over all genetically modified plants that are introduced in the U.S. Biotech companies that develop genetically modified plants must get approval from APHIS before these plants can be sold commercially. APHIS reviews each application and decides whether the plant poses a threat to other plants or animals in the environment. Your class will take on this role.

On the following pages, you will find three applications (adapted from the USDA’s application form) for genetically modified plants. Individually, read each application and check the meanings of any words that are unclear. Next, decide whether you personally think that the application should be approved or denied. Write your reasons for approving or denying the application in the margins on the side of the application. Keep in mind that you are not judging the application on whether it is practical or economical. Instead, you are deciding whether the genetically modified plant is an ethical use of biotechnology and should be allowed in this country.
**Description of Genetic Modification**

California Lights Douglas fir trees are a new variety of fir designed for the Christmas tree market. They have been genetically modified to glow in the dark. The modification was made possible by inserting genes that create luciferase, the same compound that fireflies use to produce light. Luciferase glows with a green light when it reacts with a second chemical, luciferin. The needles of the California Lights tree produce a large quantity of luciferase. Luciferin is provided in a special fertilizer that is fed to the tree. The tree will glow as long as the fertilizer is applied. Trees that are cut will glow for up to two weeks before the luciferin is depleted.

**Potential for Transfer of Genetic Material**

The gene that expresses luciferase can potentially transfer to any offspring of the parent tree. The gene is dominant, and the cross breeding of a California Lights Douglas fir with a conventional tree will show the trait in approximately 75% of the offspring. However, California Lights trees are intended to be grown on large-scale tree farms. Native trees are not usually mixed in with the cultivated trees on tree farms, and all trees grown are eventually cut down to be sold. Therefore, it is unlikely that the luciferase gene will be transferred to native Douglas firs.

**Potential for Undesirable Propagation (Weediness)**

The luciferase gene has no effect on the reproductive properties or growth rates of the tree. Even so, Douglas firs grow slowly and are not considered a weed.

**Impact on Other Species**

This genetic modification is also expected to have no impact on endangered or threatened animal life. The trees will have the same traits as conventional Douglas firs, except for production of luciferase. Luciferase is not known to be toxic to any organisms.

Animal species that use Douglas fir trees for nesting may be scared off by the green glow of the trees. However, a tree farm will probably have many varieties of trees growing at the same time. Animal species that dislike the glowing effect will be able to nest in other trees nearby.
Type of plant: Corn

Transgenic Modification Type: Herbicide Resistance

Description of Genetic Modification

A corn variety, “Illinois Gold RM 100,” was modified by inserting genetic material that provided resistance to glyphosate. Glyphosate is a common herbicide. By adding this gene, Illinois Gold corn will not be affected by herbicides that will remove other plants from corn fields. This modification is already commonly used in many crops.

More importantly, Illinois Gold also includes a gene for glyphosate production. Individual plants of Illinois Gold corn are able to produce their own herbicide. The plant is able to produce enough herbicide to eliminate undesirable plants in a 1’ radius, while the plant itself remains unaffected by the herbicide.

Potential for Transfer of Genetic Material

The genes for glyphosate production and glyphosate resistance may be transferred by pollination to any plant that can cross-breed with Illinois Gold corn. In general, other varieties of corn will be able to receive these genes, and some seeds from cross-breeding will produce plants that show glyphosate production, glyphosate resistance, or both. Both of these genes are recessive, and only one-quarter of seeds from cross-bred corn will show any given trait.

Corn does not pollinate with other plants, but some recent studies have shown the possibility for genetic material to transfer from corn to other plants, such as milkweed. The mechanism of genetic transfer is not yet clear in these cases.

Potential for Undesirable Propagation (Weediness)

Corn is not currently recognized as a weed pest. It is possible that Illinois Gold corn, able to produce glyphosate herbicide, may kill nearby plant growth and out-compete other plants. Field trials have not been conclusive.

Impact on Other Species

Glyphosate herbicides do not contain any substances considered toxic to humans, mammals, or other vertebrates. The use of Illinois Gold corn may actually reduce the amount of toxic chemicals used in farming because it allows growers to apply glyphosate in place of other more toxic herbicides that have a greater affect on native species.

Glyphosate herbicides have been shown to have a detrimental affect on some types of invertebrates, including earthworms. Current research indicates that the harm is caused by additives, such as surfactants in the herbicide, not the glyphosate itself. Different formulations of glyphosate herbicide may reduce effects on invertebrates.
**Type of plant:** Western Lily (Lilium Occidentale)
**Transgenic Modification Type:** Appearance

**Description of Genetic Modification**

The Western lily is a rare but beautiful flower growing on the Pacific coast. Only a few sites in California and Oregon are known to have viable populations of this lily. It prefers low coastal areas along the edges of wetland bogs and does not grow in drier soil. The Western lily is listed as endangered by the U.S. Fish and Wildlife Service, with only 28 known sites where it currently grows. The major threats to the population are loss of its wetland habitat for agriculture and illegal harvesting by collectors who are attracted to its colorful flowers.

Samples of the Western lily have been genetically modified by altering the gene that controls flower color. An allele from the common lily has been added, which gives the flowers a dull green color. By making the flowers less attractive, the plant is less noticeable and less attractive to collectors. The original allele, which produces bright red and yellow flowers, is still present as a recessive trait. If the lily population recovers, the plants can be cross-bred to retrieve the original color.

**Potential for Transfer of Genetic Material**

The allele for flower color can be transferred to any other member of the lily family. However, this has always been true, since the gene was originally from the common lily. The allele will not necessarily show as a dominant trait in other varieties of lily.

**Potential for Undesirable Propagation (Weediness)**

The Western lily is listed as endangered and is unlikely to become so numerous that it is considered a weed. In any case, the genes for flower color have no effect on the growth rate or reproduction rate of the plant.

**Impact on Other Species**

The Western lily is an endangered species, and this genetic modification will help its population to recover. Hummingbirds are known to feed on the nectar of the plant. It is not known whether changing the color of the flower will prevent hummingbirds from finding it.
Discuss each application as a class. Try to identify all potential benefits and risks of the new genetically modified plant. Your instructor might lead this discussion or appoint someone in the class to lead. After all issues have been discussed thoroughly, decide on the status of the application. Your class may take one of three actions:

1. Approve the application
2. Deny the application
3. Return the application to the company for changes

A majority vote is required for each of these actions. If your class cannot reach a majority on any of the three, return to a discussion of the issues and then re-vote. After the class reaches a decision on each application, individually answer the questions on the following page.
1. Did your class tend to favor new applications or oppose them? Why do you think this was the case?

______________________________________________________________________________________________________

2. Do you think genetic modification of crops (food plants) should be treated differently than modification of other plants? Why or why not?

______________________________________________________________________________________________________

______________________________________________________________________________________________________

3. What ethical issues of biotechnology are addressed in the USDA approval process? What ethical issues are ignored?

______________________________________________________________________________________________________

______________________________________________________________________________________________________

______________________________________________________________________________________________________

4. Does this system of approving genetically modified plants seem like a responsible one? Why or why not?

______________________________________________________________________________________________________

______________________________________________________________________________________________________

______________________________________________________________________________________________________
Expansion

Select one of the Expansion activities below:

1. Search the Internet to find an actual example of a company applying to the USDA to sell a genetically modified plant. The USDA calls this a "Petition for Non-Regulated Status." The petition could be one that was approved, denied, or one that is still pending. Summarize the features of the new plant variety and the USDA’s response in one to two paragraphs.

2. Besides the USDA, two other federal agencies regulate biotechnology in the United States: the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA). Just as the USDA controls the introduction of new plant varieties, the FDA and the EPA also have specific roles. Find out how each of these agencies regulates biotechnology.

3. Identify and describe three crops that are commercially bred using the methods described above: selective breeding, vegetative propagation, and genetic modification.

4. Identify at least one area company that conducts agricultural or plant biotechnology research (widen your search as far as necessary to locate a company). Visit their web site or call them to find out the nature of their research. If possible, visit a field test site of one of their products.
There are thousands of plant species worldwide that are threatened with extinction. Here is just a small sample of threatened and endangered plants in the United States:

- Chapman’s waxweed (*Cuphea aspera*)
- Smooth purple coneflower (*Echinacea laevigata*)
- Fraser fir (*Abies fraseri*)
- Green mountain maidenhair fern (*Adiantum viridimontanum*)
- Kauila (*Colubrina oppositifolia*)
- Harbison hawthorn (*Crataegus harbisonii*)
- Okeechobee gourd (*Cucurbita okeechobeensis*)
- Scrub balm (*Dicerandra frutescens*)
- Mexican flannelbush (*Fremontodendron mexicanum*)
- Dakota wild buckwheat (*Eriogonum visheri*)
- Pine Hill flannelbush (*Fremontodendron decumbens*)
- Gentner’s fritillary (*Fritillaria gentneri*)
- Showy stickseed (*Hackelia venusta*)
- Small whorled pogonia (*Isotria medeoloides*)
- Elegant fawn-lily (*Erythronium elegans*)
- Wolf’s evening primrose (*Oenothera wolfii*)
- Silvery phacelia (*Phacelia argenta*)
- Oregon semaphore grass (*Pleuropogon oregonus*)
- Malheur wire-lettuce (*Stephanomeria malheurensis*)
- Thompson’s clover (*Trifolium thompsonii*)

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor’s Occupational Outlook Handbook at: [www.bls.gov/oco](http://www.bls.gov/oco)
The major cause of plant extinction is habitat loss—people taking land for other uses like farming and construction. However, endangered plants are also threatened by a number of other factors in their environment, including water levels, pesticides, and competition from non-native plants. How could biotechnology help or hurt the prospects of these endangered species?

Choose one of the plant species given on the previous page. Conduct research to find out the conditions under which it grows and why it is threatened. Then develop at least one way in which this species could be helped by biotechnological modification. Give specific details. (For example, a species might be dying out because its habitat is being overrun by exotic plants that grow taller and cut off light to the endangered species. The endangered species could be modified to grow taller shoots, helping it to compete against other plants.)

Next, think of one way that this species could be harmed by biotechnology. Of course, no one would intentionally modify an endangered species so that it fails. However, a modification that was intended as a benefit could turn out to be a weakness. Or, other plant species nearby could be modified in a way that has a negative effect on the endangered species. Again, provide specific details. (In the example above, modifying the species to produce taller shoots might also cause the shoots to be more likely to bend and break, killing the plant. Or, an endangered species might have a competitive advantage over invasive plants because it can absorb certain nutrients from the soil that other plants cannot. Modifying other plants to absorb these nutrients would eliminate the small advantage that the endangered species had.)

Use the space provided in the Inventor’s Logbook on the following page. Be prepared to present your findings to the class.
### Unnatural Selection

**Name:**

**Date:**

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetative Propagation Activity</strong></td>
<td>Successfully followed instructions, documented procedure in writing and with photos, worked well as a team.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Successfully followed most of the instructions, documented procedure in writing and with photos, worked well as a team.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Followed some of the instructions, documented most of the procedures in writing and with photos, difficulty working as a team.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Did not follow instructions well, documented little of the procedure in writing and with photos, did not work well as a team.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Government Biotechnology Regulation</strong></td>
<td>Presented logical arguments for or against the approval of each of the given applications.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Presented logical arguments for or against the approval of at least two of the given applications.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Arguments were presented, but were not very thorough.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Arguments were illogical or lacking in depth.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Self-Assessment of Biotechnology Regulation Activity</strong></td>
<td>Showed the ability to assess the process used in this activity, including individual and classroom biases.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Showed the ability to assess the process used in this activity, but did not identify biases.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Commented on the process used in this activity, but showed minimal insight.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Accepted the process without comment.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Endangered Species and Biotechnology</strong></td>
<td>Provided a detailed summary of the status of one endangered plant species. Included plausible positive and negative effects of biotechnology on this species.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Provided a detailed summary of the status of one endangered plant species. Included at least one positive or negative effect of biotechnology on this species.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Provided a summary of the status of one endangered plant species. Lacked detail or plausible positive and negative effects.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Researched the given species, but did not provide specific information as requested.</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total Points**
Learning Cycle Two

A Little More Control
Introduction

As you learned in the previous learning cycle, newly cloned plants need a regulated environment to increase their odds of success. The plastic bag used in the previous learning cycle created a miniature greenhouse, regulating the humidity and temperature for the cutting. The micro-propagation technique that we will use in a subsequent learning cycle likewise requires a regulated environment. However, this technique requires an even more sterile and regulated environment to succeed. Before you begin the actual micro-propagation technique, you will need to have the environment prepared and the conditions controllable. This learning cycle will show you ways to adjust the physical environment around your micro-propagated plants to give them the best possible environment for growth.

Priority One: Environmental Protection

Objectives

After completing this learning cycle, you will be able to:

1. Describe physical conditions necessary for optimum plant growth.
2. Create a sterile enclosure, which uses sensors to monitor the physical conditions inside.
3. Apply digital logic and programming to automate monitoring and controlling of physical conditions.
Exploration

Humans realized long ago that plants need sufficient light and appropriate temperature to grow. Early farmers must have noticed that crops growing in direct sunlight were much more productive than crops growing in the shade of a tree. More recently, biologists realized that plants actually manufacture their own food from basic nutrients and light energy. More light reaching a plant allows the plant to make more food and grow more quickly, at least up to a certain point.

Surprisingly, biologists have also found that plants do best when they have some time to “rest” without light and that some plants do better when not placed in direct sunlight. Through experimentation, the optimum balance of light and dark for many plants was determined to be sixteen hours of light followed by eight hours of darkness. The African violet plants that you will micro-propagate are fairly typical and will do best if they follow this cycle. African violet plants also do best when kept at a temperature around 75˚ F.

Consider This

What physical conditions need to be monitored or controlled to help young plants grow best?
In the following activity, you will meet in your Primary Challenge teams and design and construct an enclosed environment for your micro-propagated plants and cuttings from the materials provided by your instructor.

Your enclosed environment must:

- Provide enough room for the team’s cuttings and four Petri dishes, which will contain your micro-propagated plants. (It cannot exceed three feet high or three feet wide.)
- Provide access to place and work with your propagated plants.
- Be able to allow access to lighting (which you will regulate) either inside or outside the container.
- Incorporate a method to measure and regulate the temperature inside.
- Be sterilized and remain sterile.

You will only have about two class periods to design and construct your enclosure, so use your time wisely. You will have access to a limited amount of materials. The enclosure should be large enough to contain your propagated plants, but still fit on a table or desk top. Your instructor will choose the primary material (wood, PVC pipe, plastic, etc.) for the construction. You will also have access to plastic sheeting and other basic materials like tape, glue, and scissors.

Once you have created the enclosed environment, add the lighting element provided by your instructor.
Reflection

Answer the following Reflection questions in your Inventor’s Logbook spaces.

1. Why is it important for the micro-propagated plant to be placed in an enclosed environment?

2. What other variables besides light and temperature can be controlled in your environment?

3. How were you able to solve the access problem and still keep the enclosure closed?
Now that you have an enclosed environment for your plant and access to light, you can integrate a system to regulate the lighting. In this activity, you will use sensors to monitor the light that reaches your young plants. A sensor is a device that measures a physical quantity and then converts that measurement into an electrical signal. Sensors in modern automobiles continuously monitor such quantities as engine temperature, oil pressure, and wheel speed.

Electricity is a very versatile form of energy and the electric signals from sensors can be used in a variety of ways. These signals can be displayed on an electronic readout, stored on a hard drive, or used by a computer to perform complex tasks. In this activity, you will build a circuit and program a microcontroller using the BASIC Stamp® HomeWork Board™ to process the signals and store the results.

A Light Meter

You will also need access to a personal computer that has the BASIC Stamp Editor software program. You may need to share this equipment with other groups, so budget your time appropriately.

In the following activity, you will be programming the BASIC Stamp (BS2) microcontroller to “read” the amount of light being exposed to the photocell sensor. You will be able to determine the amount of light by the numbers displayed on the computer screen.

Electronic parts need to be handled with care and stored in a container until they are ready to be used.

Your team should gather the following materials before beginning this activity:

- BASIC Stamp HomeWork Board
- BASIC Stamp serial programming cable
- 9 V battery
- CdS photocell
- 220 ohm resistor
- 0.01 µF capacitor
1. To begin this activity, connect the CdS photocell and the resistor to match the schematic diagram below. Be sure that each item is placed as shown in the schematic.

![Figure 1. Visual CdS Photocell wiring diagram and schematic](image1)

![Figure 2. CdS Photocell wiring diagram and schematic](image2)

2. Open the BASIC Stamp Editor software on the computer and type in the following program. Type it exactly as shown, including all punctuation, spaces and line breaks. (Computer programs are very sensitive to small differences in formatting.)

```basic
'{$STAMP BS2}
'{$PBASIC 2.5)

CdsIn   VAR Word

DO
    HIGH 0
    PAUSE 5
    RCTIME 0, 1, CdsIn
    DEBUG HOME, "CdsIn = ", DEC5 CdsIn
LOOP
```

![Figure 3. CdS Photocell wiring](image3)
3. Connect the programming cable to the computer and the HomeWork Board and then insert the battery. You should see a green light on the board turn on.

4. Press the “CTRL” and “R” keys at the same time to load the program. After the program loads, you should see a new window open on the computer screen, displaying a readout of $CdsIn$.

You have now successfully programmed the BS2 and are ready to test the device.

1. Shine a bright light on the CdS photocell. What value is displayed on the screen?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2. Cover the photocell with your hands. What value is displayed on the screen? What does the number on the screen represent?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
An Explanation of the Program

Now that you have successfully programmed the BS2, you need to understand the program you inserted into the software so you can further manipulate it. Below is a step-by-step breakdown of the computer program.

Computer programs can seem very cryptic until you understand the special words and symbols that they use. Here is a line-by-line explanation of the program that you ran on the BS2 microcontroller.

'\{\$STAMP BS2\}
'\{\$PBASIC 2.5\}

These two lines are special instructions to tell the BASIC Stamp Editor what version of the BASIC Stamp hardware (BS2) and what version of the software that you are using (2.5). These lines need to appear at the beginning of every program.
CdsIn VAR Word

This line tells the BS2 that you will be using a new variable called CdsIn to store information. CdsIn is the level of the input signal from the CdS photocell. Like a variable in algebra, CdsIn represents a quantity whose value is unknown or that can change from time to time. (The term Word tells the BS2 to reserve a certain amount of memory for this variable. For the BS2, a Word is two bytes.)

DO . . . LOOP

The DO command, followed by the LOOP command three lines later, makes the BS2 repeat this section of the program over and over again. As it repeats, it performs the instructions inside the loop continuously. If the DO and LOOP lines were left out, the program would display one value on the screen and then stop.

HIGH 0
PAUSE 5

These lines make the BS2 send a 5V signal to the circuit, then wait for five milliseconds. This gets the CdS photocell ready for measurement.

RCTIME 0, 1, CdsIn

This line tells the BS2 to read the level of the sensor connected to pin 0 and to store the level in memory as CdsIn. Notice that this is the variable you created earlier.

DEBUG HOME, "CdsIn = ", DEC5 CdsIn

This line tells the BS2 to send information to a new window on the computer screen. The window will display “CdsIn = “ and a number. Anything inside quotation marks is printed exactly as written. The second CdsIn is really the variable that you are using. The BS2 substitutes its value before sending it to the screen.
A Simple Modification

The light-measuring circuit that you just built has quite a few practical uses. However, it seems to work backwards. When the light is strong, the number on the screen is low. When the sensor is completely dark, the number is the highest. Wouldn’t it make more sense if the number on the screen got larger when the light was stronger? Let’s make a change to the program to accomplish this reversal.

Adding just a few lines to the program will make this change. Insert the following program into the BASIC Stamp Editor:

```
'{$STAMP BS2}
'{$PBASIC 2.5}

CdsIn  VAR Word
CdsOut VAR Word

DO
  HIGH 0
  PAUSE 5
  RCTIME 0, 1, CdsIn
  CdsOut = 5000 - CdsIn
  DEBUG HOME, "CdsIn = ", DEC5 CdsIn
  DEBUG " CdsOut = ", DEC5 CdsOut
LOOP
```
Run the program and notice the change. By adding these lines, you have created a new variable named `CdsOut` and set its value to always be equal to \((5000 - \text{CdsIn})\). Now, the program will display `CdsOut` as a number that increases when the light on the photocell gets brighter.

Doing some math on the input variable to get a more useful output is known as signal conditioning. Note that the number 5000 in the equation is completely arbitrary. Many other values would work just as well. (However, if `CdsOut` goes below zero, you will see strange results. The BS2 handles negative numbers in an unusual way.)

Now, place the light meter next to the plants that you are growing.

What is the light reading with the grow lights on?  ________________

What is the reading with the grow lights off?  ________________

You will be able to build upon the programming knowledge you just acquired in the next activity. However, you will need to first remove all of the electronic components on the HomeWork Board and place them back into the container. You will need to start the next activity with a clean board.
Reflection

Answer the following questions in your Inventor’s Logbook spaces provided.

1. Based on your light meter readings from the previous activity, what do you think is the minimum light level for your plants to grow effectively?

2. Besides monitoring grow lights, what are two other practical applications for the circuit that you just built?

3. What other types of sensors could you connect to the BS2?

4. This light meter doesn’t really need all the power of a microcontroller like the BS2. What are some advantages, though, of using the BS2?
Engagement

The plants that you are growing will do best if they have about sixteen hours of direct light and eight hours of darkness each day. Unless there is someone willing to wait around your classroom to turn the lights on and off, you will want to devise a way to control them automatically. You’re in luck. The BS2 can do this easily.

In the light meter that you constructed earlier, you used the input/output (I/O) pins on the BS2 to read a signal. These pins can also be used to send signals. However, these output signals are very weak. The BS2 can be used to turn on a very small light like an LED, but not a regular light bulb or a grow light. So, what can you do? You will need to use another device in between the BS2 and the light. This “in between” device switches on and off in response to signals from the BS2. You can see that, with a little programming, the device will provide the automatic switching capability that you want.

There are several devices that can do this. In this lab, you will use a clever device known as an X10 unit. Besides being powerful enough to turn on a light, the X10 is a wireless device that lets the BS2 be far away from the light that it is controlling. The X10 unit connects to the BASIC Stamp HomeWork Board and also to a wall outlet. The X10 unit can send signals through an electrical outlet to another X10 unit connected to a lamp.
Follow the steps below to connect and program the X10 unit using the BS2.

1. Connect the BS2 and X10 units as shown in Figure 4 on the previous page.

2. Type the following program into the BASIC Stamp Editor:

   ```
   '{$STAMP BS2}
   '{$PBASIC 2.5)

   DO
     XOUT 14,15,\0\0
     XOUT 14,15,\0\uniton
     SLEEP 57600

     XOUT 14,15,\0\0
     XOUT 14,15,\0\unitoff
     SLEEP 28800
   LOOP
   ```

There are several new instructions in this program that are worth explaining. The instructions that do all the work are the `XOUT` instructions. `XOUT` is an instruction that sends a command to the X10 unit. The first instruction gets the attention of the transmitter unit, while the second instruction turns the remote unit on or off. The BS2 can control many remote units. The numbers inside the brackets tell the transmitter which remote unit to send a command to. Your instructor may have you use different numbers in place of \0\0.

The rest of the program is simply a way to make the BS2 wait sixteen hours with the light on and eight hours with the light off. The `SLEEP 57600` instruction tells the BS2 to shut down and wait for 57,600 seconds—sixteen hours. After this time is over, the BS2 essentially wakes up, turns the remote unit off, and goes to sleep again for another eight hours (28,800 seconds).
You may want to adjust the **SLEEP** time to modify this activity to sixty seconds for **uniton** and thirty seconds for **unitoff**.

3. Now plug the X10 interface device into an empty outlet close to your computer. Plug the X10 Appliance Module into a different outlet. Next plug the grow light into the bottom of the X10 Appliance Module device.

4. Attach the battery to the HomeWork Board and press “CTRL” + “R” to run the program.

Does the light shut off after sixty seconds? If not, check your program and your wire connections to find the problem.
A Smart Timer

The previous section showed you how to make the BS2 act as a timer to control the grow lights for your young plants. If the plants are in a sunny area, though, they may not need the lights on during the middle of the day. Wouldn’t it be nice if the timer were smart enough to not turn on the lights when the plants are getting enough light already?
You can write a “smart timer” program by combining the light meter with the simple timer. Begin by typing and loading this program into the BS2:

```
'{$STAMP BS2}
'{$PBASIC 2.5}

CdsIn   VAR Word
CdsOut  VAR Word
Minute  VAR Word

DO
  FOR Minute = 1 TO 960
    HIGH 0
    PAUSE 5
    RCTIME 0, 1, CdsIn
    CdsOut = 5000 - CdsIn
    DEBUG HOME, “CdsOut = “, DEC5 CdsOut
    IF (CdsOut < 2000) THEN
      XOUT 14,15,[0\0]
      XOUT 14,15,[0\UNITON]
    ELSE
      XOUT 14,15,[0\0]
      XOUT 14,15,[0\UNITOFF]
    ENDIF
    SLEEP 60
  NEXT

XOUT 14,15,[0\0]
XOUT 14,15,[0\UNITOFF]
FOR Minute = 1 TO 480
  SLEEP 60
NEXT
LOOP
```
Look carefully at this program. You will probably realize that the program is really just a combination of the light meter program and the timer program. Notice that the light meter program is stuck inside one of the `FOR . . . NEXT` loops. Like the other instructions inside this loop, the light meter instructions will be carried out once per minute.

The key to this program is the line that begins with `IF`. The `IF` instruction provides a way for the BS2 to make a decision. There are three parts to the `IF` instruction - a true/false statement to check, what to do if the statement is true, and what to do if the statement is false. Together, they are written:

```
IF (statement to check)
THEN (what to do if true)
ELSE (what to do if false)
ENDIF (the end of the instruction)
```

Look at the `IF` statement in the program above.

What does it check for? __________________________________________

What does it do if the check is true? ______________________________

What does it do if the check is false? ______________________________

Explain what the `IF` statement does in real-life terms.

______________________________________________________________

______________________________________________________________

______________________________________________________________
Assemble the light meter circuit and the timer circuit on the HomeWork Board. Load and run this program. As you test the circuit, there are a few things to keep in mind:

- To get a level that works best with your system, you will need to change the value 2000 in the IF statement.
- To speed up your testing, you will probably want to reduce the sleep time to just a second or two.

The CdS photocell is supposed to measure the natural light in the room, so it should be placed where it will not receive light from the grow lights. (If you doubt this, find out what happens if the photocell is positioned under the grow lights when the room is dark.)
Expansion

Select one of the Expansion activities below.

1. Research some of the external factors that are being used and controlled in a biotechnology lab and explain their roles.

2. Research other types of sensors that can be connected to the BASIC Stamp. Begin by visiting Parallax's web site (www.parallax.com) but don’t be limited by the selection that is available there. Search for “sensors” on the Internet to find a wide variety of devices. Select three different sensors to investigate more fully.

3. Modify the smart timer program to turn the lights off if the temperature near the plants is over 75 degrees Fahrenheit.

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor’s Occupational Outlook Handbook at: www.bls.gov/oco
In this learning cycle, you have learned a bit about how sensors and microcontrollers can be used to monitor and control physical factors in the environment. This learning cycle focused on light. Obviously, proper light is important for plant growth, but there are other physical factors that are also important. To prepare for the challenge, you will need to conduct research to find out which physical factors need to be considered for plant growth and develop a plan to monitor and control these factors.

First, brainstorm physical factors that could affect the growth of your plants, including once they are transplanted into potting soil. Try to think of a wide variety of possible factors. Some may not easily come to mind.

Next, do some research to find out the optimum range for each factor that you listed for the plant species you are propagating. You might find out, for example, that plants grow best when the humidity is between 50% and 70%. You may also discover that some factors you listed appear to have no effect on plant growth. You can remove those from your list.

Finally, come up with a plan to manage each of these factors. “Manage” in this case means measuring the physical factor and keeping within a certain range. For each factor, you will need to decide whether it is best managed automatically using a device like the BASIC Stamp or manually. Automatic devices, such as the light timer you built, might be best for some physical factors. Others may be best managed by a human being who can check and make adjustments as necessary. Be prepared to defend your choice of control for each physical factor.
# A Little More Control

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosed Environment</td>
<td>Designed and created a well-thought-out container that met all of the constraints.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Designed and created a well-thought-out container that met most of the constraints.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Designed and created a container that met only a few constraints.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Designed and created a container that did not meet the constraints.</td>
<td>1</td>
</tr>
<tr>
<td>Sensors</td>
<td>Integrated a light sensor into a usable measuring device. Applied the device to real-world measurements.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Integrated a light sensor into a usable measuring device. Did not make real-world measurements.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Integrated a light sensor into a generally usable device with minor errors.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Attempted to construct a device with the sensor.</td>
<td>1</td>
</tr>
<tr>
<td>Automatic Control</td>
<td>Built a system that accurately controlled light levels based on sensor input.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Built a system that controlled light levels based on sensor input. Some fine-tuning of the control was lacking.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Built a system, but automatic control was erratic.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Built a system but did not have success with automatic control.</td>
<td>1</td>
</tr>
<tr>
<td>Factors affecting plant growth</td>
<td>Described at least four factors that affect plant growth, including optimum parameters for each.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Described at least three factors that affect plant growth, including optimum parameters for each.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Described only one or two factors with optimum parameters for each.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Conducted research, but failed to find useful data on factors that affect plant growth.</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total Points**
Learning Cycle Three

One Good Clone Deserves Another
In this learning cycle, you will learn how to clone plants through a process called micro-propagation. This involves understanding how to get rid of contamination (especially bacteria) on the plant, isolating cells that are actively dividing, and then using growth hormones and nutrients in media to eventually produce large numbers of plants.

Micro-propagation, unlike the cutting method can be used to grow a whole plant from a single cell. The DNA of the new plant is an exact copy of the existing plant, so micro-propagation is really a form of cloning. However, researchers can engage in the genetic manipulation of the cell during the micro-propagation process to introduce new genetic traits. The DNA containing the new genetic traits can either be transferred to the new plant through a bacterium that infects the plant tissues and incorporates part of its DNA into the plant, or the DNA can be “shot” into the plant cells. Researchers can then let the manipulated cell develop into a completely mature plant and examine the spectrum of physical and growth effects of the genetic manipulation process within a relatively short period of time.

Micro-propagation regenerates new plants from small pieces of plant tissue because each cell is capable of developing along a programmed path, leading to the formation of an identical plant. However, not all parts of a plant are suited for micro-propagation. Plants are made up of several different types of cells. Some cells contain chlorophyll to help the plant make food. Others have hard cell walls to provide support for the plant. The cells that we are interested in make up tissues in plants called the meristem. These cells are located in the growing parts of the plant such as the roots, stems, and veins in the leaves. Micro-propagation is based on getting a small number of
meristem cells to grow outside of the plant and start producing lots of other cells that are able to start making roots, stems, and leaves.

Living things are fragile, and the meristem cells pulled out of a plant are very fragile indeed. These cells must be given everything they need to grow and multiply. Successful micro-propagation relies on aseptic or sterile conditions. The initial stage of cutting the plant, disinfecting it, and placing it on a medium must be done without contaminating it with bacteria or fungi. The following activities will introduce you to techniques that will enable you to successfully micro-propagate plant tissue.

Objectives

After completing this learning cycle, you will be able to:

1. Describe the resources and techniques used to clone plants using the micro-propagation technique.

2. Explain the importance of hormones for cell differentiation and plant growth.

3. Utilize sterile procedures and techniques necessary for plant micro-propagation.
Bacteria are the most common organisms on the face of the earth. They are everywhere and affect almost every aspect of our lives. Vaccines and medicines have been created to combat the disease-causing bacteria called pathogens. Many of the products we buy, including soap, detergent, and toothpaste contain an anti-bacterial agent. Not all bacteria, however, are bad for us. Millions of bacteria are on our skin and in our nose, mouth, and stomach. Some of these bacteria are essential for us to survive. They help us digest our food, produce vitamins, and prevent harmful pathogens from invading our bodies. Bacteria are also used to create many of the food products we consume, including yogurt and cheese.

Bacteria are living, one-celled organisms. Microscopic in size, bacteria use organic matter for their food and produce waste products. Bacteria require food, water, and a suitable temperature to survive. In the following activity, you will be able to examine the bacteria that are living on your skin. You will provide the bacteria from your skin with an ideal environment in which to grow and multiply, including all of the essentials it needs to survive. In a matter of 24 hours, the bacteria will multiply and become noticeable.

In your Primary Challenge teams, obtain the following from your instructor:
(1) Petri dish containing an agar medium
(1) Permanent marker
On the lid of your Petri dish, draw an X with the permanent marker, dividing it into four quadrants. Number each of the four sections. Each member of your team will choose one of the four numbers and place one of their fingers into the agar medium in the space corresponding with their quadrant number. (Agar is a stiff gelatin that comes from seaweed and provides a stable environment for living organisms to grow.) Each member should then thoroughly wash their hands.

Once all team members have placed their fingers into the Petri dish, replace the lid so the labeled quadrants correspond where each team member has placed their finger. After the lid has been correctly placed, set the Petri dish inside the enclosed environment you created in the previous learning cycle and make sure the lights will remain on overnight.

When you return, examine the bacteria under a microscope and compare the different parts of the quadrant. Document what you see inside the Petri dish in the space provided below:

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
Because of the prevalence and hardiness of bacteria, the procedures used in micro-propagation must be aseptic. A clean, sterile environment and instruments are paramount for success. Bacteria that could possibly contaminate the plant tissue reside on dust particles and fungi on the leaf, on the instruments, on the person dealing with the plant, and simply in the air. The bacteria, if given the chance, will overtake the meristem cells of the plant, killing them in the process. All of the tools and the leaf itself must be cleaned and sterilized before they are ready to be used.

The entire micro-propagation process has been broken down into three steps. Steps 2 and 3 must be performed in conjunction with each other during one class period. The sterilized leaf must be placed in the agar medium, otherwise it will die. You must utilize your time efficiently, especially since your team will be sharing equipment. You should review the procedures in Steps 2 and 3 either while your instruments are sterilizing in Step 1 or after you have completed the Petri dish activity. Step 1 will enable you to sterilize the instruments you will be using to create the explants from the leaf and increase your odds of success.
Step 1: Equipment Preparation

Working in a clean, sterile environment, each team should obtain a pair of tweezer forceps and a scalpel. Students should then place each instrument in aluminum foil and sterilize each in one of three ways:

- Baking them in an oven at 350˚ F for 15 minutes
- Placing them in a pressure cooker at 15 psi for 15 minutes
- Placing them in an autoclave for 15 minutes

Carefully remove instruments with oven mitts and allow them to cool. Instruments can be stored unopened at room temperature until they are ready to be used. Remember, from now on the instruments are sterile and the parts of the instruments that come in contact with the plant material or Petri dishes should never be touched.

Each team should obtain the following:
- Tweezer forceps
- Scalpel
- Access to an oven, pressure cooker, or autoclave
- Oven mitt

Safety

Be extremely careful when handling or using the scalpel because of the very sharp edge. Also, take extreme caution when removing the instruments from the sterilization method for they will be very hot.
Reflection

Answer the following question in your Inventor's Logbook spaces provided.

1. Explain how the process used above to sterilize your instruments removes the bacteria.
Engagement

Now that your instruments are sterilized and ready to use, you can prepare and cut the leaves, creating explants (tissue cultures). Before bringing a new plant into the world, however, you will need to make sure that you have a good home for it. You need to make sure that your plant has all the basic resources it needs to survive and thrive. The most essential resources needed for a very young plant are a stable support to grow upon and a source of nutrients.

There are two types of support you can provide the plant. One is the agar used in the earlier activity. The other type of support used is a liquid solution. However, the plant must be given support so it does not drown in the solution. You will be using the agar to support your plant.

The nutrient medium mixed in with the agar that you are using to grow the new plants is more complex than it appears. Besides water, there are actually about a dozen different chemical ingredients in the media. The most important of these ingredients are listed in Figure 1 below.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Concentration</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agar</td>
<td>5-10 g/L</td>
<td>Makes the solution form a gel</td>
</tr>
<tr>
<td>Mineral Salts</td>
<td>2-10 g/L</td>
<td>Provides vitamins and minerals needed by the plant</td>
</tr>
<tr>
<td>Sugar</td>
<td>30 g/L</td>
<td>Provides a source of carbon for the plant</td>
</tr>
<tr>
<td>Cytokinin</td>
<td>0.1 – 10 mg/L</td>
<td>Plant hormone that stimulates growth. Promotes shoot development. Inhibits root development.</td>
</tr>
<tr>
<td>Auxins</td>
<td>0.1 - 10 mg/L</td>
<td>Plant hormone that stimulates growth. Promotes root development as well as growth of undifferentiated callus cells. Inhibits shoot development.</td>
</tr>
</tbody>
</table>

*Figure 1. Components of the agar media*
Notice especially the last two entries in the table on the previous page. Plant biologists have found that adding certain chemicals, called growth hormones, to the nutrient media can have large effects on the growth of the new plant. Certain ratios of growth hormones encourage the new plant cells to keep dividing without forming different types of cells. This mass of cells is called a callus. By adding growth hormones in other ratios, it is possible to help the new plant cells to differentiate into roots, stems, and leaves.

**Step 2: Plant Preparation**

Put on the splash goggles, a lab apron or coat, and a pair of disposable gloves. Clean your gloved hands by squirting them with the ethanol solution. Re-clean them any time you touch a non-sterile surface or material. Spray your work surface with the ethanol solution. Open the foil packets containing the sterilized instruments. Spray both with the ethanol solution before placing them onto the work surface. Each team member will have to share the instruments.

<table>
<thead>
<tr>
<th>Your team should gather the following materials before beginning this activity:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4) Lab aprons or coats</td>
</tr>
<tr>
<td>(4) Splash gogles</td>
</tr>
<tr>
<td>(4) Disposable sterile gloves</td>
</tr>
<tr>
<td>(4 containers with screw-cap lids (50-100-mL))</td>
</tr>
<tr>
<td>(1 L) 10% Bleach/detergent solution</td>
</tr>
<tr>
<td>(1 L) Distilled water</td>
</tr>
<tr>
<td>Access to squirt bottle with 70% ethanol solution</td>
</tr>
<tr>
<td>(4) African violet leaves (fresh and healthy)</td>
</tr>
<tr>
<td>Tweezer forceps</td>
</tr>
</tbody>
</table>
To disinfect the African violet leaves:

1. Using the tweezer forceps, place the leaf into the jar (size of jar depends on size of leaf).

2. Pour the 10% bleach/detergent solution into the jar, filling the jar three-fourths full. Attach the lid to the jar.

3. Let the leaf sit in the solution nine to ten minutes, gently agitating the mixture every twenty to thirty seconds.

4. Pour off the bleach into the sink, keeping the lid loosely in place over the container and being careful not to splash any of the bleach solution (bleach will leave white spots on clothing).

5. Remove the lid and pour distilled water over the leaves, filling the jar approximately halfway.

6. Replace the lid and gently agitate the mixture for two to three minutes to rinse the bleach off the leaf.

7. Pour off the rinse water in the sink, keeping the lid loosely in place.

8. Rinse with sterile water a total of four times.

Your African violet leaf is now sterile. All subsequent activity with the leaf should be done with caution, using sterile procedures. Open one container at a time, and never leave the lid off of any container longer than necessary.
Step 3: The Procedure

To cut the leaves into tissue cultures (explants):

1. Using gloved hands, spray your hands, the scalpel, the forceps, and your work surface with the ethanol solution. (If using the enclosed environment, make sure you remove the bacteria Petri dishes and spray down the inside with the ethanol solution.)

2. Using the scalpel and forceps, cut off any bleach-damaged portions of the leaf in an empty, sterile Petri dish.

3. Next, holding the leaf with the forceps, cut the leaf into strips (about 0.75 in x 0.75 in). Pieces of the leaf used as explants should have a section of vein running through them.

4. Place two or three of the strips (explants) into the Petri dish containing the prepared agar medium. Hold the cover of the Petri dish at a 45-degree angle when placing the leaf inside the dish to avoid introducing contaminates. Make sure the underside of the explants make good contact with the medium. The medium contains nutrients and hormones designed to stimulate cell division.

Your team should gather the following materials before beginning this activity:

- (1) Scalpel
- (1) Tweezer forceps
- Access to squirt bottle with 70% ethanol solution
- (4) Empty Petri dishes
- (4) Petri dishes with prepared agar medium
- Parafilm
- Permanent marker
- Label stickers
5. Replace the cover of the Petri dish and wrap with parafilm.

6. Label your explants with your name, the date, and any other relevant information.

7. The explants are ready to be placed in the closed, regulated environment you created in the previous learning cycle. Make sure you remove the bacteria-filled Petri dish because the bacteria can be transferred to your explants. Also, spray down the inside of your enclosed environment with the ethanol solution prior to placing your explants inside. Remember, they should be kept under light for sixteen hours per day and at a temperature around 75° F.
Expansion

Select one of the Expansion activities below:

1. Search for “micro-propagation” on the Internet. What types of crops are currently cultured using micro-propagation?

2. Interview a horticulturist or expert gardener. Ask him or her questions about propagation techniques and other forms of technology the or she uses.

3. Search for “microbiology” on the Internet. What is microbiology? What do microbiologists do? What are some other careers dealing with the study of microbes?

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor’s Occupational Outlook Handbook at: www.bls.gov/oco
Keep a laboratory journal, including photos, in the space provided or in a separate notebook, documenting the procedure and the progress of your explants.

You should be looking for small green shoots to form on or near the cut surfaces. New growth could take two to three weeks before it is visible. You may need to examine your explants under a microscope to see the growth. After five to six weeks, the growth should be easily visible. Make sure you compare your explants to the cutting you propagated earlier.

If, however, the explants were contaminated in the process, it will only take three to four days for fungus or bacteria to grow. Fungus contaminates will have a fuzzy appearance and bacterial contaminates will have a slimy appearance. Remove contaminated Petri dishes promptly to avoid spreading the contamination. Contaminated dishes should be wrapped, sealed, and discarded appropriately. Keep any notes in the Inventor’s Logbook space below.
# One Good Clone Deserves Another

Name: | Date:  
---|---

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>Successfully completed activities, used time wisely, and developed comprehensive plan for Engagement.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Successfully completed activities, used time wisely, and developed a plan for Engagement.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Completed activities, did not use time wisely, discussed but did not develop a plan for Engagement.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Did not complete activities, did not use time wisely, and did not discuss a plan for Engagement.</td>
<td>1</td>
</tr>
<tr>
<td>Engagement</td>
<td>Successfully completed Steps 1 and 2 with little difficulty, worked well as a team.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Successfully completed Steps 2 and 3 with some difficulty, worked ok as a team.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Completed Steps 2 and 3 with difficulty, did not work as a team.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Did not complete Steps 2 and 3, did not work as a team.</td>
<td>1</td>
</tr>
<tr>
<td>Preparing for the Challenge</td>
<td>Documented process, took pictures, developed an outline.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Documented process and took pictures.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Did not document process, but took pictures.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Did not document process, nor take pictures.</td>
<td>1</td>
</tr>
<tr>
<td>Inventor’s Logbook Entries</td>
<td>Fully answered all entries and provided good examples.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Answered most of the entries and provided some examples.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Answered few entries and provided few examples.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Did not answer entries and did not provide examples.</td>
<td>1</td>
</tr>
</tbody>
</table>

Total Points
Learning Cycle
Four

Too Hot to Handle?
BIOTECHNOLOGY COVERS A WIDE RANGE OF APPLICATIONS within many different disciplines. The following learning cycle will introduce you to another application: genetically-modified (GM) food. Although GM food may not seem directly related to the propagation of plants, the knowledge and tools required to propagate plants is necessary to genetically modify plants that are going to be consumed as foods.

GM food is considered a “hot” topic, in that it is controversial and the source of much debate around the globe. Genetically modifying a plant is not given much thought until it is going to be consumed for food. A new field has emerged to deal with these problems called bioethics. Bioethics involves determining and weighing the potential benefits and risks involved in a given biotechnology application.
Many see the potential benefits of biotechnology solving world hunger, curing diseases, and improving the environment. Others, however, fear the unforeseen consequences and potential damage of biotechnology, especially when applied to humans. These and other issues surrounding biotechnology will be debated and discussed during the Engagement phase of this learning cycle.

**Objectives**

After completing this learning cycle, you will be able to:

1. Analyze and understand the potential consequences of a given biotechnology.

2. Identify the different factors that are involved in the development and marketing of a technology that affects human health and/or the environment.
Do consumers have the right to know what they are eating?

Exploration

As discussed in Learning Cycle One, genetic modification involves humans working directly with the genetic material of an organism. A piece of genetic coding from the gene of one organism is inserted into the gene of another for the purpose of achieving a desired trait. Food containing genetically modified ingredients is already on our grocery store shelves. However, GM foods have been met with resistance by many people. Some countries and companies have refused to use or plant GM foods or crops.

Concerns about GM food center on the perceived inadequate testing to ensure the safety of GM foods for human consumption and for the environment. Many argue that profit alone is driving the development of GM foods, preventing reliable long-term measures to ensure safety. Other concerns include threats to food security, local farmers’ rights and future, ownership of genetically modified foods, access to resources, and the sharing of the benefits.
The GM crop Bacillus thuringiensis (Bt) corn, for example, has a pesticide in its genetic makeup so pests will die when they feed on the plant. Some fear, however, that “super bugs” will develop that are resistant to the toxins and can no longer be killed with conventional pesticides.

Proponents of GM foods, however, point to the potential solving of world hunger and the possible health benefits of GM foods. Scientists, for example, are developing crops that can be grown in arid, drought-ridden environments. Others are working on what has been named “functional foods”--foods with ingredients added that would help tackle health-related issues like vitamins deficiency and vaccination. For example, genetically modified “golden rice” has been developed, which contains extra vitamin A.

Many different issues have emerged with this hotly debated technology. One important issue is that of labeling. Many people, both for and against GM foods, believe labels should indicate what ingredient has been genetically modified and how.
To complete this activity, conduct research on a GM food or crop and create, either electronically or by hand, a label for the food product that you select. The label will need to accurately describe the genetically-modified ingredients and the process used to modify them. The label will also need to be balanced; that is, known potential benefits and risks need to be included. In addition, the label is a marketing tool. So, you should design a label that would best sell the food product.

In order to assess how well your label meets all of the criteria, you will need to perform consumer research. Your consumer research should consist of a survey administered to about ten to fifteen people from outside of your class. The survey should include four or five questions that cover the label’s design, the information displayed, and ultimately, whether or not the person would purchase this product based on the label you created. After you have administered the survey, you will need to analyze your data. For example, what percentage of those you surveyed said they would buy the product? Using this data, write a one-paragraph summary about your survey findings, whether or not you would change the label, and how.
Reflection

Answer the following questions in your Inventor’s Logbook provided below.

1. Identify one potential benefit and one potential risk of GM food. Does one outweigh the other, in terms of consuming the GM food? Why or why not?

2. Do consumers have a right to know what is in the food they buy? Is it up to the consumer to research a food product or should the product’s manufacturer provide the information?

3. As you designed your label, was it difficult to include the potential risks when trying to best market the product? Is it difficult to balance these two issues?
You have been exposed to some of the procedures, techniques, and tools involved in biotechnology while working through this Learning Unit. You have also become familiar with some of the ethical considerations involved with this hotly debated technology. Perhaps you are starting to form your own opinion about some of the issues involved with biotechnology. You will now have the opportunity to research and debate one of the major issues surrounding biotechnology: its regulation.

In your Primary Challenge teams, you will need to research and identify the major considerations involved in the regulation of biotechnology. Each team will need to prepare a packet of information that highlights several of these major considerations in order to support your answers to the debate questions on the next page. Your packet of information can include the photo-laboratory journal you created for your Primary Challenge solution.

Each team will need to gather information so your team can decide its stance on the regulation of biotechnology. (This decision is for the purposes of debate; your team’s stance does not necessarily have to reflect your own views on the issue.) Your team’s decision should be supported by the information you find so you can support your argument during the debate.
Constraints/Requirements

Each team’s packet of information must contain the following:

- One-page summary of the issues surrounding the regulation of biotechnology that your team identified and researched.

- Three articles discussing the regulation of biotechnology (Internet, newspaper, magazines, etc).

Debate Questions:

1. Is regulation important for biotechnology?

2. Should the regulation of biotechnology be decided on a case-by-case basis or regulated as an entire entity?

3. Are there some forms of biotechnology that should be regulated more closely than others?

4. What or who should decide if a biotechnology should be allowed?

5. Should public opinion or scientific evidence or both determine the regulation of biotechnology?
Debate Process

After each team has compiled its packet of information and worked through the debate questions, your instructor will lead the debate. The debate will follow the format outlined below.

- Your instructor will ask a question (some questions are not listed) directed at a randomly chosen team.
  - Each team will have the opportunity during the debate to answer a question first.
  - The same student can only answer an initial question for the group once. (The same student can offer multiple rebuttals during the debate.)

- Each team will have two minutes to prepare and give a response.
  - Your instructor will time the debate with a stop-watch.

- After the initial response to a question, other teams will have an opportunity to offer a rebuttal. Any team can then enter the debate with their opinion on the issue.
At the completion of the debate, reflect on the debate by answering the following questions:

1. Did you already have an opinion about the regulation of biotechnology before the debate? Did your opinion change?

2. Why do you think the regulation of biotechnology is such a hotly debated issue?

3. Did the plant-cloning process you performed help shape your opinion about biotechnology?
Expansion

Select one of the Expansion activities below:

1. Another hotly-debated issue concerning genetically-modified food and animals is food patents. Biotech companies have patented the GM plants and animals they have developed to ensure against what has been termed “bio-piracy,” or the stealing of their invention. Research GM food patents and develop a one-page summary that answers the following questions. What are both sides of the issue? What other measures have biotech companies taken to ensure against bio-piracy? Do companies have the right to patent living organisms?

2. Many instances have occurred where companies (including fast-food restaurant chains) or entire countries have banned the use of GM foods. Research an instance either in the United States or abroad where a GM food was banned. Document the reasons for the ban and how the biotech company marketing the GM food responded. Develop a one-page summary of the incident demonstrating both sides of the issue.

3. In addition to genetically modifying food and animals, there have been other biotechnological developments in the field of microbiology. Bacteria have been used in many different biotechnology applications. Research either bio-mining or the use of bacteria to produce missile propellant. How is bacteria used in these applications? Why is this considered a biotechnology? What are the possible consequences, both good and bad, that must be considered?
Meet in your Primary Challenge teams. If your micro-propagated plant has developed small green shoots visible to the unaided eye, you can transplant them into pre-transplant medium. You will follow the same procedures as when you placed the explant into the Petri dish. For further direction, see your instructor.

Each team should then complete its photo laboratory journal. You should compare the progress of each explant within the team and answer the following questions. Keep notes and records in the Inventor's Logbook space on the following page.

- How many survived?
- Why did some survive when others failed?
- How could you have improved your chances of success?
## Too Hot to Handle?

**Name:**

**Date:**

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Points</th>
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</thead>
<tbody>
<tr>
<td><strong>Exploration</strong></td>
<td><strong>4</strong> Label is extremely accurate, balanced and marketable.</td>
<td></td>
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<tr>
<td></td>
<td><strong>3</strong> Label is accurate and mostly balanced and marketable.</td>
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<td></td>
<td><strong>2</strong> Label is somewhat accurate, balanced and marketable.</td>
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<td><strong>1</strong> Label is not accurate, balanced and marketable.</td>
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<tr>
<td><strong>Engagement</strong></td>
<td><strong>4</strong> Packet demonstrates a full grasp of the major concepts, addresses most of the stated requirements, and successfully contributed to preparation and debate.</td>
<td></td>
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<tr>
<td></td>
<td><strong>3</strong> Packet demonstrates a full grasp of the major concepts, addresses most of the stated requirements, and contributed to preparation and debate.</td>
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<td></td>
<td><strong>2</strong> Packet demonstrates a partial grasp of the major concepts, addresses some of the stated requirements, and minimally contributed to preparation and debate.</td>
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<td></td>
<td><strong>1</strong> Packet demonstrates a limited number of the major concepts, addresses a few of the stated requirements, and did not contribute to preparation and debate.</td>
<td></td>
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<tr>
<td><strong>Inventor’s Logbook Entries</strong></td>
<td><strong>4</strong> Fully answered all entries and provided good examples.</td>
<td></td>
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<td></td>
<td><strong>3</strong> Answered most of the entries and provided some examples.</td>
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<td></td>
<td><strong>2</strong> Answered few entries and provided few examples.</td>
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<tr>
<td></td>
<td><strong>1</strong> Did not answer entries and did not provide examples.</td>
<td></td>
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<tr>
<td><strong>Preparing for the Challenge</strong></td>
<td><strong>4</strong> Lab journals completed and questions fully answered.</td>
<td></td>
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<tr>
<td></td>
<td><strong>3</strong> Lab journals mostly completed and questions answered.</td>
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<td></td>
<td><strong>2</strong> Lab journals incomplete, some questions answered.</td>
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<tr>
<td></td>
<td><strong>1</strong> Lab journals not complete, questions unanswered.</td>
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<td></td>
<td><strong>4</strong> Extensive preparation started.</td>
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<td></td>
<td><strong>3</strong> Preparation started.</td>
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<td></td>
<td><strong>2</strong> Preparation not yet started.</td>
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</tr>
<tr>
<td></td>
<td><strong>1</strong> Preparation not started.</td>
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**Total Points**