Agriscience/ Biotechnology

Facilitators Guide

4-H Science

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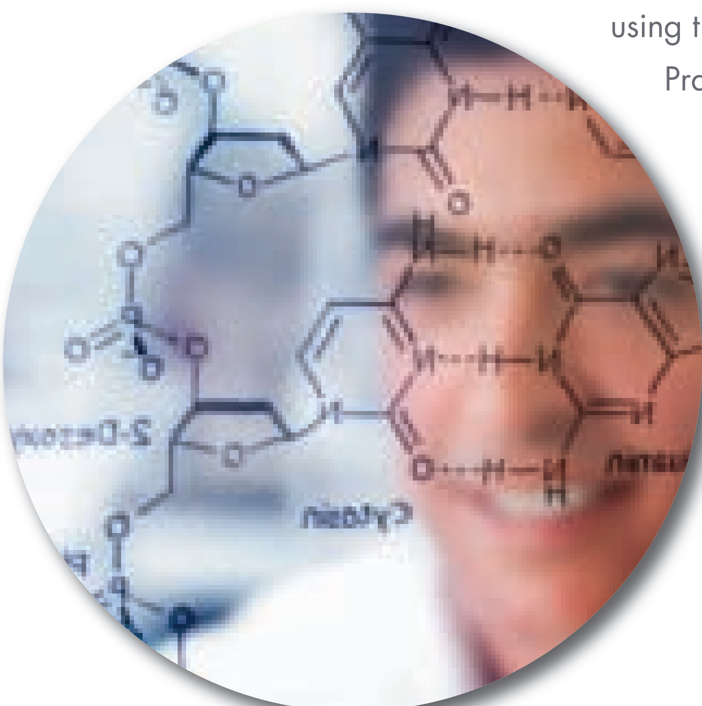
WELCOME TO THE Agriscience/Biotechnology Facilitators Guide

Today, many young people are generationally and geographically removed from farming and agriculture. Yet, it is vital that these young leaders and future decision makers understand the critical role of agricultural science innovation in addressing the world's most pressing problems. 4-H, with more than 1.4 million urban members, is uniquely positioned to reach new and underserved urban youth audiences. 4-H has systems and the infrastructure in place to share promising practices and strategies that can engage and excite urban teens about agriscience and biotechnology. These tactics will lay a foundation for increased outreach and impact with urban youth audiences.

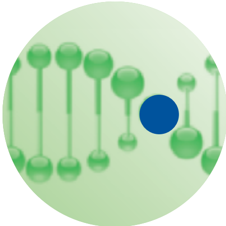
In 2012, National 4-H Council in partnership with the United Soybean Board (USB) and five Land Grant Universities conducted four Agriscience/Biotechnology demonstration programs in ten urban areas of Delaware, Illinois, Indiana, Missouri, and Ohio. These programs are part of the larger 4-H Science in Urban Communities Initiative, and were designed using the 4-H Science in Urban Communities Promising Practices Guide. The heart of these programs was educating 4-H teens and adult volunteers about some of the basics of agriscience and biotechnology through hands-on and place-based activities. Teens taught middle school youth several science activities focused on improving understanding of agriculture biotechnology and basic science skills.



As a result of this programming, it was evident that a guide for professionals and volunteers to deliver these programs was needed in order to increase the potential to reach more youth. The purpose of this guide is to provide substantive science-based foundational knowledge of agriscience/biotechnology through the use of presentations, discussions and hands-on activities. Learning science based information can promote informed participation in discussions about these topics. This facilitators guide was developed with funding from the United Soybean Board (USB) for key professionals and volunteers to gain a better understanding of agriscience/biotechnology, and to then be able to use the modules within this guide to train other professionals and volunteers so that they will be equipped to facilitate youth agriscience/biotechnology programming.

The background material and modules in this guide provide agriscience concepts and related activities including agricultural literacies, challenges for agriculture, an introduction to biotechnology, and agriscience/biotechnology career awareness. They are designed to improve base knowledge about agriscience related to plant biotechnology through the use of seven modules. Each module includes an introduction, a PowerPoint slide set, hands-on activities, discussion topics, and review questions.

A big picture view of this professional development guide is presented in Table 1. Basic organizational structure of the *Agriscience/Biotechnology Guide* establishes five main categories of agricultural science concepts and related activities and resources. These are: Agricultural Literacy, Challenges for Agriculture, Introduction to Agricultural Biotechnology, Science of Biotechnology, and Agriscience/Biotechnology Career Awareness. Each of the main categories includes modules, as well as related activities and resources.



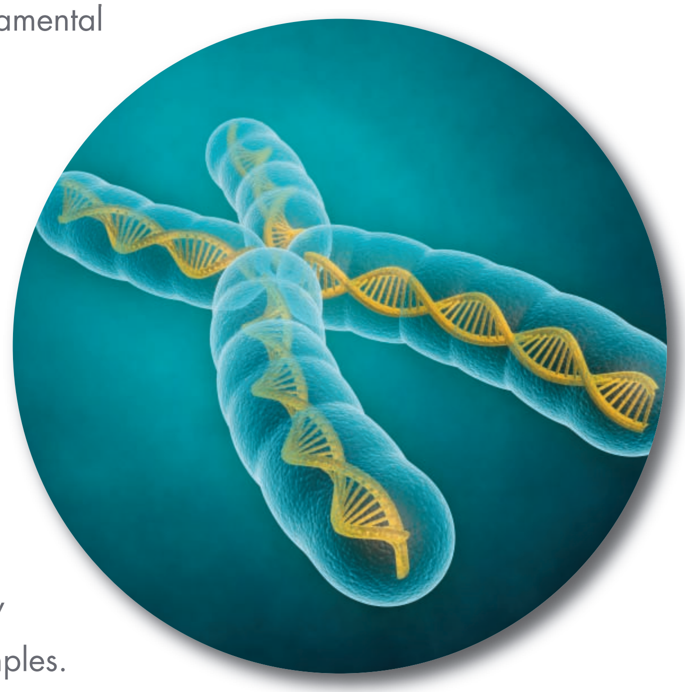
OVERVIEW
Agriscience/Biotechnology Facilitators Guide

PART ONE: Introduction to Agriscience/Biotechnology

This section will provide an introduction to agriscience/biotechnology and why it is important to be knowledgeable on the topic. How biotechnology plays a role in your everyday life—through food, fiber and fuel—and how crops are selected and produced for these different roles will be addressed. Table 1: Organizational Overview of the *Agriscience/Biotechnology Facilitators Guide* provides a big picture overview of the topics covered in the guide. Table 2 includes web resources that have been reviewed and are reliable sources of additional information. Weblinks include sources that are independent, sponsored by industry, affiliated with museum or science centers, or linked with universities. Much additional information, activities, resources and ideas can be found within these sites.

PART TWO: Agriscience/Biotechnology Modules

This section includes seven modules covering topics from What is Biotech? to What is DNA?. Three modules will address basic knowledge and social aspects of biotechnology, while four modules will address fundamental science concepts underlying biotechnology.



Module 1: What is Biotechnology?

This module is intended to introduce your participants to the basics of biotechnology, and how specifically biotechnology is used in agriculture. Historical perspectives of biotechnology are also included.

Module 2: Why Biotech?

This module introduces the role biotechnology plays in everyday life through hands-on examples.

Module 3: DNA Defined

This module seeks to review social issues surrounding biotechnology, evaluating the issues from all different perspectives.

Module 4: The Biotechnology Debate

This activity reinforces the process of DNA extraction, the first step for many laboratory procedures in biotechnology, including gel electrophoresis and DNA sequencing and genomics.

Module 5: Improving our Plants

This lesson introduces methods of genetic manipulation, which involves the conventional method of breeding and the genetic engineering method of cloning.

Module 6: Unraveling DNA Sequence

This lesson introduces DNA sequencing, which scientists use to know where genes are located in the genome.

Module 7: Gene On or Gene Off?

This lesson introduces the topics of gene expression and how microarrays are used to study in what way genes are expressed.

How to Use this Guide

The professional or volunteer who needs to learn more about agriscience/biotechnology in order to lead training for other professionals and/or volunteers should do the following:

Step 1: Read the Overview of Agriscience/Biotechnology starting on page 10. Later, as you become familiar with the materials and are looking for further resources and information, you can review the Biotechnology Web Resources in Table 2, on page 20.

Step 2: Review Table 1: Organizational Overview of the Agriscience/ Biotechnology Facilitators Guide starting on page 18 to become familiar with the layout of the modules. Then review the modules on page 26 through 112.

Each module contains one or more activities. Some are included with this guide, while others are found online. When offering training for volunteers, not all activities can be fit into a reasonable period of time. Therefore, this guide offers the flexibility to choose how many and which activities will be used when offering a training. A rough estimate of time needed to demonstrate and practice each activity in a training session is approximately 30 minutes. Time listed with the instructions for each activity generally refers to the time needed to conduct the full activity, as with a youth audience.

Modules 6 and 7 offer important, yet more complex, material related to the application of biotechnology. Both utilize online animations, along with activities, to demonstrate hard-to-understand topics. When time or audience interest permits, these modules can be utilized. It is recommended for those unfamiliar with biotechnology to start with activities in modules 1–5.

Step 3: After reviewing the modules and activities associated with them, select an activity(s) from each of the first 5 modules. The amount of time allocated for training will determine which and how many activities. Some suggestions for 4-hour, 8-hour or 1½-day trainings are included below. Within each example schedule, alternate suggestions are included. A rough estimate of time needed to demonstrate and practice each activity in a training situation is approximately 30 minutes. Time listed for each activity generally refers to the time needed to conduct the full activity, as with a youth audience.

The employment of guest speakers and/or field trips is **highly encouraged.** Much can be gained from visiting seed companies, universities, research labs, science museums, and related venues. Bringing in guest speakers or setting up a panel of speakers, with expertise in any area related to agriscience/biotechnology affords an excellent opportunity to connect industry, university and science education partners. Information learned through speakers or field trips will greatly enhance the materials encompassed in this guide.

Step 4: Organize and facilitate training using the modules for professionals and volunteers (adult and teen) who will be delivering agriscience/biotechnology programs to youth. Please note that each module outlines the materials/supplies you will need to be prepared for the training.

4-Hour Training Example Schedule

1:00 – 1:30 **Welcome and Overview**

1:45 – 2:45 **Biotech 101**

3:00 – 4:30 **Activity Explorations** (choose 2–4)

- Soy Plastic, *Module 2: Why Biotech?*, page 39
- Soy Ink and What Makes NesQuik™ Quick?, *Module 2: Why Biotech?*, page 41
- Cell Model or DNA Model, *Module 3: DNA Defined*, page 65
- DNA Extraction, *Module 3: DNA Defined*, page 72

4:30 – 5:00 **Wrap Up, Reflection & Processing**

8-Hour Training Example Schedule

9:00 – 9:30 **Welcome and Overview**

9:30 – 10:30 **4-H Ages and Stages** (if new volunteers or professionals); or
Biotech 101 (If audience does not need Ages and Stages)

10:30 – 11:00 **Break**

11:00 – 12:00 **Biotech 101**

(If started with Biotech 101, combine time with either lunch or break to schedule a field trip; or shift time to plan an interactive session with a panel or guest speaker; or add additional activities to the schedule, for suggestions, see note on 1½-day training example.)

12:00 – 1:30 **Lunch with Guest Speaker**

1:30 – 4:00 **Activity Explorations** (2–4) (with a 15 minute break)

- Soy Plastic, *Module 2: Why Biotech?*, page 39
- Soy Ink and What Makes NesQuik™ Quick?, *Module 2: Why Biotech?*, page 41
- Cell Model or DNA Model, *Module 3: DNA Defined*, page 65
- DNA Extraction, *Module 3: DNA Defined*, page 72

4:00 – 4:30 **Wrap Up, Reflection & Processing**

1 1/2-Day Training Example Schedule

DAY 1

8:00 – 8:30 **Introduction, Program Overview**

8:30 – 9:30 **Teambuilding, Ice Breakers**

9:30 – 10:30 **Ages and Stages**

10:30 – 12:00 **Biotech 101 or Field Trip**
(Field trip examples include Science Museum, Children's Museum, Science Center, Industry partner—Seed or Crop businesses or processing facility, University partner)

12:00 – 1:30 **Return and Meal and Break** *(or Guest Speaker, or extend time for field trip)*

1:45 – 4:30 **Biotech 101 or Field Trip**

1:45 – 2:45 **Biotech 101 or start Activities**

3:00 – 4:30 **Activity Explorations** (2–3)

- Soy Plastic, *Module 2: Why Biotech?*, page 39
- Soy Ink, *Module 2: Why Biotech?*, page 41
- Cell Model or DNA Model, *Module 3: DNA Defined*, page 65
- DNA Extraction, *Module 3: DNA Defined*, page 72

(If already completed Biotech 101, suggestions to extend activity time are to separate Soy Ink into two activities, do both Cell model and DNA model.)

4:30 – 5:00 **Reflections on the day**

5:00 – 5:30 **Break, Room Check-in if needed**

5:30 – 7:00 **Meal and Guest Speaker**

(If guest speaker is not desired, shorten meal time and continue with activities, or do field trip into the evening)

Evening activities—if needed:

- Have groups of 2–4 participants practice teaching the activities to each other;
- Allow time for planning programs in local areas within small groups.

DAY 2

8:00 – 8:30 **Reflection and Discussion on Prior Day**

8:30 – 11:00 **Activity Exploration** (choose 2–4) and break

- Sequencing with LEGO®, *Module 6: Unraveling DNA Sequence*, page 101
- Biotech Case Study (Debate) – minimum time 45 minutes,
- *Module 4: The Biotechnology Debate*, page 81
- Apple Genomics Project Animations – minimum time 1 hour, *Modules 5, 6,& 7* pages 89, 97, 109
- Face the Fat: Engineering a Better Oil, *Module 2: Why Biotech?*, page 53 *(If activities were completed on prior day, morning could be utilized for a field trip, panel, guest speaker, or practice teaching activities)*

11:00 – 12:00 **Wrap Up, Reflection & Processing**

OVERVIEW OF Agriscience/Biotechnology

Biotechnology has helped scientists bring consumers better agriculture products and practices, but in a manner that is often considerably faster with the use of modern technologies. This guide will help provide some basic fundamental knowledge so that you as a consumer can make informed decisions about this new technology that will benefit both you and society as a whole. Biotechnology is changing the way we grow, produce, market and eat our food, as well as impacting the environment and industry. Our young people will need to understand the underlying science of agriculture biotechnology so that they are able to guide future research and development in biotechnology, as well as protect our environment and feed our families.

Plants and People: Food, Feed, Fuel, Fiber

So why learn about agriculture biotechnology? It is important to grasp the connection between plants and people. Plants provide us food, shelter, fuel, fiber for clothes and manufacturing, and feed for our livestock. Before you dive into the details of biotechnology, let's take a few minutes and review the role that plants, in particular, soybeans, play in our lives.

Over 350,000 farms in the United States produce soybeans, accounting for over 50% of the world's soybean production. Basic soy products include soybean oil, soy biodiesel, soy meal and soy hulls. According to the United Soybean Board, soybean oil, used in both food manufacturing and frying and sautéing, represents approximately 79% of all edible oil consumed in the United States. Soy meal and hulls are primarily consumed as livestock feed or included as part of feed rations. According to www.soyatech.com, 85% of the world's soybean crop is processed into meal and vegetable oil, and virtually all of that meal is used in animal feed (98%).

Soy is one of the few plant foods that provide a complete protein, as it contains all eight amino acids essential for human health. Fermented soy products, such as tofu, continue to serve as a substantial substitute for animal proteins in the diet. Soy protein is found in a wide variety of foods today, such as cereal, pasta and baked goods. Soy isolates and concentrates are used in beverages, coffee creamers, whipped topping and in dairy blends. Dairy alternates made from soy include cheese, yogurt, and frozen desserts. Processed and whole meat products can be also be improved through the addition of soy protein. Soy lecithin (pronounced less a thin), is an important product extracted from soybean oil. It is a natural emulsifier and lubricant used in many foods, commercial, and industrial applications. As an emulsifier, it can make fats and water compatible with each other. For example, it helps NesQuick™ chocolate milk mix dissolve in your tall glass of milk.

For information about a soybean's journey from farm to market, the United Soybean Board's report, *Farm to Market*, gives a nice overview. Specifically pages 1–4 are a good place to start and include a nice graphic about how soybeans move in the United States.
http://www.unitedsoybean.org/wp-content/uploads/FarmToMarketStudy2.pdf

Improving our Crops

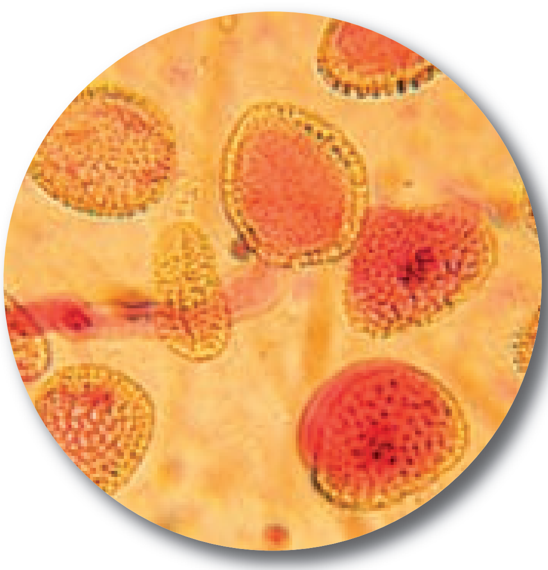
Soybeans, along with all of the crops grown commercially or for home consumption, have been selected to be the best. Growers and gardeners want plants that grow well, are resistant to disease and insects and that have high yields. Plant breeders and plant science researchers use many different techniques to create plants that meet this need. Genetics, biotechnology and basic plant biology are all components of a plant breeder's tool box for improving plants. The range of modifications to plant traits can be characterized as *input* and *output traits.*

- **Input traits:** An input trait helps crop producers to increase the efficiency of production. Examples include increased yield, resistance to insects and diseases, and more efficient nutrient utilization.

  Input traits affect how the crop is grown, without changing the nature of the harvested product.

- **Output traits:** An output trait helps consumers or processors by enhancing the quality of the plant product. Examples are soybeans with heart-healthy oil profiles, soybeans that are designed for specific industry uses, such as generation of biofuels, and crops that contain higher nutrient levels, such as increased lycopene in tomatoes.

An output trait changes the quality of the crop itself by altering starch protein vitamin or oil structure or composition.



For a long time, science had only encouraged plant breeders and producers to focus on input traits of our food, fuel, fiber, and feed crops. The rapid advancement of scienctific discovery as well as development of important technologies, have shifted this focus to output traits. Soybeans are an excellent example of how biotechnology is providing ways to improve the output traits for our use.

The Science of Biotechnology: Roundup Ready® Soybeans

One of the most prevalent examples of a biotech crop is Roundup Ready® Soybeans. The $2.93 billion additional income generated by herbicide tolerant soybeans is equivalent to adding 4.3% to the value of the crop globally (ISAAA 2009). Soybeans tolerant of Roundup are an example of an input trait.

Weeds are a big problem, especially in the agriculture industry. Weeds can choke plants, block sunlight, and remove essential nutrients from the soil, thereby affecting yields and farmer revenue. Farmers apply herbicides in order to control weeds. However, many chemical herbicides kill all plants, making applying herbicides difficult. Herbicides also linger for a long time in the soil, affecting future harvests. In order to help solve this problem, chemical and seed companies have developed herbicide-tolerant crops. Such crops give farmers new alternatives for weed control.

The case of Roundup Ready® plants. Roundup (glyphosate) is a very effective, broad spectrum herbicide. It is a systemic herbicide, which means plants take it up and transport it throughout the leaves, stems, and roots. Some Roundup accumulates in growing root tips. Plants make their own amino acids, which in turn are assembled into proteins. Roundup inhibits plant growth by interfering with an enzyme involved in making certain amino acids. Because of this mechanism, Roundup kills nearly all plants.

Roundup Ready® Soybeans are a line of soybeans that can survive the roundup herbicide. This way, farmers can spread Roundup to kill weeds without killing their soybean plants. By using Roundup Ready® Soybeans, farmers gain a new weed control option that:

- is less toxic (other herbicides stick around in the environment longer);
- lets them use less herbicide;
- gives them better weed control; and
- gives them higher profit.

How did researchers create crops that were Roundup Ready? Their first approach was to find the plant enzyme that Roundup inhibited. After working on plant genomes and proteins, researchers identified the enzyme as EPSP synthase. Researchers modified a plant's own genes to make more EPSP synthase. This way, a plant produced the enzyme in excess, and would still have enough enzyme left over when the plants were sprayed with Roundup. Although the technique worked and some plants survived Roundup spraying, it did not produce the desired outcome. The second approach was to find the gene for EPSP synthase that made certain bacteria resistant to glyphosate, and then move that gene into plants. This is the basis for the successful Roundup Ready® Soybeans that farmers use today.

Soybeans are not the only biotech crop being widely grown in the U.S. Corn and cotton that have been genetically engineered through the use of biotechnology to resist insect pests and herbicides are now planted on almost half of all U.S. cropland. The introduction of biotechnology-derived products into agriculture, but are often met with controversy or raise ethical questions. Many concerns about these technologies include food safety, environmental impact, consolidation of agribusiness, and globalization of commerce, are legitimate and warrant further discussion and study. The reaction to some agricultural biotechnology, however, is in contrast to the widespread public acceptance of healthcare products, such as pharmaceuticals and diagnostic tests, developed using similar scientific techniques. Citizens are apprehensive about the potential health effects and environmental concerns associated with biotechnologies, as genetically modified organisms (GMOs) continue to be prevalent in our society.

The U.S. Food and Drug Administration (FDA) requires that all foods be evaluated before they reach the market. In the case of foods derived from biotechnology, the FDA requires a strict, full safety evaluation for all food products that contain:

- genes that are not currently present in the food supply;
- foods with altered nutrient levels;
- different composition from substances currently found in foods;
- allergenic proteins;
- new antibiotic resistant markers;
- increased levels of toxins; and
- resistance of weeds or insects to GMO crops.

Despite the promise of biotechnology for the food industry, there are still safety issues that need to be considered. Can the presence of new DNA in a plant or animal make it unsafe to eat? In line with regulation is the labeling issue; consumer groups have called for biotechnology-derived products to be labeled, a process that can also increase the prices of such foods. This labeling issue has been debated for years, and is again, in 2012, in the spotlight as consumer groups push for legislation requiring the labeling of GMO products in our food.

Biotechnology 101

Now you are ready to learn more about biotechnology. In order to be get a great overview of agriscience/biotechnology first, start with a review of basic biotechnology topics. **The Pew Charitable Trust** has a very good overview of basic biotechnology on their website pages. Users get a definition, how it is used, benefits, safety considerations, extent of biotech crops in production and regulation. Please take the time and read the material—all you need to know about biotech in a nutshell is there. **http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Food_and_Biotechnology/hhs_biotech_harvest_report.pdf**

Additionally, another great overview piece is the four-page **Biotechnology FAQ** document from USDA at **http://www.usda.gov/wps/portal/usda/usdahome?contentid=BiotechnologyFAQs.xml&navid=AGRICULTURE.** In four pages, users get a definition, how it is used, benefits, safety considerations, extent of biotech crops in production, and regulation.

Another useful overview resource comes from **The Biotechnology Institute**. The Biotechnology Institute publishes a high school classroom magazine titled *Your World, Biotechnology and You*. The issue linked here discusses agriculture biotech crops—the science involved, the benefits possible, and the concerns people have toward them. **http://getbiotechsmart.com/sites/getbiotechsmart.com/files/student/agricultural_biotechnology_a_world_of_potential.pdf**

The **Biotechnology Industry Association** has a helpful report that discusses how agricultural biotechnology delivers significant and tangible benefits, all the way from farm to fork. Agriculture biotechnology has helped to provide for more sustainable agricultural production—the benefits include a reduction in the environmental impacts of agriculture, increased production on the same amount of acreage, improved food quality, and increased farmer profitability. **http://getbiotechsmart.com/sites/getbiotechsmart.com/files/student/agricultural_biotechnology_delivering_benefits_for_farmers_consumers_and_the_environment.pdf**

Impact of Biotechnology on Global Agriculture and Sustainability

The impact of biotechnology, particularly agriculture biotechnology, is visible and needed globally. Impacts include sustainable agriculture, food production, the environment and human and animal health and welfare. A nice overview of this topic can be found on the **Get Biotech Smart** website. The linked report assesses the impact biotechnology is having on the global agriculture system from a community, health and environmental perspective.
http://getbiotechsmart.com/sites/getbiotechsmart.com/files/student/the_benefits_of_biotechnology.pdf

As the global population increases, especially in developing countries, a need for a larger food supply becomes obvious. It has been suggested that biotechnology has the potential to increase world food output and reduce food insecurity by improving crop yields and reducing crop loss. A good overview of this can be found in the USDA report linked here. This report details the role developing nations will have in becoming producers of enough food to feed their own citizens.
http://getbiotechsmart.com/sites/getbiotechsmart.com/files/student/biotechnology_and_food_security.pdf

Conclusion

Whatever your opinion of biotechnology might be, learning the underlying science is essential to seeing the larger picture of the role of biotechnology in our lives. 4-H youth will be the leaders and decision makers and it is essential that they are armed with good science information to be successful in those pursuits.

TABLE 1: Organizational Overview of the Agriscience/Biotechnology Facilitators Guide

Agricultural Science Concepts, Activities, and Resources	Modules
Agricultural Literacy • Agricultural Products (how and where they are produced) • Plants and People: Food, Feed, Fuel, Fiber • Seed Production • Yield and Yield Trends • Factors Influencing Yield	Overview and Introduction
Challenges for Agriculture • Global Food Security • Sustainability	Overview and Introduction
Intro to Agricultural Biotechnology • Biotechnology Defined • Historical Perspective • Input and Output Traits • Types of Biotech Crops (and how they work) • Regulation of Biotechnology • Public Concerns Regarding Biotechnology • International Perspective	1. What is Biotechnology? 2. Why Biotech? 3. DNA Defined

TABLE 1: Organizational Overview of the Agriscience/Biotechnology Facilitators Guide

Agricultural Science Concepts, Activities, and Resources	Modules
Science of Biotechnology • Cell Biology • DNA • Genetics • Genetic Engineering • Tools and Techniques	4. The Biotechnology Debate 5. Improving Our Plants 6. Unraveling DNA Sequence 7. Gene On or Gene Off?
Agriscience/ Biotechnology Career Awareness	Any Module, Field Trips, Guest Speakers

TABLE 2: Agriscience/Biotechnology Web Resources

Title/topic	Website	Brief Description	Modules
USDA Biotechnology	http://www.nifa.usda.gov/biotechnology.cfm	National Institute on Food and Agriculture Biotechnology page. Current topics, reports, research, resources.	1,2,3
The Apple Genomics Project	http://www.four-h.purdue.edu/apple_genomics/	Series of animations related to basic biotechnology molecular priciples. Includes animations with lessons plans and worksheets. Hosted at Purdue, funded by NSF.	5,6,7,8
Iowa State Office of Biotechnology	http://www.biotech.iastate.edu/outreach.html	Outreach section. Excellent resources for teaching biotech, curriculum, step-by-step experiments, power points, resources.	1,2,3,4
University of Wisconsin Biotechnology Center	www.biotech.wisc.edu/outreach/	Has teaching tools, ideas and explanations for exploration stations, links, and other good information.	1,2,3
Pew Charitable Trusts–Initiative on Food and Biotechnology	http://www.pewhealth.org/projects/pew-initiative-on-food-and-biotechnology-85899367237	A source of foundational research and information on the complex issues related to biotechnology and food. Unbiased resources.	1,2,3,4
The University of Utah Genetic Science Learning Center	http://learn.genetics.utah.edu/	Genetics learning site that has resources for both teacher and students. Animations, modules and includes a "Print-and-Go" lesson plan index.	5,6,7,8

TABLE 2: Agriscience/Biotechnology Web Resources

Title/topic	Website	Brief Description	Modules
Oklahoma State 4-H Biotechnology	http://oklahoma4h.okstate.edu/biotech.htm	Videos, activities, resources	1,2,3,4,5
Dolan DNA Learning Center (Cold Spring Harbor Laboratory)	http://www.dnalc.org/ http://www.dnai.org/index.htm http://www.dnaftb.org/	"Preparing students and families to thrive in the gene age." An amazing set of resources on many aspects of genetics. Many animations, movies, interactives, and resources to provide background info not only for instructors but also students. Clearinghouse for several other sites. • DNA Interactive • DNA From the Beginning	2,4,5,6,7,8
Weed to Wonder	http://www.weedtowonder.org/	Weed to Wonder tells the story of how human ingenuity transformed a common Mexican weed (teosinte) into a modern food wonder (maize).	2,3,7
Greenomes	http://greenomes.org/	College student online learning and labs related to plant science. Contain a set of laboratories illustrating key concepts of gene analysis in plants, including relationship between phenotype and molecular genotype, genetic modification of plants and detection of transgenes in foods.	6,7,8
	http://greenomes.org/experiment5.html	*Example:* module on detecting GMO food by PCR	5,6,7,8

TABLE 2: **Agriscience/Biotechnology Web Resources**

Title/topic	Website	Brief Description	Modules
University of California Biotechnology	http://www.ucbiotech.org/	Site has curriculum, research, fact sheets, videos, teaching materials, and informational resources. Provides educational resources focused broadly on issues related to agriculture, crops, animals, foods and the technologies used to improve them.	1,2,3,4,5
UC Biotech: DNA for Dinner	http://ucbiotech.org/dnafordinner/index.html	California 4-H curriculum designed for grades 3-5. Includes hands-on activities, instructions, and is downloadable as pdf.	3,4
UC Biotech: Teaching Aids	http://ucbiotech.org/resources/teaching_aids/index.html	Teaching aids. Downloadable games, and various other teaching materials	any
Biotechnology Industry Organization	http://www.bio.org/	Biotechnology Industry Organization (BIO) is the world's largest biotechnology organization. Provide advocacy, business development, and communication services members worldwide	2,3
The Children's Museum of Indianapolis	http://www.childrensmuseum.org/sites/default/files/files/%20TCM%20BIOTECH%20UOS.pdf	Yesterday, Today and Tomorrow. Agriculture Biotechnology. A biotechnology unit of study with target audience grades 6-8.	1,2,3

TABLE 2: Agriscience/Biotechnology Web Resources

Title/topic	Website	Brief Description	Modules
Biotechnology Institute	http://www.biotechinstitute.org/	Lots of great info. Funded (sponsored) mostly by corporate and industry. Videos, facts, timeline, glossary, sections for students and teachers.	1,2,3
Access Excellence Resource Center	http://www.accessexcellence.org/RC/AB/index.php http://www.accessexcellence.org/RC/AB/BA/ http://www.accessexcellence.org/RC/AB/BC/ http://www.accessexcellence.org/RC/AB/IE/	From the National Health Museum, related to Science and Technology. Many good articles, resources, background information, animations, career info, etc.	1,2,3,4 and careers
		About Biotech Index	
		• Biotech Applied– helps relate to real life. Looks at the practical applications of biotechnology.	3
		• Biotech Chronicles– history, timelines	2
		• Issues and Ethics	4
National Center for Biotechnology Information	http://www.ncbi.nlm.nih.gov/	National Center for Biotechnology Information– described as advancing science and health by providing access to biomedical and genomic information. Supported by National Institutes of Health.	5,6,7,8
National Agriculture Biotechnology Council	http://nabc.cals.cornell.edu/index.cfm	Mainly publications as resources, white papers used Nationally and Internationally. Useful for helping provide information for informed discussions.	2,3,4

TABLE 2: Agriscience/Biotechnology Web Resources

Title/topic	Website	Brief Description	Modules
University of Nebraska Plant and Soil Science eLibrary	http://passel.unl.edu/pages/index2col.php?alllessons=1&tag=Basic+Biotechnology http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=957882007 http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=991751218	Plant and Soil Sciences eLibrary, hosted by University of Nebraska. Funded by USDA and NSF. Has Biotechnology Lessons Page. - Basic Biotechnology overview page (links to 5 modules) - DNA extraction explained - Basic Biotechnology Module 1	1,2,3,4,5 5 2,3
Understanding Science	http://undsci.berkeley.edu/	Understanding Science, How Science Really Works. A nice science 101 site funded by NSF and hosted by University of CA–Berkley.	2, 3, 5
Why Biotech? (Council for Biotechnology Information)	www.whybiotech.com	"Good Ideas are Growing." Sponsored by industry, focus is pro-biotech. Lots of good information, especially current events and developments. Fact sheets, issue briefs, videos, you tube channel, an activity book for kids to download, and includes global information and facts.	1,2,3,4
Ag Bio World	www.agbioworld.org	Daily collection of news and commentaries on Biotechnology in Agriculture. Includes articles, press releases, and other interesting info, includes a global perspective as well.	any

TABLE 2: Agriscience/Biotechnology Web Resources

Title/topic	Website	Brief Description	Modules
Biotech Project– The University of Arizona	http://biotech.bio5.org	Site has some nice activities, videos and other information. NSF- and Helios-funded.	any
The European Initiative for Biotechnology Education (EIBC)	www.eibe.info/	Has a set of nice teaching materials (educational units) on various topics related to biotechnology. Geared toward high-school-aged students.	any
Get Biotech Smart	http://getbiotechsmart.com/	Sponsored by United Soybean Board. Includes tools teachers and students need to establish a connection between biotechnology and global challenges.	any
Teachers Domain	http://www.teachersdomain.org/special/biot/	Special biotechnology section of a site that focuses on digital media for the classroom. Corporate-funded (Amgen).	any
Bio-Link– Educating the Biotechnology Workforce	http://www.bio-link.org/home/	Funded by NSF. Great resource related to careers in Biotech and connecting with community college networks	careers

MODULE 1: What is Biotechnology?

Outcomes: Upon completion of the module, participants will be able to:

- Define and describe biotechnology
- Discuss the impact of biotechnology on society

Purpose: This module is intended to introduce the basics of biotechnology and how biotechnology is used in agriculture. Historical perspectives of biotechnology are also included.

Time: 1 hour

Activities: Activity 1: What is Biotechnology?
Activity 2: How Did We Get Here? Timeline of Biotech Historical and Why It Matters

Materials: flip chart paper, markers, LCD projector, slide set

INTRODUCTION

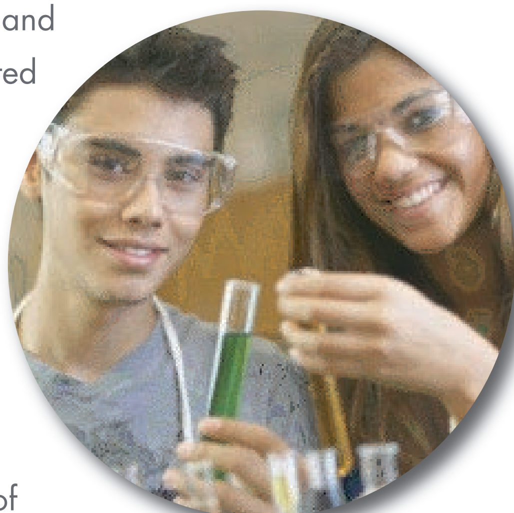
What is biotechnology?

The roots of the word biotechnology are: "Bio" meaning life and "technology" which is the application of knowledge for a practical use. The first known use of the word biotechnology was in 1919, by a Hungarian agricultural engineer named Karl Ereky.

He used it to describe a method of raising pigs on sugar beets and described it as "all lines of work by which products are produced from raw materials with the aid of living things."

http://www.accessexcellence.org/RC/AB/BC/Overview_and_Brief_History.php

Biotechnology is not a new field of science. People have been manipulating living things to solve problems and improve way of life for many generations. Plants and animals were selected for the best utilization and microorganisms were used to help make foods such as beverages, cheese, and bread. Two old examples of biotechnology are: fermentation (brewing beer, making wine, baking bread), methods that use yeast to modify the raw ingredients, and sewage treatment, which uses a complex system of microbes to breakdown organic waste.



A common misconception is the idea that biotechnology includes only DNA and genetic engineering. While DNA, genetic engineering, and

Key Words Defined

Biotechnology –
A range of tools, including traditional breeding techniques, that alter living organisms, or parts of organisms, to make or modify products, improve plants or animals, or develop microorganisms for specific agricultural uses.

DNA (deoxyribonucleic acid) –
The molecule that encodes genetic information. DNA is a double stranded molecule held together by weak bonds between base pairs of nucleotides. The four nucleotides in DNA contain the bases adenine (A), guanine (G), cytosine (C), and thymine (T). In nature, base pairs form only between A and T and between G and C—thus the base sequence of each single strand can be deduced from that of its partner.

DNA Sequence –
The relative order of base pairs—whether in a DNA fragment, gene, chromosome, or an entire genome.

genomics are important components of today's biotechnology, they are not the only components of biotechnology.

Today the USDA defines Agricultural Biotechnology as "… a range of tools, including traditional breeding techniques that alter living organisms or parts of organisms, to make or modify products, improve plants or animals, or develop microorganisms for specific agricultural uses." Modern biotechnology includes the tools of genetic engineering. Biotechnology today focuses on how living organisms can be modified to improve health, nutrition, industry and agriculture.

Key Words Defined

(continued)

Genetic Engineering –
Altering the genetic material of cells or organisms to enable them to make new substances or perform new functions.

Genome –
All the genetic material in the chromosomes of a particular organism—its size is generally given as its total number of base pairs.

Genomics –
The study of the genes of an organism and their function.

INSTRUCTIONS AND ACTIVITIES

Activity 1: What is Biotechnology?

Request a volunteer to record answers for the discussion question on a flipchart, a large piece of paper, or the chalkboard/whiteboard.

Show the "What do you think of…." slide.

Ask – What do you think of when you hear the word biotechnology? Say the first things that come to mind.

Record the responses on the paper/board. Be sure it is visible for the duration of the module.

Some responses might include: DNA, genetics, BT Corn, Roundup Ready® Soybeans, GMOs, changing organisms, agriculture, forensics, CSI and other crime-solving programs, medicine, insulin, controversy, economics, laboratories, research, etc.

Follow up discussion:

Show the "Biotechnology Defined" Slide and share the following information:

Say – The roots of the word biotechnology are: "Bio" meaning life and "technology" which is the application of knowledge for a practical use.

An all inclusive definition for biotechnology by the U.S. Office of Technology Assessment is: "Any technique that uses living organisms to make or modify products, to improve plants or animals, or to develop microorganisms for specific purposes."

Now biotechnology focuses on how living organisms can be modified to improve health, nutrition and agriculture.

Show the next slide.

Say – Now let's take a few minutes and think about where your food comes from.

Prompt some overall group discussion by asking things such as:

Ask – What did you eat and drink for breakfast?
Orange juice, cereal, toast, eggs, bacon, milk…?
How do these foods get to your table?

Have the participants share responses out loud.

Show the next slide and share the information it contains.

Say – Now we are going to watch a short video that introduces the topic of biotechnology and how it is helping to increase global food production. As you are watching this, think about how biotechnology has impacted your life and others' thus far.

View online videos (can show one or both), which can be accessed at:

http://www.whybiotech.com (2:36)

http://www.youtube.com/watch?v=qtUM18XO_sc&list=FL6vEqV5yaE6h8IrlngSsTFg&index=12&feature=plpp_video (1:19)

After the video(s), ask your audience to work in groups of 3–5 and do the following:

Say – List on a piece of paper (one per group) the ways they think biotechnology impacts their lives.

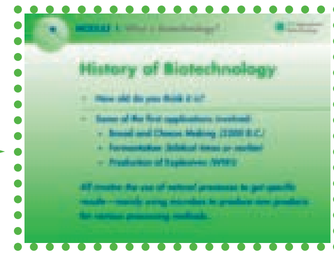
Use the board or flip chart and record samples of answers from each group. Hang the paper/poster board somewhere in the room so that it can be utilized for the next section.

Activity 2: How Did We Get Here?
Timeline of Biotech, Historical and Why it Matters

Before showing slide or giving examples below:

Ask – How old do you think biotechnology is?

Ask participants to give answers out loud.

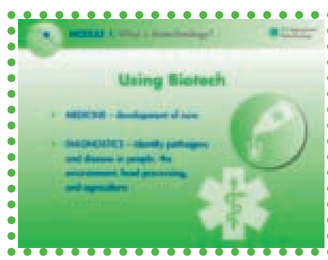


Then, show the "History of Biotechnology" slide.

Say – Some examples of "old" biotechnology are:

- Fermentation (brewing beer, making wine, baking bread)—all of these food processing methods use yeast to modify the raw ingredients.
- Sewage treatment uses a complex system of microbes to breakdown organic waste.
- Another good example of biotechnology is making cheese.

Some other uses of biotechnology are (share information on slide):



Show the timeline slides and discuss the timeline:

Say – **Biotechnology is all around us, even in some very familiar examples. As we progress through the modules, you will learn about DNA extraction, methods of genetic manipulation, DNA sequencing, gene expression, and social issues involving biotechnology.**

SHARE: Three ways that biotechnology impacts our everyday lives.

PROCESS: What is the definition of biotechnology?

GENERALIZE: How has the use of biotechnology changed over time?

APPLY: What new discoveries might be possible with the use of biotechnology?

REFERENCES

http://www.accessexcellence.org/RC/AB/BC/Overview_and_Brief_History.php

http://www.childrensmuseum.org/biotech-timeline

MODULE 2: **Why Biotechnology?**

Outcomes:
- Learn how scientific developments changed the definition of biotechnology
- Discover the important role biotechnology has in the food industry
- Learn the advantages and disadvantages that genetically modified crops can offer farmers and producers

Purpose: This module introduces the role biotechnology plays in everyday life through hands-on examples.

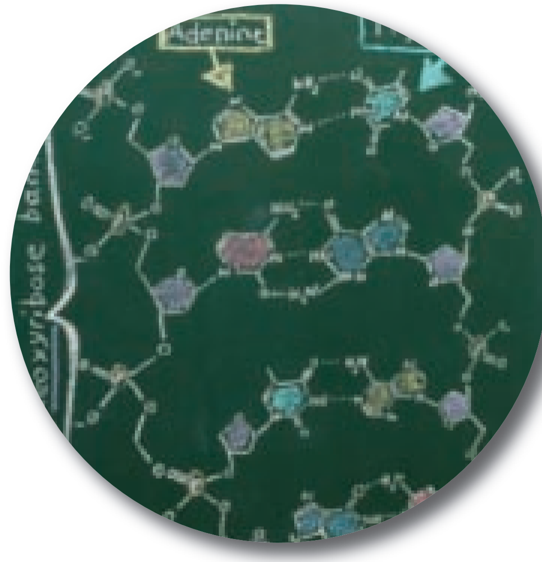
Time: 30 minutes per activity

Activities:
Activity 1: Biotechnology Impacts on Everyday Life
Activity 2: Soy Sensations: Soy Plastic
Activity 3: Agriculture in Print: Soy Ink
Activity 4: Food Science and Technology: What Makes NesQuik™ Quick?
Activity 5: Face the Fat: Engineering a Better Oil

Materials: computer, access to internet, LCD projector, slide set, supplies listed with activities

INTRODUCTION

Thanks to developments in the life sciences, biotechnology today focuses on how microbes, plants, and animals can be modified—and how such modified organisms can be used to improve health, nutrition, and agriculture.



These new developments that made the shift possible include the ability to:

- extract DNA and isolate genes from any organism;
- modify and manipulate genes;
- put altered genes back into various organisms.

Manipulation of genes in this manner is called genetic engineering.

Biotechnology based developments are changing and developing:

- *Medicine* – the development of new drugs to cure or control human diseases;
- *Diagnostics* – tests that rapidly and accurately detect pathogens in medicine, the environment, food processing, and agriculture;
- *Food Products* – new food additives and processing agents, new plants with enhanced nutritional content;
- *Environment* – new methods for treating waste products, organisms that clean up pollution, new sources of energy, and new plants that do not require chemical pesticides, fungicides, or herbicides;
- *Agriculture* – new plants that produce higher yields, fruits and vegetables with improved nutritional qualities, or crops that can grow even in adverse environmental conditions (drought, flood, and salty soils, to name a few);
- *Chemicals* – production of feedstocks from renewable resources for the chemical industry, enzymes for processing systems, and other applications.

For more information about the many developments in biotechnology, see pages 11–13 of the report on biotechnology by the Pew Charitable Trust.

http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Food_and_Biotechnology/hhs_biotech_harvest_report.pdf

There are many crops that are produced with the use of biotechnology. These crops include soybeans, corn, canola, cotton, papaya, tomatoes, and squash. Modern biotechnology has also sped up cheese production. For instance, a bacteria found in the stomachs of calves was used to make cheese. Today, a gene from the rennet, which is found in the lining of a calf's stomach, is inserted into bacteria and replicated in large amounts.

Other products that have been enhanced through biotechnology include:

- soybeans and corn that require fewer pesticides and herbicides;
- eggplants and potatoes that are resistant to insect infestation;
- papayas and potatoes that are resistant to viruses, which often diminish harvests and reduce food quality.

A chart depicting crops biotechnology products can be found on pages 42–44 of the Pew Charitable Trust Biotechnology Report.

http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Food_and_Biotechnology/hhs_biotech_harvest_report.pdf

Key Words Defined

Biotechnology – A set of biological techniques developed through basic research and now applied to research and product development. In particular, biotechnology refers to the use by industry of recombinant DNA, cell fusion, and new bioprocessing techniques.

Genetic Engineering – Altering the genetic material of cells or organisms to enable them to make new substances or perform new functions.

Biological Revolution – The era which has seen the rapid development of new technologies for the manipulation of biological processes.

These scientific developments are at the heart of the current Biological Revolution. Just like the Industrial Revolution of the 1700s and the Information Revolution of the last century, the Biological Revolution will change the way people live. The United States is home to thousands of biotechnology companies, and has the most advanced biotech industry in the world. In the U.S., as well as in many other countries, biotech companies contribute greatly to economic growth. IBISWorld estimates that the global biotech industry revenue will reach $228.6 billion in 2012, having increased on average 10% per year over the past five years.

INSTRUCTIONS AND ACTIVITIES

Activity 1: Biotechnology Impacts on Everyday Life

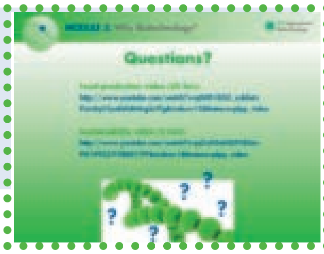
Say – Let's explore how biotechnology impacts your everyday life.

Plants impact our daily lives in many ways, beyond providing us with food and oxygen. Biodegradable plastics, ink, and packaging help reduce the amount of waste we produce and the amount of valuable resources that we consume. For example, soybeans can be used to produce plastics, ink, oils, industrial materials, and even crayons!

Show slides while discussing the methods of crop improvement.

Various methods of crop improvement have been utilized for centuries. Food crops are often plagued by pests and diseases, lower yields, and poor quality. Technology allows us to select specific traits in our food, so that crops can be resistant to pests, yield larger harvests, and have better appearance, taste, and nutrient content. Today, crop improvement approaches strive to meet three main objectives: increased crop yield, improved crop quality, and reduced production costs. Biotechnology is providing ways to address these objectives moving crop improvement forward faster, and in many ways never imagined by our ancestors.

Do – Watch one or both of these brief videos for an overview of the contribution of biotechnology to world food production as presented by industry sponsors.



Food production video (30 sec):
http://www.youtube.com/watch?v=qtUM18XO_sc&list=FL6vEqV5yaE6h8IrlngSsTFg&index=12&feature=plpp_video

Sustainability video (5 min):
http://www.youtube.com/watch?v=pjZxN3eDQ3Y&list=PLF1F9327F3B8017FF&index=1&feature=plpp_video

Do – Ask the following question and have one or more participants record their answers on post–it wall paper.

Ask – What are the impacts of biotechnology on society?

Answers can be varied and broad. A few examples include food production, improvement of cotton for clothes, industrial uses, biodiesel and ethanol.

Activities: 2–5

Have participants work in groups to conduct the activities (listed here). Instructions are found within each of the activities. These activities can be utilized in a single session, or select individual activities based on time available.

Activity 2: Soy Sensations: Soy Plastic – This activity has participants create "bio plastic" in a bag. (Page 39)

Activity 3: Agriculture in Print: Soy Ink – This activity demonstrates how soy ink can be created using common household items. (Page 41)

Activity 4: Food Science and Technology: What Makes NesQuick™ Quick? – This series of simple activities demonstrates the properties of soy lecithin, a product of soybeans, which are often genetically modified (i.e.; Roundup Ready® Soybeans). (Page 45)

Activity 5: Face the Fat: Engineering a Better Oil – These activities help identify sources and characteristics of plant fats found in the home, and how scientists are engineering healthier fats from plants. (Page 53)

SHARE: Describe the importance of history on the biotechnology we have today.

PROCESS: Why would the creation of a bioplastic be important for our environment?

GENERALIZE: How does biotechnology impact your food?

APPLY: And how does biotechnology impact those who produce your food?

REFERENCES

World Biotechnology Revenue Figures, 2012
http://www.prweb.com/releases/2012/4/prweb9453496.htm

ACTIVITY WORKSHEET
Soy Sensations: Soy Plastic

Objective

Explore how soybeans can be made into biodegradable products.

Materials

Cornstarch, soybean oil, sandwich sized-sealable bag, food coloring (liquid), microwave, water, pipette or eye dropper, tablespoon measuring spoon.

Safety Notes

1. CAUTION! The bags and plastic will be HOT after time in microwave.
2. The mixture must be thoroughly mixed or plastic will be chalky.

Procedure

1. Place 1 Tbs of cornstarch into the plastic bag
2. Add 2 drops of soybean oil
3. Add 1 Tbs of water
4. Close bag and knead it, mixing the contents
5. Add two drops of food coloring
6. Seal bag leaving a corner of the bag open to vent the contents
7. Heat bag in the microwave for 20–25 seconds on high
8. CAUTION: Bag will be HOT!
9. Remove the cornstarch and oil mixture and see what shapes you can form

What's going on?

The chemistry is that the starch in the cornstarch is binding with the soybean oil, when exposed to heat which forms the plastic. This is considered a bioplastic because it is produced from a biological source.

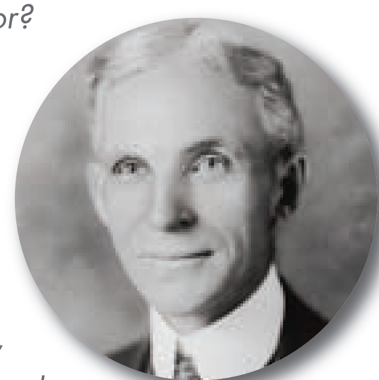
Seeds for Thought....

1. **What products could be made from biodegradable soy plastic?**

   Let them use their imaginations. Refer to web resources such as ***http://www.unitedsoybean.org/*** *for other items soybeans can aid in producing.*

2. **Explore Henry Ford's Plastic Car and his contribution to the soybean industry.**

   Henry Ford is known for his automobile, but did you know that he once made a car with all the plastic made from soybeans—even the automobile's exterior? Mr. Ford owned a large research facility. He came to the lab one day with a huge bag of soybeans. He dumped them out on the floor and told the scientists, "You guys are supposed to be smart. You ought to be able to do something with them." In time, the scientists in Ford's labs made a strong enough plastic for the gearshift knobs, horn buttons, window frames, accelerator pedals, light switch assemblies and ignition coil casings. They also fashioned the exterior of an automobile from "soybean plastic." By 1935 Mr. Ford was using one bushel of beans for every car he manufactured. (60 pounds = 1 bushel.)



3. **This is chemistry at work. How do you think the plastic was formed?**

   The starch in the cornstarch binds to the oil when the cornstarch and oil mixture is heated.

Indiana Soy Sensation: Exploring science with soybeans! 2010. DeCamp, S., C. Brady, N. Carroll, R. McKee and K.S. Orvis. Purdue University Extension, West Lafayette, IN.

ACTIVITY WORKSHEET
Agriculture in Print: Soy Ink

Minimum Completion Time
45 minutes

Skill Level
Intermediate / Age 11–13

Learner Outcomes
- Recognizes that properties of agricultural crops make them sustainable substitutes in industrial products
- Tests the properties of soy oil and soy lecithin in making ink

Science Skills
- Build/construct
- Compare/contrast
- Observe
- Predict

Life Skills
- Think creatively
- Reason

Educational Standards
- Properties and changes of properties in matter
- Science and technology in society
- Science as a human endeavor

Success Indicator
- Uses materials creatively
- Prints with different kinds of inks
- Describes the outcome process
- Describes the outcome process

How can a soybean be used to make ink? Why is soy ink good for the environment?

Ink is basically pigment mixed in a solution that will not blur when put on paper. Inks made with soybean oil are made from a renewable resource, are much more biodegradable, and print with brighter colors that don't rub off.

Do

What are the ingredients in ink? How do they work? Create your own ink and test your result.

Make soy ink

1. *Gather these materials:* 3 oz. plastic cup, paper towel, 1/8 teaspoon soybean (vegetable) oil, 1/8 teaspoon granular lecithin (found in health food stores); 1 teaspoon unsweetened powdered drink (like Kool Aid), 1 teaspoon water, stir stick, paper for printing, rubber stamp.

2. Using a stir stick, blend one teaspoon of water with a packet of unsweetened powdered drink mix in a clear 3 oz. cup.

3. Add 1/8 teaspoon of soybean oil to the cup and stir well.

4. Add 1/8 teaspoon of granular soy lecithin to the cup and continue stirring until the lumps are gone.

Note that soy oil does not mix well with water until lecithin is added. Soy lecithin (less a thin) is used for mixing fats and oils with water. Lecithin is a common ingredient in fatty foods such as chocolate candy and salad dressing. Check out the label on a chocolate bar or a bottle of creamy Italian dressing.

*Acknowledgements: Robert L. Horton, PhD, Ohio State University Extension, Carol Warkentien and Jeanne Gogolski, EP&P LLC. Content adapted from DuPont (**www2.dupont.com**) and Pioneer (**www.pioneer.com**) web pages.*

Prepare for printing

5. Take a paper towel and fold it in half, then in half again.
6. Pour the contents of your soy ink into the center of the paper towel. The soy ink is quickly absorbed.
7. Use a rubber stamp to print images on paper or stationary. Let dry.

- What happens when you scratch the dry ink?
- What can you do to make the color brighter?
- The ink dry faster?

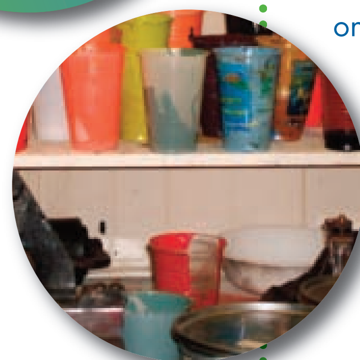
Note: Ink can stain fabrics and skin!

Learn More

What is the difference between ink and paint?

What is soy toner?

Automotive paint



Glossary

ink – liquid that contains pigments or dyes used to color a surface to produce an image or text or design.

pigment – a substance that is added to give something such as paint or ink its color.

resin – a semisolid substance used in varnishes, paints, adhesives, inks, and medicines.

solvent – a liquid capable of dissolving substances.

surfactant – a substance that reduces the surface tension of a liquid.

toner – a powder used in laser printers and photocopiers to form the printed text and images on the paper.

wax – a moldable substance of animal, plant, or mineral origin that feels slightly greasy or oily to the touch.

Virtual Fun

Inside a printing facility

Screen printing with soy ink

Soy crayons

News & Careers

Agrichemist

Printer

Nature and science together

E Bite

Do you know how ink "dries"? Pigments are mixed into water-based and other organic solvents. When the liquid in the ink evaporates, only the pigments that were once dissolved in the liquid remain.

Can you think of examples where slower drying times or faster drying times make a difference?

More Challenges

- *Answer these questions:* What problems were agriscientists and engineers trying to solve when they tested soy ink? Why do newspapers choose soy ink? Why do readers like newspapers printed with soy ink?
- *Research and experiment with soy crayons.* Compare the process of making soy crayons with soy ink. Test soy crayons and compare them to petroleum-based crayons. Design a survey to see which crayons your friends prefer.

Share

What happened when you added oil to the liquid?

How did lecithin change the mixture?

Compare your ink in terms of consistency and color and how it reacted on the paper.

Reflect

What did you know about ink and printing before you made your ink? What did you learn?

Generalize

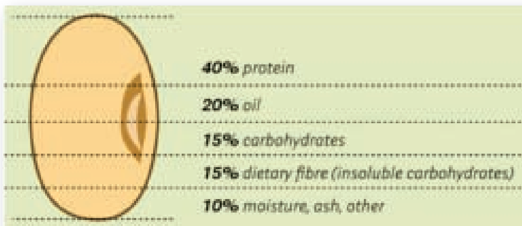
What benefits can you list for a product like soy ink?

Apply

How can you reduce your dependance on nonrenewable resources and products?

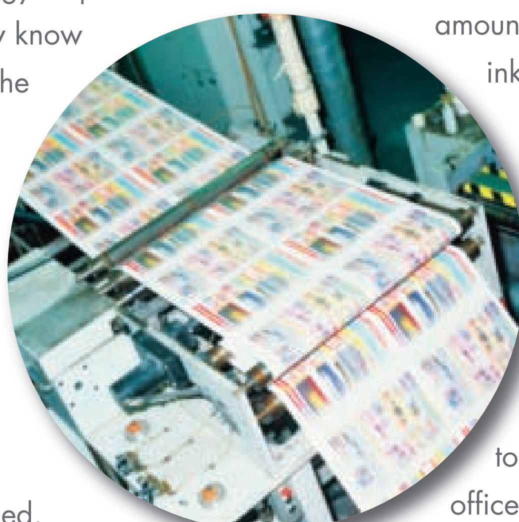
Background Information

What is in a soybean?



What part of the soybean is used to print 90% of the nation's daily newspapers?

When processed, soybeans produce about 20% oil and 40% protein. One of the best protein sources, soybeans nourish the people and animals of the world. Biotechnology helps scientists apply what they know about crops to enhance the food we eat and the products we use to make households safer, communities healthier, and the environment more sustainable.



After soybeans are harvested, they are cleaned, cracked and de-hulled. The soybean oil is separated from the soy protein (soybean meal). Soybean oil is then refined for margarine, salad dressings, plus hundreds of consumer products. The newspaper that arrives at your door each morning is printed with soy ink. The foam insulation and carpet backing in your home could be made from soy plastic. The elevators taking visitors to the top of the Statue of Liberty rely on a soy hydraulic fluid. Whether it's candles, cleaners, crayons, cosmetics, concrete sealers, engine oil, fuel, industrial lubricants, paints, roof coatings or varnishes, soybeans create natural, renewable products.

To make soy ink, soybean oil is slightly refined and then blended with pigment, resins and waxes. Soybean oil is naturally clearer than petroleum oils, making it easier to obtain brightly colored ink. Since the oil is clearer, less pigment is necessary to produce the same effect. In addition to a brighter ink, printers report that they need less ink to print the same amount of paper when compared to petroleum inks. Soy ink has been found to spread approximately 15% further, reducing ink use and printer cleanup costs.

While environmentally friendly soy ink has been used by newspapers for years, soy toner is now available for laser printers and fax machines. Soy toner is being used in many schools and offices today. The toner in most printer cartridges has been petroleum-based. About two liters of petroleum oil yield one pound of toner powder, and Volatile Organic Compounds (VOCs) are released in the process. What can you find out about VOCs and its effect on the environment?

National 4-H Council. Accessed 10/2012 from: ***http://www.4-h.org/agriscience/***

ACTIVITY WORKSHEET
Food Science & Technology: What Makes NesQuik™ Quick?

Minimum Completion Time
45 minutes

Skill Level
Intermediate / Age 11–13

Learner Outcomes
- Explores the properties of water
- Demonstrates that surfactants disrupt the surface tension of water
- Discovers the purpose of soy lecithin as an ingredient

Science Skills
- Predict
- Observe
- Record data
- Identify variables and controls
- Infer

Life Skills
- Think creatively
- Reason

Educational Standards
- Properties and changes of properties in matter
- Understanding about science and technology
- Science and technology in society

Success Indicator
- Uses materials creatively
- Makes soy protein plastic
- Describes the outcome process

Look at the ingredient labels on the food you eat and learn about chemistry.

What makes NesQuik™ Quick? You have to be a food chemist in order to answer this question. Try this series of experiments in your kitchen and discover how science is used in food technology. Record your results on the Observation Log.

Do the Activities

Penny Predictions

1. *Gather these materials:*
   1 medicine dropper, water, one penny
2. Predict how many drops of water you can fit on a penny.
3. Use the medicine dropper to add drops of water to the top of the penny. Count each drop until the water leaks off the side.
4. Were your predictions correct?
5. Repeat this test 3 times and record the number of drops. Calculate the average

Acknowledgements: Robert L. Horton, PhD, Ohio State University Extension, Carol Warkentien and Jeanne Gogolski, EP&P LLC
*Content adapted from DuPont (**www2.dupont.com**) and Pioneer (**www.pioneer.com**) web pages.*

What's the science?

Water molecules are cohesive—this means that they tend to stick together. When they stick together, they form a "skin" or a dome. Because of this, an insect can stand on the surface of a pond and you can get many drops on the top of a penny!

Test this idea with the next experiment. Look at the ingredient labels on the food you eat and learn about chemistry.

News & Careers

Food Scientist

Lab Technician

Learn More

Food science around the world

Surfactant technology

What is Lecithin?

Virtual Fun

Bizarre food ingredients

Dancing Pepper on YouTube

Attractive Molecules

1. *Gather these materials:* 1 empty plastic cup, water, 1 medicine dropper, 2 toothpicks
2. Turn over the plastic cup.
3. Use the medicine dropper to place two drops of water on the bottom of the cup about 1 inch apart.
4. Use the toothpicks to move one drop of water over to make one big drop of water. How easy was that?
5. Use the toothpicks to separate the big drop into two smaller drops. How easy was that?

What's the science?

Water molecules are cohesive—they like to stick together. Putting two drops together is easier than pulling one drop apart. Do the next experiment using chemistry to break up cohesive water molecules.

What makes the Pepper Dance?

1. *Gather these materials:* 1 small plate, water, pepper, 1 soap dispenser
2. Fill the plate with water.
3. Sprinkle a little pepper evenly on the surface of the water.
4. Using the soap dispenser, squirt one drop into the middle of the pepper.
5. Observe what happens.

What's the science?

Soap contains a surfactant. A surfactant causes water molecules that are cohesive to move apart. By watching the pepper, you can see the water molecules move.

Color Swirls

1. *Gather these materials:* 1 small plate, soy/dairy milk, 1 small bottle food coloring, 1/2 tsp lecithin (granular; found in the health food section of the grocery store)
2. Fill the plate with milk.
3. Place three equally-spaced drops of food coloring in the milk.
4. *Predict:* You are going to add a surfactant to the milk. Remember what happened to the pepper when you added a soap/surfactant? What do you think will happen when you add lecithin, another surfactant?
5. Add a few granules of the lecithin on the drops of color. Observe what happens. Was your prediction correct?

E Bite

Did you know how important the science and technology of surfactants are to the world we live in? Surfactants are an essential component not only in the food we eat but in many of the consumer and industrial products produced every day.

A significant amount of research goes into the formulation of surfactant products today to keep the consumer and the environment safe. Some of the new areas for growth in the surfactant industry include multifunctional surfactants (e.g., detergent and fabric softener all in one), more biocompatible surfactants, and surfactants based on renewable raw materials.

What's the science?

Soy lecithin is a surfactant much like soap. When added to the food coloring and milk, it causes the water molecules to separate and move. The food coloring shows how they move. Why do the molecules move more slowly in milk than they did in the water (dancing pepper)? Milk has more fat and less water molecules they move more slowly because of the fat! Show your understanding—which would move "faster," whole milk or skim milk? Why?

Why is NesQuik™ Quick?

1. *Gather these materials:* 2 empty plastic cups, water, 1/2 tsp baking cocoa, 1/2 tsp NesQuik™.
2. Turn over the empty plastic cups.
3. Place one large drop of water on the bottom of one cup.

4. Sprinkle a small amount of cocoa on the drop.
5. Observe what happens. How would you describe this to someone else?
6. Now place one large drop on the second cup.
7. Sprinkle a small amount of NesQuik™ on the drop.
8. Observe what happens. How would you describe this to someone else? What is the difference between how the cocoa looked and how the NesQuik™ looked?
9. Find "lecithin" on the ingredient label of the NesQuik™ container.

What's the science?

Soy lecithin is a surfactant. Made from soy oil, soy lecithin causes molecules to separate and breaks surface tension. The lecithin in NesQuik™ causes the water drop to spread out and the chocolate to go into the drop. The cocoa does not contain soy lecithin so it "sits" on the top of the water drop. It does not break the surface tension or cause the water molecules to separate. In order to use cocoa to make a drink, you have to stir it a long time or use heat to "break up" the cohesiveness of the water molecules in the milk. Follow the directions on the label and make yourself a snack drink with NesQuik™.

Glossary

lecithin – a fatty substance which occurs in some animal and plant tissues.

surface tension – the cohesive forces among liquid molecules that form a surface "film" which allows it to resist an external force.

surfactant – substances that adjust the surface properties, and surface tension, of the liquid or solid to which it is applied. The term surfactant is made up from letters of the words "surface active agent." Emulsifiers, detergents, foam inhibitors, and wetting agents are all examples of surfactants.

More Challenges

1. *Sticking Together:* Demonstrate the cohesiveness of water with this experiment!
2. *Gather these materials:* 2 pieces of aluminum foil, water
3. Rub two flat pieces of foil together and then let them go. Do they stick together?
4. Rub each piece with water on one side.
5. Place the two wet sides together, hold them up and let them go. Do they stick together?

What's the science?

Two pieces of foil will not stick together when they are dry. But when you add water to each of pieces and then rub the wet sides together, they stick! Water molecules are cohesive. They stick together. Can you think of other ways to demonstrate cohesion?

Share

Describe what you did to prove why NesQuik™ is quick using these science words: cohesive, surface tension, surfactant, quick.

Reflect

Check the labels on your food. What questions do you have? Where can you get the answers? Where do you see chemistry being used?

Generalize

Scientists do experiments very carefully. Why is it especially important for food technologists to be careful?

Apply

Consider food technology as a career. How do food technologists make food healthier, easier to get, and more tasty? Where can you get the answers to these questions?

Background Information

What is lecithin and what can it do?

Soybeans, just before harvest

Lecithin

Lecithin is an oily substance found in some plants (soybeans) and animals (egg yolks). After soybeans are harvested, they are cleaned, cracked and de-hulled. The soybean oil is separated from the soybean meal. Soy lecithin can be mechanically or chemically removed from the soybean oil.

Lecithin in food technology

Soy lecithin is a versatile tool in food technology. Lecithin does not dissolve easily in water, which results in its surfactant qualities. Lecithin is sometimes sold as a food supplement. In cooking, it is used as an emulsifier. Lecithin is also used to prevent sticking in nonstick cooking spray.

Lecithin also acts as an emulsifier, or mixing agent. When used as an ingredient it helps fat and water stay mixed. As an emulsifier, lecithin improves the smoothness and creaminess of chocolate. That is important in both the manufacturing process and the shelf life of the chocolate.

Lecithin in other products

The unique properties of lecithin make it useful in pharmaceutical and cosmetic applications as well as many industrial products. Lecithin is used as an ingredient in crayons, sunscreen, lip balm, the protective coating on CDs, inks, paints, textiles, lubricants and waxes. Soy lecithin is even used in today's oil fields, as a "green option" reducing friction in drill bit lubrication and to achieve viscosity requirements in fresh, saltwater and other drilling muds.

Observation Log

Chemistry and biotechnology are used to solve food problems and to make food healthier and more convenient. Be a food chemist and discover why NesQuik™ is so "quick!" Collect your lab notes on this page as you do your experiments.

Penny Predictions

How many drops of water fit on the penny?
Test 1:
Test 2:
Test 3:
Average for all three tests:
Difference between my prediction and the average:

Here is what the penny looked like with the water on top. Draw 2 different angles.

Angle 1

Angle 2

Attractive Molecules

Was it easy or difficult to put the drops together?

1	2	3	4	5
very easy				very difficult

Was it easy or difficult to separate the one drop into two drops?

1	2	3	4	5
very easy				very difficult

What Makes Pepper Dance?

Draw a picture of the pepper on the surface of the water BEFORE you added the surfactant.

Draw a picture of the pepper on the surface of the water AFTER you added the surfactant

Color Swirls

What do you think will happen when you add the soy lecithin (a surfactant) to the food coloring in the milk? Write your prediction here.

Test your prediction. What happened? Write it here.

Why is NesQuik™ Quick?

Describe this experiment in pictures here. Use step by step drawings.

National 4-H Council. Accessed 10/2012 from: ***http://www.4-h.org/agriscience/***

ACTIVITY WORKSHEET
Face the Fat: Engineering a Better Oil

Minimum Completion Time
45 minutes

Skill Level
Intermediate / Age 11–13

Learner Outcomes
- Recognize trans-fats, saturated, unsaturated, polyunsaturated and trans fats in personal eating habits.
- Identify sources and characteristics of plant oils and animal fats in foods

Science Skills
- Categorize/order/classify
- Compare/contrast
- Evaluate

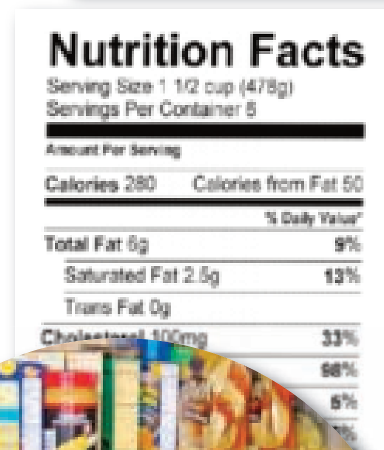
Life Skills
- Make decisions
- Acquire and evaluate information

Educational Standards
- Personal health
- Science and technology in society

Success Indicator
- Conduct a survey of fats found in the foods at home
- Calculate daily fat intake for friend or family member

What kinds of fat do you eat? Where are the fats in your food? What are you doing to meet the trans fat challenge?

Fats get a bad rap when it comes to your diet. Your body needs some fats for energy and cell growth. But some fats are healthier than others. Do you know the difference? It is time to face the facts about fats. Check your own food choices and you will understand why scientists are trying to engineer better oils and reduce the amount of trans fat in foods we enjoy.



Acknowledgements: Robert L. Horton, PhD, Ohio State University Extension, Carol Warkentien and Jeanne Gogolski, EP&P LLC
*Content adapted from DuPont (**www2.dupont.com**) and Pioneer (**www.pioneer.com**) web pages.*

Do:

1. *Gather these materials:* foods from your pantry or refrigerator that have nutrition labels (soup, crackers, cereal, peanut butter, jelly, margarine, vegetables, juice, milk, vegetable oil, etc.), Face the Fat Observation Log.
2. Check the labels for Total Fat. Sort your foods into two groups: foods that have fat grams, and foods without fat grams.
3. Rank order them from the food with the most fat grams to the food with the least fat grams; use the "per serving" amount. Record your observations on the Log.
4. Now check the labels for saturated fat and trans fat. Sort into two groups: those with saturated fats and those with saturated AND trans fat.
5. Group the foods with similar amounts of saturated and trans fats. What do you see? What surprised you? Record your observations on the Log.
6. Do any of the labels mention the better fats, polyunsaturated and/or monounsaturated? What foods have these fats listed?
7. What ingredient provides the "fat?" List all the different kinds of oils that you see in the ingredient labels on the Observation Log. Can you draw any conclusions from comparing the oils and the amount of fat?
8. Choose one of the foods that you like to eat and check out the portion size. How much fat do you eat when this food is one of your choices? Compare your fat intake with the recommended amount. How are you doing? Record your observations in the Log.
9. Interview someone else in your family and help them to calculate how much fat they consume in a day.

EBite

Better Oils in Plants

Besides health benefits, there are other reasons biotechnologists are working to develop better oils in plants. Scientists have the hungry customer and the cook in mind. To make the consumer happy, the chef and restaurant owner need to find oils for frying and baking that taste good and make the chef's job easier. When new and healthier oils are developed, tests are conducted to find out if the new oils will satisfy both the chef and the customer.

A healthier french fry

Here are some Oil Tests:

Extended Shelf Life – Put different kinds of oil in wide-mouth jars exposed to room temperature and light. Over time, check the oils for smell, taste and appearance. Oils exposed to light and air have a rancid, unpleasant smell. Which ones are the best? Most experts suggest that oils be stored in the refrigerator for freshness purposes.

Don't try this at home:
Cooking for Engineers
Smoke points of fats

Use test strips for more oil information:
Oil Testers

Learn More

Oil Profile

Trans Fats

Biotech and Better Oils

More Challenges

- *How much fat do you eat each day? Is it "bad fat" or "better fat?" Keep a record for one week. Do you need to take action to reduce the amount of fat and/ or the kind of fat you eat each day?*
- *Research the amount of fat found your favorite fast foods. Which fast foods are your favorites? What kinds of oils do the restaurants use in the fried and baked foods?*

News & Careers

Plenish™ is a New Oil

Healthier Oil

Virtual Fun

Meet the Fats

Share

What did you discover in your kitchen?

Which foods did you find that had fats?

What kinds of fat do these foods have?

Reflect

Consider the foods that you like to eat. What kinds of fat are in these foods?

Generalize

Why are scientists trying to engineer better oils? What effect could these better oils have on our health?

Apply

Now that you know about fats, what changes do you need to make in your own daily diet?

Background Information

What are the words to look for when you want to find the fats in our food?

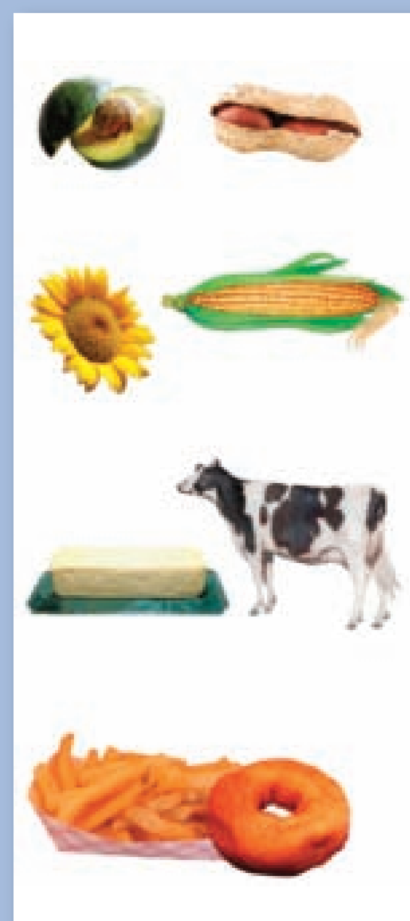
Fats in foods

There are four major dietary fats in the foods we eat: saturated fats, trans fats, monounsaturated fats and polyunsaturated fats. The four types have different chemical structures and physical properties. The bad fats, saturated and trans fats, tend to be more solid at room temperature (like a stick of butter), while monounsaturated and polyunsaturated fats tend to be more liquid (like liquid vegetable oil). Most foods contain several different kinds of fats–and some kinds are better for your health than others are.

What foods contain which fats?

Type of Healthy Fat	*Food Source*
Monounsaturated fat	Olive oil, peanut oil, canola oil, avocados, nuts, and seeds
Polyunsaturated fat	Vegetable oils (such as safflower, corn, sunflower, soy, and cottonseed oils), nuts and seeds

Type of Harmful Fat	*Food Source*
Saturated fat	Animal products (such as meat, poultry, seafood, eggs, dairy products, lard, and butter), and coconut, palm, and other tropical oils
Trans fat	Partially-hydrogenated vegetable oils, commercial baked goods (such as crackers, cookies and cakes), fried foods (such as doughnuts and french fries), shortening, and margarine



What are scientists doing to improve the fats in our foods?
Scientists and biotechnologists have identified soybean traits that can yield oils that are trans free and still produce fried foods that consumers like. Soybean oil is roughly about 14% saturated fat. Through selective breeding, that has been reduced to 6% or 7%, and you can increase the monounsaturated fat up to 70%. Not only does that improve the oil nutritionally, but by changing the fatty acid ratio toward the more stable monounsaturate, it automatically lowers the proportion of polyunsaturate fats.

Glossary

Trans fats – created in an industrial process that adds hydrogen to liquid vegetable oils to make them more solid; partially hydrogenated oil.

Saturated fats – have chemical make-up in which carbon atoms are saturated with hydrogen atoms; solid at room temperature.

Monounsaturated fats – have one double-bonded (unsaturated) carbon in the molecule; liquid at room temperature, but turn solid when chilled.

Polyunsaturated fats – have more than one double-bonded (unsaturated) carbon in the molecule; liquid at room temperature and when chilled.

Observation Log

Gather lots of foods with nutrition labels from your pantry and refrigerator.

1. Check the labels for Total Fat and sort the foods into two groups: Foods With Fat Grams and Foods Without Fat Grams. Do the foods in each of these groups have anything in common?

ORDER	Foods With Fat Grams	ORDER	Foods Without Fat Grams

2. Rank order them from the food with the most fat grams to the food with the least fat grams; use the "per serving" amount.

   Out of the foods with Fat Grams, list the three foods with the most Total Fat per serving grams here:

   1.

   2.

   3.

   List the three foods with least amount of Total Fat grams per serving here:

   1.

   2.

   3.

Now check the labels for saturated fat and trans fat. Sort all the foods with Fat into two groups: those with saturated fats and those with saturated fats AND trans fat. List those foods that have both kinds of fat here:

1.

2.

3.

When you group foods with similar amounts of saturated and trans fat, what do you notice about them? Are these foods similar? What do they have in common?

Do any of the labels mention the "better fats"—polyunsaturated or monounsaturated? List those foods here:

1.

2.

3.

What ingredient provides the "fat?" List all the different kinds of oils that you see in the ingredient list.

1.

2.

3.

4.

5.

Is there any connection between the type of oil and the amount of fats? What do you know about these fats?

Fats and Me

Choose one of the foods that you like to eat and calculate how much fat you eat when you enjoy this food.

Grams of fat _______ X number of portions ____________ = grams of fat _______

How much fat should you get in one day? It depends on how many calories you consume and how active you are. Most teens need about 2,200–2,800 calories a day. Here are your recommended amounts of fat consumption.

Calories	Max grams of fat	Max grams of Sat Fat
2,200	61 86	17 or less
2,400	67 93	19 or less
2,600	72 101	20 or less
2,800	78 109	22 or less

How are you doing? Do you need to change the foods you eat?

Interview a family member. How much fat are they consuming?

National 4-H Council. Accessed 10/2012 from: ***http://www.4-h.org/agriscience/***

MODULE 3: **DNA Defined**

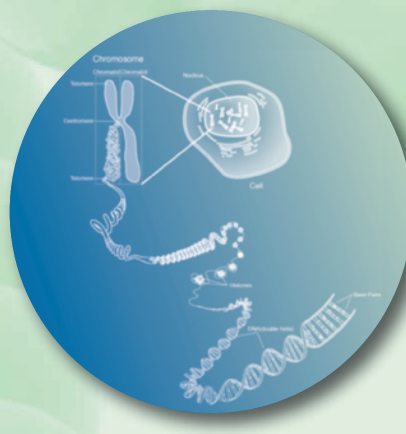
Outcomes: Upon completion of the lesson, participants will be able to:

- Describe the process of DNA extraction and its purpose
- Demonstrate the ability to follow instructions in a lab exercise
- Explain the function of each material in the DNA extraction process
- Assess the results of the DNA extraction activity
- Understand main parts of the cell and be able to create model of cell

Purpose: This activity reinforces the process of DNA extraction, the first step for many laboratory procedures in biotechnology, including gel electrophoresis and DNA sequencing and genomics.

Time: 30 minutes per activity

Activities:
Activity 1: DNA and the Cell
Activity 2: Cell Model
Activity 3: Does This Have DNA?
Activity 4: DNA Extraction



Materials: flip chart paper, markers, supplies for DNA extraction (see activity), examples of living (fruit, animals, plants), previously-living (fossils, hair, wood, dried fruit or beans, paper, bone, cotton) and non-living objects (plastics [petroleum-based], metal, rock, glass), LCD projector, slide set and computer

INTRODUCTION

DNA

Every living organism has DNA. DNA is like the instructions for each cell. DNA is found in the nucleus of a cell. Inside each cell's nucleus there is a copy of that organism's genome. Normally the genome is made up of chromosomes, which are tightly coiled strands of DNA.

Every DNA molecule is made up of two chains of nucleotides (A,C,T,G). A sugar phosphate back bone of each chain holds the nucleotide bases. The two chains are held together with hydrogen bonds. There are four different bases and only certain bases will pair with each other. Adenine (A) always pairs with thymine (T) and guanine (G) always pairs with cytosine (C). This sequence of nucleotides in DNA, found in each cell's nucleus, is passed from parents to offspring. Within these sequences are the directions for the organism—such as a plant—to build leaves, or stems or flowers.

Living organisms use the information contained in DNA to create proteins. To create a protein, the DNA needs to be decoded into a molecule called RNA through a process called transcription. The information contained in the RNA is "read" in order to make different proteins through a process called translation.

Key Words Defined

DNA (deoxyribonucleic acid) –
The molecule that encodes genetic information. DNA is a double stranded molecule held together by weak bonds between base pairs of nucleotides. The four nucleotides in DNA contain the bases adenine (A), guanine (G), cytosine (C), and thymine (T). In nature, base pairs form only between A and T and between G and C—thus the base sequence of each single strand can be deduced from that of its partner.

DNA Sequence –
The relative order of base pairs, whether in a DNA fragment, gene, chromosome, or an entire genome.

Nucleotide –
A subunit of DNA or RNA consisting of a nitrogenous base (adenine, guanine, thymine, or cytosine in DNA and adenine, guanine, uracil, or cytosine in RNA), a phosphate molecule, and a sugar molecule (deoxyribose in DNA and ribose in RNA). Thousands of nucleotides are linked to form a DNA or RNA molecule.

There are regions within the code of DNA, some that give instructions for making certain proteins, and others that are hypothesized to be just taking up space. We just don't know what those unknown regions are for yet. The regions that have information are called genes and are made up of specific units: a start sequence, a stop sequence, and regulatory information. These sequences tell the organism what to make and how to make it. Genes are packaged into units called chromosomes, which are made up of both DNA and protein.

The entire DNA that makes up an organism is called a genome. Researchers can map regions of the total genomes that encode for genes. They do this by looking at the DNA molecule base by base. By sequencing DNA, researchers can read the order of bases (A,C,T,G) in the DNA molecule. All living things have different numbers of chromosomes, but all the members of a particular species, such as humans, apples, or cows, have the same number of genes and chromosomes.

For example:

- A human has about 40,000 genes;
- Human genes are packaged into 46 chromosomes;
- Since the genes come in pairs, all humans have 23 pairs of chromosomes.

Key Words Defined (continued)

RNA (Ribonucleic Acid) –
A chemical found in the nucleus and cytoplasm of cells—it plays an important role in protein synthesis and other chemical activities of the cell. The structure of RNA is similar to that of DNA. There are several classes of RNA molecules, including messenger RNA, transfer RNA, ribosomal RNA, and other small RNAs, each serving a different purpose.

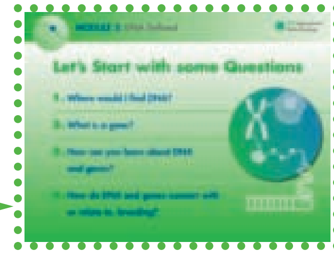
Gene –
The fundamental physical and functional unit of heredity. A gene is an ordered sequence of nucleotides located in a particular position on a particular chromosome that encodes a specific functional product (i.e., a protein or RNA molecule).

Genetic Code –
The sequence of nucleotides, coded in triplets (codons) along the mRNA, that determines the sequence of amino acids in protein synthesis. A gene's DNA sequence can be used to predict the mRNA sequence, and the genetic code can in turn be used to predict the amino acid sequence.

INSTRUCTIONS AND ACTIVITIES

Activity 1: DNA and the Cell

Show the "Let's start with some questions" slide.



Say – Using the questions on the slide please work in small groups or pairs to answer the questions on the slide.

After 5 minutes, reconvene the large group and take a poll as to what their answers to the questions were. If time permits, the answers to each question can be recorded on flipchart or chalk/dry erase board.

Say – You will learn the answers as we proceed through the rest of the lesson.

Say – Now we will review some basics of biology that will help us better understand how biotechnology works, and where DNA is found in the cell.

The text on each slide is what can be explained and shared.

Note: the live version of the animation captured in the slides can be found at: http://www.four-h.purdue.edu/apple_genomics/

Key Words Defined (continued)

Genome –
All the genetic material in the chromosomes of a particular organism—its size is generally given as its total number of base pairs.

Nucleus –
The central cell structure that houses the chromosomes.

Living Objects –
Objects that are a carbon and water based cellular form with complex organization and heritable genetic information. Objects that have signaling and self sustaining processes.

Previously-Living Objects –
Inanimate objects that previously were living. Examples are: fossils, hair, wood, dried fruit or beans, paper, bone, and cotton.

Activity 2: Cell Model

Follow directions from **http://getbiotechsmart.com/** to build a model of the cell. Build a model of a cell by reviewing and downloading one of the following cell modeling activities.

http://www.deltaeducation.com/downloads/samples_dsm/DNA_SampleActivity.pdf

http://oklahoma4h.okstate.edu/scitech/FOG/2.2B.PDF

http://www.childrensmuseum.org/themuseum/biotech/ediblecellcookie.htm

Constructing DNA models is another good way to visualize the structure of DNA and the components that it is made of. Here are two examples.

http://getbiotechsmart.com/sites/getbiotechsmart.com/files/candy_dna.pdf

http://www.childrensmuseum.org/sites/default/files/files/%20TCM%20BIOTECH%20UOS.pdf

Ask – Why would understanding the cell be important in biotechnology?

Brief Answer: *In order to understand biotechnology and genomics and how scientists can manipulate genes, it is important to understand cell structure and what is happening in the cell before anything should be done.*

Key Words Defined (continued)

Never-Living Objects –
Inorganic and inanimate objects are not living. Some examples are: plastic (petroleum based), metal, rock, and glass.

Translation –
The process in which the genetic code carried by mRNA directs the synthesis of proteins from amino acids.

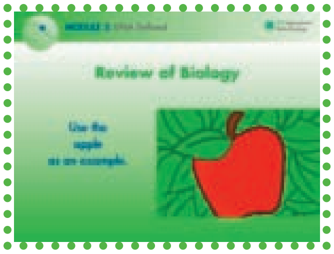
Transcription –
The synthesis of an RNA copy from a sequence of DNA (a gene)—the first step in gene expression.

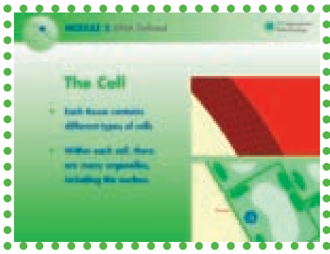
Cell –
The smallest structural unit of living matter capable of functioning autonomously. The basic unit of any living organism that carries on the biochemical processes of life.

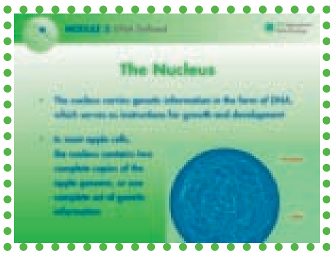
Key Words Defined (continued)

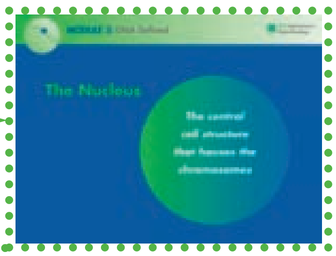
Chromosome –

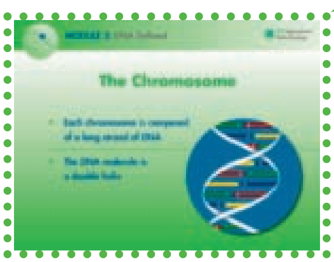
A self replicating structure consisting of DNA complexed with various proteins and involved in the storage and transmission of genetic information—the physical structure that contains genes. One of the threadlike "packages" of genes and other DNA in the nucleus of a cell. Different kinds of organisms have different numbers of chromosomes. Humans have 23 pairs of chromosomes, 46 in all—44 autosomes and two sex chromosomes. Each parent contributes one chromosome to each pair, so children get half of their chromosomes from their mothers and half from their fathers.

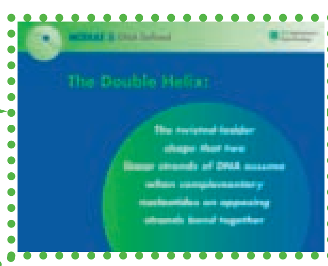


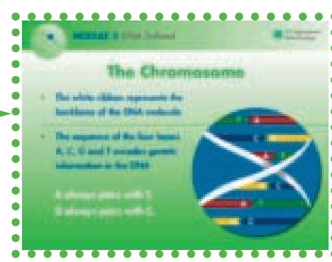


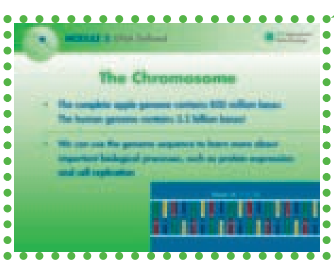












Ask – **What would be some limitations or consequences of not understanding a cell before it is manipulated?**

Brief Answer: *You might not reach your desired outcome. If you don't reach your desired outcome, you may not understand where the "manipulation" procedures went wrong. Ethically, it might be a bad decision because the outcome may not be socially acceptable.*

Some of the technologies that led to the change in biotechnology are:

- The ability to isolate genes from any organism;
- The ability to modify and manipulate genes;
- The ability to put altered genes back into various organisms.

These sciences allow genes to be transferred from any species for plant (or other organism) improvement.

Show the next two slides.

Activity 3: Does This Have DNA?

Do – **Display (or pass around) various items to the group, including "living", "never-living", and "previously-living" objects. Have participants sort the objects into categories based on their identifications. Place three pieces of paper with the categories written on them at a central place in the room, and have participants group the objects and list them on the paper.**

Say – **Please sort the objects into categories as a group based upon their identifications. The three categories I would like you to sort them into are living, never living, and previously living.**

Ask – **How and why did you categorize each object the way you did?**

Most likely, participants will sort objects into only two categories: "living" and "non living." If this is the case, point out that some of the objects were "previously living".

Ask – Do the previously living objects have DNA, since they were alive at a previous time?

Yes, most of the time previously-living things still contain DNA or traces of DNA. Initiate a discussion in which participants may re-categorize objects, if necessary, to include "living," "never-living," and "previously-living" objects.

Ask – How do you know that "living" cells (and "previously-living" cells) contain DNA if they cannot see physical proof of the DNA itself?

Possible answers might include studying the objects or cells, testing or otherwise evaluating the objects.

Activity 4: DNA Extraction

Say – In the next activity, DNA Extraction, you will be extracting and observing DNA from living cells.

The activity is on pages 72–74.

Say – As we begin the next activity, let's try and answer a few more questions.

Ask –

- **What do you know about DNA?**
- **What do you want to know about DNA?**
- **Why would it be important to understand cells and how DNA works? (This could lead to a discussion about biotechnology and soybeans, and types of research and development being conducted.)**

Say – As you proceed through the activity, please read and follow each direction carefully. Also, ask questions and take notes on any observations you make.

This may be a classroom demonstration where you can have each participant complete a step, or you can split the participants into multiple groups if you have enough materials.

Two versions of the DNA extraction methodology are suggested: included is one for strawberries (simple) and a link for one for bananas (a variation that adds a few more steps). Also, please substitute common household items for scientific lab supplies where needed. Both methods are designed to use common household ingredients.

Overview

Participants will extract DNA from a strawberry using everyday materials and observe its physical appearance.

Objectives

As a result of participating in this activity, participants will:

- know how to extract DNA from strawberries;
- observe what DNA looks like to the naked eye;
- learn that DNA is found in every living and once-living thing;
- understand that DNA is found in all the food we eat.

Guiding questions to interact with group, especially while the solution is filtering since it takes 10+ minutes.

Ask –

- **What was the purpose of mashing up the strawberry?**
- **What does the extraction buffer do? (*Hint:* Extraction buffer contains soap. What does soap do when you wash your hands?)**
- **What does the filter do?**
- **What do you see appearing after adding the alcohol?**
- **What happened when you added the filtrate to the alcohol?**
- **What did the DNA look like?**

Be sure to allow participants a few minutes to use a paper clip to spool the DNA out of the tube to look at it. If allowed to dry, it would look like fine threads.

Say – Now that the exercise is complete, let's discuss the results.

Ask – Did you expect the DNA to look/turn out like this? Why or why not?"

Ask – What are some ways we could we change the outcome of this laboratory activity?

Answer: *Use a different DNA source, use a different soap/detergent, change the amounts of DNA source or soap/detergent, alter the time requirements for each step, etc.*

SHARE: What are the major steps of DNA extraction? What was the purpose of each step and materials used?

PROCESS: What were the results of the DNA extraction activity? What did the DNA look like?

GENERALIZE: Why is DNA important for biotechnology?

APPLY: The strawberries you extracted DNA from were once living—what does this mean about the foods you eat?

REFERENCES

http://www.four-h.purdue.edu/apple_genomics/
http://ucbiotech.org/resources/display/files/dna_extraction_from_strawberrie.pdf
http://www.biotech.iastate.edu/publications/lab_protocols/DNA_Extraction_Smoothie.pdf

ACTIVITY WORKSHEET
Strawberry DNA Extraction
TEACHER/LEADER

Science Objective
To show students a method to extract DNA from strawberries.

Time
30 minutes

Materials
- 1 zip-type, freezer bag (6″x 9″), quart or sandwich size)
- 1 coffee filter, cone shaped, #2 size
- 1 plastic cup, 5 oz.
- 1 plastic pipette (optional)
- 1 paperclip
- 1–2 strawberries
- 10 mLs DNA extraction buffer (soapy, salty water)
- 15 mLs ice-cold ethanol or rubbing alcohol (available from drugstore) in test tube

Lab Preparations
The following solutions should be prepared in advance of the lab.

DNA extraction buffer

Materials:

- 50 mLs of a clear hair shampoo with EDTA (Eg., Suave). Do not use one that contains a conditioner or color.
- 1 tsp of NaCl (table salt)
- 450 mLs water

In a one-quart container, gently mix the materials so as not to create alot of bubbles. Provide pipettes or other measuring devices for students to draw 10 mLs of the extraction buffer from the container to add to their plastic bags with mashed strawberries. If pipettes are not available, measuring cups with mL markings can be used.

Organization Tips

A good way to help organize lab materials for students is to sort the necessary items into plastic boxes or large gallon-size zip-top bags. Use boxes about the size of a standard shoebox. (Regular shoeboxes work as well.) This saves time during class and you know that the students will have the necessary items. Replace the consumed items after each class.

Example of contents of student boxes for this lab:

- 1 pipette
- 1 cone-shaped coffee filter
- 1 5 oz. plastic cup
- 1 plastic freezer bag

Lab Activity

1. Tell students that today they will have the chance to see what actual DNA looks like by extracting DNA from a strawberry.
2. Hand out the Strawberry DNA Extraction Worksheets.

3. Ask the group, "How do we isolate DNA from the cell?" (What is the method? It is called DNA Extraction.) To understand how DNA extraction is done, you will extract DNA from strawberries today.
4. Ask students where DNA is found.
5. Follow instructions on student page to extract DNA from strawberry.
6. While the solution is filtering, ask the them what the four main steps were of the DNA extraction.
   - Crushed the cells to release the DNA.
   - Used the buffer to separate the DNA from the other cell components.
   - Filtered out the large particles.
   - Precipitated out the DNA using ethanol.
8. Ask the participants what the DNA looked like.

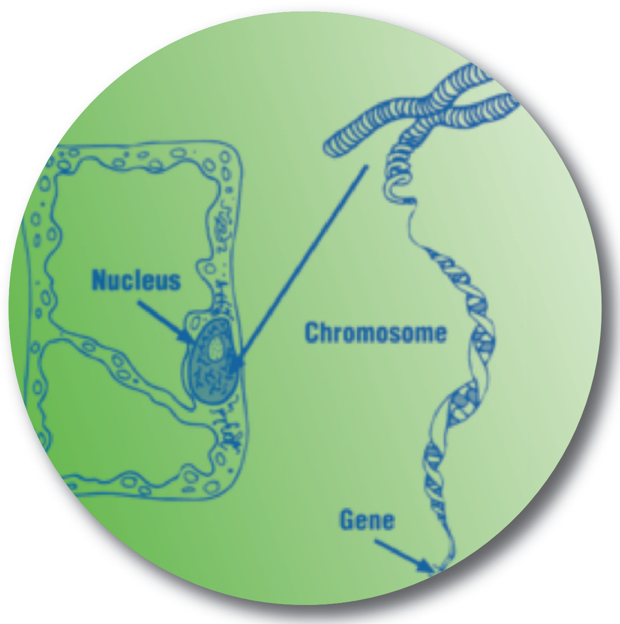
For more information about DNA, check out the website listed below:
http://www.dnaftb.org/dnaftb/29/concept/index.html

Reference

http://ucbiotech.org/resources/display/files/dna_extraction_from_strawberrie.pdf

ACTIVITY WORKSHEET
Strawberry DNA Extraction
PARTICIPANT INSTRUCTIONS

1. Have one partner get the supplies while the other partner gets the strawberry and removes the stem and leaves.
2. Place one strawberry in a zipper bag.
3. Mash up the strawberry for 2 minutes.
4. Add 10 mLs of the extraction buffer to the bag.
5. Mash again for 1 minute. While one partner is mashing the other partner should do Step 6.
6. Drape the coffee filter in the cup. Make sure the top part of the filter is folded over the top of your cup and that the bottom of the filter does not touch the bottom of the cup.
7. Pour the mashed strawberries extraction buffer mixture into the filter and let drip into the bottom of the cup. This takes about 10 minutes.
8. One partner gets a test tube that contains ice-cold ethanol. Tube should be no more than half full of cold ethanol.
9. Using a pipette, remove some of the strawberry extract from the cup. Carefully pipette the strawberry extract into the alcohol in the test tube and watch the solution precipitate (separate). DO NOT SHAKE THE TUBE!!! *Very gently* swirl the tube once or twice. Then let the tube remain undisturbed. Note: if a pipette is not available, the strawberry extract can be carefully poured into the alcohol.



10. Watch where the alcohol and extract layers come in contact with each other. Keep the tube at eye level so you can see what is happening.

    What do you see appearing? (Sketch what you see in the box and note any other observations.)

11. Using a paperclip that you re-shape into a hook, swirl, scoop or pull your DNA strand from the tube or container it is in. You can save it in another clean tube, if available.

MODULE 4: The Biotechnology Debate

Outcomes: Upon completion of the lesson, participants will be able to:

- Reflect on what they have learned about biotechnology
- Discuss social issues surrounding biotechnology

Purpose: This module seeks to review social issues surrounding biotechnology, evaluating the issues from all different perspectives.

Time: 45–90 minutes

Activity: Biotechnology Debate

Materials: computer, access to internet, LCD projector, slide set

INTRODUCTION

While biotechnology has been a useful tool in plant science, it has also initiated a worldwide debate on its use. Many questions have arisen, not only in the mass media, but also in classrooms and at home. By evaluating, studying, and debating the ethics of biotechnology, researchers become more reflective about their work, and the lay public can provide input on how science should be conducted.

In general, "ethics" are defined as the standards, values, or ideals that people use in order to make a judgment about whether something is right or wrong. There are ethical norms in society that determine what is acceptable and who is responsible for what. Ethics can be different from one culture to the next.

The issue of bioethics can be complicated to outline, much less discuss. Ethics can be tied up with religious belief, and the concept of manipulating nature through biotechnology. Ethics comes into play when sustainability issues and environmental safety are discussed. Another ethical issue involves the role that large corporations play in biotechnology, which, in turn, leads to debates on the distribution of food and profit from biotech work.

Biotechnology will always be surrounded and plagued by issues. Discussing and debating these issues is healthy, and you should seek to clarify your own understanding of these issues, as well as encouraging the young people you work with to do the same.

Despite the promise of biotechnology for the agriculture industry, there are still safety issues that need to be considered. One issue is food safety. Can the presence of new DNA in a plant or animal make it unsafe to eat? Culture could also come into play, especially for consumers whose beliefs might require them to avoid certain foods, or foods prepared in a specific manner. So yet another angle to question could be "are biotech foods prohibited by any religious groups?"

There are several government agencies involved in regulating the release of biotechnology-derived products and foods in the market. However, the specific methods they use to regulate product and food release is often called into question. This makes regulation of biotechnology-derived products and foods complicated as well

In line with regulation is the labeling issue. Consumer groups have called for biotechnology-derived products to be labeled, a process that could also increase the prices of such foods. This labeling issue has been debated for some time, and the issue may finally make its way in front of national lawmakers in 2013.

INSTRUCTIONS AND ACTIVITY

Activity: The Biotechnology Debate

Say – There is a tremendous diversity of ethical issues in agriculture, especially agricultural biotechnology. With this comes a need to understand beliefs and principles across and within different groups in our society, which allows for coexistence and hopefully prevents social conflict. It is important to realize that the acceptance of any technology, new or old, is based not only on how sound the science is related to that particular technology, but also on how the new technology is perceived socially, politically, and economically.

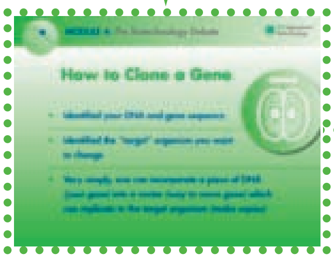
Key Words Defined

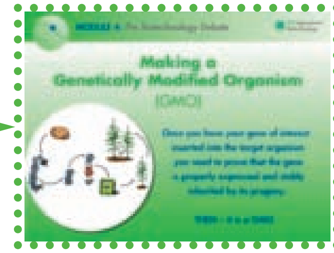
Ethical Norms –
Recognized common ethical norms, but different individuals interpret, apply, and balance these norms in different ways in light of their own values and life experiences. Most societies also have legal rules that govern behavior, but ethical norms tend to be broader and more informal than laws.

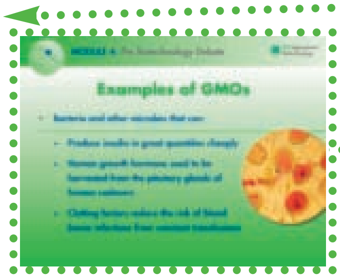
Ethics –
Code of conduct that distinguishes between acceptable and unacceptable behavior.

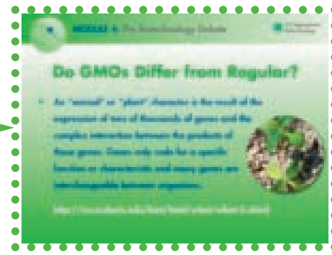
Biotechnology-Derived Products –
Products that are a direct result of a specific biotechnology. For example Roundup Ready® Soybeans or BT Corn.

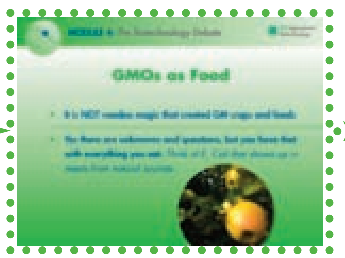
Utilize the following set of slides to introduce the role biotechnology plays in creating genetically modified organisms.

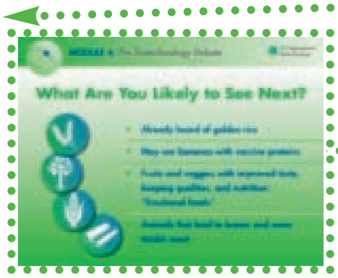












Say – **Today we will be addressing the controversial aspects of biotechnology. In recent years, Genetically Modified Organisms (GMOs) have been "hot topics" in this arena. We will have a debate on the benefits and costs of biotechnology practices—"The Great Biotechnology Debate."**

Divide into 2 to 4 groups. Assign each group a "side" (benefits or costs) of the debate to represent: Biotechnology—the Benefits and Costs.

Allow 20 minutes to research information to support a side of the argument. Choose one group member to record the Internet sources, and another to list several important points to be shared as part of the debate. Researching phrases like biotechnology, genetically modified organisms or genetic engineering may be a good start.

Say – **A gentle reminder is that you might not agree with the side you were chosen to represent, and this is ok. Often we learn more about a situation or topics if we are able to look at all sides of it. There is an expectation that everyone handle themselves in a respectful, positive manner. This includes waiting your turn when speaking and keeping the volume of your voice to a minimum.**

Choose which side will begin the mock debate first by drawing out of a hat or flipping a coin. Set a timer for 5 minutes for each side to share their important points. Then allow follow-up comments and questions of 5 minutes for each side again. If the group is large and has been broken into four, repeat until all groups have had a chance to share. If a mock debate proves difficult, simply switch the activity to a guided round table where each group shares a few points and then a discussion is held. A closing wrap-up discussion may be helpful to re group and focus on the positive aspects of the activity.

Do – **Begin the debate.**

Another option for discussing and exploring issues around biotechnology is to use a pre-determined scenario or a case study. An example, *Bioethics Institute Case Study: Edible Antibiotics in Food Crops*, can be found here:

http://www.biotech.iastate.edu/publications/bioethics_outreach/classroom/ediblevaccines.html

(from: Zeller, M., T. Riordan, H. Zaleski, D. Herzfield, and K. Orvis. 2002. *Edible Antibiotics in Food Crops*. In: G. Comstock (Ed.), Life Science Ethics. Iowa State Press; Ames, Iowa)

SHARE:

What are the social issues surrounding the topics biotechnology and genomics?

PROCESS:

Why can a topic like biotechnology be so controversial?

GENERALIZE:

What can you share with a friend or neighbor about the costs and benefits of biotechnology?

APPLY:

How does this activity help us critique where we get our information on topics like this?

REFERENCES

http://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm

Zeller, M., T. Riordan, H. Zaleski, D. Herzfield, and K. Orvis. 2002. *Edible Antibiotics in Food Crops*. In: G. Comstock (Ed.), Life Science Ethics. Iowa State Press; Ames, Iowa.

http://www.biotech.iastate.edu/publications/bioethics_outreach/classroom/ediblevaccines.html

MODULE 5: Improving Our Plants

Outcomes: Upon completion of the lesson, participants will be able to:

- Restate the fundamentals of plant improvement
- Explain the limitations of conventional methods of plant improvement
- Describe basic steps in genetic engineering or rDNA technology
- Explain the importance of microorganisms in genetic engineering

Purpose: This lesson introduces methods of genetic manipulation, which involves the conventional method of breeding and the genetic engineering method of cloning.

Time: 45 minutes to 2 hours, depending on how much time is utilized for viewing animations.

Activity: Improving Plants

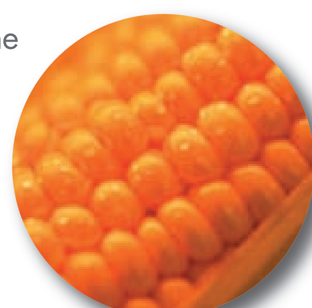
Materials: internet access, computer, LCD projector or computer lab, and slide set

INTRODUCTION

The development of agriculture required identification of plants that could be cultivated, harvested, and stored reliably. Productivity and quality of crops have been improved continuously since the start of organized agriculture about 10,000 years ago.

The basis for crop improvement is genetic variation between and within individuals. Scientists have a sound understanding of how traits are inherited through basic genetic mechanisms. This knowledge is then utilized to develop genetic combinations in plants with desirable characteristics through traditional plant breeding methods, as well as aided with biotechnology or genetic engineering. Identification of plants that are to become desirable cultivated varieties in natural populations is a simple strategy was used by early agriculturists. This is known as "selection." Plants that are used in agriculture are selected for different characteristics.

For many crops today, simple selection is still utilized to identify useful or important characteristics such as insect or disease resistance. Biotechnology helps propel the process of selecting important characteristics, so that we are able to see improvements in our crops much faster than 100 years ago. With the development of genetics and our understanding of how traits are inherited, crop improvement now relies heavily on biotechnology-assisted plant breeding. Plant breeding can be described as the deliberate hybridization of plants with complementary traits and selection of top lines that combine these traits successfully.



Key Words Defined

Genetic Engineering –
Altering the genetic material of cells or organisms to enable them to make new substances or perform new functions.

Cloning –
Using specialized DNA technology to produce multiple, exact copies of a single gene or other segment of DNA to obtain enough material for further study.

Bacteria –
Single-celled or noncellular spherical or spiral- or rod-shaped organisms lacking chlorophyll that reproduce by fission—important as pathogens and for biochemical properties.

Plant Breeding –
Can be described as both an art and a science that leads to changing genetics of plants in order to produce desired characteristic(s). Plant breeding is done utilizing many different techniques ranging from simple selection of plants with desirable characteristics to more complex techniques utilizing biotechnology.

INSTRUCTIONS AND ACTIVITY

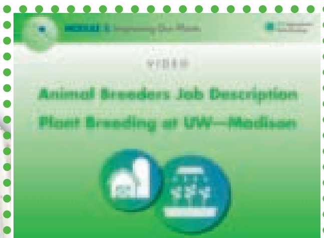
Activity: Improving Plants

Say – To begin today's activity, you will see two short videos that will introduce you to the topics of animal and plant breeding. As you watch the videos, think about how you may have seen these processes before.

View online videos accessed through YouTube:

Animal Breeders Job Description (1:48)
http://www.youtube.com/watch?v=deTJdi8yu2w

Plant Breeding at UW—Madison (4:30)
http://www.youtube.com/watch?v=bSd5cmBnlps



Ask – Were you surprised at what you saw in the two video clips?

Key Words Defined

Complementary DNA (cDNA) –
DNA synthesized from an RNA template by the enzyme reverse transcriptase.

Complementary Sequence –
Nucleic acid base sequence that can form a double-stranded structure with another DNA fragment by following base-pairing rules (A pairs with T and C with G). The complementary sequence to GTAC for example, is CATG. Cytosine (C) A nitrogenous base, one member of the base pair GC (guanine and cytosine) in DNA.

RNA (Ribonucleic Acid) –
A chemical found in the nucleus and cytoplasm of cells; it plays an important role in protein synthesis and other chemical activities of the cell. The structure of RNA is similar to that of DNA. There are several classes of RNA molecules, including messenger RNA, transfer RNA, ribosomal RNA, and other small RNAs, each serving a different purpose.

Say – Next you will learn information on the conventional method of genetic manipulation—which is known as breeding—as we go through the slides.

Key Words Defined

(continued)

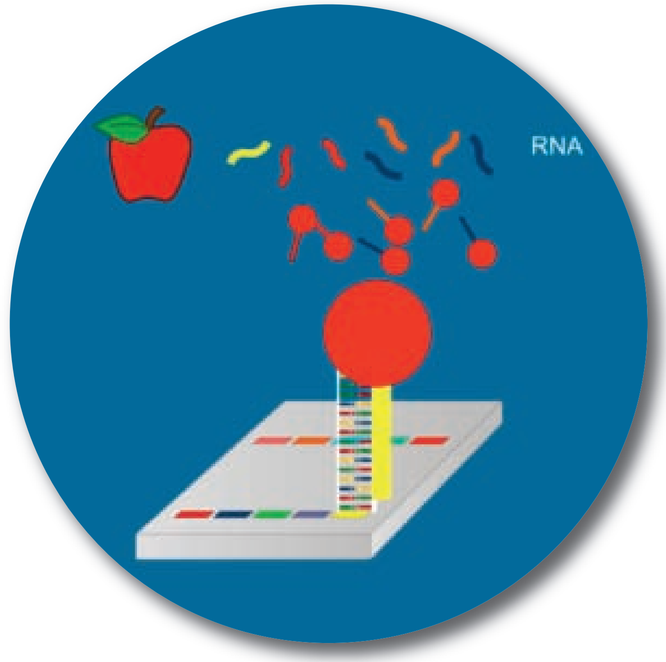
Messenger RNA (mRNA) – RNA that serves as a template for protein synthesis.

Recombinant DNA – Genetically-engineered DNA prepared by transplanting or splicing genes from one species into the cells of a host organism of a different species. Such DNA becomes part of the host's genetic makeup and is replicated.

Replication – The process of duplicating or reproducing, as the replication of an exact copy of a polynucleotidestrand of DNA or RNA.

Restriction Enzyme – Any of a group of enzymes that catalyze the cleavage of DNA at specific sites to produce discrete fragments, used especially in genetic engineering.

Animations found at **www.four-h.purdue.edu/apple_genomics** can be utilized to further explore these topics of plant improvement.



Four animations to be utilized for this module are:

- DNA Cloning into Plasmid Vectors
- Gene Expression. From DNA to RNA
- cDNA Cloning
- Isolating Plasmid DNA from Bacteria

After going through the slides and animations, the following questions can guide a discussion.

Ask – Why are restriction enzymes so important in cloning?

Brief Answer: *DNA molecules are very large—restriction enzymes are needed to "cut" the DNA strand at specific sequences of bases so they are ready to study further. Restriction enzymes each have their own "code of bases" to "cut" from the DNA molecule.*

Ask – What role do bacteria play in the cloning process?

Brief Answer: *Bacteria have plasmids, which are small circular DNA molecules. They can be isolated from DNA, and they are "cut" to make room for the foreign DNA inserted into them. Then, they replicate through normal mitosis. The plasmids can then be transferred into a host bacterium. Bacteria help make copies of recombinant plasmids.*

Ask – What is mRNA? Describe how it is made. Why is it important?

Brief Answer: *Messenger ribonucleic acid (mRNA) is created from DNA. First RNA polymerase "reads" the genes and copies the information to RNA. Then, enzymes remove bases that do not encode proteins (introns), and different enzymes "glue" the other bases (exons) together. mRNA is important because it contains a sequence of bases that code for a specific protein, and it can be used to learn about an organism's genes and protein.*

SHARE: Can you describe basic steps in genetic engineering as it relates to plant improvement?

PROCESS: What are the limitations of conventional methods of plant improvement?

GENERALIZE: What is the importance of microorganisms in biotechnology and genetic engineering?

APPLY: What is the major difference between conventional breeding and genetic engineering?

REFERENCES

www.four-h.purdue.edu/apple_genomics

MODULE 6: **Unraveling DNA Sequence**

Outcomes: Upon completion of the lesson, students will be able to:

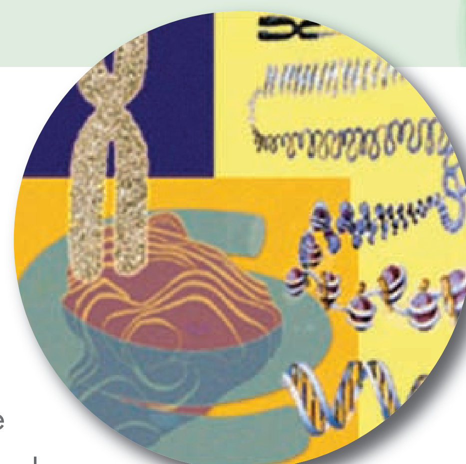
- Describe the methods of DNA sequencing
- Connect importance of DNA sequencing with biotechnology

Purpose: This lesson introduces DNA sequencing, which scientists use to know where genes are located in the genome.

Time: 30 minutes per activity

Activities: Activity 1: A Roadmap of Genes
Activity 2: The Apple Genomics Project
Activity 3: Modeling DNA Sequencing with LEGO® Blocks

Materials: computer with Internet, LCD projector, slide set, LEGO® Block Kits, LEGO® Sequencing Worksheets



INTRODUCTION

Genomics is the identification and the sorting of all pieces of DNA contained in the cell of an organism. Researchers in genomics take the identified pieces of DNA and attempt to construct a detailed roadmap of the organism's genome. A genome is essentially the database of an organism's genes. Once the genome is complete, the researchers determine the entire nucleotide sequence of DNA.

Sequencing of a genome is essential to understanding an organism's genome. DNA sequencing utilizes several different laboratory methods and tools, such as Polymerase Chain Reaction (PCR), electrophoresis, and now, automated sequencing machines. These methods are widely used in society for things such as paternity testing, screening for genetic disorders and for forensics in criminal cases.

DNA sequencing today is largely based on the methods of Fred Sanger, who received a Nobel Prize for his method. His method involves the use of modified nucleotide bases to terminate chain elongation. Using those dideoxynucleotide triphosphates (commonly referred to as dideoxynucleotides or ddNTPs), which cannot form the phosphodiester bonds necessary for chain elongation, the DNA synthesis process can be stopped anytime one of these molecules is incorporated into a forming strand.

Key Words Defined

Genomics –
The study of genes and their function.

Genes –
The fundamental physical and functional unit of heredity. A gene is an ordered sequence of nucleotides located in a particular position on a particular chromosome that encodes a specific functional product (i.e., a protein or RNA molecule).

DNA Sequencing –
Determination of the order of nucleotides (base sequences) in a DNA or RNA molecule or the order of amino acids in a protein.

Four reactions are set up to replicate a given portion of DNA. Each includes all four normal bases plus one of the ddNTPs.

As the normal bases are incorporated, the chain elongates. Every so often, a modified base is incorporated and the elongation process stops. Because there are many chains being formed simultaneously, the result of the reaction is a large pool of various sized chains of DNA. Given a sequence of ATAGCA, the possible chains would be A, AT, ATA, ATAG, ATAGC, and ATAGCA.

Using special fluorescent dyes, automated sequencing machines perform dye enhanced sequencing and use lasers to excite the molecules as they pass through a separation column. The color produced is analyzed and recorded as a base identification. This automatic reading process eliminates the need for manual reading. The output is digital and usually includes some basic analysis information.

The animation (activity) describes the process of DNA sequencing in which the four bases of DNA are used to determine specific information regarding what genes are being expressed. DNA sequencing provides a graphic view of how this process occurs.

What is the real value of measuring level of nucleic acids and/or proteins? Knowing how much of a given gene is expressed is not useful unless you know when and where it is being expressed. Only then can conclusions be drawn about its importance in the plant. Studies are often restricted to specific tissue types to understand what genes are

Key Words Defined (continued)

Electrophoresis –
A method of separating large molecules (such as DNA fragments or proteins) from a mixture of similar molecules. An electric current is passed through a medium containing the mixture, and each kind of molecule travels through the medium at a different rate, depending on its electrical charge and size. Agarose and acrylamide gels are the media commonly used for electrophoresis of proteins and nucleic acids. Because of DNA's negative charge, the fragments move through the gel toward the positive electrode. The shorter the fragment, the faster it moves.

Automated Sequencing Machines –
Uses the Sanger method of sequencing together with flourescent labeling, computers, and capillary electrophoresis. The use of automated sequencing machines allowed the human genome to be sequenced faster than expected.

responsible for activities in certain regions of a plant. Nucleic acids and proteins taken from these tissues are studied using the methods mentioned above.

By sampling the same tissue types at various intervals, a gene profile can be established. The study of these tissues may be expanded to include several days, and if the pattern holds true, a basic hypothesis may be formed in order to further understand what it is that you are studying.

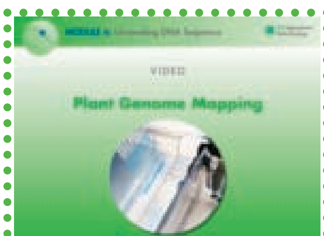
INSTRUCTIONS AND ACTIVITY

Activity 1: A Roadmap of Genes

First watch a short video clip on plant genome mapping developed by students at Iowa State University.

Say – **As you watch the video, pay close attention to all of the details of the process, so you may get a better understanding of what happens at the molecular level.**

View online video *Plant Genome Mapping* (7:34) which can be accessed through YouTube
http://www.youtube.com/watch?v=dC-r3uoSuRg



Key Words Defined (continued)

Modified Nucleotide Bases – The dideoxyribonucleotides (ddDNA) "modified nucleotide base" do not have a 3′ hydroxyl group, hence the DNA strand can not be made longer once the modified base is part of the strand. This stops the building of that DNA strand and the process starts over. Thus, these molecules form the basis of the dideoxy chain termination method of DNA sequencing, which was developed by Frederick Sanger in 1977.

Polymerase Chain Reaction (PCR) – is a tool that can focus in on a segment of DNA and copy it billions of times over. PCR is based on using the ability of DNA polymerase to synthesize new strand of DNA complementary to the original template strand.

Ask – What were they showing in this video? Why is this process important? Why is PCR a good method for amplifying short segments of DNA?

Brief Answer: *The process of the Polymerase Chain Reaction (PCR), in an effort to map a genome, is a technique often used with forensic samples (hair, dry blood, etc.) to help solve crimes—like the in TV show CSI—and with mummified remains or fossils—like the movie* Jurassic Park.

Say – This process doesn't take much time. In a matter of 2.5 hours, billions of DNA molecules are synthesized from 1 molecule, making it a very efficient process.

Say – The next slides will cover some basics of molecular biology that are helpful in understanding how we are able to sequence DNA.

Utilize the following set of slides (on the next page) to introduce molecular biology and sequencing basics. The text on each slide is what can be explained and shared.

Key Words Defined
(continued)

Complementary Sequence – Nucleic acid base sequence that can form a double stranded structure with another DNA fragment by following base pairing rules (A pairs with T and C with G). The complementary sequence to GTAC for example, is CATG. Cytosine (C) A nitrogenous base, one member of the base pair GC (guanine and cytosine) in DNA.

Nucleotides – A subunit of DNA or RNA consisting of a nitrogenous base (adenine, guanine, thymine, or cytosine in DNA; adenine, guanine, uracil, or cytosine in RNA), a phosphate molecule, and a sugar molecule (deoxyribose in DNA and ribose in RNA). Thousands of nucleotides are linked to form a DNA or RNA molecule.

Polymerase, DNA or RNA – Enzyme that catalyzes the synthesis of nucleic acids on preexisting nucleic acid templates, assembling RNA from ribonucleotides or DNA from deoxyribonucleotides.

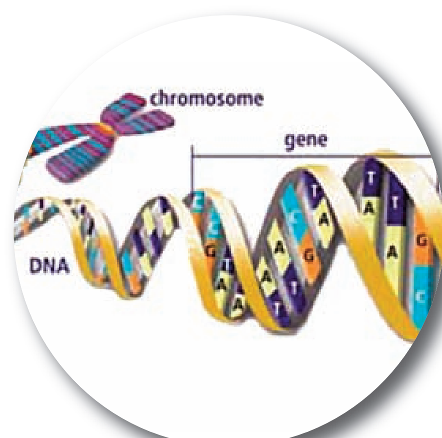
Key Words Defined

(continued)

Double Helix –
The twisted ladder shape that two linear strands of DNA assume when complementary nucleotides on opposing strands bond together.

DNA Sequence –
The relative order of base pairs, whether in a DNA fragment, gene, chromosome, or an entire genome.

Base Sequence –
The order of nucleotide bases in a DNA molecule determines structure of proteins encoded by that DNA.



Activity 2: Online Animations from The Apple Genomics Project

Go to **www.four-h.purdue.edu/apple_genomics**

Divide the group into groups; no more than 2–3 per computer. Individuals having their own computer is the ideal situation.

Say – Read the information found in the Sequencing section under Apple Molecular Biology on the Apple Genomics Website, and then view the animation Modeling DNA Sequencing with LEGO® Blocks.

After completing the animation activities:

Ask – How are two identical double-stranded DNA molecules created?

Answer: *First, the two strands of DNA must be separated. Then, DNA Polymerase uses each strand as a template to make a new, complementary strand. Then you have two identical double-stranded DNA molecules because each base is properly paired (A with T, G with C).*

Ask – Why are LEGO® blocks used to represent nucleotides in this animation?

Answer: *LEGO® blocks give a good visual representation of nucleotides because they are a common item that many of us are familiar with. In the animation, LEGO® blocks with connectors are nucleotides with the hydroxyl (–OH group on the sugar). LEGO® blocks lacking connectors represent dideoxynucleotides—those nucleotides without the –OH group on the sugar.*

Ask – How is it that newly-synthesized DNA molecules can be different sizes?

Brief Answer: *Because some nucleotides are dideoxynucleotides, and they lack the hydroxyl (–OH) group on the sugar, which is needed to connect with another nucleotide. Therefore, another nucleotide cannot be added, ending the sequence. Dideoxynucleotides are like LEGO® blocks with no connectors.*

Ask – What is the purpose of a DNA sequencer? What does it do?

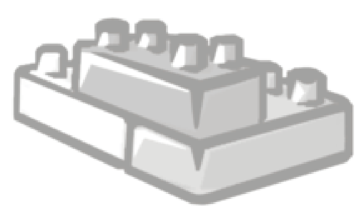
Brief Answer: *It identifies the dideoxynucleotides at the end of each molecule—therefore, it reads the sequence (or the order) of the molecules.*

Activity 3: Modeling DNA Sequencing with LEGO® Blocks

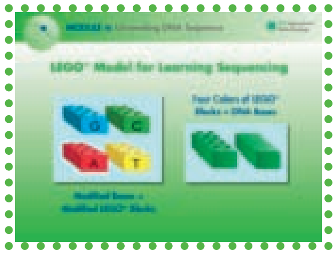
You will need the worksheets on pages 101–104 and a LEGO® Sequencing Kit.

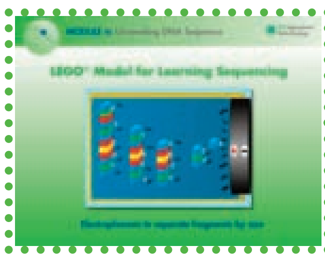
Say – Working in a group, this activity will demonstrate the method of DNA sequencing using LEGO® blocks with and without connectors. Participants will act as the enzyme RNA polymerase, which creates strands of DNA, and this creates a complementary strand of DNA. This is the foundational concept for the polymerase chain reaction, PCR, which is a basis for DNA sequencing.

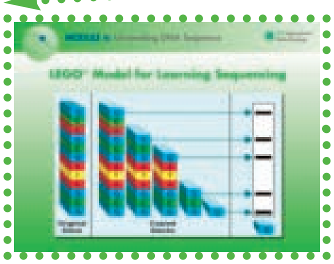
You will give participants a model of the DNA sequence, the "template." You can create the template out of any sequence of red, yellow, blue or green LEGO®. From that model, each group will create a complementary DNA strand by choosing the appropriately-colored base pair.



Utilize the following set of slides to explain the concepts of the LEGO® Model for Learning Sequencing. The text on each slide is what can be explained and shared.







Say – Remember, C, the blue block, pairs with G, the yellow block; A, the red block, pairs with T, the green block. When you select a dideoxynucleotide, a block with no connectors, remember your sequence ends there, and you will need to make another sequence (stack of LEGO® blocks). The goal is for each group to assemble all the different length strands of DNA that would be created in the sequencing reaction. On the worksheet, label the template strand and the complementary strand.

Participants then begin to randomly select LEGO® blocks by color, building a complementary model of the template. If the first block of the template is a blue LEGO® (C) the students will first select a yellow block (G), then they will select the next complementary color block, and so on.

Each of the groups has only done a fourth of the reaction as RNA polymerase because each group represents the four bases—the four colors—a group only knows where one base, A, T, G or C, is located. If one would put the sequences in order based upon height, like the animation presented, then you could "read" the sequence.

Say – There are now automated machines that can sequence DNA very rapidly. What used to take two weeks can now be done in two hours!

SHARE: What are the methods of DNA sequencing and why are they important?

PROCESS: What technology makes rapid DNA sequencing possible today?

GENERALIZE: Why is knowing the sequence of DNA important?

APPLY: What are some ways that DNA sequence is used in agriculture and science?

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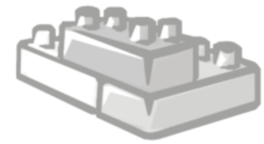
ACTIVITY WORKSHEET
Modeling DNA Sequencing with LEGO® Blocks



Kit Assembly

The LEGO® Sequencing Kit is designed to give hand-on visualization of the process of DNA transcription. LEGO® blocks can easily be ordered to create these sets, or they can be created from mixed boxes of LEGO® available via general retail. However, with retail LEGO®, blocks with flat tops are still needed. Home-made versions of flat top blocks can be created. This is easiest with DUPLO LEGO®, but not impossible with regular-size LEGO®. The kits utilize only 4 colors, red, blue, green and yellow. Color substitutions are acceptable, provided flat top blocks are available for the colors that are selected. Additionally, modifications to blocks for the visually impaired is easily accomplished by attaching three unique textures to one side of each brick, such as Velcro, sand paper, soft fabric, and leaving the fourth smooth.

Materials for 1 Kit

- 2″ x 2″ regular and flat top LEGO® blocks, in 4 unique colors for the kit
  –Red, Yellow, Blue and Green are suggested
- Set of 5 matching containers that will hold number of LEGO® blocks required for kit

Instructions

1. Purchase LEGO® blocks either from shop.lego.com or retail. LEGO® Pick a Brick sells 2 x 2 flat bricks for $0.10 each. A minimum of 16 flat bricks in each of the 4 colors is needed to create one kit. Flat blocks and regular blocks must be the same size.
2. Separate LEGO® by color and by modified (flat top) or regular. There should be 8 piles upon completion.
3. Assemble the modified blocks. Attach a flat block onto a regular LEGO® block of the same color.
4. Sort LEGO® blocks into the 5 containers as shown here. This arrangement provides the minimum number of blocks to create a DNA template up to 16 blocks long.

Set	Modified (Flat top)	Regular Blue	Regular Red	Regular Yellow	Regular Green
Blue	16 blue	16	16	16	16
Red	16 red	16	16	16	16
Yellow	16 yellow	16	16	16	16
Green	16 green	16	16	16	16
Template	0	16	16	16	16

5. When using this kit to teach DNA sequencing, working in small groups (3–5) is advisable. Utilization of four kits per group of 20 has been successful in training or classroom settings.
6. The template container should not be handed out to the participants, but used by the leader/teacher to first create a template strand of DNA for the group to replicate.
7. The number of bricks listed is the minimum for a kit. Using more than 16 of each color of regular bricks is acceptable, and helps make the exercise more realistic. The number of modified bricks in each container however, must be greater than or equal to the length of the DNA template used for the activity.
8. The handout for the audience participants is included and recommended for use with the kit.

* *One kit = one container with each of the following, including the modified blocks, plus one container with no modified blocks, 5 containers total.*

16 red	16 red	16 red	16 red	16 red
16 blue	16 blue	16 blue	16 blue	16 blue
16 green	16 green	16 green	16 green	16 green
16 yellow	16 yellow	16 yellow	16 yellow	16 yellow
0 modified	16 modified red	16 modified yellow	16 modified green	16 modified blue

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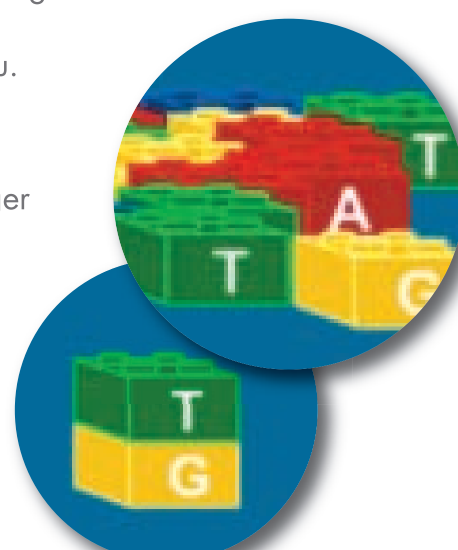
ACTIVITY WORKSHEET

Modeling DNA Sequencing with LEGO® Blocks

Activity

- **You are the enzyme, DNA polymerase, which synthesizes a new piece of DNA.**
- **The LEGO® blocks represent bases and modified bases (ACTG).**
- **You will be simulating the Sanger method for determining DNA sequence.**
- **In this exercise, you start with a known template, but in the lab this method is used to find out what an unknown sequence is.**

1. Divide yourselves into 8 teams, and make 2 groups of 4 teams.
2. There is one template per 4 teams, so you will need to share.
3. Get your LEGO® blocks out of the box and try to build the template with your blocks.
4. You should get a series of stacks of blocks that are difference length.
5. Look at your neighbors, who will have different stacks than you.
6. Try to see how the 4 teams sharing the original template, are actually each one of the reactions we talked about in the Sanger method.
7. Learn how we would then take those reactions and use electrophoresis to separate the fragments of DNA based on size to determine an unknown template or sequence.



Use this worksheet to label the template DNA strand (the strand given to you) and the complementary DNA strand (the strand you will make).

First, label the sequence of the template DNA strand. Then based upon that, label the complementary DNA strand. Next you will create the differing strands, using the blocks with no connectors. Use the rules for base pairings!

Red block = A *Green block = T* *Blue block = C* *Yellow block = G*

Template DNA Strand	Complementary DNA Strand

The complementary strand you've created above is the full DNA sequence. However, when you choose a dideoxynucleotide (a LEGO® without its connector), your sequence stops. You then must begin to make another sequence. You will have 3 different sequences when you are finished.

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MODULE 7: **Gene On or Gene Off?**

Outcomes: Upon completion of the lesson, students will be able to:

- Define gene expression
- Explain how microarrays are used to study gene expression

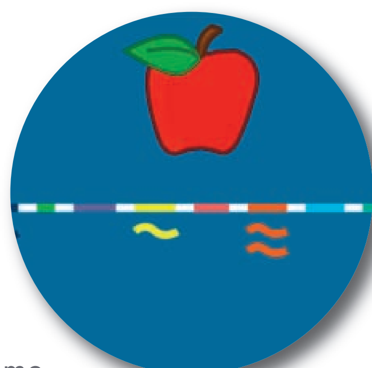
Purpose: This lesson introduces the topics of gene expression and how microarrays are used to study in what way genes are expressed.

Time: 45–90 minutes

Activities: Activity 1: Apple Genomics Word Jumble Worksheet
Activity 2: Online Amimations

Materials: Apple Molecular Biology worksheets, computer with LCD projector, computer lab

INTRODUCTION

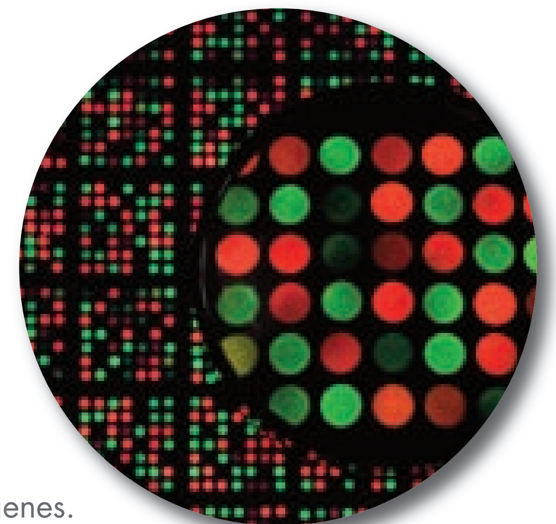


What is Gene Expression?

The term "gene" is used to define specific functional regions of the genome. Each gene carries information used to make a protein. The gene itself is not directly useful to the organism. In order to make any use of the information contained within the gene's code, the code must first be read. This method is known as DNA reading.

DNA occurs in a helix and contains four bases: Adenine, Guanine, Cytosine, and Tyrosine. Adenine attaches to a tyrosine strand, guanine attaches to a cytosine strand, and vice versa. You can compare this to having to write words. From different letters in the alphabet, you place the letters together in order to form words. It is important that the letters to be placed in the right order, such as the case when DNA is formed within an organism's cells. Such examples might include:

Wrong order: Green apple has the spots brown.
Right order: The green apple has brown spots.



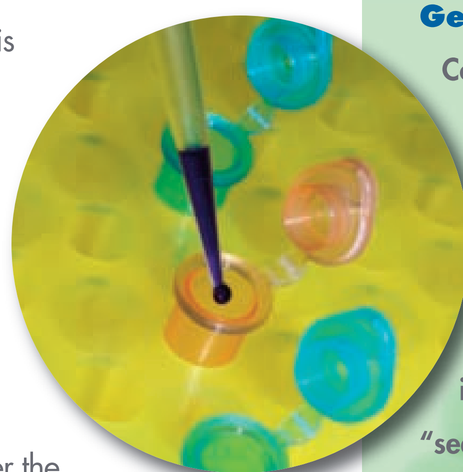
When your body makes new cells, they are producing different letters of the DNA alphabet (A, C, G, and T). These four bases will allow cells to make combinations that will eventually produce the information that your body needs in order to stay healthy and grow. The order of these DNA bases is called a sequence.

Every cell contains a full set of chromosomes and identical genes. At any given time, only a small portion of these genes are turned on, or "expressed" and create specific traits or characteristics that are displayed. There are also genes that are not expressed but instead are turned off. Gene expression is a term that is used to describe the transcription of information contained within the DNA that is used to perform critical functions of the cells.

How do we use microarrays to study gene expression?

DNA microarrays are used to study the expression of genes. A microarray is a tool for analyzing gene expression that consists of a small membrane or glass slide containing samples of many genes arranged in a regular pattern. Microarrays are used to "hybridize" specific mRNA molecules to the DNA template from which they came. By using an array containing many DNA samples, scientists can determine, in a single experiment, the expression levels of hundreds or thousands of genes within a cell by measuring the amount of mRNA bound to each site on the array.

When performing an experiment to determine the level of expression, different colors will appear on the microarray, which will help to determine what types of genes are present. The colors include green, red, yellow, and black. The color green represents the control DNA, in which either DNA or cDNA is hybridized to the target DNA. The color red represents the sample DNA, where DNA or cDNA is derived from diseased tissue hybridized to the target DNA. Yellow represents a combination of both the control and sample DNA, meaning that they were both hybridized equally to the targeted DNA. Finally, black represents areas in which neither the control nor the sample DNA were hybridized to the target DNA.



Each spot on the array is connected with a particular gene. For example, if studying gene expression for disease in soybean, each color represents either a healthy (the control) or a diseased (the sample) tissue. Depending on the type of array that is used, the location and intensity of the color will tell us whether the gene is present in the control or sample DNA. In addition, it provides an estimate of the level of gene expression in the control and sample DNA.

DNA microarrays are important for several reasons. The first reason is that microarrays are useful when a large number of genes or a small sample needs to be studied. They may be used to assay gene expression within a single sample, or to compare gene expression in two different tissue samples. Microarrays can also be used with automated systems—such as with robots or specialized machines—so that large numbers of samples can be studied quickly.

Key Words Defined

Gene Expression – Conversion of the information from the gene (DNA) into mRNA via transcription and then to protein via translation. This results in producing what you "see" or the phenotype of an individual organism.

Protein – A large molecule composed of one or more chains of amino acids in a specific order; the order is determined by the base sequence of nucleotides in the gene that codes for the protein. Proteins are required for the structure, function, and regulation of the body's cells, tissues, and organs, and each protein has unique functions. Examples are hormones, enzymes, and antibodies.

INSTRUCTIONS AND ACTIVITY

Activity 1: Apple Genomics Word Jumble

Say – DNA microarrays are used to study the expression of genes. A microarray is a tool for analyzing gene expression that consists of a small membrane or glass slide containing samples of many genes arranged in a regular pattern, or an array. First, we will do a short activity.

Participants should work for a few minutes on the word jumble handout. Allow about 10 minutes of work. Most will not be finished, and that is okay and expected. The Apple Genomics Word Jumble Worksheet is found on page 111.

Ask – Why is an activity like this difficult?

Ask – How do you think this activity relates to biotechnology and genomics?

Say – Here's how the word jumble you just worked on relates to the current topic—gene expression.

DNA Microarrays – Tool for studying how large numbers of genes interact with each other and how a cell's regulatory networks control vast batteries of genes simultaneously. Uses a robot to precisely apply tiny droplets containing functional DNA to glass slides. Researchers then attach fluorescent labels to DNA from the cell they are studying. The labeled probes are allowed to bind to cDNA strands on the slides. The slides are put into a scanning microscope to measure how much of a specific DNA fragment is present.

Translation – The process in which the genetic code carried by mRNA directs the synthesis of proteins from amino acids.

Transcription – The synthesis of an RNA copy from a sequence of DNA (a gene)—the first step in gene expression. DNA code is "read."

From different letters in the alphabet, you place the letters together in order to form words. It is important that the letters are placed in the right order (and not jumbled), such as the case when DNA is formed within an organism's cells. Such examples might include:

Wrong order: Green apple has the spots brown.
Right order: The green apple has brown spots.

When your body makes new cells, they are producing different letters of the DNA alphabet (A, C, G, and T). These four bases will allow cells to make combinations that will eventually produce the information that your body needs in order to stay healthy and grow. The order of these DNA bases is called a sequence.

Activity 2: Online Animations from The Apple Genomics Project

Go to **www.four-h.purdue.edu/apple_genomics.**

Divide the group into groups no more than 2 to 3 per computer. Individuals having their own computer is the ideal situation.

Say – Read the information found in the Gene Expression section under Apple Molecular Biology on the Apple Genomics Website and then view the animation, Using Microarrays to Study Gene Expression in the Apple. This animation explains how the chromosomes from various tissues from the apple are used to determine the level of expression of gene in the tissues. Microarrays are an integral part of studying the expression of genes.

Go to **www.four-h.purdue.edu/apple_genomics.**

When most or all are done with the lesson, lead a group discussion.

Ask – Are all apple genes expressed in any one tissue?

Answer: *No. Every cell contains a full set of chromosomes and identical genes. With only a small portion of these genes turned on, they are expressed and constitute the specific traits or characteristics that are displayed. There are also genes that are not expressed but instead are turned off.*

Ask – Why are microarrays important to the study of gene expression?

Answer: *DNA microarrays are important for several reasons. The first reason is that microarrays are useful when a large number of genes or a small sample needs to be studied. They may be used to assay gene expression in two different tissue samples. One example of this includes studying healthy and diseased tissues.*

SHARE: What is the definition of gene expression?

PROCESS: How are microarrays used to study gene expression?

GENERALIZE: Describe how scientists use microarrays to compare gene expression in two different tissues.

APPLY: The same genes can be found and expressed in many different tissues. For example, the animation showed a comparison of the genes in the leaf, flower, and fruit of the apple tree. How might genes be expressed at different levels in various tissues of a crop plant?

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www.four-h.purdue.edu/apple_genomics

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ACTIVITY WORKSHEET
Apple Genomics Word Jumble

APPEL		48	17		8					
BAIRACTE			34	24	12					
MEHSOOROCM				18	16	37	10			33
MYENEZ		41		14	38					
SONGIEMC			36	25		15		45		
INGUNEA			21							
ZHDYIREIB	2	39		19		32				
TNNIRO			20	13	35	22				
SEILAG	7			40						
GEHPATNO	47	4	23	27	43					
SIPLAMD	5	31					42			
SOIREOBM	30	9		29		44		28		
SCLIIGPN		6	49							
TIEUSS	1				46					
TECVOR	11	3		26						

DIRECTIONS:
Unscramble each of the jumbled clue words. Then copy the letters in the numbered boxes to the boxes with the same number at the bottom of the page, to reveal a hidden message.

1 2 3   4 5 6 7 8   9 10   11 12 13 14   15 16 17 18 19 20 21 22 23   24 25   26 27 28

W 29 30 31 32   33 34 35 36 37 38 39   40 41 42   F 43 44 32   45 46 47 48 49 14 .

Apple Genomics Word Jumble KEY

Facilitator Copy

Apple
Bacteria
Chromosome
Enzyme
Genomics
Guanine
Hybridize
Intron
Ligase
Pathogen
Plasmid
Ribosome
Splicing
Tissue
Vector

The apple is very important to the world economy and food supply.

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