# Biotechnology: Changing our Future

*By Rachel Naegele*

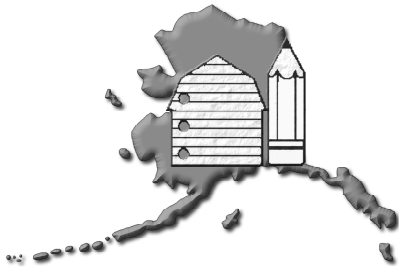
**Materials**
- See lists for two experiements
- Up-to-date information on breakthroughs in biotechnology

**Objectives**
Give students a cross-curricular overview of biotechnology, its history and insights into the possibilities and controversies it raises.

**Suggested grade levels**
7-12

**Alaska Content Standards**
Science A11,14; B1; C3,5,7 D1-5
Math E1-3
English D1-4

**Terms to Define**
gene pool
resistance markers
resistance
foliage



This project presented by Alaska Agriculture in the Classroom through funding from the Agriculture in the Classroom Consortium and the USDA. For more information, visit www.agclassroom.org/ak or www.agclassroom.org

**Introduction**

Biotechnology is modern use of biological organisms to solve a problem, i.e. genetic recombination. For example, through the use of biotechnology, scientists can alter plants to make them more suitable to the arctic conditions of Alaska. One example of this would be developing a hardier variety of tomato.

How do scientists do this? It is done by combining parts of one plant with parts of another. These bits and pieces aren't leaves, roots, or other large parts, they are genes — the genetic material of plants. By taking the genes for cold tolerance from one plant and combining them with the tomato plant, it is possible to end up with a "improved" plant.

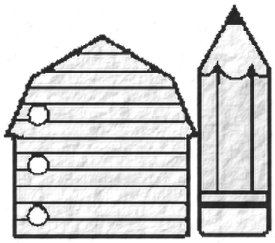
This isn't limited to environmental factors; scientists can also change flavor, storage and color. Many of these characteristics have been changed throughout the ages as man bred plants and selected those with the traits he desired most. Other characteristics, such as herbicide- and pesticide-resistance are also being genetically engineered into plants. Farmers are in a constant battle with weeds. Weeds hinder crop growth by using the limited nutrients, competing for sunlight and emitting a natural "herbicide" against the crops. Scientists have developed similar methods for use in crop systems (like corn), which can resist herbicides and pesticides. The plants, often labeled "super crops," are not the final solution to these problems. They are merely one more temporary solution to ever-changing problems, namely weeds and insects. While they remain effective, these crops provide higher yields, and require a lesser amount of pesticides and herbicides.

Biotechnology has many uses in today's society, from improving agriculture to synthesizing drugs, like insulin. Here are a few examples of plant-based uses of technology:
Disease resistance [Papaya]
Herbicide and pesticide resistance [Corn and Tomato]
Cold tolerance
Hybrids [orchids]
Pharming (the use of plants as a vector to produce pharmaceutic drugs)

**GMOs**

What are GMOs? Called Frankenfood by some people, GMOs are genetically modified organisms. While this term is generally linked to crops it is also applicable to bacteria, viruses and any other organism that has been genetically altered. (While selective breeding is a form of genetic manipulation, it is not in classed in the same category.) GMOs are viewed with varying opinions worldwide. Some common GMO myths are that they are bad because antibiotic resistance markers are used for selection, and built-in pesticides or herbicides may affect human health. While there has been no evidence to show that antibiotic resistance markers are bad, and pesticide and herbicide genes are not in the consumed portion of the plant, the truth is scientists have not been able to study the long-term effects of genetically altered organisms at this time. While there is no data to indicate that GMOs could be harmful, it is impossible to say for sure. The most prevalent concern with GMOs is the spread of GM material into wild populations. While scientists are working hard to ensure this does not happen, there is still the possibility of genetic material being transferred to a closely related wild species.

tolerance
interface
precipitate
tissue culture
herbicide
trait
DNA/RNA
pharming
genome



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**Techniques used in the manufacturing of biotechnology products**

• Tissue culture – can be used for conservation purposes of endangered species, speeds up the growing process, allows plants to be regenerated from any tissue. This technology is the basis for many plant-based studies.
• Biolistics – a method for incorporating DNA into a plant by coating small gold particles with DNA and shooting them into the tissue. The problem with this method is that the DNA can insert randomly into the genome of the plant.
• Agrobacterium – the second method for inserting DNA into a plant's genome. This method involves using this bacterium, which essentially causes the plant to form a callous (uncontrolled growth). This is useful since the callous can be removed, sterilized and grown on tissue culture to produce a new plant.
• Systemic Infection – creating infectious RNA in a test tube, transferring it into the leaves of the plant.

**Background**

Not all genetic engineering is done using high-tech equipment. Farmers and plant breeders have been selecting bigger and better plants since the beginning of time. Even today many companies use a combination of traditional breeding and biotech. Scientists have been using selective breeding since the beginning of agriculture, but it wasn't until the 1800s that genetics began to be understood. Gregory Mendel, the father of genetics, was an Augustinian monk in Austria. In the 1800s he began a series of experiments that were remarkably advanced for his day and age.

Mendel segregated two pure breeding strains of peas. Pure breeding means that it will always produce the same kind of offspring; another name for this type of line is homozygous. When he bred the two together, he found that all the offspring resembled only one of the parents. The trait from the second parent was completely lost in the first generation. However, when the offspring were bred, the missing trait reappeared, and all the offspring from this cross displayed traits from one parent or the other. He coined these traits dominant and recessive. This was the beginning of modern genetics. Mendel continued his experiments, and each time it was demonstrated every homozygous recessive strain when bred with a homozygous dominant strain would result in a first generation offspring that resembled the dominant parent. The breeding of the offspring would result in a phenotypic 3:1 ratio of dominant offspring to recessive.

Mendel discovered three basic laws governing the passage of a trait from one member of a species to another member of the same species. 1. The sex cells of a plant may contain two different traits, but not both of those traits will be expressed at the same time. 2. Characteristics are inherited independently from another. 3. Each inherited characteristic is determined by two hereditary factors (genes), one from each parents, which decides whether a gene is dominant or recessive.

Mendel's work was dismissed and was not rediscovered until 1900 when Dutch scientist Hugo DeVries performed the same experiments and came up with the same results as Mendel. During his lifetime Mendel's contribution was never recognized, but in the early 1900s, he was recognized as the Father of Genetics. It was because of this groundwork in genetics that the science of biotechnology has developed.

**Math and Genetics**

Math in genetics is mostly ratios and percentages: these tell us the frequency of a trait, and can help a geneticist predict the probability of a traits occurance. In the life of a biotechnician it is important to calculate the concentration percentages and ratios. Example word problems:

1. Harry and Jill are going to have a baby. Harry has blue eyes and Jill has brown, what are the chances that Harry and Jill will have a blue-eyed baby?

To answer this problem we would first need to know a few facts. Jill is heterozygous for brown eyes (Bb), and Harry is homozygous for blue (bb; the blue color is recessive so to have a visible phenotype it must be homozygous.). The ratios for each eye color are Bb and bb. The probability that their baby will have brown eyes is one half (calculate by doing a Punnet Square). Now if you wanted to know what the probability that all five of their children will have brown eyes, the equation would be as follows: 1/2 x 1/2 x 1/2 x1/2x1/2. (The probability of each of their five children having brown eyes is 3 percent).

2. Dr. Love is constructing a new petunia. He knows the gene on which the desired traits are located, but he doesn't know if the traits are linked (genes located so closely they tranfer as a single unit). After performing several test crossings and back crossings he ends up with several frequencies of the traits, listed below. These traits can be organized into groups, recombination groups and parental groups. Note: parental plants occur with the greater frequency in a population.

45 blue petals with yellow stripes (parent plants)
65 pink petals with orange stripes (parent plants)
13 blue petals with orange stripes
16 pink petals with yellow stripes
Total amount of flowers tested = 139

Using this data, students can compare the ratio of parental phenotypes to recombinant (changed) phenotypes.
Total amount of offspring with parental phenotypes = 110
Total amount of recombinant phenotype offspring = 29
21 percent are recombinant and 79 percent are parental phenotypes. The traits Dr. Love wants are probably linked because the farther from 50-percent yield of recombinant plants, the more likely there is linkage.

**Possible ways biotechnology could benefits Alaska agriculture**
• Plants resistant to the cold
• Plants with shorter growing season
• Plants better suited to our conditions in general

Alaska is not a large center for biotechnology because Alaska only has one growing season each year, as opposed to other regions, which can have up to four. This does not mean that Alaska cannot benefit from molecular genetic technology. Plant breeding has allowed seed companies to have access to varieties of plants better suited to Alaska's climates: carrots, cabbages, potatoes, tomatoes, cucumbers.

**Activities**

**Experiment 1 — Isolation of DNA from Onion**
***From Access Excellence: http://www.accessexcellence.org/AE/AEPC/WWC/1993/isolation2.html***
**Materials Needed**
• Cm2 pieces of fresh onion
• 100 ml beaker
• 2 test tubes
• Glass rod scored on one end
• ICE COLD 95% ethanol
• Palmolive liquid detergent
• Non-iodized salt (sodium chloride)

• Fresh meat tenderizer or fresh
• pineapple or papaya juice
• Phenol red indicator

**Teacher Preparation**

1. Prepare the detergent/salt solution by adding 10 ml of detergent and 10 grams of salt to 90 ml of distilled water. This solution breaks down the lipid walls of the cells to release the cytosol. The salt shields the negative ends of the phosphates of the cell membrane.
2. Prepare a 5% meat tenderizer or papain solution by adding 5 grams of tenderizer (enzyme) to 95 ml of distilled water. The juice of pineapple or papaya may be substituted for the tenderizer. The enzymes will denature proteins that may contaminate the DNA.
3. The 95% ethanol must be ICE COLD. It should be left in a plastic container in the freezer overnight.
4. Prepare a 5% sodium chloride solution by adding 5 grams of non-iodized salt to 100 ml distilled water.
5. Prepare the phenol red indicator by dissolving enough phenol red powder to fit the end of a toothpick in 100 ml distilled water. The resulting solution should be a light amber color. When the phenol red indicator is added to an acid solution, it produces a pink/red color.

**Student Directions**

1. Place a cm2 piece of onion in the 100 ml beaker with 10 ml of the detergent/salt solution. Macerate the onion with the glass rod.
2. Decant the liquid from the mixture into a clean test tube. Add 3 to 4 meat tenderizer/enzyme solution. Swirl test tube to mix.
3. Carefully pour 10 ml of ice cold ethanol down the side of the test tube to form a layer on top of the onion mixture. Let stand 3 minutes.
4. Using a twirling motion of the glass rod, slowly move the scored end of a glass rod through the interface of the two layers to collect the mucus- like DNA and place in a clean test tube with the 4% salt solution.
5. Add five drops of phenol red indicator to the DNA solution. The resulting dark pink color should be due to the presence of DNA.

**<u>Experiment 2</u> — Viewing your own DNA**

DNA is a structure that can be seen with the naked eye in this activity. Students will be able to see their own DNA because the salt and detergent solutions used will break open the membranes of cells and their nuclei, and the alcohol will make the precipitated DNA more visible. The following procedure is supplied by the St. Louis Science Center. Students should not eat, chew gum or drink immediately prior to the experiment.

**Materials needed:** potable water, 3 oz. paper cups (one per student), small test tubes with caps (one per student), droppers (1 per solution bottle), paper towels, 8-percent NaCl solution, 25-percent detergent solution (like Palmolive) and cold ethyl alcohol.

1. Have each student label a 3 oz. paper cup with his or her name. Add about 5 ml of water (about 1 cm) to the cup.
2. Students will swish the water violently in their mouths for at least 30 seconds, rubbing their tongues on the inside surfaces of the checks. After 30 seconds, the students will spit the water into their cups.
3. Set the cups aside and add 1 ml (10 drops) of the 8-percent NaCl solution into each test tube.
4. Pour enough cheek water into the the students' test tubes so that each student's test tube is half full. Bend the cup to make a pouring spout and poor slowly; if there is too much, pour some back.
5. Add 1 ml (10 drops) of the detergent solution into each test tube and cap tubes.
6. Gentle rock (Do NOT Shake) test tube back and forth to encourage mixing of contents without forming bubbles. Remove cap and keep test tube upright.

7. Add 5 ml of ice cold ethyl alcohol to each tube, filling the tubes.

8. Students will observe the interface for the precipitation of the DNA. Small bubble with white strings attached will slowly make their way to the top of the alcohol. This is DNA.

9. When observations have been made, recorded and discussed, students will dispose of materials as directed.

**Possible Essay Topics**

Mendel and the history of genetics
Benefits of biotechnology to Alaska farmers
GMOs
Resistance markers
How it works
Why it works
Improving our earth with genetics research
Improving our way of life with biotechnology
Space efficiency of genetically engineered crops
Punnet squares: their use historically and today
How Dolly the sheep changed our world
Organic vs. GMOs
Effects of biotechnology on the environment
Health benefits and detriments of genetic engineering
Pharming

**Related Websites**

http://www.biotech.wisc.edu/education/index.html
http://www.biotech.wisc.edu/education/chymosin.html (experiment)
http://www.accessexcellence.org
http://www.ars.usda.gov
http://www.biotechknowledge.monsanto.com/
http://www.biopoint.com/engaging/MENDEL/MENDEL.HTM
http://www.mendelweb.org/
http://biology.clc.uc.edu/courses/bio105/geneprob.htm
http://www.mansfieldct.org/schools/mms/staff/hand/geneticspageone.htm