Berkeley Engineers and Mentors

Lesson Plan: Biotechnology (Elementary School/ High School Part I)
Lesson Type: Module-based
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Materials
For discovering DNA demo (done in groups of 3-4):
10 Multi-colored gum drops (candy)
10 Toothpicks
2 Red vines (candy)

For strawberry DNA extraction (done in pairs):
1 water bottle
1 Heavy duty Ziploc bag
1 strawberry
10ml DNA extraction buffer (900ml water, 50ml dishwashing detergent, 2teaspoons salt)
1 Cheese cloth
1 Funnel
1 Plastic test tube (or any tube)
20ml ethanol

For GFP transformation (done in groups of 2):
2 tubes of harmless E. coli cells (will be provided) (enough for the whole class)
1 small tube of KCM buffer (provided) (enough for the whole class)
1 tube of clean ddH_2O water (provided) (enough for the whole class)
1 container of ice
1 42C water bath
1 small tube of Plasmid DNA containing GFP (provided) (enought for the whole class)
2 Pasteur pipettes
1/2 Agar plate
1 Incubator (if cannot find an inexpensive equivalent, might be able to use the one in Stanley B144)

For genetic variation demo:
1 normal tomato, 1 long-lasting tomato
1 normal corn, 1 sweet corn
1 pluot, 1 aprocot, 1 plum
1 Small knife for cutting fruit

Agenda:
(1.5 hour session)

The goal of this lesson is to introduce students to the biotechnology revolution that has occurred in the past fifty years since the discovery of the double helix. Students will learn about the major discoveries and interesting facts about biotechnology that are relevant to their lives. Students will "discover" DNA on their own through an interactive demo involving Lego blocks. Students will

extract the DNA of strawberries to visualize genetic material. Student will also have a chance to look at GMOs and understand how DNA can be manipulated to produce more desirable products. Lastly, students will learn about genetic engineering through the transformation of bacteria with DNA that encodes for green fluorescent protein.

- Introduce interesting biotechnology history -10min
- Demo #1 Discovering the Double Helix -15min (active learner)
- Demo #2 DNA Extraction -15min (visual learner)
- Transformation of bacteria with Green Fluorescent Proteins -20min (sensing learner)
- Demo #3 Understanding GM foods -10min (reflective learner)
- Worksheet -5min
- Concluding discussion -10min
- Index card question -5min

The overall progression of the lesson plan is designed in a sequential order to help students comprehend the relationship between DNA and genetic engineering.

Introduction

Introduce interesting biotechnology history

Begin the session by asking students what they think biotechnology is. Then proceed to draw a historical timeline that contains some important events in biotechnology. During this time, allow student questions about each of the events. Conclude the historical review with some of the current projects in genetic engineering. Then back track to the discovery of DNA to introduce the first demo.

Demo #1 Discovering the Double Helix

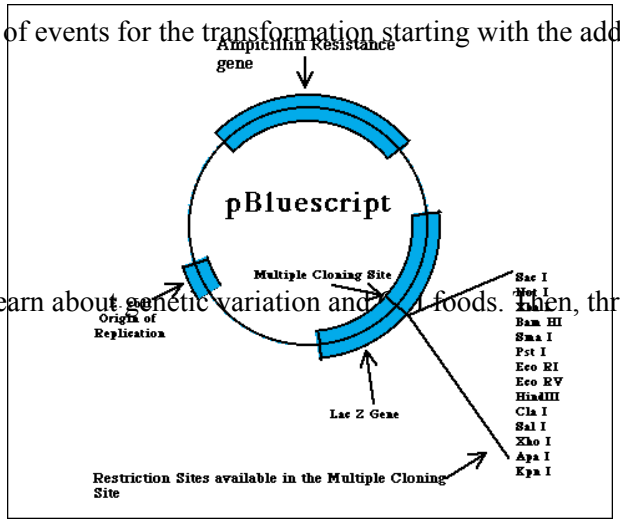
Introduce this demo by choosing two volunteers from the students. These two students will be constructing the double helix using candy. During the process of assembly, walk through each step and explain the significance of each piece of candy (i.e. red vine = phosphate backbone, gum drops = bases, twisting = gives double helix structure, width of toothpick = 20 angstroms).

Demo#2 Strawberry DNA Extraction

This activity can be done either in small groups or at the front of the class. The idea is to talk through the activity at each step and to explain the principles behind each step.

Transformation of bacteria with Green Fluorescent Protein

A pictorial approach is best for the elementary school students since what is happening is too small to see. Introduce students to the components of a bacterial plasmid (circular DNA), which are origin of replication, antibiotic resistance gene, and the gene of interest (GFP). It would be helpful to draw a sequence of events for the transformation starting with the addition of KCM



Demo#3 Genetic Variation

GM foods are produced from the altering of DNA in the host organism. Altering DNA results in changes in the appearance of the product. The point of this demo is to illustrate the genetic variability, whether natural or engineered, that is present due to slight differences in genetic material. Students will first learn about genetic variation and GM foods. Then, three pairs of fr

Activities

Demo #1 Discovering the Double Helix

Students will construct their own double helix using gum drops, red vine, and toothpicks. The goal of the

activity is to reconstruct a 3D double helix for a visual understanding.

Procedures:

1. Construct a ladder using the red vines and toothpicks, with the toothpicks as the rungs
2. Thread two gum drops onto each toothpick
3. Twist the ladder counter-clockwise to get a double helical shape

Demo#2 Strawberry DNA Extraction

Procedures:

1. Prior to the start of the mentoring session, prepare the extraction buffer by mixing the three components and slowly inverting the bottle.
2. Place one strawberry in a Ziploc bag
3. Smash and grind strawberry until it is thoroughly smashed
4. Add 10ml of extraction buffer to the bag
5. Kneed the bag for 1 minute
6. Assemble filtration apparatus with cheese cloth on top of funnel dripping into the test tube
7. Pour the contents of the bag into the apparatus
8. Pour cold ethanol into the tube and observe the DNA crashing out of solution

Transformation of bacteria with Green Fluorescent Protein

Procedures:

1. Competent bacterial cells will be prepared
2. From a tube of GFP plasmid, take out a very small amount of liquid and put into a clean tube
3. Take out about 10X more competent cells and place into the clean tube
4. Mix the contents of the clean tube around with the Pasteur pipette
5. Place the tube into a container of ice for 10minutes
6. Place the tube into a water bath for 2minutes
7. Place the tube back into ice for 5minutes
8. Spread the contents of the tube onto the agar plate
9. Place agar plate into an incubator overnight

Demo#3 Genetic variation

Students will compare differences between GM and non-GM fruits, noting their size, color, shape, and perhaps even taste.

Three sets of fruits will be used for the activity: tomatoes, Pluots, and sweet corn. With each set, discuss the appearance, properties, and taste of the fruits and vegetables in small groups or in front of the class.

Closing Discussion

Review each of the demos and go over the main point for each of them. For demo#1, ask: What is the structure of DNA? Double Helix. What are the bases that compose DNA? Adenine, Guanine, Cytosine, and Thymine. How was DNA discovered? Through understanding its structure. For demo#2, ask: What is the white stuff that becomes visible after adding ethanol? DNA. What does adding ethanol do to the solution? DNA is only soluble in water, and the addition of ethanol causes the DNA to crash out of solution. For demo#3, ask: What is genetic engineering? It is the alteration of DNA for a specific purpose such as modification of foods and production of pharmaceutical drugs.

Mentors can also discuss the current advances in biotechnology such as drug production and biofuels. In drug production, metabolic pathways of bacteria (i.e. enzymes in cell) can be re-engineered to produce compounds that were naturally produced in plants. One example is artemisinin, an anti-malarial drug that can now be mass produced in E. coli. In biofuels, many different prokaryotes and single-celled

eukaryotes (yeast) has been engineered to produce ethanol and hydrocarbons.

Worksheet
See below

Index card take home question
In your next trip to the supermarket, note down how many variations there are of one type of fruit. What do you think causes those differences?

Background
Introduce interesting biotechnology history

The field of biotechnology has exploded in recent years with many discoveries and applications that promises solutions to some of today's most pressing issues such as biofuels and environmental remediation. However, human has used organisms and facilitated their evolution for thousands of years. The practice of artificial selection and domestication of plants and animals dates back 9000-10000 years. Around 4000 B.C., it was known that Egyptians used yeast to ferment their food. This resulted in the creation of many new food products including bread, cheese, and wine. Fastfo

rward a couple thousand year, in 1790, Edward Jenner discovered vaccines that could prevent the previously deadly disease of small pox by injecting a weaker version of the virus, which causes cow pox, into a person to build their immune system against the disease. Then, in 1865, Gregor Mendel discovered the principles of heredity through his work with pea plants. Biotechnology has steadily gained prominence, but it wasn't until 1919 that the word "biotechnology" was first used in print. In 1953, Watson and Crick discovered the double helix structure of DNA. From this discovery, our ability to directly manipulate the fabric of life became a reality, and genomic data became available and made genetic engineering possible. Another milestone in genetic engineering occurred in 1981 when the FDA approved insulin made from recombinant bacteria. Today, biotechnology has been applied to drug development, genetic engineering, food production. Biotechnology has impacted our lives in many small and yet important ways. Enzymes are used to produce vitamins identical to those from our food. The stonewashed jeans now do not need to be stonewashed to have the same look because enzymes are used instead to treat the fabric. In recent years, compostable plastics have been made from organic materials such as corn. Another breakthrough with biotechnology is the use of agricultural waste, biomass, to produce biofuels. Biotechnology treatments has provided new solutions for leukemia, arthritis, multiple sclerosis, and other diseases.

Demo #1 Discovering the Double Helix

Watson and Crick discovered the structure of DNA in 1953. It was known in the 1940s that DNA was the molecule of life. Scientists already knew that DNA consisted of four bases adenine, guanine, cytosine, and thymine. However, no one knew, at that point, the structure of DNA. There are four distinct features of DNA that took many years of research to discover: 1. Phosphate backbone is on the outside and bases inside 2. Double helix structure 3. The two strands of DNA run antiparallel 4. Specific molecular pairing among the four bases.

Demo#2 Strawberry DNA Extraction

DNA extraction has enabled recombinant genetic engineering where DNA from one organism can be isolated and then placed into another organism. In this exercise, the basic principles that enable DNA extraction will be explored. Strawberries are used for this exercise because they are octoploid, meaning they have eight copies of each type of chromosome. One principle used is surfactant chemistry. Surfactants such as soaps dissolve the phospholipid bilayers of cell, releasesing the cellular contents including DNA. Salt is used to separate DNA-binding proteins from DNA. The salt ionic interactions outcompete the weaker interactions between the protein and the DNA, resulting in the ionic binding between the negatively charged phosphate backbone and the positive ions of the salt. A third principle is

the use of solubility. DNA does not dissolve in ethanol. Hence, the addition of ethanol to the solution with DNA will crash out the nucleic acids.

Transformation of bacteria with Green Fluorescent Protein

The transformation of bacteria refers to the insertion of circular DNA into a bacterial cell. The purpose of transformation is to enable recombinant DNA technology where the DNA taken up by bacteria can either express a novel protein within the bacteria or be used to regulate some cellular function. The bacterial cells originally carry its own genomic DNA. However, when the bacterial cell is exposed to extreme conditions such as heat shock, it will take up foreign DNA as a survival mechanism. Transformation takes advantage of this natural process to insert the plasmid (circular DNA) of choice into bacteria and to amplify the desired DNA.

A plasmid is a piece of DNA about 2000 to 10000 base pairs. In our particular plasmid, there is DNA that encodes for the production of the green fluorescent protein (GFP). GFP is a protein originally found in jelly fish. When a light of wavelength 395nm (UV light) shines on the protein, it emits a light of around 509nm (green). This property of GFP makes it a very versatile molecular biology tool. In biotechnology, GFP is fused to another protein of interest and used as a reporter of the expression of the protein.

DNA is very hydrophilic, but the cell wall is hydrophobic. Hence, DNA will not easily pass through the bacterial cell wall. The addition of KCM to the cells introduces a high concentration of potassium and creates small holes in the cell walls to allow the DNA to pass through. The heat shock at 42C in the water bath and the subsequent icing forced the DNA into the cell. The plating of the transformed cells on to agar provides a sugar source for the bacteria to grow and reproduce.

Demo#3 Understanding GM Foods/Genetic variation

GM foods refer to food that comes from genetically modified organisms. GM foods were first introduced in the early 1990s and are traditionally plant foods such as soybean, corn, cotton seed oils, and others. The techniques for producing GM foods rely on altering the DNA of the host organism via mutagenesis (causing mutations in the DNA), directed gene fusions and excisions, or selective breeding. The purpose of genetically modifying foods to usually to introduce a superior quality to the plants of interest. These can include pest resistance, enhancement of vitamins, increase in size, and retardation or advancement of ripening. GM foods have been a hot topic of debate in the past two decades, but by 2010, many of the foods consumed are already genetically modified (93% soybeans, 86% corn, 95% sugar beet).

The three particular sets of fruits that will be featured are tomatoes, pluots, and sweet corn. Long-lasting tomatoes became available in 1994. Because these tomatoes produce less substances that cause it to rot, they stay fresh longer. This allows tomatoes to be harvested simultaneously, and also ripen in the sun (therefore, making it taste better). A disadvantage of the first GM tomatoes is that they had antibiotic resistance in them which can be transferred to humans. The premature exposure to antibiotics could result in more resistant bacterial strains. Pluots are a cross between plums and apricots, and are fortified in vitamin C but have no sodium or cholesterol. Sweet corn is modified to be resistant to crop spray and they produce insecticides that kill pests. The disadvantage of producing this type of corn is the disruption of ecological balance. Endangered insects that eat corn will die because of the inherent toxins engineered to be produced in the sweet corn.

References

History of Biotechnology
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Genetic Engineering Lesson Worksheet

Fill in the blank

1. A circular piece of DNA inserted into bacteria is called _____.
2. Green Fluorescent Proteins were originally isolated from _____.
3. _____ is the process of inserting DNA into bacterial cells.

Connect the lines to the best answers

Watson and Crick	Plum and Apricot
Mendel	DNA Extraction
Double Helix	Heredity
Pluot	discovered DNA
Ethanol	20 angstroms wide

Draw the bacterial transformation process
Note: Somethin easier for elementary school (draw DNA) keep worksheet for high school