Synthetic Biology Activity Book

small ACTIVITES. big IMPACT

- This activity book has been developed by the UNBC-Canada iGEM Team at the University of Northern British Columbia.

Our Initiative

Bringing Synthetic Biology to the North

Our team is dedicated to sharing the field of synthetic biology with young learners to garner interest and excitement about the amazing world synthetic biology has to offer. With all of our team members haven grown up in Northern British Columbia, we reflected on our elementary and high school experiences, and recognized that what was collectively missing was enthusiasm for science and introductions to the ample fields that exist. Therefore, we wanted to us our presence in our community and those surrounding to introduce youth to synthetic biology and its vast applications.

What is Synthetic Biology?

Synthetic Biology can be thought of as genetic engineering. Just as engineers use blueprints to build things that perform a certain function, synthetic biologists use DNA as the blueprint to program living cells to perform a new function. As DNA is highly variable, synthetic biologists have a seemingly infinite amount of possible functions to give living organisms. These capabilities point to synthetic biology being the future of healthcare, environmental science, energy production, and much, much more.

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BACKGROUND

Our bodies are very complex. They are made of billions of microscopic cells, which work together to build the different parts of our body. Within each cell is DNA, or deoxyribonucleic acid. Every person has a genome, which is all the DNA in your body. To make sure each cell can fit all this DNA, DNA is wrapped up into tight structures called chromosomes. DNA can be thought of as a blueprint, that tells each of the cells in our body what to do. For example, DNA tells hands to be hands, heads to be heads and eyes to be a certain color. Every cell in your body has the same DNA, but the cells communicate with each other and will only use some of the DNA they contain. Not only do we as humans have DNA, so do bacteria, plants, and animals!

Strawberries for example, have 4.4 times less DNA than humans. However, they contain they contain eight copies of their chromosomes whereas humans contain only two copies. This property of strawberries, along with their red color, makes them great candidates to extract DNA and see on a macroscopic level.

LEARNING OBECTIVES

In this experiment we will be isolating DNA from strawberry cells. This serves as an introduction to the chemicals needed to isolate DNA and what each chemical does. The dish soap breaks down the cell walls, so the DNA can be free. The table salt, separates the compounds that bind to the DNA. The isopropanol, precipitates the DNA i.e. turns the DNA into a solid layer. In addition, students will be introduced to the concept of DNA and how it makes humans humans and strawberries strawberries.

Strawberry DNA Extraction

PROCEDURE

1. Measure 90mL water and put into a cup
2. Add 10mL dish soap
3. Add a 1/4 tsp of salt and mix until salt is dissolved
4. Place a strawberry in a Ziploc bag
5. Pour extraction mixture into bag with strawberry
6. Make sure to remove as much air as possible from bag and seal
7. Use fingers to mash, mush and squish the strawberry, try to remove large chunks
8. Filter the mushed-up strawberry through the strainer into a clear plastic cup, the more you filter the better!
9. Add 5mL chilled isopropanol to extract in cup, wait 30 seconds, the DNA can be seen as a white layer on top of the red solution below
10. Optional: remove DNA with tweezers

MATERIALS

- Carton of strawberries
- Dish soap (any brand)
- Table salt
- Chilled 95% isopropanol
- Water
- Ziploc bags
- Strainer
- Clear disposable cups
- Optional: tweezers to remove DNA at end

CONCEPT CHECK

- ☑ Which chemical broke down the cell wall?
- ☑ What does the salt do?
- ☑ In the cup, what layer (top or bottom) is the extracted DNA?

DNA Model and Eat it Too

BACKGROUND

All living things are built from and operate based on the instructions laid out by DNA. Such instructions are divided into sections called genes. Every gene provides instructions for making proteins. Proteins are the molecules that direct specific functions in a cell. Cells work together to make tissues and tissues work together to make organs and organ systems.
All DNA has the same basic structure, which is easily compared to a ladder. In DNA, the backbone, made of alternating sugar molecules and phosphate molecules, is compared to the sides of a ladder. The rungs of DNA, like the rungs or steps on a ladder, are composed of nitrogenous bases. However, unlike a straight ladder, DNA is twisted into a structure called a double helix.

Taking a deeper look, we learn that there are four nitrogenous bases that make up the rungs of DNA. Where two bases pair to form a single rung. These bases are adenine (A), thymine (T), guanine (G), and cytosine (C). These bases follow special rules, Chargoff's Rule, to pair correctly into what are called complementary base pairs. To ensure proper gene instructions, adenine always pairs with thymine, while guanine always pairs with cytosine. Each gene is made up of millions of pairs of DNA.

LEARNING OBECTIVES

In this activity we will be building DNA double helixes. This serves as an introduction to the basic structure of DNA. If DNA is taken out of a cell, and stretched out, it resembles a twisted ladder. The sides of the ladder is the DNA backbone made of sugar and phosphate molecules. The rungs of the ladder are chemical bases, called nitrogenous bases. There are four bases, adenine (A), thymine (T), guanine (G), and cytosine (C). The bases follow special rules to pair together into complementary base pairs, where adenine always pairs with thymine, and guanine always pairs with cytosine.

DNA Model and Eat it Too

PROCEDURE

1. Use the following code to designate a marshmallow color to a single base:
   - Adenine (A) = yellow
   - Thymine (T) = orange
   - Cytosine (C) = pink
   - Guanine (G) = green
2. Choose one of the following DNA sequences:
   - Sequence 1: ATGCTATAGAAC
   - Sequence 2: GTGTTATGAATT
3. Assemble the rungs of the DNA through complementary base pairing. Take your 12 toothpicks and line them up in a row (like the steps of a ladder) on your desk.
4. Follow the DNA sequence you chose and put marshmallows on the toothpicks down the row in order of the sequence.
5. Add your complementary marshmallow base to each toothpick. Remember A pairs with T and G pairs with C.
6. Add a licorice backbone to each side of your DNA sequence.
7. Carefully twist your DNA molecule into a double helix.

MATERIALS (per student)

- 2 pieces licorice
- 12 toothpicks
- 9 pink marshmallows
- 9 yellow marshmallows
- 9 green marshmallows
- 9 orange marshmallows

CONCEPT CHECK

- ☑ Which base pairs with A? Which pairs with C?
- ☑ What is the DNA backbone made of?
- ☑ What do the call the shape of DNA?

Adapted from: http://teach.genetics.utah.edu/content/dna/HaveYourDNAandEatItToo.pdf

Name Bracelet

BACKGROUND

The genetic code is made up of four nitrogenous bases, Adenine, Guanine, Cytosine and Thymine or A, G, C, and T respectively. Within a DNA strand two bases pair together in a process called complementary base pairing. This is highly specific, where A always pairs with G and T always pairs with A. These four compounds are the building blocks of your DNA. DNA is the substance that holds the blueprint for every cell, fiber and structure in your body. Within a cell, DNA is translated into the proteins that make up your body. Translation of proteins occurs in segments of 3 bases, called a codon, and many codons linked together make a protein.

In this experiment we will use beads to make a bracelet that spells your name, favorite animal or favorite character. By following the chart attached to this activity, you will use 3 beads for one letter. After having created a strand that represents your identity, try reading it backwards and comparing with your friends. The objective of this experiment is to represent that DNA has a sense and a non-sense reading direction, and that similar words or names can be written with different combinations.

LEARNING OBECTIVES

In this experiment we want your class to recognize that the letters on the bracelets are the same as a protein code of DNA, where every three beads represents one letter, just like three nitrogenous bases equals one codon. If a mistake is made sometimes the word doesn't make sense. Also note that some letters have more than one Identifier. This works great if you can't find a certain bead and helps prevent mistakes. Try reading the bracelet backwards. Does the word make sense? DNA is the same way, it can only be read one way.

Furthermore, can you find two people with the same name? If so did they spell it the same way? Common names work best to compare. The name Caitlin and the name Kaytlyn are spelled very differently but still produce the same functional identifier.

Name Bracelet

PROCEDURE

1. Help the students cut themselves a piece of string about a foot in length.
2. Distribute beads or spread them out over a large area
3. Help students pick an identifier (Name, animal, hero ect)
4. Use the bead code attached with this activity to spell out the identifier
5. Exchange with a friend
6. Get your friend to decode your DNA bracelet
7. See if you can find anyone with the same identifier as you

MATERIALS

- A large set of beads that are of four different colours
- At least one print out of the attached table at the back of this activity for every two students
- Some string
- A pair of scissors

CONCEPT CHECK

- ☑ Which base pairs with A, which with G?
- ☑ How many beads represent one letter? How many nitrogenous bases represent one codon?
- ☑ Does a word make sense if a mistake is made?
- ☑ Does it make sense to read your bracelet backwards? Can you read DNA backwards?
- ☑ Were there two of you with the same name? Did you spell it the same?

Name Bracelet

The color pattern per letter. Either set of three may be used per letter.

Letter	Bead Combo	Letter	Bead combo
A	RRR, RRB	N	WKB,WKW
B	RRW, RRK	O	WKK, KKB
C	RBR, RBB	P	KKW, KKK
D	RBW, RBK	Q	KBR, KBB
E	RWR, RWB,	R	KBW, KBK
F	RWW, RWK	S	KWR, KWB
G	RKR, RKB	T	KWW, KWK
H	RKW, RKK	U	BBR, BBB
I	WWR,WWB	V	BBW, BBK
J	WWW, WWK	W	BWR, BWB
K	WBR, WBB	X	BWW, BWK
L	WBW, WBK	Y	BRK, BKB
M	WKR	Z	BKW, BKK

Adapted from: https://www.genomebc.ca/education-resource/dna-code-bracelet/

Grow Your Own Bacteria

BACKGROUND

Bacteria are everywhere! Bacteria are tiny organisms that are so small you are unable to see them with the naked eye but they cover your body, line your stomach and are an important part of every ecosystem. Some bacteria are important for your health, while others can make you very sick. To investigate bacteria, or bring them into view, it is possible to large group of bacteria so that we can see them. Every bacteria has a favorite food, preferred temperature and even special salt tolerances but every bacteria loves sugar. In this experiment we will grow the bacteria from your hands by feeding them jello. Placing your hand on a well prepared cup of jello will transfer bacteria from your skin to the jello. After a few days in a warm environment, some circular colonies should show up, these colonies are the same bacteria that is on your hands!

LEARNING OBECTIVES

In this experiment we will be attempting to grow the bacteria from our hands. Bacteria are everywhere and can be helpful to us or harmful to us. Just like us, bacteria have a favorite food that they like to eat and grow on, as well a favorite temperature. We will be splitting the class into 3 groups. Group one will not wash their hands before touching the jello, group two will wash their hands with just water and group 3 will wash their hands with soap and water before touching the jello. Now we expect that the jello from unwashed hands will either grow the quickest and or the largest. The gelatin in serving as the food source for the bacteria. Make sure to throw the jello out before they get too large and stinky!

Grow Your Own Bacteria

PROCEDURE

1. Prepare the gelatin as described on the packaging a day in advance. Make sure there are enough portions for each student to have 1 cup.
2. Split the class into 3 groups: dry hands, hands washed with water, hands washed with soap and water.
3. Carefully spread your hand or fingers across the surface of the gelatin.
4. Cover with a lid, or pan to prevent contamination.
5. Place tray in a warm location for a few days.
6. Return each morning or afternoon to see and compare from the previous days
7. For added difficulty or interest, record the number of colonies each day.

MATERIALS

- 1 jello cup per student (1 small cup with 5mL of jello will do), note the cup must be wide enough to fit a hand
- Soap
- Water

CONCEPT CHECK

- ☑ Why are the bacteria visible now?
- ☑ Why did we cover our jello with a lid?
- ☑ Which of the three groups had the most bacterial growth? Why might this be?
- ☑ Did soap and water have more of an effect than just water? Why?

Adapted from: https://uniavisen.dk/en/five-biological-experiments-you-can-do-at-home/

Phage Tag

BACKGROUND

There is a whole world that exists invisible to the naked eye. This microscopic world thrives mostly unnoticed by humans, however the way in which their world works is similar, in more ways than not, to our own world. Phages or more commonly known as viruses are microscopic DNA carriers that function to transport their own and other organisms' DNA from one organism to another. These phages are intriguing because instead of reproducing on their own, as most other organisms do, they hijack host machinery to reproduce more phages for them. Phage infection can have three effects: positive, negative or no effect. The phages causing a negative impact are called pathogenic. The flu for example, is caused by a virus and spread by contact with someone who is infected. Washing your hands is a very important way to minimize the spread of pathogenic phages.

This activity will help demonstrate the propagation of phages between organisms, in this case human to human transfer of phages. Phage tag uses students as models to help to show how quickly and easily phages/viruses can be spread.

LEARNING OBECTIVES

Around us is a world we can't see. This microscopic world can directly and indirectly affect us. Phages and viruses are a good example of this, we can't see them, but pathogenic phages can harm us. Phages/viruses need a host to survive, without host machinery they can't reproduce and increase their population. It is important to stress that washing our hands can help diminish the spread of all microscopic organisms!

Phage Tag

PROCEDURE

1. Choose one student to be the original/starting phage. This student will tag other students to infect them.
2. Once a student is tagged, they themselves become infected and contain the “infected DNA”. The tagged students must wait 5 seconds before they can begin tagging other students; this is to simulate the growth of the phage before it can infect others.
3. The goal of game is for all students to be tagged and “infected”

CONCEPT CHECK

- ☑ Why do you think the newly infected person has to wait 5 seconds before entering the game as a phage?
- ☑ Real viruses spread similarly to how the infection spreads in this game would does would this make viruses phages dangerous?
- ☑ Are all phages bad/dangerous?

Candy Chromatography

BACKGROUND

Chromatography is the collective term for a family of laboratory techniques used for the separation of mixtures. It involves passing a mixture dissolved in a "mobile phase" through a stationary phase, which separates the substance to be measured from other substances in the mixture and allows it to be isolated and viewed. These substances are typically separated by polarity. Polar things can be called hydrophilic or “water-loving” and non-polar things are called hydrophobic or “water-hating”.

Chromatography uses the concept that ”like attracts like”. Meaning that polar substances attract other polar substances and non-polar substances attract other non-polar substances. Generally in chromatography the stationary phase is non-polar and the mobile phase is polar. During the separation of your mixture the non-polar components of the mixture will stick to the stationary phase and the polar components will move with the mobile phase.

LEARNING OBECTIVES

In this experiment we attempt to separate the colors in candy dyes according to their different polarities. The candies that move further up the filter paper are more polar and not very non-polar. We know this because the dye is more attracted to the polar salt solution (mobile phase) and thus will move further up the paper. The colors that move less far up the paper are the non-polar ones, we know this because they are more attracted to the non-polar paper. Each of the color dyes has a different molecular structure and thus a difference in polarity, if this difference in polarity is substantial enough the colors will completely separate as they move up the paper.

Candy Chromatography

PROCEDURE

1. Cut filter paper into at least 3' x 3' squares and draw lines 1/2 inch from the bottom
2. Label a dot for each color
3. Extract dye from candies by placing each color candy into a drop of water that can be placed on a piece of tin foil, for 2 minutes
4. Once these colors have dissolved out dot them onto their labelled spots on the filter paper using a toothpick, and let the dots dry
5. Make a 1% saline solution using 1/8 a teaspoon of salt and 3 cups of water and shake
6. Pour about a centimeter of the solution into a jar and place the filter paper with the dots on the lower side into the jar
7. Allow the solution to climb up the filter paper using capillary action, the different dyes should travel different distances, observe the difference
8. Pull out the paper once the liquid gets about half an inch from the top

MATERIALS

- Candies of different colors M&M and/or Skittles
- Coffee filters or filter paper
- Tall clear glass or jar
- Water
- Salt
- Pencil (no pens or markers)
- Scissors
- Ruler
- Toothpicks
- Aluminum foil
- Empty 2 liter bottle and cap

CONCEPT CHECK

- ☑ Which candies contained mixtures of dyes?
- ☑ Which ones seem to have just one dye?
- ☑ Do similar colors from different candies travel up the paper the same distance?
- ☑ What does hydrophobic mean?
- ☑ Polar things are attracted to _____?
- ☑ Why do the different colors separate?

Adapted from: http://weirdsciencekids.com/candychromatography.html

Capillary Action

BACKGROUND

Water molecules are often considered to be “sticky” and have adhesive and cohesive properties. Adhesion happens when water sticks to other things, like when it’s raining and water sticks to windows! Cohesion happens when water molecules stick to themselves, which is how the water droplets on the rainy window are able to form.

Capillary action is the ability of water to move through small spaces without the help of gravity but through adhesion, cohesion, and surface tension. Capillary action occurs when water wants to stick to other objects more than it wants to stick to itself; that is, its adhesion is stronger than its cohesion. This is an important property because without it water wouldn’t be able to move around! For example, plants and trees use capillary action to move water up from their roots to their stems or trunks. It is also important to move water around in your own bodies so that your blood and oxygen can also move around!

LEARNING OBECTIVES

Cohesion is water sticking to itself, adhesion is water sticking to other surfaces. Capillary action happens when water wants to stick more to objects than to itself, this tendency is what allows water to move!!

In this experiment we will see that the water is able to move up the paper towel because of the little holes in it. Once the water is at the top of the paper towel roll, gravity helps it get down to the empty glass. The water will keep moving until both glasses are equal which means they are balanced, or in equilibrium.

Capillary Action

PROCEDURE

1. Roll a big piece of paper towel up and tie each end with a rubber band
2. Fill one glass so that it's almost full and put an empty glass beside it
3. Bend the paper towel into an arch so that each end of it is in one of the glasses
4. Watch what happens to the water!
5. Now get 3 glasses and place them in a line
6. Pour water into the two glasses on the end, leaving the middle glass empty
7. Pick two different food coloring dyes and place them into the full glasses
8. Roll two pieces of paper towel separately and tie the ends again with rubber bands
9. Bend the two rolls into arches and put them into the glasses so they are all connected
10. Watch what happens to the middle glass!

MATERIALS

- Small, clear glasses (can be plastic)
- Kitchen paper towel roll
- Rubber bands
- Food coloring

CONCEPT CHECK

- ☑ What happened to the water?
- ☑ Why do you think that happened?
- ☑ What color ended up in the middle glass?
- ☑ Did the water move faster when there were two or three glasses?
- ☑ Why doesn't all the water move from the full glass to the empty glass?

Adapted from: Adapted from: https://www.bluebearwood.co.uk/how-water-moves-capillary-action/

Enzymes in Action

BACKGROUND

Enzymes exist all around us and in all living things, they exist within our very own bodies, to that of our pets, to the plants on our windowsill. Cellular reactions are occurring nonstop in our bodies, enzymes are used within an organism to help initiate, speed up, or assist such cellular processes. Enzymes are a class of proteins that are found all over the body and carry out various different functions where each reaction is specific to the enzyme. For example, the enzyme amylase found in the mouth, breaks down starch, while the enzyme pepsin can only break down proteins in the stomach. Enzymes are location specific too and highly selective over the type of environment they work effectively in. Pepsin, for example, works well in a highly acidic environment such as in the stomach while amylase prefers a more neutral environment like that within the mouth. A change in optimal environment will affect the productivity of the enzyme.

Catalase is another very important enzyme. Catalase works to breakdown hydrogen peroxide to yield oxygen gas and water. When hydrogen peroxide is added to a fresh slice of raw potato, a reaction between the potato and the peroxide occurs. Initially, it seems as though the peroxide is breaking down the potato. However, it is catalase from the surface of the potato that is breaking down hydrogen peroxide into water and oxygen gas. The bubbles that is observed in the mixture is the release of O_2 rising to the top to escape into the environment.

LEARNING OBECTIVES

In this experiment we will learn that enzymes are biological catalysts, or a type of protein that speeds up cellular reactions within the body. Enzymes exist not only in humans, but also in other animals and plants. Enzymes are specific to one reaction, and can't be used to speed an alternative reaction, for example, amylase can't be used in place of pepsin. Enzymes are also environment specific, and can not speed up a reaction if conditions are not optimal. Catalase is an enzyme that breaks down hydrogen peroxide forming oxygen gas and water as the products. In this activity, we will see catalase on the surface of the potato acting to break down hydrogen peroxide.

Enzymes in Action

PROCEDURE

1. Cut out slice of fresh potato to reveal the inside of the potato
2. Place potato slice in the glass jar
3. Pour hydrogen peroxide into the jar until the potato is completely submerged
4. Observe reaction
5. Talk about the reaction products, oxygen gas (bubbles) and water

Take it Further!

1. Switch out the potato with another vegetable, fruit, or object (i.e. a rock or penny) and add hydrogen peroxide.
2. Switch out hydrogen peroxide for another liquid (i.e. sugar water, vinegar, bleach, etc.) and add the potato.
3. Heat the potato for 30 seconds to 1 minute before adding hydrogen peroxide.
4. Freeze the potato overnight before adding hydrogen peroxide.
5. Switch out the raw potato for a cooked potato.

MATERIALS

- Glass jar
- Hydrogen peroxide
- Potato slice
- Additional liquids (i.e. bleach, vinegar, water, etc.)
- Additional vegetables/other items (i.e. apple, carrot, a rock, penny, etc.)

CONCEPT CHECK

- ☑ What happened when the peroxide is added to the potato?
- ☑ Given your knowledge on enzymes, what do you think is happening?
- ☑ What happened when you changed the hydrogen peroxide for another liquid? What do you think this tells you about the enzyme catalase?
- ☑ Did the reaction time or intensity change after changing the fresh potato to a microwaved or frozen potato?
- ☑ What happened when you exchanged the raw potato for a cooked one? What do you think happened to catalase?

Adapted from: https://thehomeschoolscientist.com/the-lab-report-enzyme-experiment/