Blue Gene Baby (https://www.youtube.com/watch?v=aqlGlaNlcWE)

Target Grade: Elementary/Middle
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Brief Overview

In this lesson, mentees will be delving into genetics and DNA. The students will first explore natural selection through a simulation, then create a DNA model to learn about the structure of DNA and the pairing of nucleotides. Finally, the lesson concludes with mentees extracting their own DNA. By the end of the lesson, students will have a general understanding of the structure, components, and importance of DNA, as well as how natural selection influences our genetics.

Teaching Goals

- Understanding natural selection and the role of genetic diversity
    - **Natural Selection:** a process that results in the adaptation of populations to their environments over time; because there is genetic diversity, heritable traits that favor survival become more common in the following generations
    - Individuals in a population often vary in their heritable traits, contributing to genetic diversity, and this diversity allows for natural selection to occur.
- Understanding the structure and importance of DNA
    - **DNA:** an essential molecule that contains the genetic information of organisms. This genetic code is important in telling our bodies how to carry out its functions properly.
- Understanding DNA nucleotides and base pairing
    - There are four **nucleotides** (molecules that make up DNA):
        - **Adenine (A), Thymine (T), Cytosine (C), Guanine (G)**
    - **Base Pairing:** When bases pair up in DNA, A only pairs with T, and C only pairs with G, due to their structures and chemical nature.
- Understanding how to extract DNA
    - DNA is released by breaking the membranes of cells by using a detergent. Then DNA is separated from the remaining cell fragments by taking advantage of the fact that DNA is an extremely polar molecule.

Careers and Applications

Biologists, geneticists, researchers, and doctors make use of genetics and DNA everyday, from analyzing disease susceptibility to diagnosing diseases and finding out how they are spread and developed. The advances in cancer research and disease treatments rely on these concepts to understand cancer at a molecular level and how we can find a cure. Additionally, there are many services now that can sequence your DNA to tell you information about your family ancestry and other interesting things!

Agenda

- Introduction
- Module 1: Toucan Play That Game (15-20 min)
- Module 2: Edible DNA (10-15 min)
- Module 3: Decode Base Pairs (5-10 min)
- Module 4: Extract Your Own DNA (15-20 min)
- Conclusion

Introduction

Mentors can begin by asking what students know about genetics and DNA and briefly introduce why genetics is important to understand (**genetics** is the study of genes, heredity, and DNA of organisms, and learning about this information is important for our health, especially in disease prevention and treatment). Mentors can also ask students whether they have heard of services like ancestry.com, 23andme.com, etc.; these services sequence your DNA to tell you many things about yourself, such as your family ancestry (where your family is from) and susceptibility to certain diseases. Finally, ask students about natural selection and what they know about it. You can explain how natural selection can lead to extinction of species; for example, the characters from the Ice Age movie (i.e. Manny, a woolly mammoth, and Diego, a saber-tooth tiger) are examples of species that were negatively affected by natural selection and driven to extinction (in this case, climate change was a major factor that caused these mammals to go extinct).

Module 1: Toucan Play That Game

Introduction

In this module, kids will be learning about natural selection through an activity to understand the importance of genetic diversity and segue into how DNA is associated with these processes.

Teaching Goals

1. **Natural Selection:** a process that results in the adaptation of populations to their environments over time; because there is genetic diversity among individuals, heritable traits that favor the survival of individuals will become more common in the following generations
    a. This is also referred to as descent with modification, because the descendants of

the current population evolve to become better adjusted to their environments.
   b. Individuals in a population vary in their heritable traits, contributing to genetic diversity and allowing natural selection to occur.
   c. The favorability of a trait also relies on an organism's environment; the same trait may be favorable in one environment, but detrimental in another environment.

Background for Mentors

Natural selection is an important mechanism in evolution, and it depends on a few observations:

1. Most traits are heritable.
   a. Traits are often passed down, or inherited, from parents to offspring.
2. There are more offspring born than can survive.
   a. Because there is a limited amount of resources (i.e. food, habitat space, etc.) available and thus an environment cannot support all of the offspring born, there will be competition for resources between members of a population.
3. Offspring are genetically diverse.
   a. Offspring vary in the traits inherited from their parents, and this gives rise to a generation with a diverse set of features.

Thus, in a population, some individuals will inherit traits that increase their chances of survival and reproduction. This advantage will give them a better opportunity of surviving and producing offspring with the same favorable traits in the next generations. Since the favorable traits are heritable and organisms with these traits will have more offspring, these traits will become more common in future generations. Over a longer period of time, this population will become better suited to its environment.

However, every environment favors a different trait, and one trait that is favorable in one environment may be deleterious in another environment. For example, Darwin observed this when he studied the finches on the Galapagos Islands. Each island had a different finch species, and these species all descended from a common ancestor, but the only modification was a beak that was adapted to the primary food source on that island. For instance, if the primary food source on one island was seeds, then the finches on that island had a beak specialized for feeding on seeds. However, on a different island, the main food source could be insects, and a finch with a beak specialized for feeding on seeds would not be able to survive. Therefore, the environment also plays a critical role in determining the favorable traits of populations.

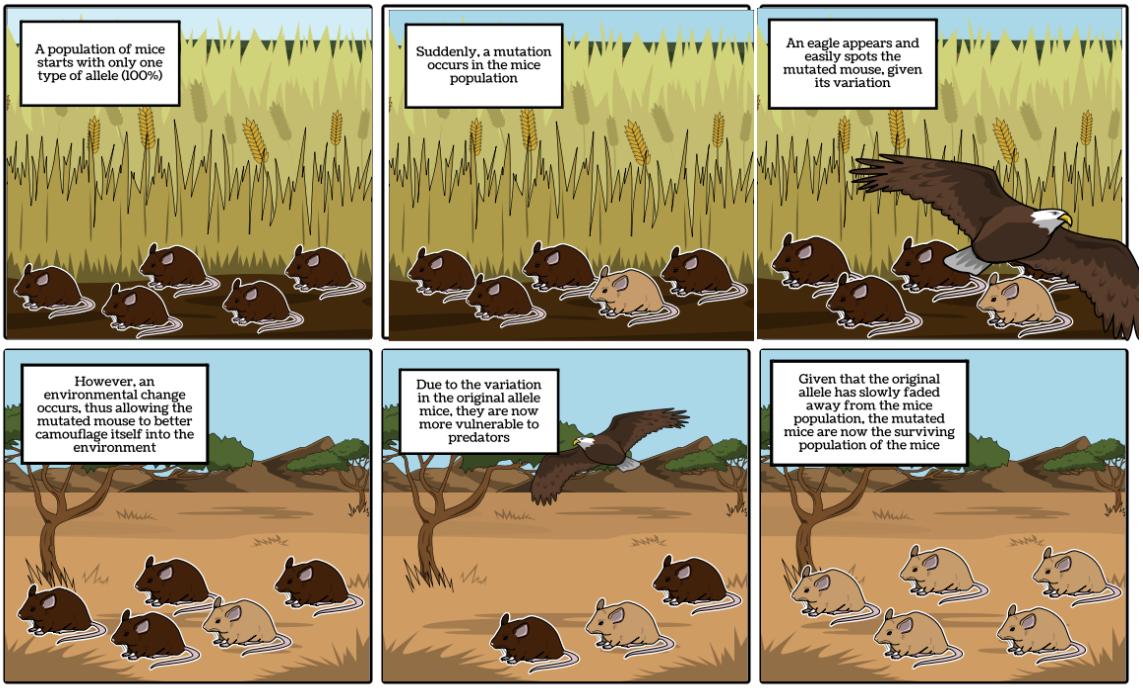

Figure 1: A visual representation of variation and how certain traits are favored in different environments (brown fur is more favorable in a marshland environment, while tan fur is more favorable in a grassland environment)

Materials

- 10 spoons per site
- 10 toothpick taped onto popsicle sticks per site
- 10 clothespins per site
- 100 Raisins
- 100 Kidney beans
- 100 Beads
- 1 small Dixie cup per student

Procedure

Background: In this activity, students will be simulating the effects of natural selection on bird beak shape and how certain environments affect this process. Students will be assigned a beak type, and they will compete against other students to see who can gather the most food in a certain amount of time.

1. Split the students into 3 groups, and assign each group a bird beak type (spoon, toothpick taped onto popsicle sticks, clothespins). Also, give every student a small cup. Explain that the goal of the activity is to collect the most food and survive to the next round by only using one hand to hold their beak and collect food into their cup.
    a. To survive, students need to collect at least **10** food particles in one round.
2. There are 3 rounds, with a different food source in each round. The varying food sources represent the different environments that the students will face. Tell students that the 3

food sources are raisins, kidney beans, and beads, and ask them to hypothesize which beak type will be the best for collecting each food source.

3. For each food source (raisins, kidney beans, marshmallows), repeat this process:
    a. Find a large surface (table, ground) and sprinkle the food source evenly throughout the area.
    b. Tell students that they have **30 seconds** to gather as much food as possible into their cups, only using their assigned beaks (spoon, toothpick-popsicle stick, clothespin).
    c. After time is up, have students count the number of food they have collected. If they have less than 10, then they do not survive to the next round.
    d. For the students who survived, repeat this process again until there are only a couple students remaining, and record their beak type.
4. After the simulation, ask students which beak type worked the best for each food source. The spoon beak and clothespin beak should be more effective at collecting kidney beans, while the toothpick-popsicle stick beak should be more effective at collecting raisins and beads. Conclude with a discussion about how this simulation reflects how natural selection works in real life.

Additional Notes for Mentors

There are many ways to make this module more flexible to fit your site better! For instance, if you have a larger group of students, you can split up the students and conduct the simulation in smaller groups. If you have a smaller number of students or if your class is getting too rowdy, you can give each student their own space and own pile of food source. Also, if you are worried about time, you can shorten the time of each generation to 20 seconds. You can also shorten the generation time as more and more generations pass.

Module 2: Edible DNA

Introduction

In this module, kids will be learning about the importance of DNA and creating a DNA model to examine its unique structure and components.

Teaching Goals

1. **DNA:** an essential molecule that contains the genetic information of organisms. This genetic code is important in telling our bodies how to carry out its functions properly.
    a. DNA is inherited by children from their parents, explaining why you may share many traits with your parents! However, you are not an exact replica of your parents, because you inherit a random mix of DNA from your parents, giving you unique and different DNA.
    b. Humans share about 99.9% of their DNA, but the remaining 0.1% of DNA is what makes individuals unique. This 0.1% usually codes for phenotypic differences, such as eye color, hair color, etc. and also predisposition for certain diseases.
2. **Structure of DNA:** DNA is composed of four different nucleotides and has a special

double helix structure.

a. The nucleotides bind together to create two strands that spiral together to form a helical structure, somewhat resembling a ladder.

Background for Mentors

DNA (deoxyribonucleic acid) contains the genetic information of humans. It is primarily housed in the nucleus of the cells of your body. The genetic code of DNA is comprised of four nucleotides: adenine (A), thymine (T), cytosine (C), and guanine (G). The ordering of these bases encodes the information that our bodies need to properly carry out its functions. Additionally, the pairing of nucleotides attaches to a backbone to form a double helix shape that is characteristic of DNA.

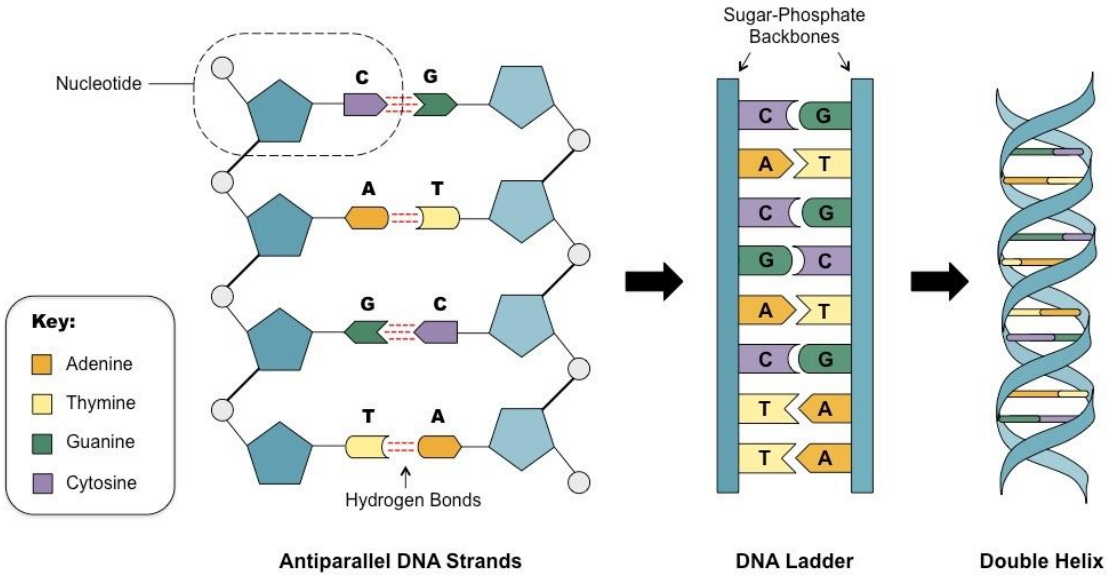

Figure 2: DNA from base pairs to double helix structure

DNA directs the synthesis of proteins, which carry out the everyday functions of our body, such as facilitate chemical reactions (enzymes), protect the body from viruses and bacteria (antibodies), provide structure, support, and movement (actin), transmit signals throughout the body (growth hormones), and many other important functions.

DNA is also the genetic material that is passed down from generation to generation. A child receives DNA from both their father and mother; this unique inheritance of parental DNA explains why children tend to look like a combination of their parents but not exact replicas, with certain traits from mom or dad and other traits unique to the children.

Materials

- 2 pieces of licorice per 3-4 students
- 12 toothpicks per 3-4 students

- 6 of each color of gummy bear per 3-4 students
- If your site does not allow candy, use these materials instead:
    - 2 long pieces of air-dry clay per 3-4 students (replacing licorice)
    - 2 jars each of 4 different colors of playdough (replacing gummy bears) per site

Procedure

1. Start with a discussion about DNA and why it is important. Have one or two mentors begin preparing the materials to distribute to the students during this discussion.
    a. DNA is an essential molecule that carries the genetic information of humans, and this genetic code is important in helping us function properly!
    b. You can also explain why we tend to resemble our parents (we inherit DNA from our parents), yet we are not exact replicas of them (because we inherit a unique combination of DNA from our parents, we will have some traits that differ).
2. Pass out the materials to the students. Each group of 3-4 students should have 2 pieces of licorice, 12 toothpicks, and 6 of each color of gummy bear.
3. **Red** gummy bears represent *adenine (A)*, **yellow** gummy bears represent *thymine (T)*, **orange** gummy bears represent *cytosine (C)*, and **green** gummy bears represent *guanine (G)*. Because the next module will explain nucleotides and base pairs, for the purpose of this module, tell students that **red** always pairs with **yellow** and **orange** always pairs with **green**.
4. Stick the gummy bears with the right pairing onto the toothpicks with the ends of the toothpicks poking slightly out of the gummy bear, following this pattern: T A C G T A T G A C G G (on the left side, the order of colors should be yellow, red, orange, green, yellow, etc.).
5. Stick one end of all the toothpick-gumdrops into a piece of licorice, and repeat to attach the other end of the toothpick to the second piece of licorice.

Figure 3: (a) Licorice Pieces Attached (b) Completed DNA Model

6. Slightly twist the model to form a double helix shape. Explain to students that this shape

is known as a double helix, a characteristic shape of DNA. The two pieces of licorice represent the backbone that holds all the nucleotides (gummy bears) together to form DNA!

Additional Notes for Mentors

When twisting the model, be careful to not twist too much, because the toothpicks may detach from the licorice. Also, make sure that students don't eat their DNA model! We will be using it for the next module, but you can let them know that there will be extra candy at the end of the lesson! However, if the kids are distracted by their models, mentors can take them away for the rest of the lesson.

Module 3: Decode Base Pairs

Introduction

In this module, kids will be learning about the nucleotides that make up DNA and the rules of how they are paired together. Then, they will be decoding segments of DNA to test their knowledge!

Teaching Goals

1. **DNA nucleotides:** There are four nucleotides, molecules that make up DNA:
    a. Adenine (A), Thymine (T), Cytosine (C), Guanine (G)
2. **Base pairing:** When bases pair up in DNA, A only pairs with T and C only pairs with G, due to their structures and chemical nature.
    a. **optional: A and T pair up, because they can only make two hydrogen bonds; C and G pair up, because they can make three hydrogen bonds.

Background for Mentors

A nucleotide is a molecule made up of 3 components: a nitrogenous base, a deoxyribose sugar, and a phosphate group. Nucleotides are the structural components of nucleic acids, such as DNA and RNA.

Adenine (A) and guanine (G) are purines (2-carbon nitrogen ring bases), while cytosine (C) and thymine (T) are pyrimidines (1-carbon nitrogen ring bases). In a DNA helix, two purines cannot fit, while two pyrimidines leave too much space between them, preventing hydrogen bond formation. Thus, only purines will pair with pyrimidines, leading to the base pair rules of A pairing with T, and C with G. A and T pair together, because they both can only form two hydrogen bonds with each other, while C and G can both only form three hydrogen bonds with each other. Because the formation of hydrogen bonds is favorable for the stability of DNA, these pairings are observed.

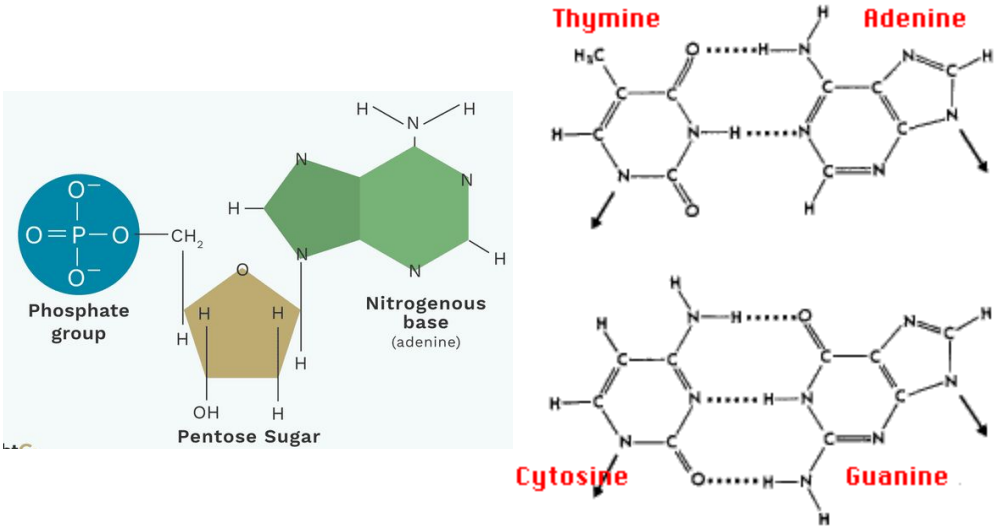

Figure 4: (a) Nucleotide Structure (b) Nucleotide Pairings

Materials

- 1 marker per group of 3-4 students
- 1 DNA message paper per group of 3-4 students (made during decal)

Procedure

1. Look at the DNA model that the kids created in the previous module. Explain that the licorice pieces are the **backbone** of DNA, made up of gummy bears, which are the **bases**. Each base is connected to another base (each gummy bear is connected to another gummy bear), and this connection between them is known as the **pairing of bases**.
2. Ask the kids if they remember what the rule for connecting the gumdrops was (*red* always pairs with *yellow*, and *green* always pairs with *orange*).
3. With the rule in mind, tell the kids to write down the rule on their DNA message paper, leaving some space under each rule.
4. Next, explain what DNA bases are, how they make up DNA, and base pairing rules (ex. A, T, C, G, they form the backbone of DNA, they pair together to connect two strands of DNA, A pairs with T, and C pairs with G).
5. Tell the kids that the **red** gummy bears are **A**, and the **orange** gummy bears are **C**, and see if they can figure out which bases the green and yellow gummy bears represent. After they figure it out, tell them to write it down next to the rules they wrote earlier.

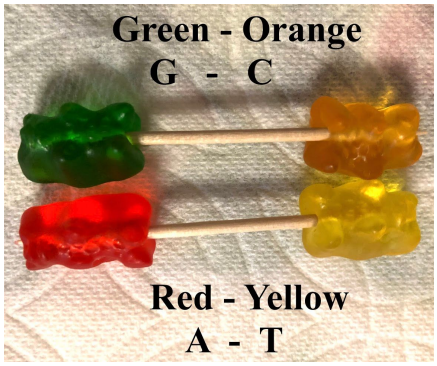

Figure 5: Colors and Bases Associated with Gummy Bear Pairings

6. Now, the kids will be practicing the base pair rules and decoding a set of sequences to test their understanding of the rules.
    a. Have the kids take turns decoding the sequences:
        i. ATC TGA GGA AAT GAC CAG
            1. Answer: TAG ACT CCT CTG GTC
        ii. TCACCTGAAGTGGACT
            1. Answer: AGTGGACTTCACCTGA
            2. See if the kids notice that the first 8 bases are the complementary base pairs of the last 8 bases!

Additional Notes for Mentors

This module is a bit more advanced, so it's okay if your kids do not understand every detail! Feel free to adjust the module and change things to fit your site! (i.e. for more advanced sites, you can explain why certain bases pair with each other by talking about hydrogen bonding and spacing between bases.) Additionally, if you are running short on time, you can skip this module.

Module 4: Extract Your Own DNA

Introduction

In the final module, kids will be extracting their own DNA!

Teaching Goals

1. The overall process of extracting DNA requires breaking the membranes of cells to release the DNA by using a detergent and separating DNA from the remaining cell fragments by using the fact that DNA is an extremely polar molecule.
    a. We will be using water and salt in our DNA extraction process to collect mouth cells. Then, we add dishwashing detergent to the cells to release the DNA inside. Finally, we use isopropyl alcohol to cause DNA to precipitate and be extracted.

Background for Mentors

The first step of DNA extraction requires collecting cells, and in this module, we are going to

swish water in our mouth to remove the cells lining the inside of our cheeks. If you swish the water around longer and more vigorously, you will collect more cells.

To break the cell membranes and release DNA, we add dishwashing detergent, because it is **amphipathic**, indicating that it has both **hydrophobic** (resistant to water) and **hydrophilic** (interacts with water) properties. Because the cell membrane is composed of a lipid bilayer consisting of a hydrophobic core and hydrophilic outside, the amphipathic detergent molecules can break apart the lipid bilayer and cause the membrane to fragment and DNA to be released.

To separate and extract the DNA from other cell debris, we take advantage of the high polarity of DNA. Because DNA has negatively charged phosphate groups along its backbone, it is an extremely polar molecule that can easily dissolve in water. Additionally, the DNA in our solution is even more polar due to the positive ions from the salt we added earlier. Thus, we need to use another substance that is significantly less polar than DNA to successfully separate it, so we will be using isopropyl alcohol. Because the very polar DNA cannot dissolve in the less polar isopropyl alcohol, DNA will precipitate out and form a white, stringy layer that we can extract.

Materials

- 2 small clear disposable cups per group of 3-4 students
- Water
- 2 teaspoons of salt per group of 3-4 students
- 5 mL (cold) 91% isopropyl alcohol per group of 3-4 students
- 2 mL 25% dishwashing detergent per group of 3-4 students
- 1 thin bamboo skewer per group of 3-4 students

Procedure

Extra Notes: It may be easier to have one mentor per group of 3-4 students, because this module can get messy and difficult to manage. If it gets out of control, you can use candy as leverage to get kids to stay focused (there will be extra gummy bears that they will get at the end of the lesson). You will need a cup of water for each group of students. If having your students get water themselves is a distraction, have mentors fill the cups up with water at a water fountain before the module starts.

1. Have the kids drink a mouthful of water first to clear their mouth. Next, the kids will swish a mouthful of water around in their mouth for 1 minute, and then spit it into the small cup. Add one teaspoon of salt to the cup and mix together. Make sure only 1 kid per group is extracting their DNA, but the rest of the group will help with the next steps.
2. Add 4-5 drops of dishwashing detergent into the cup and **gently** mix with one end of the bamboo skewer. Try not to create too many bubbles when stirring. Then, add another teaspoon of salt into the cup, and mix gently again until all the salt and dishwashing soap dissolves.

Figure 6: Salt Solution Mixture (your DNA, salt, and dishwashing detergent)

3. Have mentors pour the isopropyl alcohol into the cups for the students to avoid messes and spills.
    a. It is easier if each mentor has a cup of isopropyl alcohol and then distributes their cup to a group of students to make the process quicker.
    b. To distribute the isopropyl alcohol, hold the cup at an angle and ***slowly*** pour the isopropyl alcohol down the *side* of the cup with your salt solution. This should cause a thin layer to form on top of the salt solution mixture.
4. Wait two minutes for the DNA to be separated. Soon, the kids will see small, filament-like strands in the middle layer between the salt solution and isopropyl alcohol layers; this is their extracted DNA!

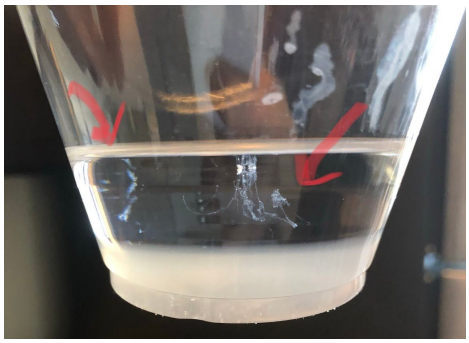

Figure 7: DNA Strands in Between Isopropyl Alcohol and Salt Solution Layers

5. Using the clean end of the skewer, have the kids gently slide it all the way to the bottom of the tube, and slowly spin it as they pull the skewer out to collect their DNA!

Additional Notes for Mentors

Make sure that students are not eating any snacks or food during the lesson, because they may end up extracting food chunks instead of cells.

Conclusion

Hopefully the kids had a good time learning about genetics and DNA! You can conclude by briefly reviewing the concepts they learned (what the bird beak simulation showed about natural

selection, what DNA is and what it is comprised of, how we extracted our own DNA).

References

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Summary Materials Table

Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
Spoons	10 per site	N/A	Inventory
Toothpicks	12 per group of 3-4 students + 10 per site	$5.99 for 1000	Amazon
Popsicle sticks	10 per site	N/A	Inventory
Raisins	100 per site	$11.80 for 2 lbs.	Amazon
Kidney beans	100 per site	$12.99 for 2 lbs.	Amazon or any grocery store

Beads	100 per site	$5.57 for 1000 beads	Amazon
Small dixie cups	1 per student	$15.99 for 600 cups	Amazon or inventory
Licorice	2 pieces per 3-4 students	$12.53 for 5 lbs.	Amazon
Gummy bears	6 of each color of gummy bear per 3-4 students	$12.15 for 5 lbs.	Amazon or any grocery store
Markers	1 marker per 3-4 students	N/A	Inventory
DNA message handout	1 per 3-4 students	N/A	Make during decal
91% isopropyl alcohol	5 mL per 3-4 students	$19 for 32 oz. (6 pack)	Amazon
Dishwashing detergent	2 mL per 3-4 students	$12.68 for 2 56 oz.	Amazon
Thin bamboo skewer	1 per 3-4 students	$8.37 for 1000 skewers	Amazon or inventory
Clear plastic cups	1 per 3-4 students	$14.29 for 200 cups	Amazon
Playdough	2 jars each of 4 different colors per site	N/A	Inventory
Clay (air-dry clay)	2 long strips per 3-4 students	N/A	Inventory