Thunder Only Happens When There's DNA

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Field(s) of Interest: Biology, Genetics

Brief Overview (1-3 sentences):
Mentees will be observing different phenotypes through a whole-class bingo activity, viewing real-life DNA with an extraction demo, and modelling protein chains with bead bracelets. The main takeaway should be that DNA is a very tiny physical structure that functions as a blueprint for our bodies to produce proteins, giving us the phenotypic variation that we can directly observe.

Agenda:

- Introduction (5 min)
- Module 1: You Can Go Your Own Way (Because of Phenotypic Variation) (10-15 min)
- Module 2: She Broke Down and Let Me In (To The Nucleus) (15-20 min)
- Module 3: We'll Never Break the (Amino Acid) Chain (15-20 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:

- ➔ Trait
- ➔ Observation
- ➔ Qualitative Observation
- ➔ Quantitative Observation
- ➔ Phenotype
- ➔ DNA
- ➔ Base
- ➔ Double Helix
- ➔ Gene
- ➔ Allele
- ➔ Genotype
- ➔ Structure
- ➔ Function
- ➔ Proteins
- ➔ Amino Acids
- ➔ Polypeptides
- ➔ Central Dogma of Biology
- ➔ RNA
- ➔ Codon

Background for Mentors

Module 1

- **Trait**
- **Phenotype**
- **Observation**
  - **Qualitative Observation**
  - **Quantitative Observation**

Adapted from: A Concrete Taste of Genetics by Matthew Sit

A **trait** refers to a specific characteristic of an organism, such as eye color, hair color, or height. Traits can be influenced by genetics, the environment, or both.

An organism's **phenotype** refers to their full set of *observable* physical, biochemical, and behavioral characteristics.

For example, the state of having brown hair, blue eyes, and being tall is one complete *phenotype*. "Brown hair," "blue eyes," and "tall" are all individual *traits*.

To make an **observation** is to use your senses to gather information about a biological phenomenon or organism. We can make observations about an organism's traits and phenotype by noticing and recording various physical characteristics and how they differ from each other.

A **qualitative observation** focuses on the descriptive qualities of organisms or events, such as their color, smell, texture, or behavior, to provide detailed, contextual information.

A **quantitative observation** is an observation that collects numerical data using objective measurements, such as counting, measuring, or weighing.

For example, a quantitative observation would be that a human has two ears, while a qualitative observation would be that a human has attached earlobes.

Figure 1: *Humans have a wide variety of phenotypes*

Module 2

- **DNA**
  - **Base**
  - **Backbone**
  - **Double Helix**
- **Gene**
  - **Allele**
- **Genotype**

DNA, or deoxyribonucleic acid, is the molecule in living cells that encodes all of an organism's genetic information. DNA is a type of nucleic acid. It provides the instructions living things need for growth, repair, development, and reproduction.

DNA is composed of two strands of nucleotide **bases**, each on a backbone. There are four types of bases: adenine, guanine, thymine, and cytosine, abbreviated A, G, T, and C. The backbone of each strand provides structural stability for the bases. When the two strands come together, bases pair together and the resulting double-stranded structure is twisted into a **double helix**.

A **gene** is a segment of DNA that provides instructions for a specific trait or function in an organism. Genes are typically thousands of bases long, but can range in size from a few hundred to millions of bases long.

Alleles are different variants of genes. Different alleles cause the variation that we observe in biological traits. While one gene segment may code for a specific trait, such as eye color, different alleles of that gene will code specifically for brown eyes, blue eyes, etc.

Genotype refers to an organism's complete set of genes, specifically the combination of alleles it has. The genotype provides the blueprint that, along with environmental factors, determines an organism's phenotype, or their full set of observable physical traits.

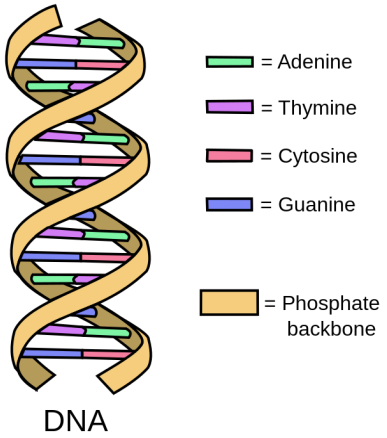

Figure 1: *Double helix structure of DNA*

Module 3

- **Structure**
- **Function**
- **Proteins**
  - **Amino Acids**
  - **Polypeptides**
- **Central Dogma of Biology**
- **RNA**
- **Codons**

A foundational concept of biology is that in a living system, structure dictates function.

- **Structure** refers to the spatial arrangement and physical makeup of a thing.
- **Function** is the job or role that that thing performs.

Structure and function are tightly interwoven in biological systems. The specific structure of a cell, organ, or organism enables its function, and its function can, in turn, influence its structure.

For instance, the structure of DNA gives way to its function: producing proteins.

Proteins are long, complex molecules with an array of biological functions, such as providing structural support, catalyzing metabolic reactions, transporting molecules, and defending against pathogens. Variations in protein structure or quantity give rise to variation in our physical traits.

The building blocks of proteins are **amino acids,** which join together to form chains called **polypeptides**.

The chain structure of DNA resembles the chain structure of proteins, which is crucial to their function.. We have all of the different proteins we need to live because even though there are only 20 types of amino acids, all of the different combinations of polypeptide chains fold and twist to enable a massive array of biological functions.

The **Central Dogma of Biology** describes the flow of genetic information from DNA to RNA to protein. This process involves two main steps: a segment of DNA is copied into an RNA molecule, then the RNA sequence is used to assemble a protein, which can then carry out biological functions.

RNA, or ribonucleic acid, is another type of nucleic acid. Its structure is similar to DNA, with bases and a backbone. RNA sequences also contain adenine (A), guanine (G), and cytosine (C), but thymine (T) is replaced with uracil (U).

A **codon** is a sequence of three RNA bases. Each codon corresponds to a specific amino acid. When proteins are being produced, cellular machinery “reads” a codon and adds the specific amino acid that codon represents to the growing polypeptide chain.

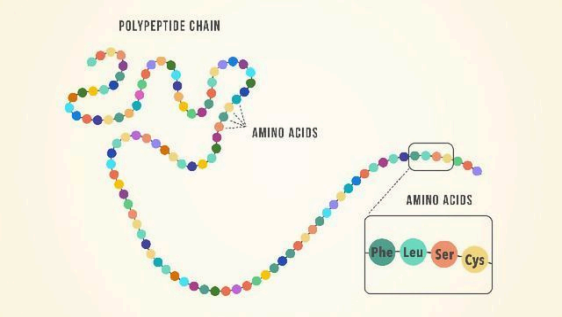

Figure 1: Amino acids make up a polypeptide chain

Introduction

DNA is found in all living things, controlling the production of the proteins that our bodies need to develop and function. Understanding DNA is essential to understanding much of human health and developing treatments to many diseases.

Concepts to Introduce	**Questions to Pique Interest**
1. Scientists use quantitative and qualitative observations to capture ideas about the living world. 2. DNA is a physical structure that serves as a blueprint for our bodies to produce our observable traits. 3. Our traits are attributable to the proteins that are produced from DNA. 4. Advanced: The Central Dogma of Biology states that genetic information flows from DNA to RNA to proteins.	● What are some characteristics that most or all humans have? ● What are some ways in which humans differ from each other? ● How do doctors find out if you have a higher risk for certain diseases?
Scientists, Current and Past Events	**Careers and Applications**
● CRISPR technology is being used for genome editing. Using this technology, scientists have pioneered a cure for sickle cell anemia, an inherited red blood cell disorder. ● 19th-century chemist Rosalind Franklin discovered the double-helix structure of DNA.	● The fields of genetics and genomics research the structure and function of our DNA, developing new technologies to understand the human genome better. ● Physicians use the gene sequences of patients to diagnose and treat genetic disease.

Module 1: You Can Go Your Own Way (Because of Phenotypic Variation)

Adapted from: A Concrete Taste of Genetics by Matthew Sit

Mentees will learn how to make observations about their and their classmates' phenotypic traits.

Teaching Goals

1. **Trait:** a physical characteristic of an organism (eye color, hair texture, or height)
2. **Phenotype:** the set of all of an organism's specific traits
3. **Observation:** details that you notice through the use of your senses
    a. **Qualitative Observation:** describing something (ex. having detached earlobes)
    b. **Quantitative Observation:** measuring or counting something (ex. having 2 ears)

Materials (per student)

- Phenotype bingo card w/ pictures
- Pen/pencil/marker

Different Methods for Teaching

1. **Trait:** Give the mentees a specific trait (i.e. fur on cats or eye color), and have them brainstorm different versions of the trait (i.e., long-hair, short-hair, spots, etc.)
2. **Phenotype**: Then, have them describe a certain animal with **ALL** of its traits (i.e. a small, short-haired, brown, cat with gray eyes)

Procedure

1. Pass out one phenotype bingo card to each mentee.
2. Make sure all mentees have access to a writing utensil (pass out, use own, share)
3. Have mentees get up from their seats and search for classmates with traits from the bingo card.
4. After 5 minutes have passed, have mentees sit back down.
5. Mentees can share their findings with the whole class.

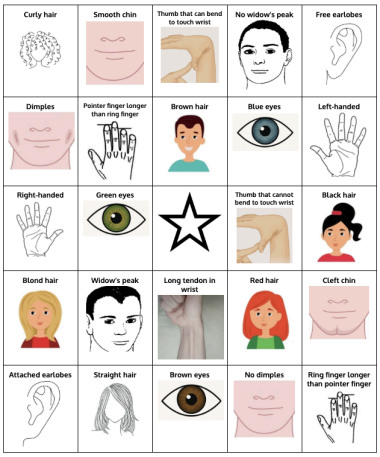

Figure 1: *Phenotype bingo card*

Classroom Notes

For older mentees, spend less time on this module and more time on 2 and 3.

Module 2: She Broke Down and Let Me In (To The Nucleus)

Mentees will learn the structure of DNA and observe that DNA is a physical substance through a self-DNA extraction.

Teaching Goals

4. **DNA:** the substance that provides the instructions for your body to grow and work
    a. **Base:** the building blocks from which DNA is made
    b. **Double Helix:** a twisty ladder-like chain that forms when 2 strands of bases connect
5. **Gene:** a segment of your DNA that codes for a specific trait
    a. **Allele:** different versions of a specific gene for a trait
6. **Genotype:** the specific combination of genes that give an organism its unique phenotype

Materials (per mentee)

- Small clear disposable cup
- Water
- 1 tsp salt
- 10 mL 91% isopropyl alcohol
- 3 mL 25% dishwashing detergent solution (one dropper-full)
- 1 toothpick

Different Methods for Teaching

3. **DNA**: Like the **instruction manual** to a LEGO set (manual on how to build a car)
    a. **Base:** The **individual steps** outlined in the manual (put the wheels on the axles)
    b. **Double Helix:** show shape to mentees (draw on board, etc)
4. **Gene:** A **section of the instruction manual** that tells you how to make a certain part of the build (the engine)
5. **Allele**: **Variants** of the same section of the instruction manual (one manual tells you how to make a blue engine, another tells you how to make a red engine)
6. **Genotype**: the **different instruction manuals/varieties of LEGO sets**; the exact list of pieces and steps that make different structures

Procedure (Demo)

1. Have the mentees drink a mouthful of water first to clear their mouth.
2. Swish a second **small** mouthful of water around in your mouth for 30 seconds
3. Spit it into the small cup.
4. Add 1 tsp of salt to the cup and mix together, either by stirring with the toothpick or swirling the cup gently.
5. Add 1 dropper-full (around 3 mL) of detergent solution to the cup. Mix **gently** with toothpick, being careful not to make too many bubbles.

Figure 1: Adding salt to the cup

6. Pour the isopropyl alcohol into the cup:
    a. Hold the cup at a slight angle.
    b. **Slowly** pour the isopropyl alcohol down the side of the cup.
    c. This should form a layer on top of the salt/spit solution around 0.5-1 cm thick.
    d. Do not mix layers.
7. **Wait two minutes** for the DNA to separate and clump in the mixture.
8. Cloudy, filament-like strands will begin to form in the liquid. This is extracted DNA!
    a. This may not be visible if there are a lot of spit and bubbles. It will be clearer when mentees spin the toothpick around in the solution.
9. Using the clean end of the toothpick, gently insert it into the cup.
10. Slowly spin the toothpick as you pull it out to collect you DNA!

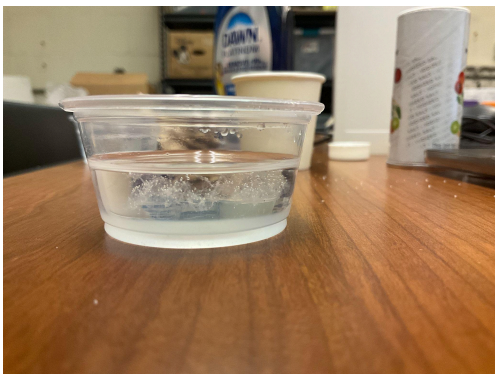

Figure 2: *Alcohol layer on top of soap/salt/spit solution*

Figure 3: *Extracted DNA in alcohol layer*

Classroom Notes

Have napkins/towels on hand as the spitting part can get messy! It may be easier for mentors to distribute salt and dropper out soap solution for the mentees.

Module 3: We'll Never Break the (Amino Acid) Chain

Mentees will relate structure to function by learning that DNA serves as a blueprint to make proteins. Mentees will model protein formation by making a bead bracelet based on a DNA or RNA sequence.

Teaching Goals	**Materials (per mentee)**
7. **Structure:** how something is built or what it is made of 8. **Function:** what something does/what its job is 9. **Proteins:** biological building blocks that your body creates using DNA as a blueprint a. **Amino Acids:** single protein units b. **Polypeptides:** long chains of amino acids 10. **Central Dogma of Biology:** DNA makes RNA which makes proteins 11. **RNA:** a simplified version of DNA that provides a direct blueprint for proteins 12. **Codon:** a sequence of three bases that correspond to a specific amino acid	**Younger/less advanced mentees: Reading DNA** • 20 beads, 5 of each color • 1 pipe cleaner • Reading DNA instruction sheet **Older/more advanced mentees: Decoding Codons** • 20 beads, 5 of each color • Length of string (precut) • Decoding Codons instruction sheet

Different Methods for Teaching

Depending on your mentees' level, you can decide whether to teach about Central Dogma and the flow of genetic information.

- On a high level, DNA is the instruction manual for your body to make proteins. *This is a sufficient explanation for the **Reading DNA version of the activity.***
- Getting deeper, RNA is involved as an intermediate and DNA is read specifically in codons. *This explanation is necessary for the **Decoding Codons version of the activity**.*

7. **Amino Acids vs. Polypeptides**
    a. Amino acids are like the different **individual LEGO bricks** that build up the whole structure (i.e. 2x2, 4x4, etc.)
    b. Polypeptides are the **different structures**/combinations that LEGO bricks can make (house, car, etc)
8. **Proteins** and thus your **phenotype** are the result of following all the LEGO instructions (your final build)
9. **RNA**: Like a person reading out the LEGO instructions while you put together the bricks (an intermediate between DNA and proteins)
10. **Codons:** 3 individual steps of the instruction manual

Procedure

Reading DNA *(applicable if you DID NOT teach about Central Dogma)*

1. Pass out one Reading DNA instruction sheet, 5 of each color bead (20 total), and 1 pipe cleaner to each mentee.
2. Following the instructions on the sheet, thread the bead corresponding to the first given base onto the pipe cleaner, tying it securely at the end.
3. Reading the sequence left-to-right, thread the other beads onto the pipe cleaner one-by-one, modelling a growing amino acid chain.
4. Secure the last bead at the end.
5. Chains can be left as keychains or tied into bracelets.

Decoding Codons *(applicable if you DID teach about Central Dogma)*

1. Pass out one Decoding Codons instruction sheet, 5 of each color bead (20 total), and 1 pre-cut string to each mentee.
2. Following the instructions on the sheet, thread the bead corresponding to the first given codon onto the pipe cleaner, tying it securely at the end.
3. Reading the sequence left-to-right, thread the other beads onto the pipe cleaner one-by-one, modelling a growing amino acid chain.
4. Secure the last bead at the end.
5. Chains can be left as keychains or tied into bracelets.

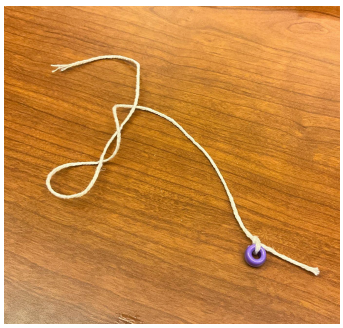

Figure 1: First bead of chain secured to string

Figure 2: Growing amino acid chain

Figure 3: Patterned polypeptide forms

Figure 4: Finished polypeptide bracelet

Classroom Notes

Conclusion

By making observations and connecting structure to function, mentees should take away that DNA is a physical structure that is responsible for the function and appearance of living things.

References

- A Concrete Taste of Genetics.pdf by Matthew Sit (Fall 2016)
- Central Dogma of molecular biology
- Proteins
- Structure and function
- Genotype vs. phenotype
- Genes
- DNA extraction adapted from this procedure

Summary Materials Table

Material	**Amount per Site**	**Expected $$**	**Vendor (or online link)**
Bingo card	1 per mentee		Print out
Marker	5-10 per site		
Small, clear plastic cup	1 per mentee		
Rubbing alcohol	~10 mL per mentee		
25% dish soap/water solution	~5 mL per mentee		
Table salt	~1-2 tsp per mentee		
Toothpicks	1 per mentee		
Plastic beads	20 per mentee		
Pipe cleaners (Reading DNA)	1 per mentee		
String (Decoding Codons)	1 bracelet length per mentee		
DNA/codons activity sheet	1 per mentee		Print out