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AG/ENVIRONMENTAL

Community Science

Tech 1: DNA Recap

Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

This document is separated into two sections, For Teachers [T] *and* Student Resources [S]*, which can be printed independently.*

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Follow the tips below in the Range field of your Print panel to print single pages or page ranges:

Single Pages (use a comma): T3, T6

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Cover Image
Bacteria in a water sample is a potential source of environmental DNA (eDNA).

AG/ENVIRONMENTAL / COMMUNITY SCIENCE

Technical (Tech) Lesson 1: DNA Recap

ACTIVITY DURATION

Two class sessions
(45 minutes each)

DRIVING QUESTION

How does the structure of DNA allow for DNA identification?

ESSENTIAL QUESTIONS

What is DNA and how does it code for proteins?

What about DNA makes it unique to each individual or species?

OVERVIEW

As scientists uncovered the structure of DNA, they opened the door to many future discoveries on how DNA codes for proteins, how it is replicated, and how it can be manipulated. Knowing how DNA works is directly related to knowing what DNA looks like. Although we cannot see it directly, we know its structure from experimental evidence.

In this lesson, students will review the structure of DNA and its function. Some teachers may decide to skip this depending on student understanding. Others might find it an important review for the structure of DNA. Each group of students is provided with the "pieces" that make up DNA. Students will then collect quantitative data about the chemical makeup of DNA. With that data, they will create a claim about the structure of DNA and support it with the data from the table. Students will then complete follow-up questions about other important aspects of DNA. Lastly, they will discuss how the structure of DNA allows for DNA identification techniques.

OBJECTIVES

Students will be able to:

Describe the structure of DNA.

Explain how the structure of DNA relates to its function.

Explain how the structure and function of DNA allow for DNA identification.

Materials
Sample of DNA Pieces
Sample of DNA Analysis Capture Sheet
DNA Identification Techniques Reading
DNA Identification Techniques Overview Capture Sheet

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.

SOCIAL-EMOTIONAL LEARNING

Students must use self-discipline and self-motivation to stay on task. Students will need to communicate effectively to collect the DNA data with their partner and complete the learning activity.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Exploring the structure and function of DNA allows students to see that all human beings are made of the same basic structure, opening up meaningful conversations about equity. Exploring the differences in DNA that result in various traits and ethnicities allows for thoughtful exploration and celebration of differences among cultures.

ADVANCING INCLUSIVE RESEARCH

While investigating the structure and function of DNA, students will understand how similarities and differences in DNA lead to diversity in human communities. They will also discuss the importance of diverse data sets to ensure that DNA identification techniques benefit communities equitably.

COMPUTATIONAL THINKING PRACTICES

Students will collect and analyze data to identify patterns. They will use those patterns to determine the structure of DNA.

CONNECTIONS TO THE PRODUCT LIFE CYCLE

In this lesson, students review the physical structure of DNA and relate the structure to its function. This molecular lens connects to the **discover** phase, as students act as researchers and consider how DNA can be used for identification.

Have you ever wondered…

If we could see DNA, what would it look like?

DNA magnified so that it could be seen with human eyes would reveal a helical ladder with nitrogenous bases making up the rungs and phosphates and sugars on the sides. The order of the nucleotide (sugar, phosphate, and base) is the key to the message it holds for the resulting protein structure.

Why does the structure of DNA matter?

Understanding the structure of the DNA molecule is the first step in understanding the role of DNA in living things. Knowing how the structure supports the function allows scientists to manipulate DNA for biotechnology purposes, such as DNA identification techniques.

MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

This lesson is the first stepping stone to future lessons focusing on DNA identification technologies. To understand how the technologies work, students will need to know the basics of DNA and the central dogma.

How does this connect to careers?

Research scientists design and carry out experiments to test new ideas, and report their findings in written journals and presentations. To understand the structure of molecules like proteins or DNA, they might use techniques such as X-ray crystallography which allows scientists to see shapes not visible to the naked eye.

How does this connect to our world?

To utilize DNA in biotechnology, it is necessary to understand its structure and function. Biotechnology requires application, and therefore the basic knowledge of structure is a prerequisite.

Day 1

LEARNING OUTCOMES

Students will be able to:

Justify a claim about the structure of DNA with quantitative evidence from the data collected.

Identify strengths and weaknesses of their model of DNA.

INDUSTRY AND CAREER CONNECTION

To understand the structure of molecules like proteins or DNA, research scientists might use techniques like X-ray crystallography which allows us to see shapes not visible to the naked eye.

Procedure

Background Knowledge: Day 1 of this lesson can be skipped if students have recently covered the structure and function of DNA. The activities in Day 1 are a good refresher and critical thinking activity if students have not worked with DNA in the recent past or can serve as a valid review to bring all students to the same level of understanding. The Day 2 discussion on DNA identification can be used without the Day 1 activity.

Whole Group (5 min)	
1	At the start of class, set the stage for the activity. Remind students that DNA is a chemical and just like all chemicals it is made of atoms of elements. When researchers first discovered DNA, they knew what was in it, but they did not know what it looked like. Tell students that you have a "sample" of DNA for them. This sample will allow them to see the components of DNA, but not the whole structure, just like scientists in the past. Their job is to take this sample of DNA and analyze it.
2	Place students in pairs. Hand out the *Sample of DNA Pieces* with the pieces cut out and the *Sample of DNA Analysis Capture Sheet*. This can be done digitally or on paper.

Small Group (40 min)	
1	Students will work with their partner to collect data and analyze the DNA according to the directions on the *Sample of DNA Analysis Capture Sheet*.
2	When students get to the checkpoint, direct them to call you over for confirmation. They can then move on to assembling their DNA based on the "rules" they developed. Use the key to make sure students have all the rules before proceeding.
3	Students will finish by working on the analysis questions. A follow-up discussion will take place during the next class.

Day 2

Procedure

LEARNING OUTCOMES

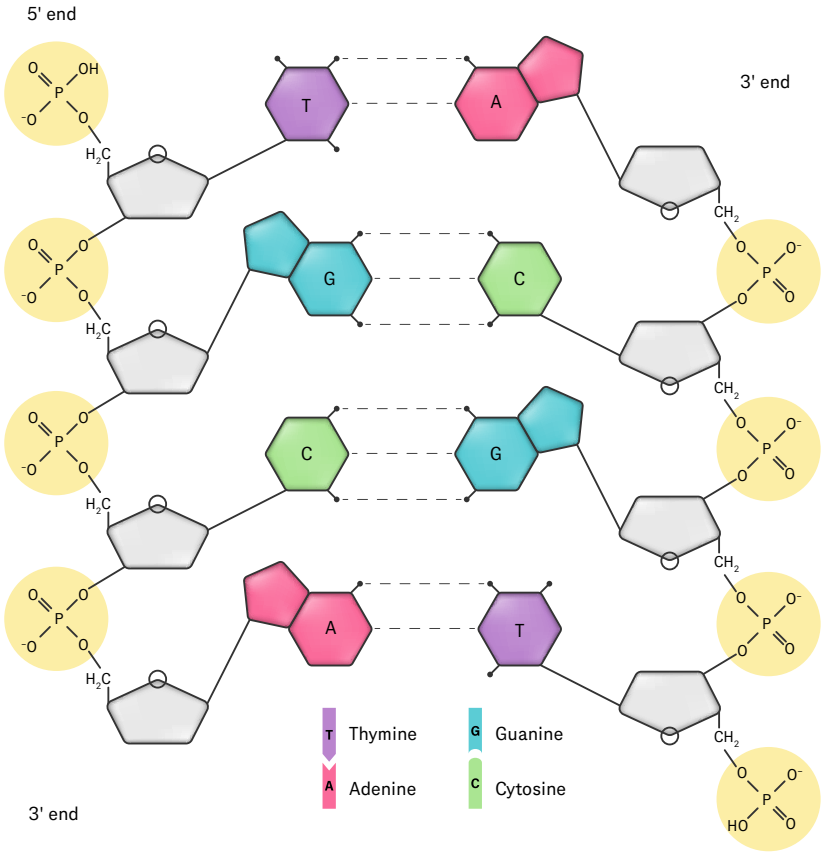
Students will be able to:

Explain how the structure of DNA allows it to be used in DNA identification techniques.

Whole Group (25 minutes)

1 Start the discussion with a picture of DNA on the board like the one provided. Ask students what components of the models they made during Day 1 are found in the diagram. Generate a list on the board. While making the list, ask students what data they had to support the "rule." Students might list the following:

- A nucleotide includes a sugar, phosphate, and nitrogenous base.
- Adenine pairs with thymine.
- Cytosine pairs with guanine.
- Adenine and guanine are larger structures.
- Cytosine and guanine are smaller structures.
- The bases make up the center of the molecule.
- The sugar and phosphates make up the outside.



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Day 2

Continued

Procedure

2	Next, ask students how their model differs from the diagram. What is represented in the diagram, but not the model? Use this opportunity to discuss what a model is, and explain that models have limitations. Students may mention the following: • Helical shape • Hydrogen bonds • Covalent bonds • Atoms that make up the nucleotides • Appropriate sequence
3	Next, ask students what DNA does. This should be a review for most students. They should answer that DNA codes for the proteins that make up living things, and these proteins are what determine the physical traits (phenotype) of individuals. Then, discuss how structure relates to function. Do a quick "Think Pair Share" with this prompt "How does the structure of the DNA relate to its function?" Student responses may include the following: • The order of the nucleotides determines the amino acid sequence of the protein. • The weaker hydrogen bonds in the center of the structure allow for DNA to be open and read by enzymes. • The helical shape allows it to fit into cells.
4	Based on the list generated from the "Share" portion of the "Think Pair Share," ask students which part of the structure of DNA could be used in DNA identification techniques. Answers should focus on the order of the nucleotides that code for proteins.
5	Ask students to think back to the previous units and have them list examples of where DNA identification was used. See sample answers below: • Behind the Scenes of Scientific Breakthroughs Unit: Examining a SNP in the human genome to determine if there is an association with longevity • Solution Seeking Microbes Unit: Analyzing insect DNA to see if it is infected with Wolbachia bacteria • Alternative Proteins Unit: Analyzing the DNA of a food product to identify if it contains Bt-corn

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Day 2

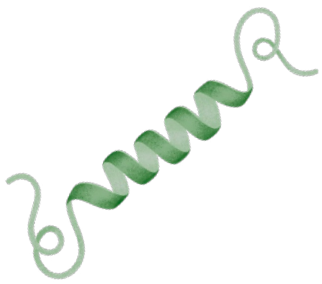
Continued

Procedure

6	Ask students how the DNA would vary from individuals of different species. Students should respond that each species has different DNA that codes for different proteins. Some species have more DNA in common depending on evolutionary history and general species type.
7	Next ask how the DNA would vary from individuals of the same species. Students should respond that in general, the DNA will be the same. You may need to push students to understand that most of the DNA will be the same but because no individuals are identical (except identical twins), there will be some differences in the DNA of individuals within a species.

Individual Work (20 min)

1	Hand out the *DNA Identification Techniques Reading* and the *DNA Identification Techniques Overview Capture Sheet* and ask students to individually work through as a follow up to the discussion. The reading will introduce the DNA identification techniques that will be used throughout this unit.
2	You can use the *DNA Identification Techniques Overview Capture Sheet* as a check for understanding and follow up with students who do not have a basic understanding of how the structure of DNA allows for DNA identification techniques.



National Standards

Next Generation Science Standards	**LS1-1 From Molecules to Organisms: Structures and Processes** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
	Science and Engineering Practices Developing and Using Models Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
Career and Technical Education (CTE)	**A3.1** Define and describe the structure and function of DNA ribonucleic acid (RNA) and proteins, explain the consequences of DNA mutations on proteins.
	A4.5 Discuss the structure and function of the macromolecules that compose cells, including carbohydrates, lipids, DNA, RNA, and protein molecules.

Sample of DNA Analysis Capture Sheet

ANSWER KEY **Do not share with students**

Directions

DNA is an amazing molecule. Within its molecular structure are the instructions to build a living thing, as well as to make that living thing function. Before scientists were able to visualize the structure of DNA, they started making detailed observations of the chemical components of DNA. One of the first methods used to study DNA was to break down the molecular structure and analyze the compounds and elements that make up DNA. From this analysis of compounds, scientists were able to determine some basic rules about the structure of DNA without visually observing it.

In this lab, you will analyze the molecular contents of a "sample" of DNA and draw some conclusions about the structure of DNA by formulating your own rules.

This lab is a simulation lab. To determine the basic compounds that DNA molecules contain, a DNA molecule has been broken into its subunits. You will be given a sample that contains a mixture of the subunits of DNA. You will need to collect data on the contents of a beaker and draw conclusions about the basic rules guiding the structure of DNA.

This is an exploratory activity based on your prior knowledge. Please do not use any outside resources while you are completing the first part of the activity; you can use outside resources after step 5.

1. Hypothesis: With your partner, form a hypothesis about the way DNA looks based on your prior knowledge of DNA.

   Draw or explain that hypothesis here.

Possible student responses: spiral or helix, ladder, ATCG (will depend on prior knowledge)

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Sample of DNA Analysis Capture Sheet

ANSWER KEY **Do not share with students**

Continued

2. Results and Data: Create a data table to organize your observations of the contents of the "sample" of DNA you received. Make sure your table has correct titles and labels. After you complete this activity, check with your teacher before continuing.

Letter or Component	Amount (Molecules)
A (adenine)	3
T (thymine)	3
C (cytosine)	2
G (guanine)	2
P (phosphate)	10
S (sugar)	10

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Sample of DNA Analysis Capture Sheet

ANSWER KEY **Do not share with students**

Continued

3. Conclusion: Use your data to determine a list of general structural rules that DNA follows. List each rule below, followed by the data that support that rule. Do not use outside resources. You may or may not need the additional dotted rows depending on the data you collect.

Rule	Supporting Data
A pairs with T.	There are three of each.
C pairs with G.	There are two of each.
A larger base pairs with a smaller one.	A is the larger base and it pairs with T, and G is the larger base and it pairs with C.
Each AT or CG goes with a S and P.	Adding up all the ATCG is equal to 10 and there are 10 S and 10 P.

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Sample of DNA Analysis Capture Sheet

ANSWER KEY **Do not share with students**

Continued

4. Make a Model: Use the rules that you wrote above to create a model of the sample DNA. Sketch or insert a picture of your model.

This will look like a ladder.

Continues next page >

Sample of DNA Analysis Capture Sheet

ANSWER KEY **Do not share with students**

Continued

5. Limitations of the Model: A model is a tool to represent an idea or an explanation. Your model represents the structure of DNA. What are some limitations of your model? Research the structure of DNA and list the limitations of your model.

Sample answers:

— It does not show the 3-D shape.
— It does not show the molecular shape.
— The order of nucleotides are made up.
— It does not show the helix.
— Other options are acceptable as well.

DNA Identification Techniques Overview Capture Sheet

ANSWER KEY **Do not share with students**

Directions
Answer these questions to ensure you understand the three DNA identification techniques.

1. What properties of DNA's structure permit the DNA identification techniques?

The order of the nucleotides (A, T, C, G) for every individual in a species is different. In addition, each half is complementary.

2. Why are these techniques valuable tools in biotechnology?

DNA identification techniques can be used to "identify" individuals, species, etc.

3. Critical thinking question: Based on what you read, hypothesize a possible purpose for selecting each technique. (Hint: This is not in the reading.)

Sanger Sequencing: This method is the most accessible. Sanger sequencing could be used to sequence any DNA and determine the order of nucleotides.

NextGen Sequencing: This can be used to identify what genetic material is present in a large amount of material. So water samples can be gathered and the DNA can be sequenced through NextGen Sequencing to see what species are there.

Digital PCR: For digital PCR it is necessary to know what you are looking for. It is a "needle in a haystack" approach, so trying to find if a specific virus is present in wastewater would be appropriate.

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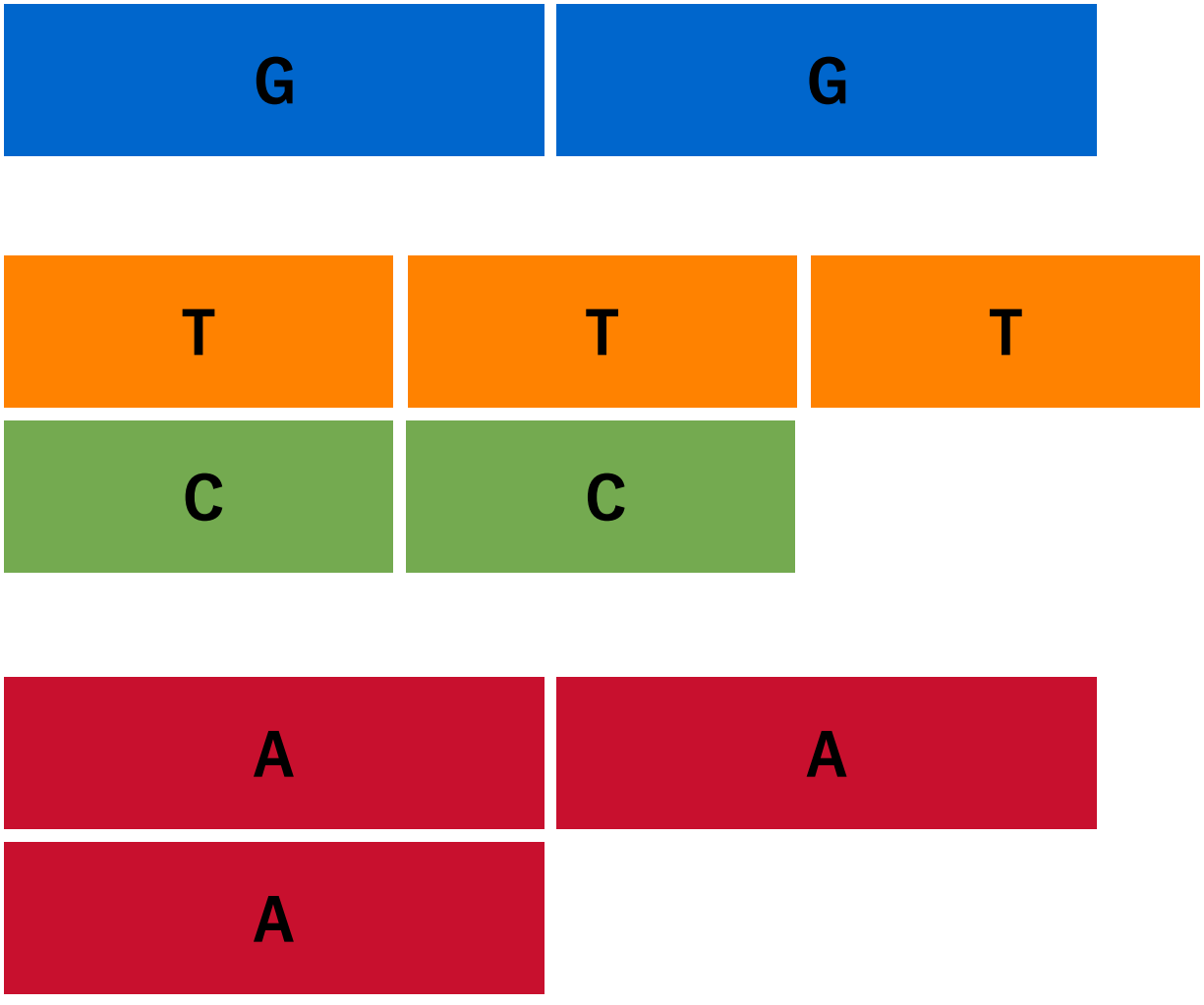
Sample of DNA Pieces

Directions
On this page and the next, is a "sample" of DNA. Each group needs one "sample" to sort. Print both pages in color and cut out each individual block. You should have:

Two guanine molecules	Three adenine molecules
Two cytosine molecules	Three thymine molecules
Ten phosphate molecules	Ten sugar molecules



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Sample of DNA Pieces

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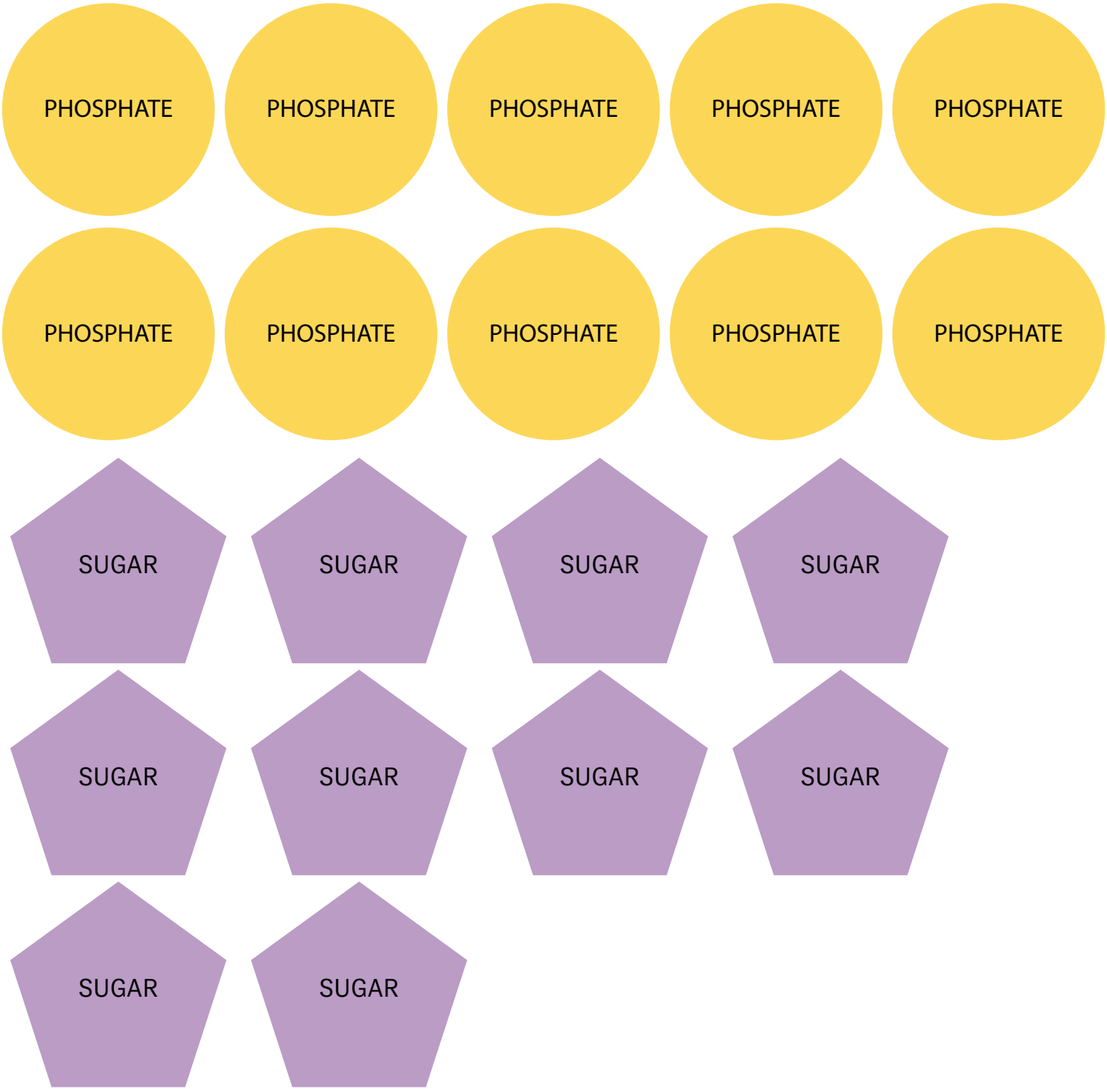

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Sample of DNA Analysis Capture Sheet

Directions

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Sample of DNA Analysis Capture Sheet

Continued

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Sample of DNA Analysis Capture Sheet

Continued

3. Conclusion: Use your data to determine a list of general structural rules that DNA follows. List each rule below, followed by the data that support that rule. Do not use outside resources. You may or may not need the additional dotted rows depending on the data you collect.

Rule	Supporting Data

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Sample of DNA Analysis Capture Sheet

Continued

4. Make a Model: Use the rules that you wrote above to create a model of the sample DNA. Sketch or insert a picture of your model.

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Sample of DNA Analysis Capture Sheet

Continued

5. Limitations of the Model: A model is a tool to represent an idea or an explanation. Your model represents the structure of DNA. What are some limitations of your model? Research the structure of DNA and list the limitations of your model.

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DNA Identification Techniques Reading

Directions

Below are the three DNA identification techniques you will be learning about in this unit. Each technique utilizes the structure and function of DNA to help the user answer a question. Eventually, you will choose one of these techniques to help you plan community-focused research.

Read the overview of each DNA Identification Technique. Based on the overview, answer the two questions on the next page. This will show your understanding of how an individual's DNA structure provides invaluable identification resources for biotech research and industry.

Sanger Sequencing

This method of DNA Identification determines the sequence or the order of the nucleotides. It is named after its inventor, Frederick Sanger. Sanger sequencing uses polymerase chain reaction (PCR) to make many copies of the desired segment of DNA. Special nucleotides are then integrated into the normal nucleotides used for the PCR. These special nucleotides cause the PCR copying to stop when they are added, because they are missing an oxygen atom and therefore the next nucleotide cannot bind. These special nucleotides also floresce or glow. All of these random segments of differing length PCR copies are then put into order with a modified electrophoresis technique. A computer reads the glowing end nucleotide and determines the order based on the color of the fluorescence. Each nitrogenous base is a different color.

NextGen Sequencing

Next-generation sequencing (NextGen or NGS) is based on the ability to sequence millions of DNA fragments at the same time. This new technology builds off of and streamlines Sanger sequencing. NGS is also much less expensive than other forms of sequencing. During NGS, individual fragments of DNA are isolated by attaching them to a solid surface. This complicated process allows for more sequencing at the same time. The end result is several small fragments of sequences which are compared to a reference database to identify the species of origin.

Source : *Next Generation Sequencing —An Overview*, Ranjeev Hari, Suhanya Parthasarathy, in Encyclopedia of Bioinformatics and Computational Biology, 2019

Digital PCR

Digital PCR (dPCR) is based on the same process as standard PCR. The main difference is the size of the DNA replicating reaction. This technique is able to detect and amplify low levels of DNA because it creates PCR reactions in nano-liter sized droplets. The droplets are made from the standard PCR reactants and a lipid solution. After multiple PCR amplification cycles, the droplets are checked for fluorescence. Fluorescence can tell if the DNA is present and quantify how much DNA was in the sample.

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DNA Identification Techniques Overview Capture Sheet

Directions

Answer these questions to ensure you understand the three DNA identification techniques.

1. What properties of DNA's structure permit the DNA identification techniques?

2. Why are these techniques valuable tools in biotechnology?

3. Critical thinking question: Based on what you read, hypothesize a possible purpose for selecting each technique. (Hint: This is not in the reading.)