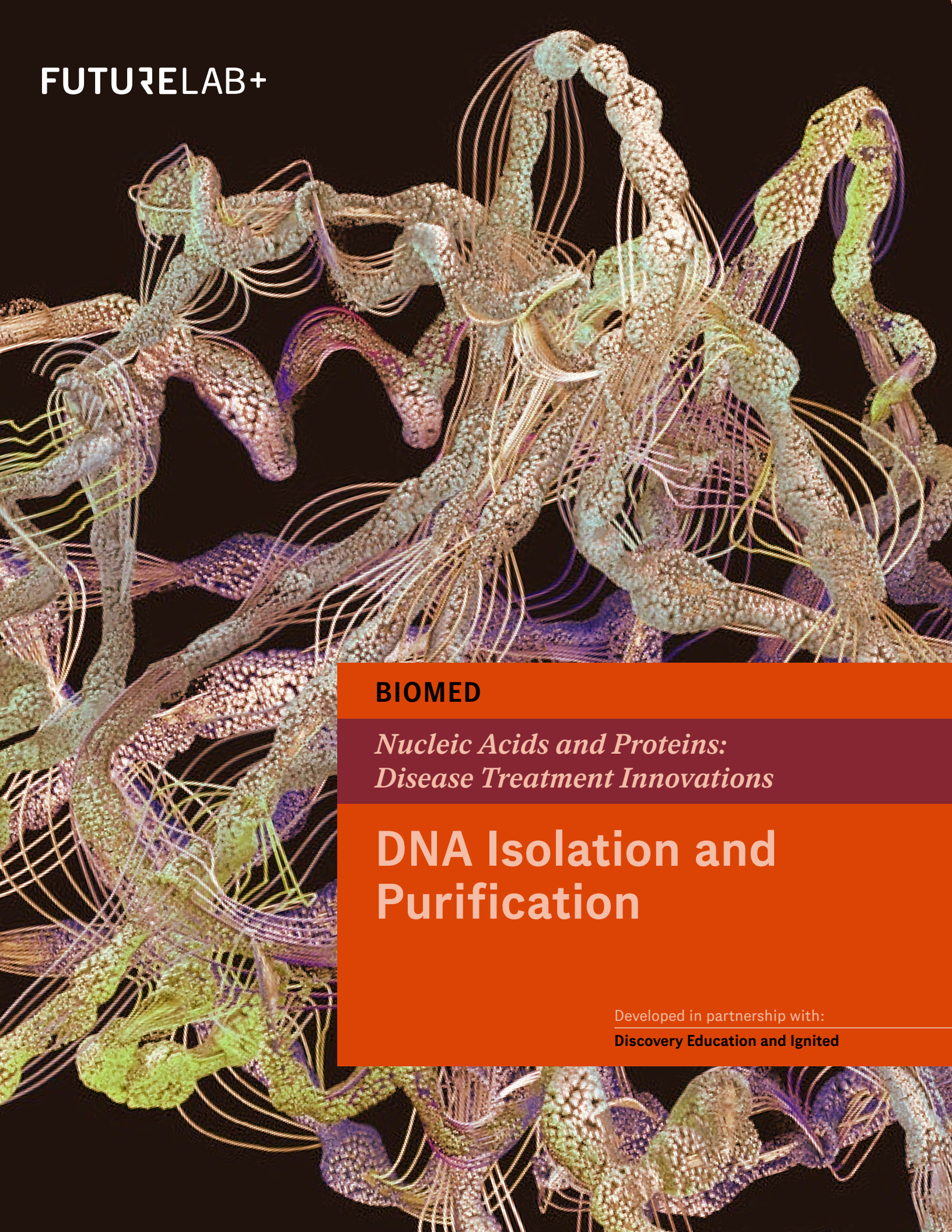
FUTURELAB+



BIOMED

Nucleic Acids and Proteins: Disease Treatment Innovations

DNA Isolation and Purification

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.*

Select the appropriate printer icon above to print either section in its entirety.

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

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Cover Image
This is an illustration of a protein.

BIOMED / NUCLEIC ACIDS AND PROTEINS: DISEASE TREATMENT INNOVATIONS

DNA Isolation and Purification

DRIVING QUESTION

What techniques are used to isolate and purify DNA from cells?

OVERVIEW

Until very recently, genetic diseases were thought of as incurable. Due to advances in biotechnology, that line of thinking may no longer hold true. In some cases, scientists can fix a patient's faulty gene by manufacturing a healthy gene and inserting it into the patient's DNA.

In this lesson, students will review the techniques used to isolate and purify DNA molecules from cells. They will explore tools that are used to cut and separate DNA samples to analyze for medical, agricultural, and evolutionary applications. Students will also understand how DNA helps customize medication and increase a drug's effectiveness.

ACTIVITY DURATION

Five class sessions
(45 minutes each)

ESSENTIAL QUESTIONS

How can DNA be extracted from the nucleus of a cell?

How do scientists work with DNA?

How does the structure of DNA allow it to be separated by electricity?

How can the analysis of DNA be used in society?

How can DNA be used to prescribe specific medicine to patients?

OBJECTIVES

Students will be able to:

Identify and **describe** how the structure of DNA allows it to be separated by electricity.

Describe the step-by-step process of DNA extraction.

Conduct a virtual gel electrophoresis.

Analyze the results of gel electrophoresis as it applies to paternity, forensic, and evolutionary cases.

Examine how DNA can be used to prescribe specific medications to patients.

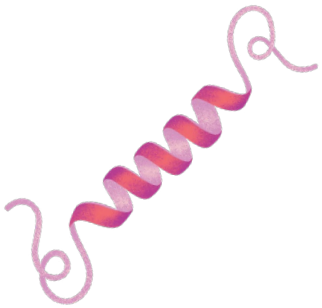
Synthesize agricultural, medical, and forensic applications in society for DNA extraction.

BACKGROUND INFORMATION

In this lesson, students will learn about DNA extractions, gel electrophoresis, pharmacogenomics, and applications of these techniques in society. Students will need an understanding of macromolecules, protein synthesis, and heredity.

Materials

- **Highlighters**
- **Scissors**
- **Examining the Structure of DNA**
- **DNA Extraction—Virtual Lab Capture Sheet**
- **Restriction Enzyme Practice Capture Sheet**
- **Gel Electrophoresis Virtual Lab Capture Sheet**
- **Analyzing the Results of Gel Electrophoresis Capture Sheet**
- **Pharmacogenomics Video Capture Sheet**
- **SNP Analysis, Haplotypes and Pharmacogenetics Capture Sheet**
- **Biotechnology Applications Infographic Assignment**
- **Design Journal**



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 will need to engage respectfully and exercise self-management while working in pairs and in small groups throughout the activities. Students will discuss the use of DNA purification in DNA paternity testing, all while practicing social awareness of classmates who may be sensitive about this subject, which encourages empathy. This is a complex ethical question and students will determine their opinions, and learn about the manipulation of DNA, which might hold personal significance to them or others.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Students will have an opportunity to learn how people of color, such as Flossie Wong-Staal, have made major contributions to science. Throughout the lesson there are opportunities for the teacher to call out when resources and technology have been created by culturally diverse scientists, students, and researchers. This affirms students' cultural connections and encourages acceptance of equal standards of recognition in our communities.

ADVANCING INCLUSIVE RESEARCH

In this lesson, students examine data from clinical trials in order to understand how slight differences in DNA can lead to big differences in reactions to new therapies. Through this activity, they gain insight into why it is important to have a diverse array of clinical trial participants in order to effectively assess a treatment's effectiveness.

COMPUTATIONAL THINKING PRACTICES

In this lesson, students develop a more granular understanding of how DNA can be separated into component parts and used to design treatments and therapies. As students learn about gel electrophoresis, they use the computational thinking strategy of decomposition to examine short sequences of DNA. Then, they use the computational thinking strategy of abstraction to isolate a particular DNA sequence. Finally, students rely on the computational thinking strategy of analyzing data to examine how people with different sequences of DNA react differently to therapies.

CONNECTIONS TO THE PRODUCT LIFE CYCLE

This lesson focuses on the **development** aspect of the product life cycle as students investigate different techniques of DNA separation. Only through understanding the essentials of DNA can students hope to ultimately comprehend how DNA can be used to cure diseases. Through the integration of authentic role plays, students will develop the skills and dispositions necessary for success in a career that plays a role in the product life cycle.

Have you ever wondered…

Why are nucleic acids so special?

All living organisms on earth have nucleic acids. In fact, nucleic acids are one of the characteristics of living things. Nucleic acids are composed of monomers called nucleotides. The nitrogen bases in nucleotides are complementary to each other. Adenine will form hydrogen bonds with thymine in DNA or uracil in RNA. Guanine will form hydrogen bonds with cytosine. This is what makes DNA universal. DNA follows these rules in every organism, from bacteria to animals. That is how genetic engineering and modification are possible!

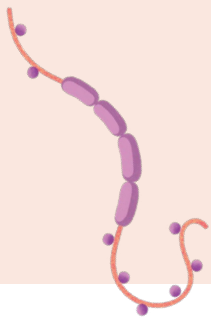
Who was the first scientist to discover DNA?

In 1869, a Swiss chemist named Friedrich Miescher was the first to discover nucleic acids. Miescher discovered a substance containing both phosphorus and nitrogen in the nuclei of white blood cells found in pus.

MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

It is important to understand how DNA can be isolated and purified from cells in order to then comprehend how DNA can be used to prescribe specific medications to patients. Scientists can use the structure of DNA to build an understanding of how drugs work on cells and in different parts of the body, and to investigate the challenges of getting drugs to specific parts of the body.



How does this connect to careers?

Laboratory technicians analyze samples such as body fluids and chemicals. Some are specifically tasked with extracting RNA and DNA in labs. They assist scientists with keeping records and conducting tests.

Molecular biologists understand the structure and role of macromolecules such as DNA, RNA, and proteins within cells. They publish articles on their findings and collaborate with other scientists such as chemists, biologists, and biochemists.

How does this connect to our world?

Various nucleic acid-based tests have been cleared and approved by the Food and Drug Administration's Center for Devices and Radiological Health (CDRH). These tests analyze variations in the sequence, structure, and expression of DNA and RNA to diagnose disease, medical conditions, and infection with an identifiable pathogen, or to help determine genetic carrier status.

Day 1

LEARNING OUTCOMES

Students will be able to:

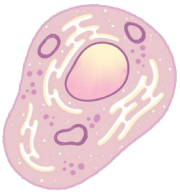
Conduct a virtual lab to extract DNA from a cheek cell.

Identify reasons why scientists isolate and extract DNA.

Describe the steps involved to purify DNA.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

These type of teaching strategies are excellent for cooperative teaching. This empowers culturally diverse students to take part in group activities. The Four Corners strategy helps students develop listening, critical thinking, and decision-making skills within a safe activity. According to eHow.com, this strategy "works well to engage all students in conversations about controversial topics."



Procedure

Whole Group (10 minutes)

Students will participate in a *Four Corners* activity to determine prior knowledge. Post the letters A, B, C, D in each corner of the room. Display the following questions and have students walk to the corner of the room that they think represents the correct answer. Have students discuss with each other why they selected that particular answer and not the others. One student from each corner will explain to the whole class why their group selected that answer. After listening to all the group explanations, students may change their location to a different answer. This will act as a simple poll of what the class has decided is the correct answer, based on the explanations they heard. Share the correct answer with them before continuing to the next question.

1 Which of the following is NOT a potential source of DNA for analysis?

a. hair roots

b. red blood cells

Explanation: Although blood is an excellent source of DNA, the DNA does not come from the red blood cells, as these cells have no nuclei. Rather, the DNA comes chiefly from white blood cells in the blood.

c. epithelial cells in urine

d. saliva

2 Which element does DNA have that proteins, lipids, and carbohydrates do not?

a. hydrogen

b. oxygen

c. sulfur

d. phosphorus

Explanation: Hydrogen and oxygen can be found in all macromolecules, sulfur can be found in certain proteins, but phosphorus can only be found in nucleic acids.

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Day 1

Continued

Procedure

3 Which statement is incorrect?

a. DNA can only be found in the nucleus of a eukaryotic cell.

Explanation: During cell division the nuclear envelope disappears and DNA is found outside of the nucleus. Both mitochondria and chloroplasts contain DNA.

b. RNA can be found both inside and outside the nucleus of eukaryotic cells.

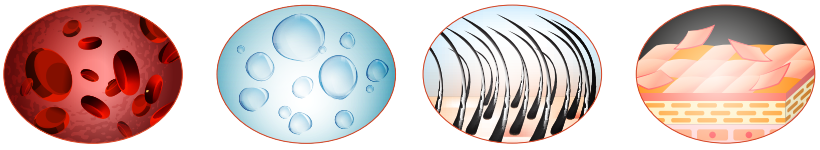
c. In prokaryotes, DNA is found freely in the cytoplasm.

d. Viruses can have single-stranded DNA as their genome.

Small Group (30 minutes)

1 Distribute the *DNA Extraction—Virtual Lab Capture Sheet* to each student and review the directions. Explain that they will work with a partner to complete the *DNA Extraction Virtual Lab*.

Major sources of DNA



Blood | Saliva | Hair | Skin cells

2 To facilitate cooperative learning, consider providing only one source of technology to each pair of students. This will drive students to work together and proceed through the virtual lab at the same pace.

Individual Work (5 minutes)

1 Have students complete a *3-2-1 Bridge* style exit ticket on a sheet of notebook paper using their capture sheet from the DNA extraction virtual lab as a resource. Students should complete the following:

a. Identify three reasons to extract DNA from a cell.

b. Describe the steps in the following two processes: DNA purification and DNA extraction.

c. Ask one question that you have after completing this virtual lab today.

INDUSTRY AND CAREER CONNECTION

In this activity, students will discuss the importance of using specific laboratory equipment and chemicals as it relates to the structure of DNA. Students will need to display resilience and cooperation while working in small groups.

Day 2

Procedure

LEARNING OUTCOMES

Students will be able to:

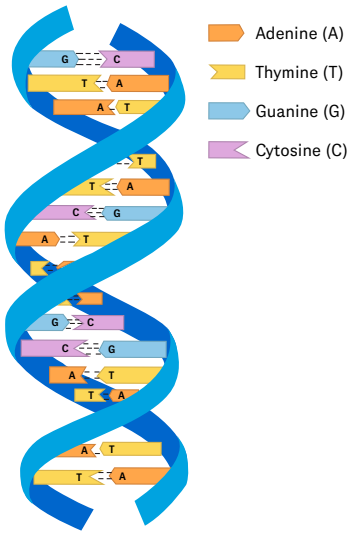
Demonstrate how restriction enzymes cut DNA by locating restriction sites.

Describe how the chemical structure of DNA allows it to be separated using electricity.

COMPUTATIONAL THINKING IN ACTION

Examining the structure of DNA is one way to use the computational thinking strategy of decomposition. This important strategy involves breaking something down into its component parts in order to solve problems and gain understanding.

DNA double helix



Teacher Note > *On Day 1, students learned how to isolate DNA. Today students will discover how isolated DNA can be cut using restriction enzymes.*

Whole Group (15 minutes)

1 Begin class by projecting the image of *Examining the Structure of DNA*. You can also make copies for each student. Explain that the chemical structure of DNA allows it to be separated using electricity in a process called gel electrophoresis. Invite students to work with a partner to examine the structure of DNA and answer the following questions.

- Explain why the shape of DNA is referred to as a double helix.

Answer: DNA has two sugar-phosphate backbones that coil around itself. The monomer—building block—of a nucleic acid is a nucleotide.

- Identify the three components of a nucleotide.

Answer: Sugar (deoxyribose), phosphate, nitrogenous base

- Identify the four nitrogen bases found in DNA.

Answer: Adenine, thymine, guanine, and cytosine

- Identify which base pairs always form hydrogen bonds with each other?

Answer: Adenine pairs with thymine and guanine pairs with cytosine.

- Describe the location of the nitrogen base pairs—are they found in the middle of the helix or on the outside?

Answer: The nitrogenous base pairs are located in the middle of the double helix.

- Identify the two components of a nucleotide that make up the backbone of the DNA molecule.

Answer: Sugar and phosphate

- What charge do the phosphates have in the DNA molecule?

Answer: Phosphates have a negative charge.

2 Invite students to share their answers with the class, making any necessary corrections. Ask students to predict how electricity could separate DNA if it were cut into several pieces. Some students may remember that like charges repel and opposite charges attract. Explain that students are going to model the process of gel electrophoresis by building on their knowledge of restriction enzymes from Lesson 2.

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Day 2

Continued

Procedure

COMPUTATIONAL THINKING IN ACTION

As students learn about restriction enzymes, they are seeing how bioengineers use the computational thinking strategy of decomposition to identify a particular sequence of DNA and the strategy of abstraction to isolate the sequence through gel electrophoresis.

Whole Group (10 minutes)	
1	Review that restriction enzymes (also called restriction endonucleases) are proteins that are naturally found in bacteria and are used to cut up foreign DNA, which eliminates infecting organisms like viruses.
2	Some restriction enzymes create staggered cuts in the DNA producing ends with single-stranded DNA overhangs (often referred to as sticky ends), while others create blunt ends with no overhangs.
3	Each enzyme recognizes and cuts specific DNA sequences. For example, BamHI recognizes the double-stranded sequence: 5'—G/GATCC—3' 3'—CCTAG/G—5'
4	When BamHI recognizes and cuts this site, it always does so in a very specific pattern that produces ends with single-stranded DNA overhangs. Demonstrate how to find the restriction site in the following segment of DNA using the BamHI enzyme. Also show students where the DNA would be cut. TTACGTTAGGATCCGGCATT AATGCAATCCTAGGCCGTAA TTACGTTAG GATCCGGCATT AATGCAATCCTAG GCCGTAA
5	Ask students to identify how many segments of DNA there are after using BamHI.
6	Explain that scientists often use several restriction enzymes at the same time to cut DNA into multiple fragments that could be separated using electricity.

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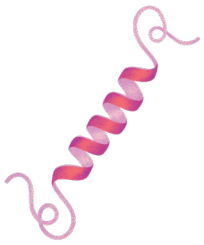


Day 2

Continued

Procedure

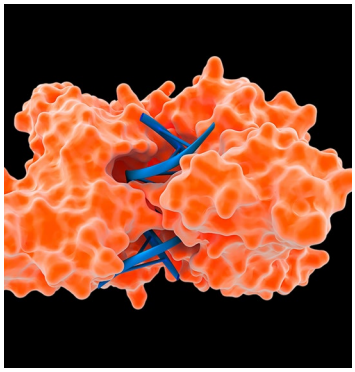


Image shows an illustration of a restriction enzyme.

Small Group (20 minutes)	
1	Students will work with a partner to identify restriction enzyme patterns and demonstrate where each restriction enzyme would cut the DNA. Distribute the *Restriction Enzyme Practice Capture Sheet* to each student and read the introduction and instructions. Explain that students will:
	a. Use the restriction enzymes Bam HI, Hin dIII, and EcoRI to identify and label the sites where each would cut the DNA sequence provided.
	b. Record the number of cuts, the number of fragments, and the length of each fragment created by each of the three enzymes.
	c. Using the data collected, draw the banding patterns that would result if these fragments were run on an electrophoresis gel.
2	Circulate around the room to help students find restriction sites, count the length of DNA fragments, and answer questions.
3	Have students compare answers with three other students to determine the accuracy of their results.
4	Explain that in the next class session, they will explore how the process of gel electrophoresis separates the DNA fragments that they created with their restriction enzymes in today's activity.

Teacher Note > *Collect the Restriction Enzyme Practice capture sheet as an exit ticket to informally assess whether students grasped the content and where reteaching may be necessary.*

Day 3

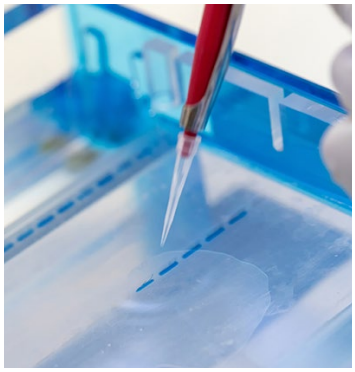
Procedure

LEARNING OUTCOMES

Students will be able to:

Describe the process of gel electrophoresis.

Explain the forensic, medical, and evolutionary applications of gel electrophoresis.



Teacher Note > *On Day 2, students cut isolated DNA into fragments and demonstrated where each fragment could be found in a gel based on size. Today, they will investigate how the segments were separated based on size by exploring gel electrophoresis.*

Small Group (5 minutes)

1 Invite students to examine the DNA fragments that were placed on the electrophoresis gel from their activity in the previous class session. Have students work with the same partner as before to answer the following questions:

a. What charge does DNA have, negative or positive? What component of the nucleotide gives DNA its charge?

Answer: negative charge, phosphate group

b. Electricity is used to separate fragments of DNA. At which end of the gel would you place the negative electrode? The positive? Add a positive and negative sign to each end of the gel.

Answer: The negative sign should be added to the start side and the positive sign should be added on the opposite side.

c. What size of DNA fragments traveled the farthest in the gel?

Answer: smaller fragments

2 Using *Pick a Stick* or another equitable calling strategy, randomly call on students to share their answers and scientific reasoning with the class.

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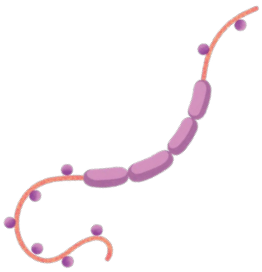
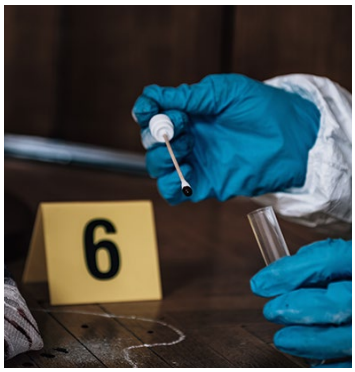


Day 3

Continued

Procedure



Individual Work (20 minutes)

1 Explain to students that they will sort and measure DNA strands by running their own virtual gel electrophoresis. Show students what the *Gel Electrophoresis Virtual Lab* looks like. Also point out the yellow section on the bottom of each page. Instruct students to read each section carefully before moving forward. Many may want to start moving forward immediately when they access the lab. If they miss an important piece of information, however, and click the back button, in some sections it may force them to complete the section again.

2 Explain that students will work with a partner to complete the virtual lab. After they are finished, they will use this information to answer paternity, forensic, and species identification questions.

3 Distribute the *Gel Electrophoresis Virtual Lab Capture Sheet* to each student and review the directions. Circulate around the room to help students with any questions.

Whole Group (15 minutes)

Teacher Note > *It is important to note that before DNA from a crime scene can be analyzed and compared to exemplars, it must first be extracted—and subsequently purified and amplified.*

1 Explain to students that DNA is often left behind at a crime scene. It is present in all kinds of evidence, including blood, hair, skin, saliva, and semen. Scientists can analyze the DNA in evidence samples to see if it matches a suspect's DNA.

2 Distribute the *Analyzing the Results of Gel Electrophoresis Capture Sheet* to each student. Read scenario number 1 and invite students to identify the car thief and provide evidence for their claim. Ask for a volunteer to share their claim and evidence.

COMPUTATIONAL THINKING IN ACTION

Here, students are using the computational thinking strategy of abstraction to "zoom in" on the small bits of DNA sequences that make individuals and species unique.

Continues next page >

Day 3

Continued

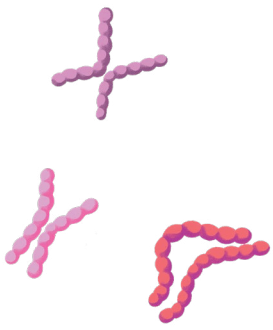
Procedure

3	Explain to students that everyone, except identical twins, has a unique set of DNA. You inherit half your DNA from each biological parent. Your DNA is more than 99.9% the same as your biological parents. Your DNA is more similar to your biological grandparents or other biological relative than to that of a random stranger. Paternity tests are used to determine a biological parent. There are other DNA tests that can help identify biological parents or other biological family members.
4	Read scenario number 2. Have students examine the fragments of DNA created by the restriction enzymes to see if it looks like a combination of the two biological parent's DNA. Invite students to determine whether the person is the biological parent of the child by justifying their claim using evidence from the gel. Use a non-volunteerism strategy, like *Pick a Stick*, to call on a student to share their claim and evidence.
5	Explain to students that DNA fingerprints can also be used to identify evolutionary relationships between different species. Read scenario number 3. Invite students to determine which species of bear is more closely related to the common ancestor. Call on a student using *Pick a Stick* to share their claim and evidence.

Teacher Note > *This activity can be jigsawed or organized as stations.*

Individual Work (5 minutes)

As an exit ticket, in their design journal, have students develop a *brief constructed response* explaining how the use of restriction enzymes and the structure of DNA facilitate the process of gel electrophoresis.



Day 4

Procedure

LEARNING OUTCOMES

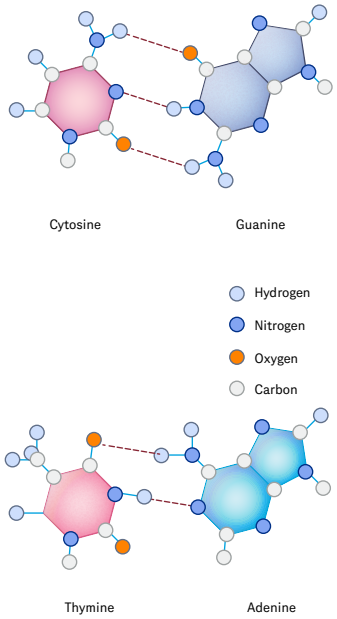
Students will be able to:

Identify single nucleotide polymorphisms (SNPs) in DNA sequences for 14 patients.

Categorize DNA sequences into haplotypes based on similar SNP sequences.

Prescribe a medication to a fictitious patient based on their DNA sequence.

Nucleotides



Teacher Note > *Students have learned how to isolate and purify DNA. They have explored how DNA can be separated and analyzed in paternity, forensic, and evolutionary applications. Today they will explore a medical application of DNA purification.*

Whole Group (10 minutes)

1 Begin class by using a *Stand and Share* protocol to ask the class the following questions:

- **a.** Do you know anyone who is allergic to any medications?
- **b.** Have you, or someone you know, ever had an adverse reaction to a medication?
- **c.** Have you, or someone you know, ever taken a medication that didn't work that well?
- **d.** Can DNA help doctors choose the right treatment for each individual?

2 Distribute a copy of the *Pharmacogenomics Video Capture Sheet* to each student. Ask students to read each statement and predict if it is true or false.

3 Watch the video *Pharmacogenomics: The Right Drug, for the Right Patient, at the Right Dose*. Instruct students to write the correct answers on the capture sheet while they watch the video. Review the correct answers after the video is complete.

Teacher Note > *English language learners may have difficulty with some of the vocabulary present in the video. Provide definitions for challenging words such as pharmacogenomics and genetic variation. Selecting closed captions is also a useful strategy.*

Whole Group (5 minutes)

Explain to students that people respond differently to medications. Discuss the various responses or reactions to drugs or vaccines. Some people die from adverse drug reactions, others have serious side effects, and others have no problems at all. Scientists, physicians, and the pharmaceutical companies think that variation in response to drugs could be due to genetic variation. Pharmacogenetics aims to figure out how an individual's genetic make-up might correlate to their reaction to specific drugs. With genomics and other biotechnology tools (such as microarrays), pharmacogenetics is playing an increasingly dominant role in precision medicine. If pharmacogenetics is successful, in the future a physician might prescribe a course of treatment based on an individual's genotype.

Continues next page >

Day 4

Continued

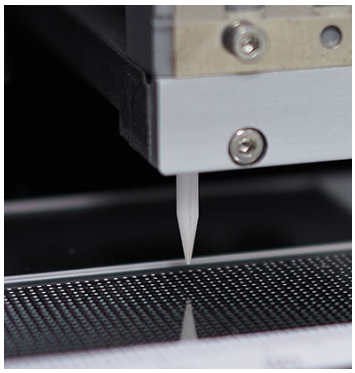
Procedure

COMPUTATIONAL THINKING IN ACTION

Here, students are using the computational thinking strategy of analyzing data to review how different patients reacted to abuterol.

Small group (25 minutes)	
1	Distribute *SNP Analysis, Haplotypes and Pharmacogenetics* and read the directions. Place students into small groups of three and distribute highlighters and scissors to each student.
2	In step one, students will find SNP locations in a region of DNA for 14 patients.
3	In step 2, students will create haplotype groups by looking at a number of SNPs in a particular region of DNA. People with the same SNPs in that region are placed in the same haplotype group.
4	In step 3, students will examine data from a study to determine how each haplotype responded to the albuterol.

Individual Work (5 minutes)	
1	To close the activity, have students analyze a sample of DNA from a patient and determine if they would prescribe albuterol for the patient. Collect the students' capture sheets, review their responses, and use this as a formative assessment to determine if reteaching is required.
2	If students need additional help, they can review the step-by-step process using this online resource *Making SNPs Make Sense*.



Day 5

LEARNING OUTCOMES

Students will be able to:

Describe the step-by-step process of DNA extraction.

Identify and **describe** a medical application using extracted DNA.

Identify and **describe** a forensic application using extracted DNA.

Identify and **describe** an agricultural application using extracted DNA.

Create an infographic summarizing DNA extraction and its applications to society.

Procedure

Teacher Note > *Students have learned many different applications of using DNA that has been isolated and purified. Today, they will synthesize their understanding by describing examples of each application.*

Small Group (15 minutes)

1 Inform students that many crucial discoveries and breakthroughs in the field of biology, and specifically molecular biology, are due to significant contributions of people of color. Many of their contributions have led to modern science, treatments, and medications we use today. Ernest E. Just was an early 20th-century African American biologist who contributed to various areas of biology. Many of his contributions are still not fully appreciated today. Explain to students that they will have the opportunity to learn about one individual today. However, encourage them to learn more about scientists, like Just, who are still not well-known even though they made large contributions to their fields of study.

2 Divide students into groups of four. Students will use the *Placemat* strategy to answer questions about the text individually, and use the center area to write answers the group decides are most interesting. Have students read the online article *In Memoriam: Flossie Wong-Staal, Ph.D. | Center for Cancer Research* individually to answer the following questions on their portion of the placemat.

a. What was her major accomplishment, according to the article?

Answer: She was a major figure in the discovery of HIV and the first person to clone the virus.

b. Describe two personal characteristics that helped Flossie in her career.

Answers will vary. Sample answers might include entrepreneurial spirit and graduated cum laude.

Continues next page >

Day 5

Continued

Procedure

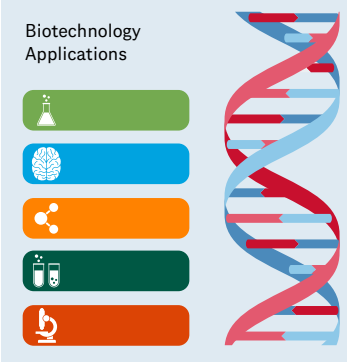
c. What are three things that stood out to you while reading this article?

Answers will vary. Sample answer: Education was very important. She started her own research company. She was an immigrant.

d. Develop one question that you would have asked Flossie if you could interview her.

Answers will vary. Sample answer: What prompted your interest in science?

3 Have each group share one item from the center of their placemat.



Individual Work (25 minutes)

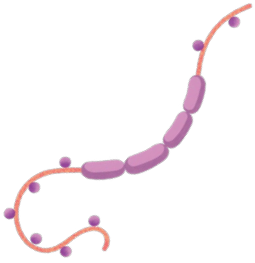
Explain that in this session students will create an infographic that demonstrates their understanding of the various applications for the use of isolated and purified DNA. Distribute the *Biotechnology Applications Infographic Assignment* and review the objective, assignment criteria, and grading rubric. Links are provided on the student resource that will help students with their research. You can provide additional resources if necessary.

Individual Work (5 minutes)

Invite students to use their **Design Journal** to capture how content learned in this lesson connects to the overarching problem they are investigating. Students should summarize how gel electrophoresis can use the properties of DNA to create a DNA fingerprint. They can also explain how DNA can be used to prescribe specific medicine to patients.

The following links provide opportunities for exploration into molecular biology:

Molecular Biology
Science Article
Studies from Schier Lab Featured in Science Breakthrough of The Year



National Standards

Next Generation Science Standards

LS1.A: Structure and Function
Systems of specialized cells within organisms help them perform the essential functions of life. All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.

Science and Engineering Practices
Developing and using models
Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Crosscutting Concepts
Structure and Function
Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Scale, Proportion, and Quantity
Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

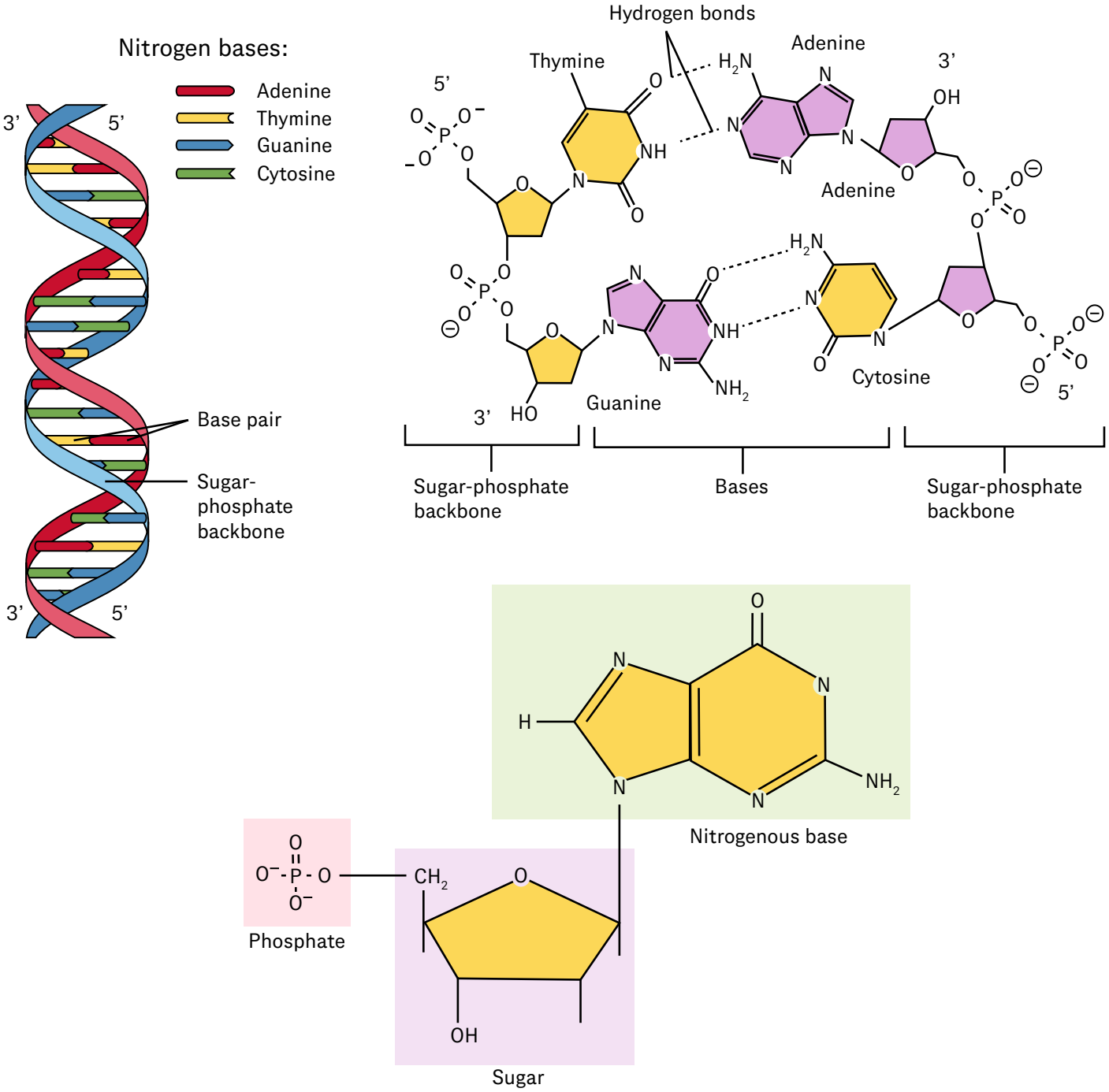
Career and Technical Education (CTE)

A3.3
Employ standard techniques of DNA extraction, purification, restriction digests, bacterial cell culture, and agarose gel electrophoresis and document and evaluate results.

A3.5
Predict outcomes of DNA and protein separation protocols.

Educator Resources

Examining the Structure of DNA



Gel Electrophoresis Virtual Lab

ANSWER KEY **Do not share with students**

Directions
Use the Gel Electrophoresis Virtual Lab link to answer the following questions.

1. Scientists use gel electrophoresis whenever they need to sort DNA molecules by

length

2. Describe the "gel" that is used in this process.

It is a rectangular piece of gel that acts as a filter to sort the DNA strands.

3. After DNA is loaded into the holes (wells) at one end of the gel, what makes the DNA molecules move through the gel filter?

An electric current pushes the DNA molecules through the gel from one side to the other. (DNA molecules have a negative charge and are attracted to the opposite, positive side of the gel.)

4. Describe how the movement through the gel of short DNA strands differs from medium and long strands. How does this "sort out" the DNA strands of various lengths?

The short strands can squeeze through the gel more easily than longer strands. In a given amount of time, the short strands are able to travel farther across the gel than medium and large strands. When the electricity stops, the strands stop at a position on the gel and have been separated based on size.

5. After the DNA strands are sorted out by length, why is the gel stained? Are individual DNA molecules visible?

The stain allows the DNA strands to be seen where they stopped in the gel. The stain reveals groups of DNA strands that are the same length, not individual molecules.

6. List the five major steps required to do the entire gel electrophoresis procedure.

First, make the gel.
Second, set up the apparatus.
Third, load the DNA sample into the gel.
Fourth, hook up the electrical current and run the gel.
Fifth, stain the gel and analyze the results.

Continues next page >

Gel Electrophoresis Virtual Lab

ANSWER KEY **Do not share with students**

Continued

Run the Gel, Steps 1–5

1. To make a gel, agarose and buffer are added to a flask. The mixture is heated, allowed to cool, and poured into a plastic tray called a mold. The ends of the mold have been taped to prevent the melted agarose from spilling out. A plastic comb is placed into the gel at one end to make a series of holes called wells. The DNA samples will be loaded into the wells.

   Please note: It is important to remove air bubbles before the gel has a chance to cool. Bubbles will interrupt the movement of DNA during electrophoresis.

2. Buffer is poured into the electrophoresis box. The mold containing the gel is just barely in the buffer. The buffer conducts electrical current and keeps the gel from drying out.

3. A clean tip is placed on the micropipette. Loading dye is added to the DNA sample. The micropipette is then used to load the DNA sample into a well on the gel. The DNA size standard is loaded into an adjacent well. The size standard contains DNA strands of known length and provides a reference by which to estimate the size of stands in the sample.

4. The gel box is plugged into a power supply with a red and a black cord. The black end generates a negative charge and the red end generates a positive charge. All DNA strands have a negative charge. Once the power is on, all the DNA strands move through the gel towards the positive charge at the other end of the gel. Short DNA strands move through the gel more quickly than long strands. The shorter stands will migrate farther than the longer strands.

5. The gel is taken out of the electrophoresis box, carefully rinsed with water, and then stained. The stain binds to groups of DNA strands. These groups of DNA strands will show up as bands on the gel when viewed with UV light. The three bands represent groups of DNA strands of the following sizes: 6000, 3500, and 1500

   In DNA analysis, the band pattern created by a DNA sample is called a "DNA profile" or "DNA fingerprint".

Analyzing the Results of Gel Electrophoresis Capture Sheet

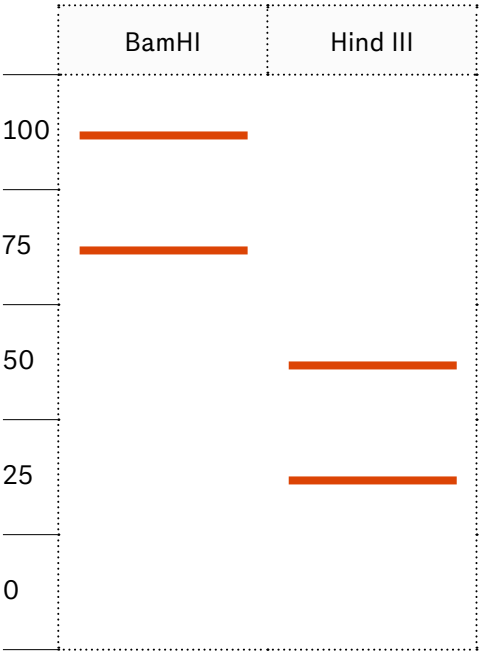
ANSWER KEY **Do not share with students**

Directions
Read the scenarios as part of you class discussion. Respond to each italized statement *and provide evidence for your claim.*

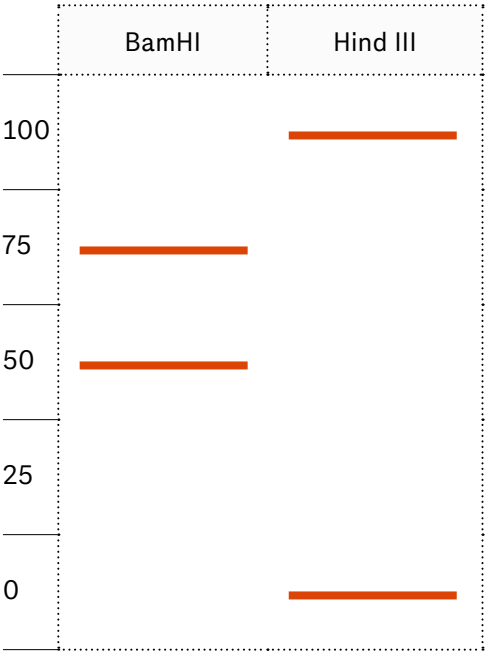
Case # 1 *(Forensic Application)*

A stolen car was found on the side of the road with an empty bottle of soda. Detectives were able to collect enough DNA from the saliva left on the top of the bottle. Below are the results of the gel electrophoresis from the crime scene and two suspects who were seen near the abandoned car. *Identify the car thief and justify your response using data from the gel electrophoresis.*

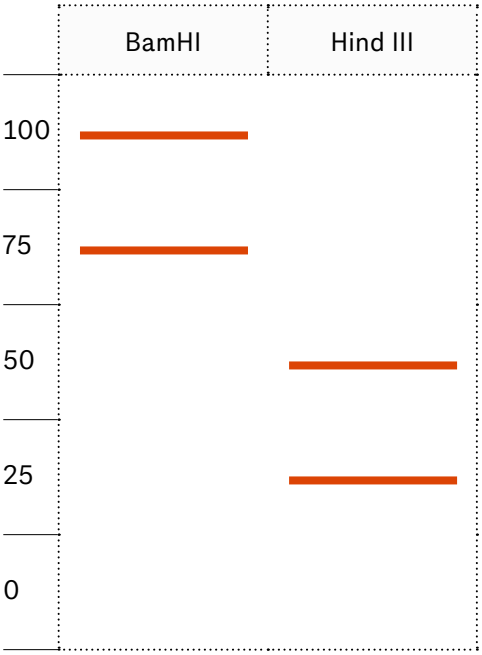
Crime Scene DNA Sample



Shari 'Sticky' Finger



Bobby 'Bandit' Riley



Bobby appears to be the car thief due to the fact that 4/4 of his DNA fragments match the crime scene DNA sample. Shari's DNA only had 2/4 matching fragments.

Continues next page >

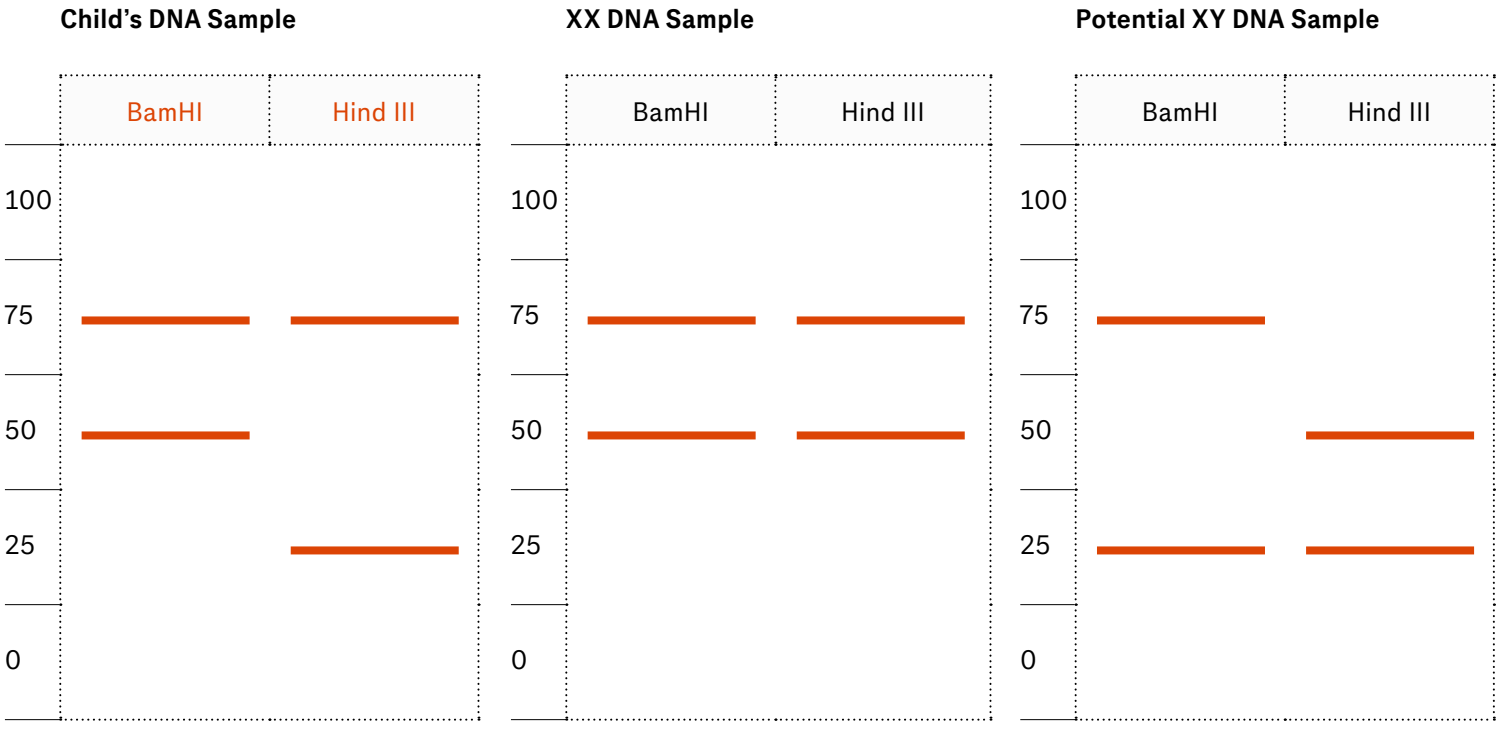
Analyzing the Results of Gel Electrophoresis Capture Sheet

ANSWER KEY **Do not share with students**

Continued

Case # 2 *(Paternity Application)*

A mother files a lawsuit for child support against a person she claims is the XY biological parent of her child. The potential biological parent claims that he does not have biological children. Below are the results of the gel electrophoresis of the child, biological mother, and potential biological parent. *Determine if the potential biological parent is the XY biological parent of the child and justify your response using data from the gel electrophoresis.*



The man is not the child's father because there is no match between the fragments found at 50 bp and 25 bp positions of the specified restriction enzyme.

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Analyzing the Results of Gel Electrophoresis Capture Sheet

ANSWER KEY **Do not share with students**

Continued

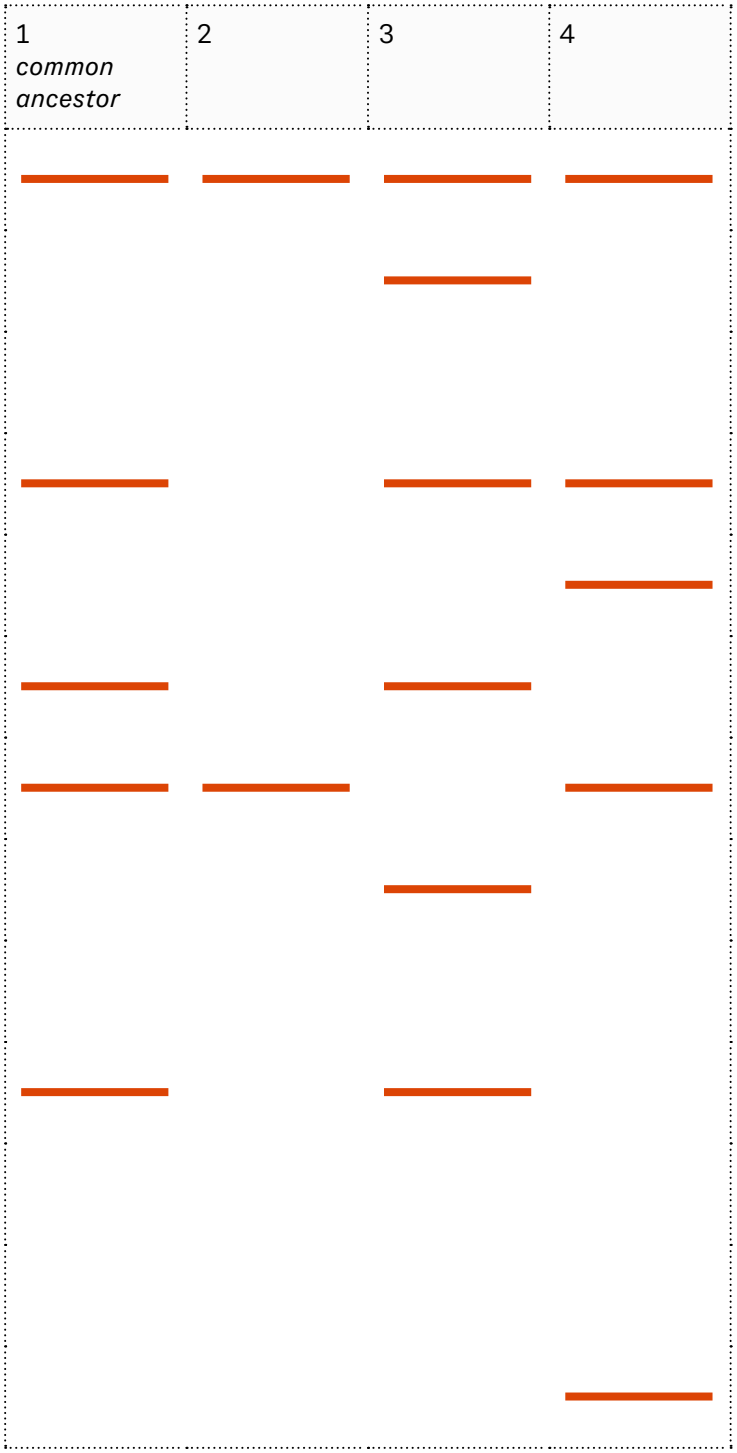
Case # 3 *(Evolutionary Application)*

As species differentiated over evolutionary time, the DNA sequences in their genes acquired slight changes. According to evolutionary theory, these changes accumulate over time: species that diverged from each other long ago have more differences in their DNA than species that diverged recently. Scientists use this degree of difference as a molecular clock to help them predict how long ago species split apart from one another. In general, scientists say the longer ago two species split, the more distantly related they are.

Which species of bear is more closely related to the common ancestor? Provide evidence for your claim.

Bear species #3 seems to be more closely related to the common ancestor because 4/5 fragments match. Bear species #2 only has 2/5 matching fragments and species #4 only has 3/5 matching fragments.

Bear Species



Pharmacogenomics Video Capture Sheet

ANSWER KEY **Do not share with students**

Directions
Before watching the video, read each statement and predict whether it is true or false. While watching the video, determine the correct answer and place it in the last column.

	Statement	My Prediction (True or False)	Actual Answer
1	Research has found all genetic variation possible.		False
2	Genetic variation is responsible for the difference of sensibility for each patient toward a certain drug.		True
3	Pharmacogenomics is the study of RNA in plants.		False
4	When medication is broken down too slowly, it accumulates in the body and causes side effects.		True
5	Pharmacogenomics can identify genes associated with metabolism and how fast the body gets rid of a medication.		True
6	Genetic profiles give information about your chance of being infected by a virus.		False
7	Pharmacogenomics is used to assess the right medication dose for a given patient.		True
8	Psychiatric disorders cannot be treated with pharmacogenomics.		False
9	When the medication is broken down too fast, it is not as effective.		True

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DNA Extraction—Virtual Lab Capture Sheet

Directions

In this virtual laboratory you will perform a cheek swab and extract DNA from human cells. Use the link DNA Extraction Virtual Lab to answer these questions.

Analysis Questions

1. What are three reasons why scientists isolate DNA?

2. What is DNA purified away from in the extraction process?

3. Where is DNA located within a cell? How much DNA is found there?

4. What is the first step in the DNA extraction process?

5. What cells are used in this virtual DNA extraction?

6. List the four major steps used to purify the DNA.

7. What does the term “lysis” mean? What is the purpose of this solution?

Continues next page >

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DNA Extraction—Virtual Lab

Continued

8. Detergent and proteinase K are two chemicals found in the lysis solution. Describe the function of each.

9. What is the purpose of the warm water bath?

10. What is the purpose of the salt solution?

11. What is the function of the centrifuge?

12. What can be found at the bottom of the centrifuge tube?

13. What is the function of isopropyl alcohol in this lab?

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Restriction Enzyme Practice Capture Sheet

Introduction

DNA fingerprinting relies on the fact that the DNA code is universal for all living things and that there are differences between individuals within that code. Because human DNA is very similar to every other human's DNA, DNA fingerprinting primarily focuses on the areas of the genetic code that vary greatly amongst individuals. These non-coding regions of DNA, called introns, have the most variable coding sequences within members of a species because they do not code for proteins.

Scientists use restriction enzymes to cut intron segments of DNA. They "run" the fragments of DNA in a gel electrophoresis, and then use the bonding patterns (created by the fragments) between individuals to determine identity. Uses for DNA fingerprinting include crime scene investigation, missing person identification, paternity testing, diagnosing genetic disorders, species identification, and many others.

Directions

1. *Using the restriction enzymes BamHI, Hind III, and EcoRI, identify and label the sites where each would cut the DNA sequence provided.*
2. *Record the number of cuts, the number of fragments, and the length of each fragment created by each of the three enzymes. Note: To count fragment lengths, only count the number of bases on the longest side of the DNA strand.*
3. *Using the data collected, draw the banding patterns that would result if these fragments were run on an electrophoresis gel.*

Restriction Enzyme	# of Cuts	# of DNA Fragments	Length of each DNA Fragment (bp)
BamHI (red colored pencil)			
Hind III (blue colored pencil)			
EcoRI (green colored pencil)			

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Restriction Enzyme Practice Capture Sheet

Continued

Enzyme	Target Sequence	Cleavage
BamHI	GGATCC CCTAGG	G GATCC CCTAG G
Hind III	AAGCTT TTCGAA	A AGCTT TTCGA A
EcoR I	GAATTC CTTAAG	G AATTC CTTAA G

Note > *The DNA sample is one continuous strand, but is presented in six sequences to save paper.*

1		2		3		4		5		6	
T	A	G	C	T	A	T	A	G	C	T	A
G	C	A	T	T	A	T	A	T	A	T	A
G	C	G	C	C	G	C	G	A	T	C	G
G	C	A	T	G	C	G	C	T	A	G	C
C	G	T	A	A	T	T	A	T	A	A	T
C	G	T	A	A	T	C	G	C	G	A	T
T	A	C	G	G	C	C	G	G	C	C	G
A	T	T	A	G	C	T	A	A	T	G	C
G	C	T	A	T	A	T	A	A	T	G	C
G	C	A	T	A	T	A	T	C	G	G	C
C	G	A	T	C	G	A	T	T	A	G	C
A	T	G	C	A	T	G	C	C	G	C	G
C	G	T	A	C	G	C	G	C	G	C	G
A	T	C	G	C	G	T	A	T	A	C	G
T	A	A	T	T	A	T	A	T	A	T	A
T	A	A	T	A	T	T	A	A	T	A	T
C	G	G	C	G	C	T	A	A	T	G	C
G	C	C	G	G	C	A	T	G	C	G	C
A	T	A	T	C	G	A	T	A	T	A	T
A	T	G	C	T	A	A	T	A	T	C	G
G	C	G	C	C	G	T	A	T	A	C	G

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Restriction Enzyme Practice Capture Sheet

Continued

Results

Draw the fragments created by each restriction enzyme in the diagram below.

		BamHI	Hind III	EcoRI
		Start	Start	Start
Fragment Length *# of base pairs*	100			
	75			
	50			
	25			
	0			

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Gel Electrophoresis Virtual Lab Capture Sheet

Directions
Use the Gel Electrophoresis Virtual Lab link to answer the following questions.

Introduction
After DNA extraction, analysis usually involves mixing a DNA sample with *restriction enzymes*. The enzymes cut the DNA molecules into fragments of various lengths. Gel electrophoresis sorts out these fragments and displays them as a pattern. This type of analysis produces different patterns for different people. The final pattern is known as the person's *DNA profile*.

1. Scientists use gel electrophoresis whenever they need to sort DNA molecules by:

2. Describe the "gel" that is used in this process.

3. After DNA is loaded into the holes (wells) at one end of the gel, what makes the DNA molecules move through the gel filter?

4. Describe how the movement through the gel of short DNA strands differs from medium and long strands. How does this "sort out" the DNA strands of various lengths?

5. After the DNA strands are sorted out by length, why is the gel stained? Are individual DNA molecules visible?

6. List the five major steps required to do the entire gel electrophoresis procedure.

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Gel Electrophoresis Virtual Lab Capture Sheet

Continued

Run the Gel, Steps 1–5

1. To make a gel, _____ and _____ are added to a flask. The mixture is heated, allowed to cool, and poured into a plastic tray called a mold. The ends of the mold have been _____ to prevent the melted agarose from spilling out. A plastic _____ is placed into the gel at one end to make a series of holes called wells. The _____ samples will be loaded into the wells.

   Please note: It is important to remove air bubbles before the gel has a chance to cool. Bubbles will interrupt the movement of DNA during electrophoresis.

2. _____ is poured into the electrophoresis box. The mold containing the gel is just _____ in the buffer. The buffer conducts _____current and keeps the gel from _____ out.

3. A clean tip is placed on the _____. _____is added to the DNA sample. The micropipette is then used to load the DNA sample into a _____ on the gel. The DNA size standard is loaded into an adjacent well. The size standard contains DNA strands of known _____ and provides a reference by which to estimate the size of stands in the sample.

4. The gel box is plugged into a power supply with a red and a black cord. The black end generates a _____ charge and the red end generates a _____ charge. All DNA strands have a _____ charge. Once the power is on, all the DNA strands move through the gel towards the _____ charge at the other end of the gel. _____DNA strands move through the gel more quickly than _____strands. The shorter stands will migrate _____ than the longer strands.

5. The gel is taken out of the electrophoresis box, carefully rinsed with water, and then stained. The stain binds to _____ of DNA strands. These groups of DNA strands will show up as _____ on the gel when viewed with _____ light. The three bands represent groups of DNA strands of the following sizes: _____, _____, and _____

   In DNA analysis, the band pattern created by a DNA sample is called a "DNA profile" or "DNA fingerprint".

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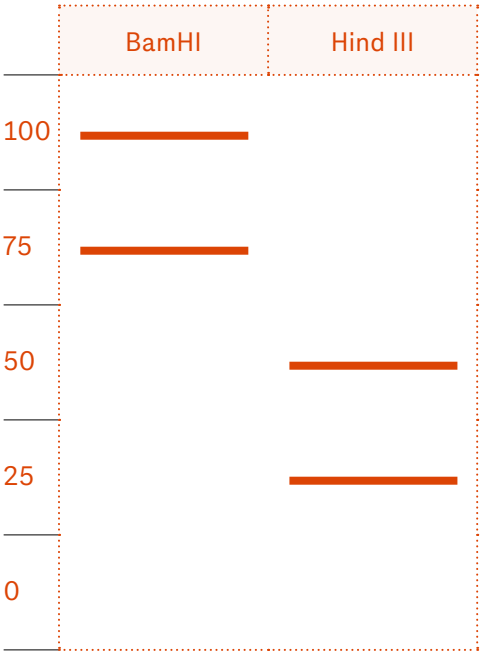
Analyzing the Results of Gel Electrophoresis Capture Sheet

Directions
Read the scenarios as part of you class discussion. Respond to each italized statement *and provide evidence for your claim.*

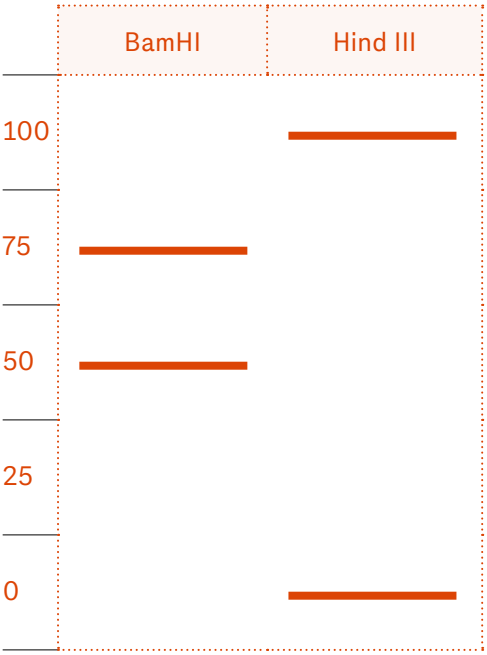
Case # 1 *(Forensic Application)*

A stolen car was found on the side of the road with an empty bottle of soda. Detectives were able to collect enough DNA from the saliva left on the top of the bottle. Below are the results of the gel electrophoresis from the crime scene and two suspects who were seen near the abandoned car. *Identify the car thief and justify your response using data from the gel electrophoresis.*

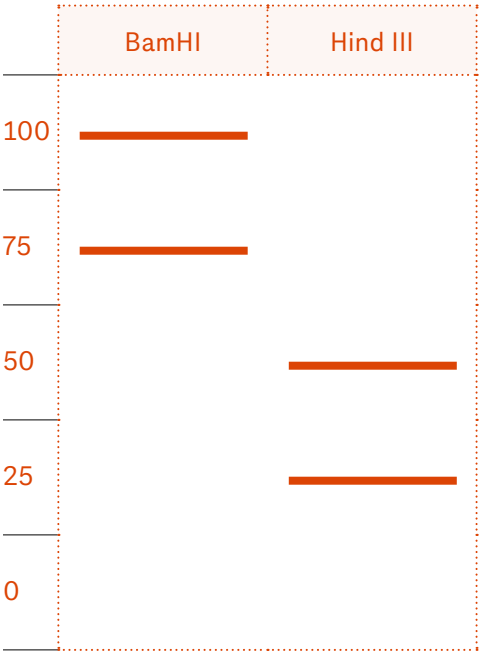
Crime Scene DNA Sample



Shari 'Sticky' Finger



Bobby 'Bandit' Riley



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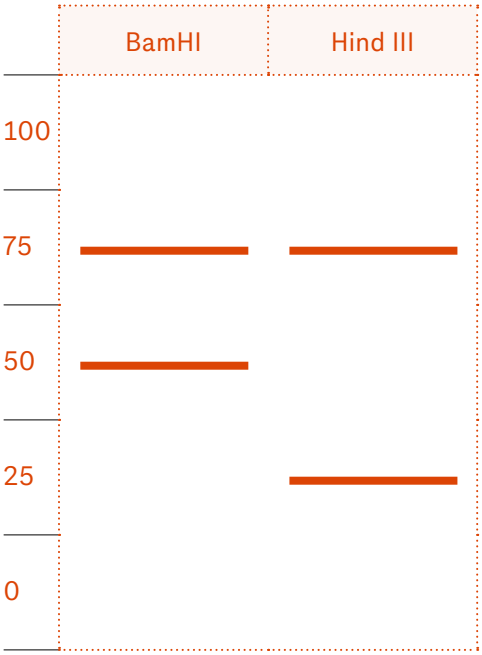
Analyzing the Results of Gel Electrophoresis Capture Sheet

Continued

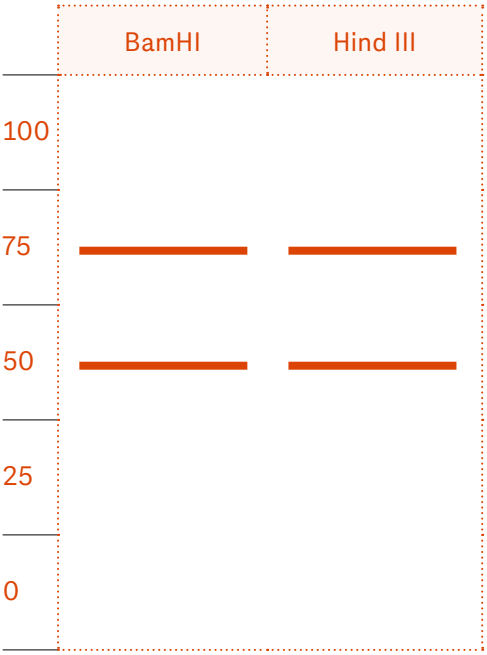
Case # 2 *(Paternity Application)*

A mother files a lawsuit for child support against a person she claims is the XY biological parent of her child. The potential biological parent claims that he does not have biological children. Below are the results of the gel electrophoresis of the child, biological mother, and potential biological parent. *Determine if the potential biological parent is the XY biological parent of the child and justify your response using data from the gel electrophoresis.*

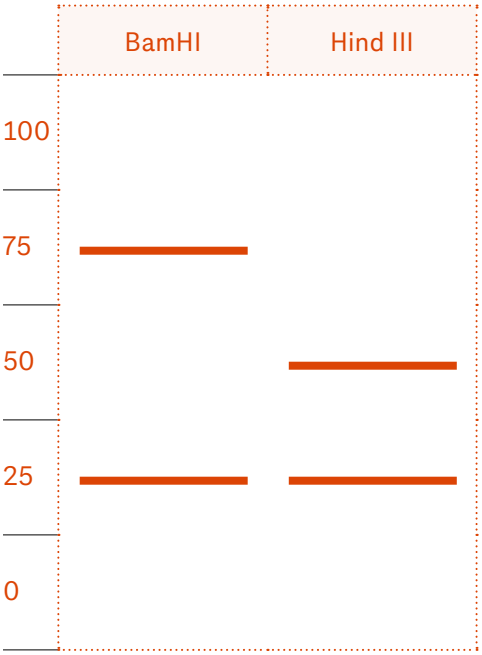
Child's DNA Sample



XX DNA Sample



Potential XY DNA Sample



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Analyzing the Results of Gel Electrophoresis Capture Sheet

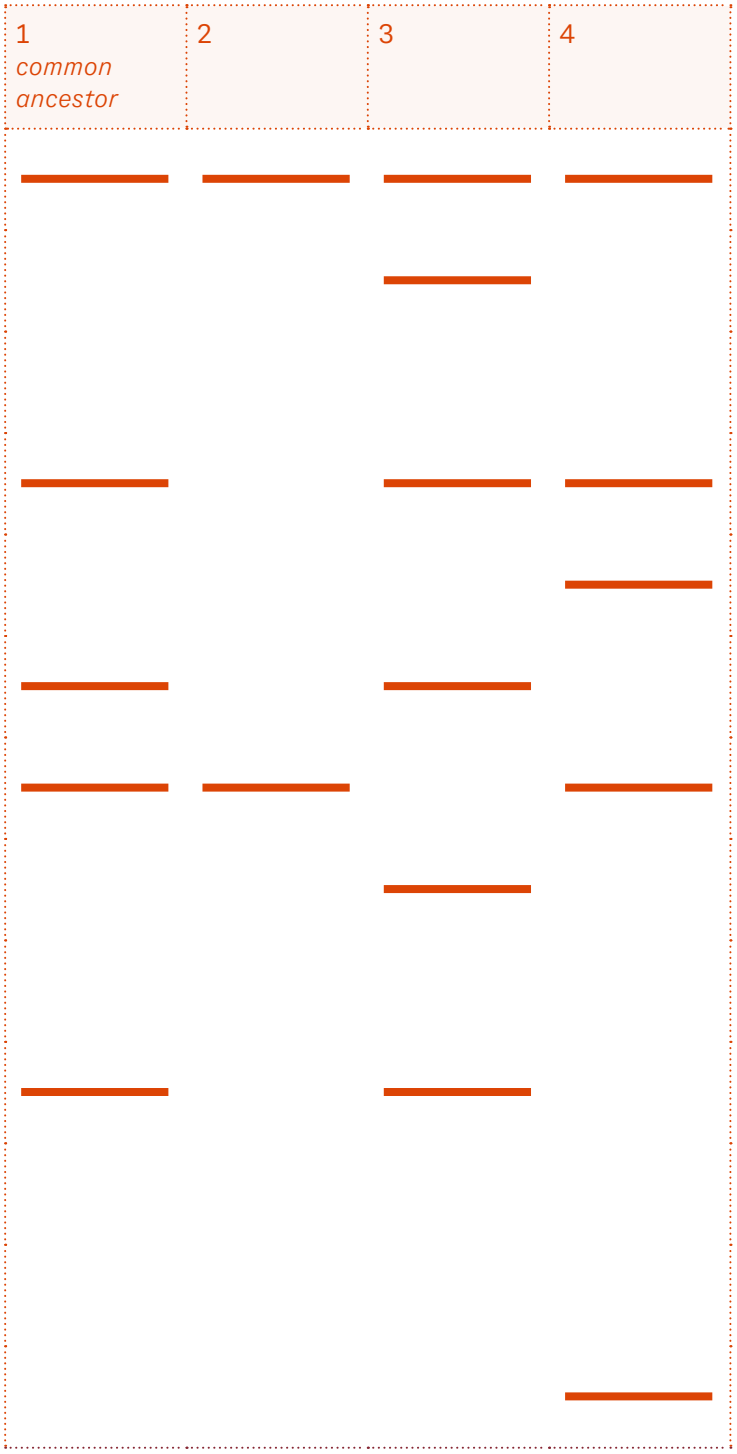
Continued

Case # 3 *(Evolutionary Application)*

As species differentiated over evolutionary time, the DNA sequences in their genes acquired slight changes. According to evolutionary theory, these changes accumulate over time: species that diverged from each other long ago have more differences in their DNA than species that diverged recently. Scientists use this degree of difference as a molecular clock to help them predict how long ago species split apart from one another. In general, scientists say the longer ago two species split, the more distantly related they are.

Which species of bear is more closely related to the common ancestor? Provide evidence for your claim.

Bear Species



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Pharmacogenomics Video Capture Sheet

Directions
Before watching the video, read each statement and predict whether it is true or false. While watching the video, determine the correct answer and place it in the last column.

	Statement	My Prediction (True or False)	Actual Answer
1	Research has found all genetic variation possible.		
2	Genetic variation is responsible for the difference of sensibility for each patient toward a certain drug.		
3	Pharmacogenomics is the study of RNA in plants.		
4	When medication is broken down too slowly, it accumulates in the body and causes side effects.		
5	Pharmacogenomics can identify genes associated with metabolism and how fast the body gets rid of a medication.		
6	Genetic profiles give information about your chance of being infected by a virus.		
7	Pharmacogenomics is used to assess the right medication dose for a given patient.		
8	Psychiatric disorders cannot be treated with pharmacogenomics.		
9	When the medication is broken down too fast, it is not as effective.		

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Biotechnology Applications Infographic Assignment

Objective
Today, you will develop an infographic on how the use of biotechnology has benefited society.

Assignment Criteria

1. Describe the process of DNA extraction.

2. Describe three different applications for the use of the extracted DNA. Describe the purpose of CRISPR.

    a. *Forensic Application*
    Describe how DNA profiling has helped to acquit or convict suspects.

    b. *Medical Application*
    Describe a successful use of gene therapy.

    c. *Agricultural Application*
    Describe how insect-resistant crops have benefited farmers.

3. Include pictures and images to help the reader understand the topic.

How to Submit
Use one of the following free infographic sites to select a template to modify and summarize your research.

Canva – Free templates

Piktochart: Create Infographics, Presentations and Reports

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Biotechnology Applications Infographic Rubric

	Score	3	2	1
	Process	The process was accurately described.	The process was described with some small errors.	The process was poorly described.
	Applications	All three applications were included and accurately explained.	Two applications were accurately explained or all three applications were included, but not explained accurately or in enough detail.	One application was explained accurately or in enough detail.
	Visuals	The images provided helped the reader understand each of the topics.	The images provided helped the reader understand some of the topics.	The images provided did not help the reader understand each topic.
	Final Score			