DNA Profiling

Answer Key

Vocabulary: DNA polymerase, DNA profiling, gel electrophoresis, gene, mutation, non-coding region, polymerase chain reaction, primer, short tandem repeat

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
[Note: The purpose of these questions is to activate prior knowledge and get students thinking. Students are not expected to know the answer to the Prior Knowledge Question.]

In 1985, Darryl Hunt was convicted of murder. While Hunt was in jail, a new method for analyzing DNA evidence was invented. The DNA evidence on the victim did not match Hunt's DNA but did match that of another prisoner. After 19 years spent behind bars, Hunt was finally declared innocent and released from prison in 2004.

1. DNA is used to tell people apart. What aspects of DNA do you think make this possible?

   Answers will vary. [Everyone's DNA is a little different. That's what makes people unique. These differences can be used to tell people apart.]

2. What are some possible uses for technology that can identify people based on their DNA?

   Answers will vary. [DNA can be used to identify who was present at a crime scene and can be used to tell if two people are related.]

Gizmo Warm-up
DNA profiling does not just compare people's entire genome side by side. Instead, a very particular part of the DNA is compared. In the *DNA Profiling* Gizmo you will learn about the differences in DNA that make DNA profiling possible and you will use that knowledge to design your own DNA profiling test.

Click on the crime lab in the **Forensic training** section. You are looking at a strand of DNA. DNA contains **genes** and **non-coding regions** between genes. Click on **Non-coding A.**

1. You are looking at a portion of the non-coding A section for three different people. Are these sections the same or different? Explain.

   The sections are all different lengths. The sequence TAAA repeats a different number of times in each person.

2. Click **Previous** then click on **Gene A.** Are there differences in gene A for the three people?

   Gene A in each person is almost identical. They are all the same length. There is one difference (a C/G pair is switched with an A/T pair) in person 2. Teacher note – it is OK if the student doesn't notice the small mutation in person 2.

Activity A: **Forensic training**	Get the Gizmo ready: • Click on **Forensic training** and **Start again**.	

Introduction: In this activity, you will learn about the principles and techniques that make DNA profiling possible. Genes code for specific traits. In people, the DNA sequences for most genes are nearly identical, since any change could result in a harmful disorder. The areas between genes do not code for any essential traits, so a change to the DNA sequence doesn't have any major consequences. As a result, these regions tend to be very different for different people.

Question: How can the differences in DNA be exploited to perform DNA profiling?

1. Observe: Click on **non-coding A.** What do you see in the middle of each of the three DNA sequences? *The sequence TAAA repeats a different number of times in each person.*

2. Compare: Turn on **Show short tandem repeats (STRs)**. An STR is a short, repeated sequence of DNA, like TAAA. They can be repeated any number of times without affecting the traits of the person. Different people usually have different numbers of repeats.

   What does this do to the length of each person's non-coding regions?

   This makes each person's non-coding region a different length.

3. Create: Your goal is to make copies of the STR region. To do this, you will make **primers** that surround the STR region. A primer is a short sequence of DNA that acts as a starting point for DNA replication.

   Click **Next**. Click on person 1's DNA to separate the two strands. Drag along the AAGGC nucleotides, and then the TCGCC nucleotides to create primers. Click **Next**. The Gizmo will add the same primers to the two other people.

   What do you notice about where the primers attach in each person?

   They bind to the same sequences in each person, on either side of the STRs.

4. Observe: Click **Next.** An enzyme called **DNA polymerase** uses the primers as a starting point to copy the DNA. Copying DNA using primers is a technique called **Polymerase chain reaction (PCR)**.

   Click **Next** again. The DNA segments are copied millions of times.

   What do you notice about the lengths of the copied DNA strands?

   Each person's copied DNA strands are a different length.

(Activity A continued on next page)

Activity A (continued from previous page)

5. Compare: Click **Next**. **Gel electrophoresis** is used to separate DNA strands of different lengths. An electric current is passed through the gel. As the current moves from top to bottom, it pulls the DNA and loading dye along with it. Click on the **power box** to turn it on.

   A. Which person's DNA band traveled the farthest? *Person 2* Shortest? *Person 1*

   B. Turn on **Show labels**. What do you notice about the length of the DNA versus the distance it traveled down the gel? *The shortest DNA travels the longest distance and the longest DNA travels the shortest distance.*

   C. Can you identify people by comparing the length of STR regions on a gel? *Yes.*

      Explain. *Each person's STR region is a different length and travels a different distance along the gel, so different people's samples will look different.*

6. Observe: Click **Next**. Then select **Gene A**.

   A. Does gene A have any STRs? *No*

      Because genes are segments of DNA that hold the instructions for producing proteins, they usually don't have large variable regions like STRs.

   B. Are there any differences in gene A between the individuals? *Yes [A small mutation]*

      Genes may contain small **mutations** that don't affect the length of the segment.

   C. Create primers and copy the DNA. What do you notice about the length of the duplicated regions? *The lengths of the DNA strands are the same for each person.*

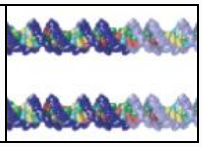
   D. Click **Next** and turn on the gel electrophoresis apparatus. What do you notice about the position of the band? *The bands all travel the same distance down the gel.*

   E. Can you identify people by comparing the length of genes on a gel? *No*

      Explain. *Each person's gel will look identical because the genes are the same length.*

7. Summarize: How can PCR and gel electrophoresis be used to identify people?

   PCR is used to copy the specific segments of DNA that differ between people. Gel electrophoresis is used to visualize the differences. The results are used to tell people apart.

Activity B: **Design and test primers**	Get the Gizmo ready: • Select **Design primers** on the left.	

Introduction: To identify people based on DNA, copies of certain segments of DNA are compared using gel electrophoresis. In this activity, you will design primers that will copy segments of DNA that will help to identify people.

Question: How can you use your knowledge to create a DNA profiling test?

1. Predict: Gel electrophoresis distinguishes DNA segments by length. To identify people by DNA, is it better to make copies of genes or non-coding segments? *Non-coding segments.*

   Explain. *Genes are the same length while non-coding segments are different lengths.*

2. Create: Pick a section of DNA you want to copy and follow the directions to create primers.

   A. Click **Preview primer.** Did the DNA copy properly? *Yes [Answers may vary]*

   B. Do you get segments of DNA that are different lengths for each person? *Yes*

   Click **Save primer** when you are satisfied. Create more primers using other parts of the chromosome. Be sure each primer set copies DNA segments that vary in length.

3. Test: Switch to the **Test primers** section. DNA was isolated from the skin and blood of four different people. Select the primers you created (now in the saved primers section) then click **Run analysis** to run the PCR and gel electrophoresis tests on the samples. You will notice that each primer creates two bands on the gel, because each person has two copies of each chromosome.

   Based on the test, match the skin and blood samples. (You can click and drag on the gel columns to rearrange them.) Use the Gizmo to check your answers.

   Which blood sample goes with each skin sample?

   Skin 1: *Varies** Skin 2: *Varies* Skin 3: *Varies* Skin 4: *Varies*
   Note: The results of this test are randomized in the Gizmo.

4. Experiment: Switch back to the **Design primers** section. Click **Clear primers**. Add primers to the bottom left and top right of the DNA and click Preview primers.

   What happens? *Nothing. The DNA is not copied.*

   DNA polymerase only copies DNA in one direction. In the Gizmo, the top strand of DNA copies left-to-right and the bottom strand copies right-to-left.

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Activity B (continued from previous page)

5. Compare: Go back to the chromosome view and choose a gene. Create primers anywhere you want in the gene and click **Preview primers**.

   A. What do you notice about the copied DNA in each person?

      The lengths of each person's copied DNA strands are all the same.

   B. Click **Save primer** and select **Test primers**. Run an analysis with the new primer.

      What do you notice about the bands on the gel? *They all traveled the same distance.*

   C. Would this primer help you distinguish people? *No* Explain.

      Since all of the bands travel the same distance, each column of the DNA profile will look the same.

6. Compare: Switch to the **Design primers** section. Select a non-coding region of DNA. Add primers to the DNA. This time place at least one primer completely inside the STR region.

   A. What do you notice about where the primer binds in individuals 2 and 3?

      The primers don't all bind to the same position within the STR region.

      Primers will bind to any complimentary sequence of DNA. Because STRs repeat, the primers will bind to more than one part of the DNA.

   B. Click **Preview primer**. What do you notice about the copied DNA in each person?

      For each person, DNA segments of different lengths are created.

   D. Click **Save primer** and select **Test primers**. Run an analysis with the new primer.

      What do you notice about the bands on the gel? *There is one wide streak.*

   C. Would this primer help you distinguish people? *No* Explain.

      All of the columns in the gel are identical, so they can't be used to distinguish people.

      Because DNA fragments of many different lengths are created, the result is a smear of bands on the gel.

7. Explain: Describe the properties of primers that were successful in distinguishing samples. What region of the DNA are they found in and what do they surround?

   The primers that were successful in distinguishing people were the ones that surrounded the STR regions of non-coding segments.

Activity C: **Solve cases**	Get the Gizmo ready: • Select **Design primers** on the left. If necessary, delete any unwanted primers.	

Question: Can you use the primers you created to solve cases?

1. Create: If you haven't already done so, create at least three primers using genes or non-coding regions that will help you distinguish DNA samples.

   Which regions did you use to create the primers? *Non-coding segments surrounding STRs.*

2. Predict: Click on **Solve cases** and check that you are on **Case 1**.

   A. Read the case details. Who do you think committed the crime? *Answers will vary.*

   B. Click **Next**. Look at the evidence bags. Which evidence bag(s) do you think will be most helpful in determining the criminal? *Answers will vary.*

3. Analyze: Click **Next**. There are four vials of DNA from the evidence and four from the suspects. Choose the primers you want to use and click **Run analysis**.

   A. Which suspects were at the crime scene? *B and C* Check using the Gizmo.

   B. Why was one suspect arrested and not the other?

   The stolen goods were found at suspect C's home and video showed suspect B in another part of the museum. [Other evidence was used to identify the criminal.]

4. Practice: Congratulations! You solved your first case. Use the Gizmo to solve cases 2-4. For each case, list the suspects that were present and who committed the crime.

Case	Suspect(s) present	Perpetrator(s)
2	*B*	*B*
3	*A, B, C, and D*	*D*
4	*B*	*None*

5. Discuss: If someone's DNA is found at a crime scene, does that mean they are guilty? *No*

   What other information might you need to know?

   Sample answer: There may be an innocent explanation for why the suspect's DNA was found at the scene and the suspect may have an alibi for the time of the crime.

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Activity C (continued from previous page)

6. Hypothesize: Select **Case 5** and read the description. DNA profiling can also be used to determine if a person is the biological parent of a child.

   A. Will a parent and child's DNA be identical? *No* Explain.

   A child receives half of their DNA from the father and half from the mother.

   B. How much DNA does a child inherit from each parent? *Half*

   Each parent contributes half of their DNA to their child, so half of a child's DNA should match each parent.

7. Solve: In paternity and maternity tests, the analysis is the same as in the criminal cases except that the DNA samples are from a son or daughter and potential parents.

   Choose up to three primers and click **Run analysis**. (Note: Only three primers are allowed in the simulation due to the size of the gel. In a real analysis, more primers are used.)

   A. Can you determine who the father of the son is? *Yes, it is man A.*

   B. How may bands do the father and son share and how many are different?

   Answers will vary based on the number of primers used but the parent and child should share half of the bands.

8. Solve: Solve **Case 6** using the Gizmo. Who is the mother of the daughter? *Woman C*

9. Summarize: How can you use DNA profiling to determine maternity and paternity?

   You can compare the DNA profiles of children to their potential parents. If about half of DNA profile is identical, the individuals are likely parent and child.

10. Discuss: Think back to the case in the beginning, where Darryl Hunt was convicted of murder. He spent 19 years in prison before DNA profiling proved his innocence.

    What are the pros and cons of using DNA profiling to solve cases?

    DNA profiling can be used to determine if a suspect was present at a crime scene. This technology can help to convict the real criminals and exonerate wrongly accused individuals. But just because a person was present at a crime scene doesn't mean they committed the crime, so some individuals may be wrongly convicted if other evidence is not considered.

    The Innocence Project has helped to exonerate hundreds of wrongly convicted people using DNA profiling.