Activity: Who Robbed the Bank?

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Summary

Students use DNA profiling to determine who robbed a bank. After they learn how the FBI's Combined DNA Index System (CODIS) is used to match crime scene DNA with tissue sample DNA, students use CODIS principles and sample DNA fragments to determine which of three suspects matches evidence obtain at a crime location. They communicate their results as if they were biomedical engineers reporting to a police crime scene investigation.

Engineering Connection

Relating science concept to engineering

Biomedical engineers who understand the science of genetics create tools, equipment and processes to accurately collect and examine DNA evidence for crime and paternity cases. These engineers also work with attorneys and in court systems to explain how DNA profiling works.

Contents

Grade Level: 7 (6-8)

Group Size: 2

Time Required: 30 minutes

Activity Dependency :None

Expendable Cost Per Group : US$ 0

Keywords: bioengineering, biomedical, biomedical engineering, biotechnology, body, DNA, DNA profiling, evidence, forensic, gene, genetic fingerprinting, genetics, human, human body, sample

Related Curriculum :

subject areas

Problem Solving
Science and Technology
Biology
Life Science

curricular units Biomedical Engineering and the Human Body
lessons DNA: The Human Body Recipe

Educational Standards

- Colorado: Math
- a. Determine probabilities through experiments or simulations (Grade 6) [2009]
- b. Express the probability of an event using fractions, decimals, and percents (Grade 6) [2009]
- Colorado: Science
- a. Develop and design a scientific investigation about human body systems (Grade 7) [2009]
- c. Gather, analyze, and interpret data and models on the functions and interactions of the human body (Grade 7) [2009]
- International Technology and Engineering Educators Association: Technology
- G. Advances and innovations in medical technologies are used to improve healthcare. (Grades 6 - 8) [2000]

Pre-Req Knowledge (Return to Contents)

Familiarity with DNA and its constituent nucleotide base pairs.

Learning Objectives (Return to Contents)

After this activity, students should be able to:

- Describe the organization of DNA into repeating nucleotide base pair sequences
- Explain how DNA profiling is used to link people to crime and paternity cases.
- Describe the role of biomedical engineering in DNA profiling.

Materials List

Each group needs:

- Suspect CODIS Analysis Worksheet, one per team
- pen or pencil
- (optional) scissors

Introduction/Motivation (Return to Contents)

A robbery takes place at a bank. As the thief escapes the building, a security guard grabs one of the bank robber's gloves. The bank robber leaves the scene in a phone service van. The phone company identifies three employees who may have been in the vicinity of the bank at the time of the robbery. All employees deny robbing the bank. Can you think of some way, besides witness testimony, that the bank robber could be identified from among the three individuals?

DNA evidence is more reliable than fingerprints at identifying people.

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DNA can identify people — even better than fingerprints. DNA is found in all of our cells: hair, teeth, bones, blood, skin. Though all humans share 99.9% of their genes, our DNA differs from everyone else's by three million nucleotide base pairs.

Our DNA is organized in 23 chromosomes in the nucleus in each of our cells. Regions in each chromosome contain what are called "junk DNA," which does not contain genes. But often, this junk DNA contains repeating nucleotide base pair sequences that can be used for matching purposes. (Show students Figure 1 or the same image in the attached CODIS Visual Aid.) In this example, you can see chromosome locations where the FBI looks for repeating sequences of DNA. They're called CODIS sites, which stands for the FBI's Combined DNA Index System.

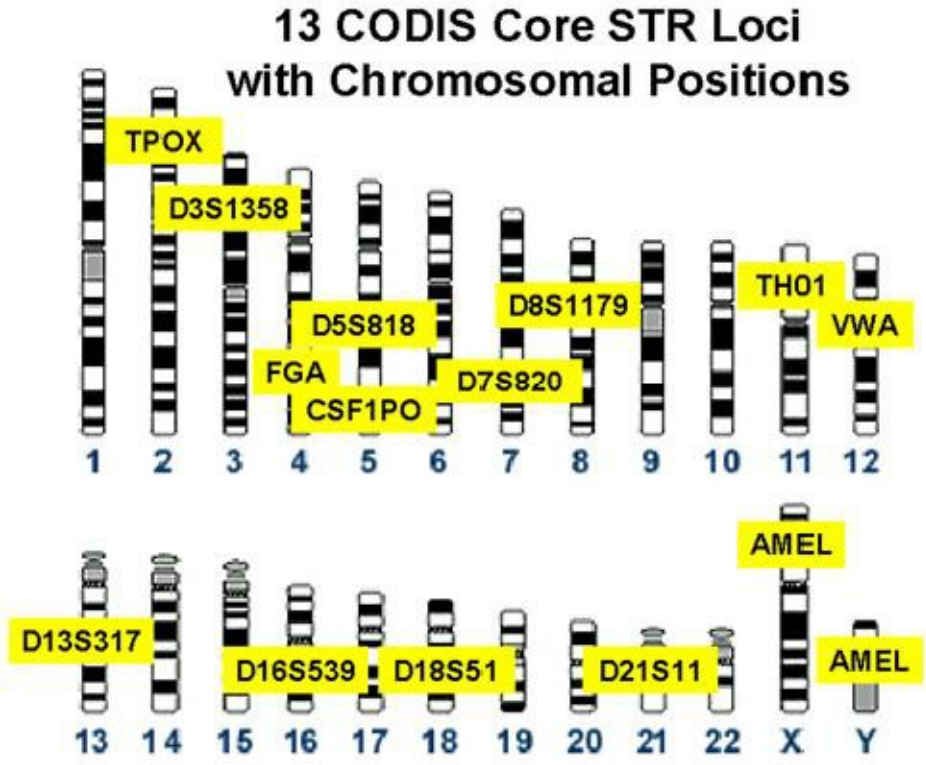

Figure 1. The 23 human chromosomes and 13 chromosomal locations at which the FBI looks for repeating DNA sequences. For this activity, note the TPOX region on chromosome 2. (X and Y count as one chromosome pair. The AMELs are not CODIS sites.)

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In our case, the police found a hair in the bank robber's glove. Remember that we have 23 pairs of chromosomes, each pair containing one chromosome from our father, the other from our mother. A DNA analysis shows that the hair in the robber's glove contains the following nucleotide base pair sequences in the TPOX region (show students Figure 2 or the same image in the attached CODIS Visual Aid).

Base Pair Sequences			
Chromosome from father		Chromosome from mother	
G	C	G	C
A	T	A	T
A	T	A	T
T	A	T	A
G	C	G	C
A	T	A	T
A	T	A	T
T	A	T	A
		G	C
		A	T
		A	T
		T	A

Figure 2. TPOX region of chromosome 2 of hair found in bank robber's glove.

Note that the GAAT sequence is repeated twice in the father's side and three times in the mother's side (the sides of each chromosome are often not the same length). Equivalently, we could say that the CTTA sequence is repeated. Why is that? (G always pairs with C, and A always pairs with T).

So now let's compare the TPOX regions of the DNA found in the bank robber's glove with the TPOX regions of the DNA of two suspects. Note that we are just looking at the one side of the DNA with the GAAT repeating sequence. This simplifies the comparison. (Show students Figure 3 or the same image in the attached CODIS Visual Aid.)

TPOX, hair in glove		TPOX, Suspect 1		TPOX, Suspect 2	
G	G	A	G	T	G
A	A	C	C	C	G
A	A	A	G	A	G
T	T	G	G	G	G
G	G	A	A	A	A
A	A	A	T	A	A
A	A	T	A	T	T
T	T	G	G	G	G
	G	A	A	A	A
	A	A	A	A	A
	A	T	T	T	T
	T	G	G	G	C
		A	A	A	T
		A	C	A	G
		G	G	T	A
		G	G	G	C
		A	A	A	T
		A	A	A	G
		T	T	T	A

Figure 3. Comparison of the TPOX region of chromosome 2 of the unknown bank robber and two suspects.

Suspect 1 matches the GAATGAAT sequence of the hair found in the glove on one chromosome, but the other chromosome does not match. Both chromosomes **must** match to show that the hair in the glove came from a specific suspect. **Thus, from just one CODIS site we already know that the hair in the bank robber's glove cannot belong to suspect 1.**

Suspect 2 matches the GAATGAAT sequence on one chromosome and the GAATGAATGAAT

sequence on the other chromosome, so you can say that suspect 2 matches at the TPOX location. To confirm that the hair belongs to suspect 2, the other 12 chromosome locations (see Figure 1) must also match. **If all 13 CODIS locations match, then the hair in the bank robber's glove belongs to suspect 2.**

The random probability that one of your CODIS sites matches with someone else's is about one in 10 (1/10). Therefore, the probability of two CODIS sites matching is 1/10*1/10 = 1/100 (one in 100). The chance of three CODIS sites matching randomly is 1/10*1/10*1/10 = $(1/10)^3$ = 1/1000 (one in 1,000). The random chance that all 13 CODIS sites match is $(1/10)^{13}$ = one in 10,000,000,000,000. The chance of being struck by lightning in your lifetime is, roughly, one in 1,000,000. So you are 10 million times more likely to be struck by lighting than you are to have the same 13 CODIS sequences as another person. This is what makes DNA profiling so certain.

Engineers can be involved in many aspects of crime scene investigation. They might use their knowledge of CAD (computer-aided drawing) to create a reconstruction of the crime scene. First they might develop a model of the room, and then determine the path of bullets and analyze the blood splatter patterns to determine the position of victims and their killers at the time of the crime. Biomedical engineers create the tools, equipment and processes to accurately collect and examine DNA evidence for crime and paternity cases. Biomedical engineers also help investigators with the analysis of the gene sequencing for DNA profiling.

Vocabulary/Definitions (Return to Contents)

base pair:	Two nucleotide bases that form a "rung of the DNA ladder." A DNA nucleotide is made of a molecule of sugar, a molecule of phosphoric acid, and a molecule called a base. The bases are the "letters" that spell out the genetic code. In DNA, the code letters are A, T, G and C, which stand for the chemicals adenine, thymine, guanine and cytosine, respectively. In base pairing, adenine always pairs with thymine, and guanine always pairs with cytosine.
biomedical engineer:	A person who blends traditional engineering techniques with the biological sciences and medicine to improve the quality of human health and life. Biomedical engineers design artificial body parts, medical devices, diagnostic tools, and medical treatment methods.
chromosome:	One of the threadlike "packages" of genes and other DNA in the nucleus of a cell. Different kinds of organisms have different numbers of chromosomes. Humans have 23 pairs of chromosomes, 46 in all: 44 autosomes plus two sex chromosomes. Each parent contributes one chromosome to each pair, so children receive half of their chromosomes from their mothers and half from their fathers.
CODIS:	Acronym for the FBI's DNA identification system: Combined DNA Index System. See: http://www.fbi.gov/hq/lab/html/codis1.htm
CODIS sites:	The 13 regions of the chromosomes at which the FBI CODIS looks for repeating DNA sequences for matching purposes.
DNA:	Deoxyribonucleic acid contains the genetic instructions that control the biological development of our cells and the proteins the cells make. DNA codes the sequence of the amino acids in proteins using the genetic code, a triplet code of nucleotide bases.
DNA fingerprinting:	A method for identifying individuals by the particular structure of their DNA. Because the structure of each person's DNA is different, just like our fingerprints, we can be identified from our DNA. This technique became known to the public as "DNA fingerprinting" because of its powerful ability to discriminate between unrelated individuals.
DNA profile:	The result of determining the relative positions of DNA sequences at several locations on the molecule. Each person (except identical twins) has a unique DNA profile when used in the context of the CODIS database, which evaluates 13 specific DNA locations.
engineer:	A person who applies his/her understanding of science and math to creating things for the benefit of humanity and our world.

gene:	Segments of DNA that get translated into proteins.
junk DNA:	Stretches of DNA that do not code for genes; "most of the genome consists of junk DNA." Junk DNA contains repeating base pair sequences that can be used for matching purposes.
nucleotide bases:	The parts of RNA and DNA involved in pairing; they include cytosine, guanine, adenine, thymine (DNA) and uracil (RNA), abbreviated as C, G, A, T and U. They are usually simply called bases in genetics. Also called base pairs.

Procedure

Before the Activity

- Make copies of the Suspect CODIS Analysis Worksheet, one per team.
- Set the stage for the activity by conducting the Introduction/Motivation section.

With the Students

1. Divide the class into pairs of students, and pass out a worksheet to each team.
2. Assist students as they complete their worksheets.
3. Have teams conclude by writing on their worksheets which suspect their DNA profiling implicates in the robbery.
4. Have the teams with the correct answer describe how they arrived at their conclusion. (Answer: Suspect 2 seems likely based on a match with four CODIS sites).
5. Have students calculate the likelihood that suspect 2, even though he matches four CODIS sites, is not the owner of the hair in the bank robber's glove. (Answer: $(1/10)^4$ = 1 in 10,000, not good enough – need more CODIS site data)
6. Have students act as biomedical engineers and analyze the results of the DNA profiling for the police investigators as described in the post-assessment activity.

Attachments (Return to Contents)

- CODIS Visual Aid (pdf)
- CODIS Visual Aid (doc)
- Suspect CODIS Analysis Worksheet (pdf)
- Suspect CODIS Analysis Worksheet (doc)
- Suspect CODIS Analysis Worksheet Answers (pdf)
- Suspect CODIS Analysis Worksheet Answers (doc)

Safety Issues

- Make sure students use care with scissors.

Troubleshooting Tips

If students have difficulty, work through the first CODIS site on the worksheet with them.
Sometimes it helps to cut out the robbery evidence CODIS data columns from the worksheet and hold them right next to the suspect data columns, making it easier to compare for matches of repeating base pair sequences.
Assessment (Return to Contents)

Pre-Activity Assessment

Discussion/Brainstorming: As a class, ask students if they can think of some way that a bank robber could

be identified if no one saw who he or she was. Remind students that in brainstorming, no idea or suggestion is "silly." All ideas should be respectfully heard. Take an uncritical position, encourage wild ideas and discourage criticism of ideas. Brainstorming is how engineers come up with creative ideas. Have them raise their hands to respond. Record their ideas on the board.

Activity Embedded Assessment

Worksheet: Have students complete the activity worksheet; review their answers to gauge their mastery of the subject.

Post-Activity Assessment

Engineering Analysis: Have students act as biomedical engineers and analyze the results of the DNA profiling for the police investigators. Have each team state which suspect their DNA profiling implicates in the crime. How certain are their results? Next, have the students write a brief one-page report on their results that they might deliver to the police investigators. In this report, they should explain the outcomes of the DNA profiling, how they arrived at their results, and how they determined the certainty of their results.

Activity Extensions (Return to Contents)

Have students conduct the online, animated Catch a Criminal activity that includes a real-world 13 CODIS site analysis using three suspects. See the Koshland Science Museum's Putting DNA to Work website: https://koshland-science-museum.org/

With the popularity of the CSI television shows, students may have some understanding of forensic evidence. Along these lines, have students investigate the creative tools, equipment and processes used to accurately collect and examine DNA evidence for crime, paternity and ancestry investigations.

What is your ancestry? Are we all related? With the advances in understanding DNA, and the availability of engineered collection and analysis tools, more and more people are aware of genetic genealogy. Have students investigate the National Geographic Society's Genographic Project — an anthropological study to map historical human migration patterns by collecting and analyzing DNA samples from hundreds of thousands of volunteers across five continents. See https://genographic.nationalgeographic.com/genographic/index.html

Activity Scaling

- For lower grades, use fewer CODIS sites and suspects.
- For upper grades, use more CODIS sites and suspects.

References (Return to Contents)

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How DNA Evidence Works. HowStuffWorks. Accessed February 24, 2009. http://science.howstuffworks.com/dna-evidence1.htm

Putting DNA to Work. Marian Koshland Science Museum of the National Academy of Sciences, The National Academies, Washington, DC. Accessed February 24, 2009. (Great DNA reference; topics include DNA and criminal justice; Catch a Criminal activity is inspiration for this activity) https://koshland-science-museum.org/

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Supporting Program (Return to Contents)

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