Using Harry Potter to Introduce Students to DNA Fingerprinting & Forensic Science

ABSTRACT
This lesson uses characters from the Harry Potter series of novels as a "hook" to stimulate students' interest in introductory forensic science. Students are guided through RFLP (restriction fragment length polymorphism) analysis using inexpensive materials and asked to interpret data from a mock crime scene. Importantly, the lesson provides an opportunity to discuss limitations of using DNA fingerprinting for forensic purposes and addresses a common misconception that the sophisticated science involved in crime-scene analysis is infallible.

Key Words: DNA fingerprint; forensics; RFLP; Harry Potter.

This lesson was presented in a 50-minute period to a target audience of seventh- and ninth-grade students. Students are asked to analyze a crime scene based on the "Harry Potter" series of novels. The lesson is an inexpensive way for schools with limited funding and limited access to laboratory equipment to bring introductory-level forensic science and molecular biology into the curriculum. The lesson also aids in "establishing a foundation for developing understanding of molecular biology at the high school level" (National Research Council, 1996).

This lesson utilizes the RFLP (restriction fragment length polymorphism) approach to DNA fingerprinting (Jeffreys et al., 1985), which provides a straightforward way to explain DNA profiling to students at this level. Although forensic scientists now use more state-of-the-art techniques, such as PCR–STR (polymerase chain reaction–short tandem repeat) analysis for crime scene investigations (Jones, 2004), RFLP analysis is still discussed in depth in current college genetics and forensic science textbooks (for examples, see Houck & Siegel, 2004; Pierce, 2008). Thus, the RFLP approach can still be considered a valuable tool for teaching DNA technology and forensic science to younger students and can set the stage for future discussions of more updated DNA profiling techniques.

Part 1: Introduction to DNA Structure & Function
The following questions can be used to probe students' understanding of basic DNA structure and function, depending on the level of previous knowledge in this area: What is the function of DNA? What does DNA look like? What is DNA made of? Because this lesson utilizes RFLP analysis, a thorough review of nucleotide pairing rules will provide the necessary framework for introducing the concept of restriction enzymes later in the presentation.

Part 2: Introduction to DNA Fingerprinting
Next, draw on students' prior knowledge of the classic fingerprinting process. Most students at this level are comfortable with the process of creating a fingerprint by rolling a finger in ink followed by blotting it on paper to produce a pattern identical to the ridges on the finger. Building on this idea, ask students "What is meant by a DNA fingerprint?" I usually introduce the concept that because everyone has their own unique sequence of DNA molecules, we can use DNA to create a one-of-a-kind pattern just as police officers do when they collect fingerprints. However, instead of producing the pattern using ink and the ridges of a finger, we use DNA and special chemicals.

I conclude this portion of the presentation with a discussion of applications of DNA fingerprinting, including its use in (1) criminal trials to either link an individual to a crime scene or to exonerate an innocent person, (2) paternity testing, (3) identification of unknown individuals (an example that resonates with students is the identification of victims from the 2001 World Trade Center attack), and (4) its use in medicine to identify genetic conditions that can be inherited in families.

Part 3: Creation of a DNA Fingerprint
Commercial kits are available that make use of bacterial DNA samples and a simplified protocol to produce a simulated DNA fingerprint (an example is Bio-Rad Laboratories’ Forensic DNA Fingerprinting Kit; catalogue no. 166-0007EDU). Because of the time constraints, the age level of the student audience, and the specialized laboratory equipment required, it may not be feasible for students to create a simulated DNA fingerprint.
fingerprint. An inexpensive alternative can be constructed using poster board (Figure 1). A simplified flowchart for creating a DNA fingerprint by RFLP analysis is shown in Figure 2.

Begin by asking students “What types of samples can be collected from a crime scene that might contain DNA?” Prompting students to think about the types of evidence they’ve seen collected on television shows such as Law and Order or CSI often spurs the brainstorming process. Try to elicit examples such as blood, urine, hair, skin cells, and saliva. For students at this age, a detailed explanation of how DNA is extracted from the samples and purified is not really necessary, beyond telling them that it is accomplished using chemicals in a lab. Likewise, an in-depth explanation of the technique of PCR is beyond the scope of this lesson. It is sufficient to tell students that PCR takes a small amount of DNA and generates millions to billions of identical copies, providing enough DNA to visualize by DNA fingerprinting. Explaining that the technique is like a “Xerox (or copy) machine for DNA” helps students relate the technique to something they are already familiar with.

Begin explanation of step 4 in Figure 2 by explaining that an enzyme is a special molecule that helps chemical reactions happen. Then introduce the concept that a restriction enzyme works by “chopping” DNA into smaller pieces (restriction enzymes can be thought of as “scissors” that cut DNA). Follow this by explaining that restriction enzymes recognize a certain sequence (or pattern) of DNA nucleotides (Figure 3).

To help students comprehend the idea that restriction enzymes only recognize a specific sequence of nucleotides (often about 6 base pairs) found within a much longer DNA molecule, I tell them it would be similar to asking a student to open a textbook and find every time the word “house” was used throughout the text. In the same way, a restriction enzyme scans a large DNA molecule (analogous to the textbook) to find its particular recognition site (analogous to the word “house”).

To illustrate how the use of restriction enzymes results in the production of unique DNA fingerprint patterns for different individuals, the following demonstration was used (Figure 4; this figure was recreated as individual poster board pieces): two DNA molecules of equal length but with a different sequence of nucleotide bases were presented to students. Both molecules contain an EcoRI site. However, the site is placed at a different position in each of the molecules.

Simulate the action of the enzyme by separating each DNA molecule into its resulting restriction fragments (Figure 4). Students will realize that although the two DNA molecules are the same size to begin with, when the molecules are cut, fragments of various sizes are produced depending on the location of the restriction enzyme site. Follow this by explaining to students that because people have variations in the pattern of their DNA nucleotides, they will have restriction sites in unique places compared with other individuals. Thus, cutting the DNA into smaller fragments will produce a unique collection of DNA fragments that can then be used as an identifier (i.e., the DNA fingerprint).

One way to preface the explanation of gel electrophoresis (Figure 2, step 5) is with an explanation of what the gel is made from. Explain that the gel is similar to gelatin (asking students how to make gelatin in the kitchen relates this part of the technique to something they are familiar with), except that it is made of the chemical agarose.

Depending on their background, students may know that DNA is negatively charged (if not, supply the students with this information). Ask them: “If you put DNA into an electric field, will it move toward a positive end or a negative one?” Elicit the response that because DNA is negatively charged, it will “move toward the positive end.” Then explain that after DNA has been cut into smaller fragments with restriction enzymes, it is loaded into wells in the gel and electricity is applied. Because large fragments of DNA have a hard time getting through the gel, they don’t migrate as quickly as small fragments do. Using the DNA molecules from the previous demonstration (Figure 4), student volunteers can actually simulate the migration of the DNA fragments to show what the expected pattern of bands on the gel would be. Reteiterate that the pattern of bands on the gel is a “fingerprint” of the DNA sample.
Part 4: The Crime

Present the students with the following scenario. Although the plot of this case is original, character names and themes were borrowed from Rowling (2003).

Harry Potter & the Case of the Half-Eaten Licorice Wand

Harry Potter is heading back to Hogwarts School of Witchcraft and Wizardry on the Hogwarts Express. He buys a package of licorice wands from the lunch trolley before leaving his train compartment with his friend, Ron Weasley. When Harry and Ron return to their compartment, they are upset to find that someone has opened Harry's candy and taken a big bite from one of the licorice wands. Harry wants to know who got into his candy without his permission.

The following suspects were seen in and around Harry and Ron's compartment at the time of the crime:

- Suspect #1: Hermione Granger
- Suspect #2: Neville Longbottom
- Suspect #3: Fred Weasley
- Suspect #4: Draco Malfoy
- Suspect #5: Luna Lovegood

Harry collects a sample of saliva from the half-eaten licorice wand. Using this evidence, can you help him solve the crime?

Part 5: Data Analysis & Interpretations

I find it useful to review the basic steps of creating a DNA fingerprint before progressing to analysis of the crime. Using a question-and-answer format, I prompt the students to talk through the DNA profiling process until reaching the final step of analyzing the DNA banding patterns on the gel.

At this point, I show students a poster-board representation of the DNA fingerprint gel from the crime scene (Figure 1) and ask them to use the data and decide who committed the crime. It is important to prompt students to justify their answer(s) using the data presented. Students should be able to articulate that because the DNA banding pattern of Suspect #3 is identical to that found at the crime scene, Fred Weasley is most likely the perpetrator of this particular crime.

Presenter Notes

For this lesson, construct the DNA fingerprint gel (or poster board) so that Fred Weasley is the suspect that will decide is guilty of the crime. In the Harry Potter book series, Fred has an identical twin brother named George. Having the guilty suspect be part of an identical twin set provides an opportunity to discuss one of the limitations of DNA profiling later in the lesson.

Part 6: Reliability & Limitations of DNA Fingerprint Analysis

If performed accurately, DNA fingerprinting is extremely reliable. It is estimated that the average random match probability for unrelated individuals is less than one in a trillion using current techniques like PCR-STR analysis (Budowle et al., 2000). This can lead to the misconception that DNA fingerprint analysis is infallible. Thus, I find it advantageous to conclude the lesson with a discussion of some of the limitations of using DNA fingerprint analysis for forensic purposes. Although this is by no means a comprehensive list, the following are several suggested topics for discussion.

1. What if one of the suspects is an identical twin?

This is a fun question to pose to students, particularly in light of the mock crime scene detailed above. The guilty suspect in the case of “The Half-Eaten Licorice Wand” is Fred Weasley, who has an identical twin brother, George. If Fred and George have identical DNA, how can an investigator identify which of the boys actually committed the crime? This caveat allows for discussion of the importance of collecting multiple types of evidence from a crime scene. Topics that may be explored include the importance of eyewitness testimonies (maybe someone on the train saw Fred commit the crime); alibis (maybe George was visiting other friends at the time the crime was committed); and collection of alternative types of physical evidence, such as shoeprints (maybe the twins wear different types of shoes and this evidence could link one of them to the crime scene). Regardless of the topics discussed, it is important to convey the idea that although DNA evidence can be quite compelling, it should not be the only type of evidence collected (or scrutinized) during an investigation.

2. Does finding a person's DNA at a crime scene always mean that he or she is guilty of a crime?

I approach this discussion by telling students that as they sit in the classroom, some of them may, in fact, be leaving DNA evidence behind that could be collected by crime-scene investigators (remind them that they are constantly shedding hair and skin cells). Thus, if a crime happens in the classroom later in the day, it is possible that an investigator could link...
an innocent student (whose DNA sample was deposited in the classroom earlier in the day) to the crime. Again, it is important to reiterate the concept that it is more effective to analyze multiple sources of evidence from a crime than to rely solely on one piece of DNA evidence.

3. Are there situations where DNA fingerprinting would not work?

Television programs such as CSI often portray forensic science as “sexy, fast, and remarkably certain” (Roane & Morrison, 2005), thus perpetuating the image that the sophisticated science involved in crime-scene analysis is infallible. In reality, techniques such as DNA fingerprinting cannot always be utilized to provide conclusive evidence for an investigation. For example, the initial integrity of a DNA sample can affect the quality of its subsequent DNA fingerprint. DNA quality can be negatively altered by conditions such as heat, humidity, and ultraviolet light (McNally et al., 1989), all of which can damage DNA by inducing random breaks in the DNA double helix. Thus, samples that suffer prolonged exposure to environmental forces may not be suitable for DNA fingerprinting. Likewise, because DNA will also degrade naturally over time, very old samples may not contain a sufficient quantity of intact DNA to be processed using this technology (note: even though PCR can be used to amplify DNA to obtain a sufficient yield to process, there must still be a source of intact original DNA to use as a template for the PCR reaction). Finally, it is important to acknowledge that there is always the possibility of error due to mistakes by crime lab technicians during DNA sample processing.

Assessment

An effective way to assess student learning for this lesson utilizes pre- and post-lesson testing. Questions can be administered to students before the lesson to provide a measure of current knowledge, and then again following the conclusion of the lesson. Results between the two question sets can then be compared. Examples of questions that have been used for this purpose include the following:

- What is a DNA fingerprint?
- What does a restriction enzyme do?
- During gel electrophoresis, do large DNA fragments move more quickly or more slowly than small DNA fragments?
- Give an example of a situation in which DNA fingerprinting may not be usable.
- Besides its use in crime scene investigations, what else can DNA fingerprinting be used for?

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References


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