Berkeley Engineers and Mentors

Whodunnit?

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Field(s) of Interest: Forensic Science, Organic Chemistry, Molecular Biology

Brief Overview:
In this lesson, the mentees will learn about the science behind different technical applications of forensic science, including ink chromatography, DNA profiling, and fingerprinting. A crime scenario will be introduced at the beginning of the lesson and each module will reveal more incriminating evidence. At the end of the lesson, the mentees will examine the evidence and identify the culprit.

Agenda:
- Introduction (5 min)
- Module 1: X Mark(ers) the Spot (15 min)
- Module 2: What Genes Are You Wearing? (20 min)
- Module 3: A Stainless Steal (15 min)
- Conclusion (5 min)

Teaching Goals/Key Terms:
- ➔ **Forensic science** - application of science to criminal investigation
- ➔ **Chromatography** - laboratory technique to separate a mixture
- ➔ **Mixture** - material made up of two or more separate chemical substances
- ➔ **DNA** - genetic instructions for all life
- ➔ **Gene** - DNA that encodes for a specific trait (like fingerprint patterns!)
- ➔ **Fingerprinting** - collecting and analyzing fingerprints for criminal investigation

Mentor Development Goals: **Written by MD**
- ➔ **Bias Consciousness**: As mentors we have an unconscious bias towards certain decisions and may gravitate towards certain mentees because of it. Being aware helps us provide equal education opportunities for all our mentees.
- ➔ **Cross-Culture Mentorship**: Bridging the gap between the mentor and the mentee which exists because of different cultural upbringings.
- ➔ Three V's
  - ◆ **Value** - Finding common ground between you and the mentees.

	◆ **Virtue** - The willingness to be available for the mentees and drive to foster a connection. ◆ **Vision** - Having a goal in mind to bridge gaps and overcome the obstacles in your way to reach it.

Mentor Development Notes

Written by Gabriel Serenil

Expand on the MD Goals for the week. What MD concepts or techniques are we trying to practice this week? This could relate to the week's MD presentation.

Different Backgrounds

In decal we discussed how small differences in cultural upbringings can lead towards an unconscious bias in the way we perceive the world around us. Tapping into these biases and being aware of them help us know when one of these biases may get in the way of connecting with the mentees. Ultimately, our connection to the mentees is linked to how effective our teaching methods are and if they will retain what we teach them. Sometimes, without a connection or motive to learn in a small afterschool program many of our concepts and activities will go in one ear and out the other, but if we form these connections with the mentees they are more likely to pay attention and have an investment to learn.

Being Aware

On a more serious note, it is always important to make sure the things one says are culturally appropriate and are inoffensive to the mentees. Being college students we often separate our lives and personalities into many different settings, like with a group of friends, lab partners, or with our professors we tend to act differently. Understanding that the things we say around our friends may not be appropriate around mentees is an important thing to be aware of just in case we discuss a topic that is more polarizing or touches close to home.

Cross-Culture Mentorship

While understanding and being aware of bias is one part of the picture, the next steps lie in bridging this gap. Keeping in mind the three V's, Values, Virtue, and Vision can go a long way in fostering a more close knit and comfortable classroom experience for mentees. Another thing to keep in consideration is the stages of cultural adaptation and how being there for a mentee now can make all the difference in helping them acclimate to a possibly new setting for them. Having a want and setting a goal for inclusivity makes a big difference.

Inclusivity and the World Around Us

Ultimately, the goals and topics we are discussing stretch much wider than just the classroom and the mentees. However, as parts of the larger role we are actively making the world a more inclusive and accepting place to be one mentee at a time.

Background for Mentors: Module 1 - X Mark(er)s the Spot

Module 1

- Chromatography
- Mixture
- Molecule
- Solvent

At crime scenes, ink may be a crucial piece of evidence. However, it is difficult to differentiate between inks, especially if they are the same color. **Chromatography** is a *chemistry technique that is used to identify specific markers or pens that the ink comes from.*

The color in ink comes from colored molecules in the ink. **Molecules** are the *smallest components of a chemical substance.* If you have ever looked at the nutrition info of M&Ms, for example, you might have seen “Yellow No. 5” listed as an artificial ingredient. “Yellow No. 5” is **synthetic**, or *man made*. Other color molecules, such as *carotenoid* in orange carrots, occur naturally.

Color theory teaches us that the three primary colors, namely red, yellow, and blue, combine to make all the other colors. In a similar way, different color molecules combine within ink to give the ink its distinct color. *If we can separate the color molecules in the ink, then we can characterize the color combination of the ink*. This allows forensic scientists to match a suspect’s marker to the ink found at the crime scene.

In ink chromatography, the ink is the **mixture** that is being separated. Mixtures are *made up of two or more separate chemical substances*; in this case, the chemical substances are the color molecules. A special kind of paper is the *stationary phase*, while a polar substance, such as water, oil, or isopropyl alcohol, is the *mobile phase,* or **solvent**. The mixture is dissolved in the solvent, which then travels up the special paper. Different molecules run up the paper at different rates and become visible on the paper.

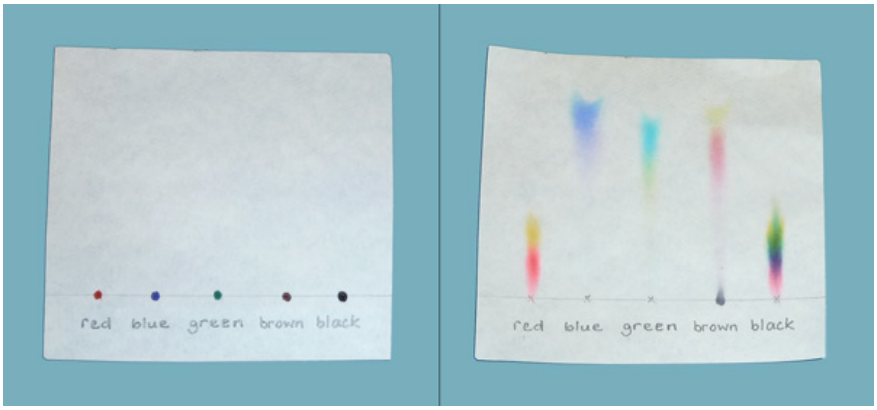

Figure 1: Example of different colored inks run out on paper

Background for Mentors: Module 2 - What Genes Are You Wearing?

Module 1

- DNA
- Genetics
- Genes
- Gel electrophoresis
- DNA profiling

DNA is the instruction manual for all of life. *DNA is present everywhere in our bodies and is essential for our development into functional human beings.* DNA is a very broad topic that could be learned in numerous ways. For this module, we still study DNA through the context of physical traits. Every individual has unique DNA that no other person on Earth shares. Not even twins have 100% identical DNA sequences.

This allows forensic scientists to identify specific individuals by extracting and analyzing their DNA. A method of analysis is **gel electrophoresis**, which is *a laboratory method used to separate DNA according to molecular size*. The mentees do not need to understand the details behind how electrophoresis works.

To simplify the explanation: DNA is loaded into an agarose gel, which contains wells at the top. Then an electric current is applied to the gel, which causes the DNA to move down the gel. The agarose gel is porous, so *DNA of different sizes moves through the gel at different speeds*. Larger DNA strands move slower, so they are visualized on the gel at a higher location. Smaller DNA strands move faster, so they are visualized on the gel at a lower location. The DNA samples being analyzed are all processed the same way, so *different DNA sequences will have different patterns on the gel.*

This is useful because DNA found on the crime scene can be matched to the DNA of suspects.

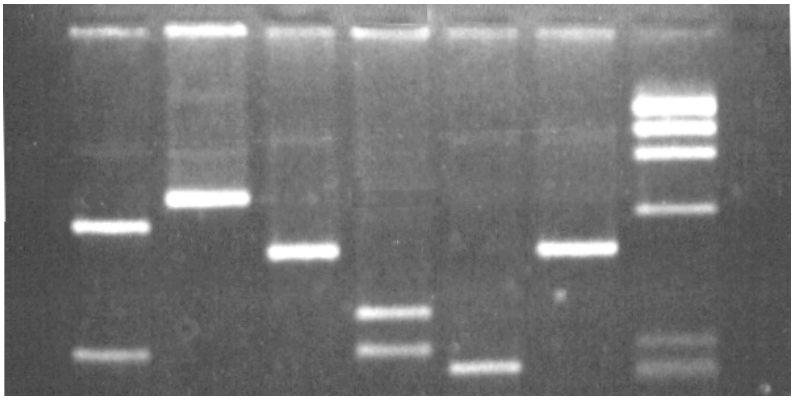

Figure 2: Example of different DNA sequences run on an agarose gel

Background for Mentors: Module 3 - A Stainless Steal

Module 1 ● Fingerprints ● Patent prints ● Latent prints ● Loop, whorl, arch	A **fingerprint** is *an impression left by the ridges of a human finger*. Just like how every individual has unique DNA, *every individual has unique fingerprints*. Forensic scientists use techniques to recover fingerprints, either full or partial, from crime scenes and analyze those fingerprints in order to match them to suspects. Fingerprints are especially useful for forensics because *they are persistent* and do not fade away easily with time. Fingerprints are also used in daily life for *security and identification purposes* - you use it to unlock your phone or while checking in at the airport. It is surprising how complex fingerprint analysis can be. **Patent prints** are visible and simply photographed. **Latent prints** need to be uncovered through various methods and therefore risk being contaminated. Latent prints are usually transferred when the body's natural oils and sweat on the skin are imprinted onto a surface. Once the fingerprint is collected, forensic scientists refer to common patterns, such as the loop, whorl, or arch, to differentiate fingerprints. **Loop**- makes up about 60-65% of fingerprints in population **Whorl**- makes up about 30-35% of fingerprints in population **Arch**- makes up about 5% of fingerprints in population  **Figure 3**: The different fingerprint pattern that can be observed

Introduction

Concepts to Introduce ● DNA ○ This can be explained through a Lego analogy. DNA can be compared to an instruction manual for how to build a Lego figure using individual Lego building blocks. The figure is the human, or other organism, and the Lego blocks are proteins. DNA dictates how the protein blocks are put together to form the final figure. ● Forensic science ● Chromatography ● Fingerprinting	**Current or Past Events** ● Forensic science is able to bring justice to “criminals” who were falsely accused and put into prison ○ As forensics improves and evolves, those serving life sentences from 20 years ago are finally being released ● Scientists have developed methods to find substances on hands that have already been washed.
Questions to Pique Interest ● Have you ever watched any crime TV shows? Do you have a favorite one? ● Do you think detectives have cool jobs? ● How do you think science can be used to catch criminals? ● What are examples of evidence that can be found on crime scenes?	**Inspiring Scientists, Careers, Applications** ● Forensic scientist ● Criminal profiler ● FBI ● Molecular biologist ● Organic chemist

Crime Scene Scenario

A crime has been committed! You and your mentees are all detectives who have just arrived at the crime scene.

The police officers present you with 3 crucial pieces of evidence found at the scene:

- Black ink that came from an unidentified type of marker
- DNA extracted from a strand of hair found on scene
- A fingerprint

Module 1: X Mark(er)s the Spot

Mentees will be learning about chromatography and how it can be used to differentiate colors in ink. They will then visualize separation of the colors in two different types of black markers.

Teaching Goals	**Materials**
1. **Chromatography**: a chemistry technique that is used to identify specific markers or pens that ink comes from. More generally, it involves a mobile phase and a stationary phase and separates the components of a mixture. 2. **Molecule**: the smallest components of a chemical substance. Examples of molecules include H2O, water, or CO2, carbon dioxide. Color molecules give ink color. 3. **Solvent**: a polar substance that dissolves the mixture. Examples are oil or isopropyl alcohol. **Tips for Virtual Sites** *We may have to resort to a simulation or a youtube video to exemplify how chromatography works.*	● Two white coffee filter strips ● Scissors ● Markers (two different black markers) ● Two pencils ● Two tall water glasses, four inches or taller ● Water ● Two binder clips

Procedure

1. Split mentees into groups depending on the size of your site
2. Draw a sizable dot with the first black marker at the bottom of a filter strip, one centimeter from the bottom end.
3. Repeat with the second black marker and the other filter strip.
4. Use a pencil to write the type of marker you just used at the top end of each strip.
5. Fasten the top of each strip (the side farthest from the marker line) to a pencil with a binder clip.
6. Let the pencil rest on the cup rim.
7. Pour water into the cup until the level just reaches the bottom end of the paper strip (**make sure the water level is below the ink**

dot).

8. When the water level reaches about one centimeter from the top (10 minutes), remove the strips from the cups.
9. Discuss with the mentees what they see
    a. How many different colors did the markers separate into?
    b. How do the two different black markers compare?
    c. If the suspects had used a red, yellow, or blue marker instead, would we have been able to identify different markers? (No, because those are primary colors, so they shouldn't be separated into different colors)
10. Show mentees the chromatography pattern of the black ink found at the crime scene (see Figure 2 - show mentees the picture on your phone)
    a. Suspect #1 uses Marker 1
    b. Suspect #2 uses Marker 2
    c. Suspect #3 uses Marker 2
    d. Suspect #4 uses Marker 1
    e. Suspect #5 uses Marker 2
    f. Which marker did the culprit use? Use this knowledge to narrow down the suspects.

Figure 1: Illustration of final visualization

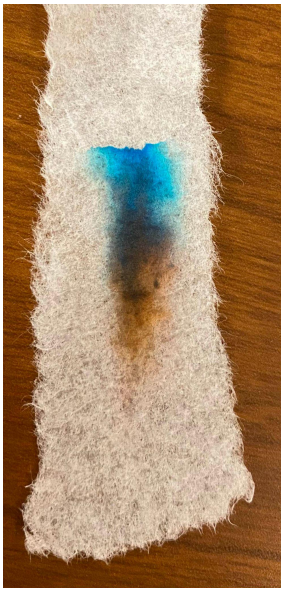

Figure 2: Chromatography pattern of black in at the crime scene

Procedure - Virtual

1) Run through this simulation with the mentees to show them how paper chromatography works. Play with the combinations of pigment and solvent and observe what changes.
    a) Using the teaching goals, explain why each plant pigment is being separated into many different colors. (Calculating the Rf value is too complex for most sites - you may skip that part.)
    b) You may also show this video to run through the actual lab with them.

Module 2: What Genes Are You Wearing?

Mentees learn about DNA's function and why it is unique for every individual. They will also learn about gel electrophoresis and how it can be used to differentiate DNA samples. They will then help build an electrophoresis chamber.

Teaching Goals	**Materials**
1. **DNA** - the instruction manual for all of life. DNA is present everywhere in our bodies and is essential for our development into functional human beings. 2. **Genes** - DNA that encodes for a specific trait (like fingerprint patterns!) 3. **Gel electrophoresis** - a laboratory method used to separate DNA according to molecular size.	Note: this will be an interactive demo for the entire site *For the electrophoresis chamber:* • Small, shallow plastic box • One agarose gel with wells • Two pieces of silver wire • Two electrical leads with alligator clips • Five 9-volt batteries • A container of sodium bicarbonate (baking soda) buffer *For the samples:* • 5 test tubes of water and glycerin mixture • 5 bottles of food coloring • 5 Needle-tip disposable pipettes

Procedure

Set the electrodes in place:

1. Bend each piece of silver wire so that it fits inside the box along its width and hooks over the side.
2. Place one “electrode” or wire above the gel in the box and one below it

Set up your power source and prepare your samples:

1. Connect the five 9-volt batteries. Clip two batteries together by inserting the positive terminal of one into the negative terminal of another. Attach the remaining batteries one by one in this way until you have a five-battery pack (refer to Figure 3).
2. Clip an electrical lead to each of the exposed terminals of the pack.
3. Prepare five different samples by mixing 1 drop of food coloring with the glycerin and water already in the test tubes - each color of food coloring will be in a separate tube.
    a. Each sample is the “DNA” of a suspect
    b. Have the mentees help with this if possible

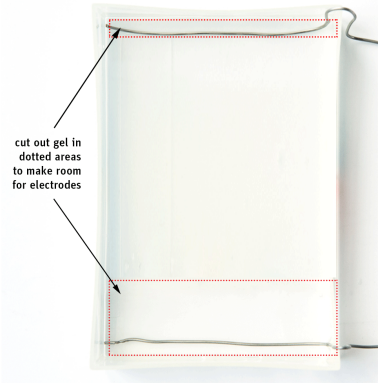

Figure 1: Placement of the electrodes in the box

Final set-up:

1. Pour in just enough sodium bicarbonate buffer to cover the solidified gel in the box (**make sure the wells are covered completely)**.
2. Use the plastic pipette to transfer about 10 microliters (enough to fill

the tip of the needle tip) of each sample to an empty well. Be sure to use a new pipette for each sample to prevent contamination between samples.
    a. You can consider demonstrating how to load one sample and have the mentees help load the other samples if possible
3. Once all the samples are loaded, connect the leads from the power supply to the stainless-steel wire electrodes attached to the box. Connect the negative terminal (not smooth circle) to the electrode at the top of the gel (near the wells) and the positive terminal to the electrode at the bottom of the gel. You should see bubbles forming along the wires when a complete circuit is made!
4. Leave the power connected for 15–20 minutes.
    a. Note: It is likely the samples will not run in this time. Just show the mentees Figure 3 and explain that there wasn't enough time for the electrophoresis to complete.
    b. Note: As it's running, move on to Module 3!
5. Show mentees the pattern of the DNA found at the crime scene (see Figure 4). Which suspect's DNA matches the crime scene DNA?
    a. Identify the culprit! DNA can be very incriminating evidence

Figure 2: The final setup

Figure 3: What the food coloring samples look like after being run out on the gel

Figure 4: The culprit's "DNA" run out on the gel

Procedure - Virtual

1. Go through this virtual lab of gel electrophoresis with the mentees and explain in your own words the descriptions at the bottom of the simulation
    a. Make sure to turn on sound - the sound effects are cool!
    b. Tailor your explanations to the learning level of your site

Module 3: A Stainless Steal

Mentees will be learning about how fingerprints are identified at the crime scene and analyzed. They will also understand why the uniqueness of fingerprints is important.

Teaching Goals

1. **Fingerprint** - an impression left by the ridges of a human finger. Just like how every individual has unique DNA, every individual has unique fingerprints.
2. **Patent vs Latent Prints** - fingerprints that can be visually identified vs invisible fingerprints that need to be recovered

Tips for Virtual Sites

While the viability of this method may vary from site to site, most children have markers and can use these to make fingerprints from home.

Materials

- Paper or index cards
- Pencils
- Scotch tape or similar tape
- Magnifying glass

Procedure - In person and Virtual

1. Be sure to do this module before the electrophoresis completes.
2. This activity is for each mentee
3. Use a pencil to scribble an area of dark graphite on the index card or paper
4. Then, rub your finger in the graphite. Make sure to get full coverage of the finger.
5. Stick a piece of tape firmly down onto your finger.
6. Stick the tape onto the other side of the index card.
7. Look for the three main fingerprint patterns with a magnifying glass - arches, loops, and whorls (refer to the Background for Mentors for examples of these patterns).
    a. For more advanced sites, feel

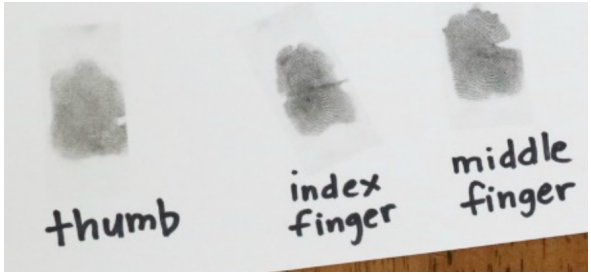

Figure 1: Examples of fingerprints made from this activity

free to Google more complex fingerprint patterns on your phone and get more in depth with your fingerprint analysis with the mentees

8. Repeat with other fingers.
9. Have the mentees compare their fingerprints with each other.
    a. Discuss where fingerprinting is used as an identification method in everyday life.
    b. Discuss why fingerprinting is convenient, but maybe not the most secure form of identification.
10. Narrow down the suspects with our knowledge of fingerprints!
    a. Suspect #2 - Loop
    b. Suspect #3 - Arch
    c. Suspect #5 - Loop
    d. Culprit had a Loop
    e. It's between 2 and 5 now - the suspense reaches a climax!
11. Now return to the electrophoresis and catch the culprit!!