Techniques and Tools in Biology:
What tools does a scientist need to solve a Forensic Investigation?

Teacher Guide

Summary of Unit:
Students return after summer vacation with varying levels of science skills. This unit is designed to review and/or teach skills and concepts needed for success in science. To keep student interest high, all the activities are related to forensic science. After reviewing the proper use of several science tools, data interpretation, and accurate measurement, students become Forensic Investigators to solve a crime. Students choose a role to play, become “experts” in their field, and become an integral part of their team when analyzing all the gathered data.

Grade Level: 9-14

Key Concepts:
• Measurement (length, mass, volume)
• Conversion (metric, English Standard)
• Temperature
• Data Tables
• Graphing
• Microscope
• Paper Chromatography
• Data Analysis
• Inference

Content Standards Addressed:
California Science Standards: Investigation and Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

   a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

   b. Identify and communicate sources of unavoidable experimental error.

   c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

   d. Formulate explanations by using logic and evidence.

Understandings:
Answers to scientific questions are achieved by diligence, careful investigation and analysis.

Essential Questions:
How accurate is collected data?
Is it important for all scientists to use the same language and standards?
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Students will know:
  a. What techniques to use to gather data
  b. The importance of accuracy and uniformity in data collection
  c. Some techniques used in solving crimes

Students will be able to:
  a. Measure length, mass, and volume.
  b. Determine temperature using a metric thermometer.
  c. Convert between metric numbers with different prefixes.
  d. Convert between metric and English Standard.
  e. Construct and interpret a graph.
  f. Effectively use and care for a microscope.
  g. Work collaboratively

Performance Task:
Students assume a role as a Forensic Evidence Specialist to solve a crime. They gather data and report out to the group (Jigsaw style of cooperative learning). When all data is shared and analyzed, the group members collaboratively prepare a conclusion, citing evidence.

Learning Plan: (See individual pages for Activities)
Day 1:
Show TV clip of Forensic TV show.
Ask students what kinds of scientific skills the investigators need (observation, microscope, measurement, data analysis)
Tell students they will be solving a crime on their own
Tell students they will review skills needed by doing a series of labs over the week
Activity 1: Bloodstain Analysis

Day 2:
Discuss measurement and standards of measurement
Discuss conversions
Activity 2A: Measurement and Conversion
Discuss mass vs. weight, solution making and accuracy
Activity 2B: Solution making

Day 3:
Discuss temperature, Celsius vs. Fahrenheit
Activity 3: Temperature Indications in a Homicide

Day 4:
Practice solving a crime by introducing “Case of the Hassled Teacher”
Discuss microscope use and care
Activity 4: Analysis of Threatening Letter
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Day 5:
Continue with “Case of the Hassled Teacher Part 2”
Discuss chemical testing, testing for pH and other poisons
Activity 5: Analysis of Poisons

Day 6:
Continue with “Case of the Hassled Teacher Part 3”
Discuss DNA Fingerprinting
Introduction to microliter pipets
Activity 6: Forensic Webquest
Introduce Performance Task, Forensic Investigation, “The Case of Romeo and Juliet”

Day 7:
Performance Task, Forensic Investigation
Jigsaw Cooperative Learning Activities “The Case of Romeo and Juliet”

Student handouts follow
Activity 1: Bloodstain Analysis
Taking Measurements, Making a Data Table, and Making Inferences

Introduction: Bloodstain patterns can be used as forensic evidence when certain crimes (such as murder or assault with a knife) have been committed.

Purpose: After completing this exercise you should be able to take measurements, record them accurately in a data table, analyze your data and make inferences regarding what you’ve observed.

Procedure:
   a. Tape butcher paper to a wall, place some on the floor and on your desk.
   b. Dip a plastic knife (with the handle wrapped in paper towel) into a tub of water.
   c. Stand on the paper and hold the knife at your side, allowing the water to drip off of the knife onto the paper.
   d. Measure the length and width of two STANDING water “stains.”
   e. Enter this data in a data table. Sketch the shape in your lab.
   f. Re-dip the knife and try running naturally with the wet knife in your hand (arm movements are OK)—being sure some of the water “stains” the paper. Measure at least two RUNNING stains. Enter this data in a data table. Sketch the shape in your lab.
   g. Now, pretend to stab at something with your wet knife near the paper on the wall. Watch carefully: DIFFERENTIATE BETWEEN UPWARD MOTION STAINS AND DOWNWARD MOTION STAINS. Measure at least two of each and enter your data in a data table. Sketch the shapes in your lab.

Analysis:
   1. What are your observations about each bloodstain shape?
   2. Refer to the activities from this part of the lab, your data, and your sketches to make inferences about the relationship between bloodstain shape and a criminal’s movements.
   3. Are results inconsistent? Why does an investigator need more than one drop of blood to determine a criminal’s actions?
Introduction: To work as a scientist, you must be comfortable making conversions and understand the units of length, mass and volume.

Purpose: After completing this exercise you should be able to convert measurements.

Procedure:
1. Review the reference chart.
2. Review the sample problem.
3. Complete the Conversion Practice problems.

LENGTH

The basic unit of length in the metric system is the meter. One meter is roughly equivalent to 39.4 inches (a little longer than a yard).

See the COMMON METRIC UNITS chart for relationships between 1 meter and other measurements.

<table>
<thead>
<tr>
<th>COMMON METRIC UNITS REFERENCE CHART</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
</tr>
<tr>
<td>1 meter (m) = 100 centimeters (cm)</td>
</tr>
<tr>
<td>1 meter = 1000 millimeters (mm)</td>
</tr>
<tr>
<td>1 meter = 1,000,000 micrometers (µm)</td>
</tr>
<tr>
<td>1 meter = 1,000,000,000 nanometers (nm)</td>
</tr>
<tr>
<td>1000 meter = 1 kilometers (km)</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
</tr>
<tr>
<td>1 liter (L) = 1000 milliliters (mL)</td>
</tr>
<tr>
<td>1 liter = 1000 cubic centimeters (cm³) (cc)</td>
</tr>
</tbody>
</table>

Conversions:
To convert one metric measurement to another, use “conversion factors.” Conversion factors allow you to change one unit to another by multiplying by “1”. Multiplying by a conversion factor does not change the value of the measurement.

Here are some examples of conversion factors:

\[
\frac{1 \text{ liter}}{1000 \text{ milliliters}} (1 \text{ liter is equal to 1000 milliliters}) \quad \frac{60 \text{ minutes}}{1 \text{ hour}} (60 \text{ min. equals 1 hr.})
\]

Both the numerator and denominator represent the same value, so multiplying by a conversion factor is actually multiplying by “1.”
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Here is a sample problem:
The small intestine is 6 meters long while the large intestine is 120 centimeters long. Which is the longest (in meters)?

Step 1: To solve this problem you must figure out what is given and what is desired.
   **Given:** 120 centimeters is the length of the large intestine
   **Desired:** meters

Step 2: Find the relationship between the units and consider the possible conversion factors.

\[
\begin{array}{ccc}
100 \text{ centimeters} & \text{OR} & 1 \text{ meter} \\
1 \text{ meter} & & 100 \text{ centimeters}
\end{array}
\]

Step 3: Choose the conversion factor whose numerator has the same units as your desired value.

\[
\frac{1 \text{ meter}}{100 \text{ centimeters}} \quad \text{(We want our answers in meters)}
\]

Step 4: **Multiply** your given value by the conversion factor. Cancel like terms.

\[
\frac{120 \text{ centimeters}}{100 \text{ centimeters}} \times 1 \frac{\text{ meter}}{1 \text{ meter}} = 1.2 \text{ meters is the length of the large intestine}
\]

Step 5: Answer the question...the small intestine is the longest at 6 meters!

**Conversion Practice:**

Convert the following to **meters** and **SHOW ALL WORK** and **CONVERSION FACTORS**:

1. 231 centimeters
2. 0.09 kilometers
3. 190 feet

**VOLUME**

Volume is the **amount of space** an object occupies. The basic metric units of volume are **liter (L)** for liquids and **cubic centimeter (cc)** for solids. A liter contains 1.06 quarts.

See the COMMON METRIC UNITS chart for the relationship between liter, milliliter, and cubic centimeter.

4. If an emergency room physician asks for “200 cc’s of type O negative, STAT,” what exactly are they asking for? (Give your answer in milliliters and “plain English”)
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Activity 2B: Solution Making

Introduction: To work as a scientist, you must be comfortable making solutions. Many solutions are made by measuring a certain amount of dry chemical (solute) and adding it to solvent (often water).

Mass vs. Weight
Mass is a measure of the amount of matter in an object. Weight is a measure of the pull of gravity on that mass. On Earth, both mass and weight can be considered interchangeable. The basic unit of mass is the kilogram.

See the COMMON METRIC UNITS chart for the relationship between grams and kilograms.

An electronic balance or triple beam balance is often used in science labs to measure DRY chemicals. Each chemical has a “formula weight” which is the masses of the chemical’s elements added together. (We will discuss and practice using formula weight when we further study biochemistry and solution-making.)

Purpose: After completing this exercise you should be able to mass dry chemicals using a balance and make simple solutions.

Solution-Making Procedure:
*Each table team is collectively responsible for making these solutions. Don’t make individually.*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Make 1 M Sodium Hydroxide (NaOH 1M) by adding 4 grams NaOH pellets to 96 mL distilled water. (Remember, when reading volume on a graduated cylinder, read the amount corresponding to the BOTTOM of the meniscus.) Label as shown below.</td>
</tr>
<tr>
<td>b.</td>
<td>Make 100 mL of 10% NaCl (Sodium Chloride) by dissolving 10 grams NaCl in 90 mL water. Q.s. to 100 mL with distilled water. (Q.s. means “bring the volume up to”) Label as shown below.</td>
</tr>
</tbody>
</table>

Label your solutions as follows:

<table>
<thead>
<tr>
<th>1M NaOH</th>
<th>10 % NaCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Date) (Per. Tbl.)</td>
<td>(Date) (Per. Tbl.)</td>
</tr>
</tbody>
</table>

1. Given the above procedures in solution making, explain how you would make a 5% Sodium Chloride solution.
2. Given the above procedures in solution making, explain how you would make a 1% Sodium Chloride solution.
3. Given the above procedures in solution making, explain how you would make a 0.5 M Sodium Hydroxide solution.
4. Given the above procedures in solution making, explain how you would make a 2 M Sodium Hydroxide solution.
5. What are sources of unavoidable error in solution making? How could these errors be minimized?
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Activity 3: Temperature Indications in a Homicide

Introduction: The metric system measures temperature using the Celsius scale. On this scale, water freezes at 0°C and boils at 100°C. Each degree is 1/100th of the scale. Normal human body temperature is 37°C and comfortable room temperature is about 21°C. A homicide detective can tell how long ago a person died by the temperature of the body when found. (They also take into account room temperature and size.) The following activity will simulate tissue cooling over a period of time (time after death). After making a graph of tissue temperature versus elapsed time, you will then be able to use your graph to guess the time that other similar tissue “died” (was no longer kept at body temperature).

Purpose: After completing this exercise you should be able to measure temperature, create a data table, graph using Excel, analyze data, and extrapolate using your graph.

Procedure:

a) Find the mass of your simulated “tissue.”
b) Record the temperature of the room.
c) Gently insert a thermometer into the “tissue.”
d) Record the temperature of the “tissue.”
e) Wrap the “tissue” in a thin piece of plastic.
f) Warm the wrapped “tissue” in a water bath on a hot plate.
g) When the “tissue” reaches body temperature, remove it and unwrap it.
h) As it cools, record the temperature every few minutes in a data table.
i) Stop recording temperature when it “plateaus” for several minutes.

Analysis: Graph your data using Excel and copy the graph into your lab. Use your graph to answer the following questions about a body with the same tissue type and found a room the same temperature as ours.

Show (on the graph) how you figured out the answer (extrapolate).

1. It is 2 pm and the body has a temperature of 25 °C. When was the crime committed?
2. The body had a temperature of 34 °C when found at 11:30pm. When was the crime committed?
3. The body had a temperature of 36.5 °C when found at 1:30am. When was the crime committed?
4. The body had a temperature of 30 °C when found at 9:30pm. When was the crime committed?
5. Of the above crimes, which has the oldest evidence? Which has the youngest evidence?
6. What are unavoidable errors in this experiment?
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Teacher’s Notes:
The Case of the Hassled Teacher Part 1

Teacher reads this story to class.
Note: This is a true story. The names and locations have been changed to protect the innocent!

Janet Marks had just been hired at Parkdale Elementary in Pennsylvania. Two months after the start of the school year she complained to her principal that she found excrement on her chair and under her desk.

She was loved by students because of her laid-back, casual and friendly style of teaching. However, she didn’t feel well-liked by other teachers at her school. Most of them believed in traditional teaching methods.

On September 10, Marks received a typed note that was mailed to her school address. The postmark was from the same zip code of the school. The note read, “Die you cow!” The police took a report and kept the typewritten note as evidence.

The following week she found another note on her desk. This time it said, “I said die!” Police investigators compared the paper and ink of the two notes.

Now introduce:
Activity 4: Analysis of a Threatening Letter, Use and Care of a Microscope
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Activity 4: Analysis of a Threatening Letter
Use and Care of Microscope

Introduction: Why do we use microscopes? An easy answer to this question is, “to see very small things.” This is only part of the answer, however. Microscopes are also used for learning about biological functions and comparing very small objects. Most cells are far too small to see with the naked eye. Fibers, hair, bullet etchings and papers are a few types of forensic evidence that are also studied with a microscope. In this part of the lab you will study some forensic evidence to see if it matches the criminal to the crime.

Purpose: After completing this exercise you should be able to use, focus, and care for a microscope, and make wet-mount slides.

Microscope Familiarization Procedure:

| a. Obtain a **monocular compound microscope** (one eyepiece) and carry it with **TWO** hands, one holding the base, the other holding the arm. Plug it in. |
| b. Familiarize yourself with the parts of the microscope by filling out the **handout** on microscope parts. |
| c. To focus, always start on **low power** (shortest objective). Focus using the **coarse adjustment knob**. When the object is in focus, turn to the **medium power objective**. You will need to make only a minor adjustment with the coarse adjustment. Turn to high power and make adjustments with the **fine focus knob**. |
| d. Clean lenses using **lens paper only**, never paper towel. Paper towel can only be used for other parts of the scope. The **diaphragm** can be used to adjust the amount of light. |
| e. The magnification of the microscope is found by **multiplying** the eyepiece lens (10X) by the objective. (4X, 10X, 40X) |

A. What is the total magnification of high power, medium power, and low power?

Forensic detectives have two letters as evidence in a crime of personal threats. Compare the two papers and ink and decide if they are generated from the same source.

**Procedure for making a wet mount slide:**

| a. Carefully remove a small sample of each of the papers, being sure you know which one is which. |
| b. Label each slide with masking tape and cut a 0.5 cm X 0.5 cm square from each sample. Include the letter “e” as part of your square. |
| c. Make a wet-mount slide by dropping water on the paper with an eyedropper and covering it with a coverslip. |
| d. Look at the sample. Make notes in a data table describing what you see. |
| e. Look at other samples. Make notes in a data table describing and contrasting the other samples. |
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Analysis: Use complete sentences to answer the following questions.

1. Focus on the “e.” Describe its position relative to how it looks on the slide when viewed with the naked eye.
2. As you move the “e” to the right in low power, which way does it appear to move when you are looking through the eyepiece?
3. As you move the “e” forward in low power, which way does it appear to move when you are looking through the eyepiece?
4. Change from low to medium to high power and focus. What happens to the “e”?
5. What happens to the field of vision as you switch from low to medium to high power?
6. What happens to the amount of light as you switch from low to medium to high power?
7. Where is the slide in relation to the objective lens now that you are in high power (closer or farther away)?
8. What are some similarities and differences between the paper fibers in the samples?
9. What are some similarities and differences between the ink types in the samples?
10. Are the two samples of evidence from the same source? Cite your data as evidence to back up your answer.
11. Prepare wet-mounts of fiber evidence and compare them. Are the fibers from the same source? Why or why not?
12. Prepare wet-mounts of the hair evidence and compare them. Are the hairs from the same source? Why or why not?
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Teacher’s Notes:
The Case of the Hassled Teacher Part 2

*Teacher reads this part of the story to class.*

The following week Marks finds a strange iridescent film on top of the drink she left on her desk. Police investigators try to learn the identity of the substance in her drink.

Now Introduce:
*Activity 5: Analysis of Drugs and Poisons Lab Activity*

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**Activity 5: Analysis of Drugs and Poisons Lab Activity**

Ward’s Lab
Catalog # 36 V 3029, Refill Kit 36 V 6419
1-800-962-2660
wardsci.com
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Teacher’s Notes:
The Case of the Hassled Teacher Part 3

*Teacher reads this part of the story to class.*

Police set up a video surveillance of Marks’ classroom. In the next three days, two teachers and one custodian entered her classroom. One teacher, Terry Booker, is seen taking a cup from her desk.

Booker is questioned and says Marks asked her to get the cup. She takes a lie detector test and fails.

Marks takes a lie detector test to see if she is making all of this up and fails, also.

Photocopied fliers are found lying around the school grounds with a picture of Marks’s face superimposed on another crude picture. The caption read, “Is this the kind of teacher you want here?”

For her safety, the school moves Marks to another school site, Sunrise Elementary.

A box addressed to Marks containing a Barbie with razor blades in her head and ketchup on her face and body is found on the steps of the new school on the first day Marks began working there. Police dusted the box, doll, and razor blades for fingerprints and found none.

Two days later, Marks calls the police and says she is run off the road. She says she sees the driver of the other car: Booker.

Booker is arrested and later released on bail, continually maintaining her innocence. The district puts her on a leave of absence. While waiting for her court appearance, she hires an evidence specialist who recommends DNA testing on the envelope flap and stamp Marks received months ago. These areas may have DNA evidence from the saliva (cheek cells in saliva contain DNA).

Now introduce:

*Activity 6: Molecular Biology Tools: Pipeting with a Microliter Pipet*
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Activity 6: Molecular Biology Tools:  Pipeting with a Microliter Pipet

Introduction: A microliter pipet is often used in biotechnology. Very small amounts of enzymes, DNA samples, and chemicals are required for reactions in small “1 mL tubes.” The pipets are also used to load samples onto an electrophoresis gel, the kind of gel used in DNA Fingerprinting. The following is a recipe to cut DNA into pieces before analyzing the sample on a gel.

Purpose: After completing this exercise you should be more familiar with microliter pipets and the volumes dispensed by these tools. You will use this tool when performing DNA Fingerprinting later this semester.

Procedure:
A. Observe your teacher as you are introduced to
   P20
   P200
   P1000
B. Observe your teacher as she demonstrates how to change the measured volume on the pipet.
C. Try to find the two “stops” described by your teacher.

Convert the following to microliters and SHOW ALL WORK.  1000 microliters = 1 mL

1. 0.023 mL Eco RI enzyme
2. 0.9 mL buffer
3. 0.0086 mL DNA sample
4. How much, in milliliters, will be in the 1 mL reaction tube after adding #7-9 above?
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Teacher’s Notes
Activity 6: Forensic Webquest

Direct students to:

http://www.pusd.info/online/humanbio/Forensic%20Science%20Webquest/forensics_webquest.htm

After answering all questions and participating on the discussion board, students are to further their research in one particular area:

Fingerprints
Documents, Forgeries, Handwriting
Trace evidence
Entomology and Lie Detection

As they return to the lab, they will need this information to solve a crime “The Case of Romeo and Juliet”

Performance Task: Cooperative Learning Jigsaw
“The Case of Romeo and Juliet” pdf file found at:
http://powayusd.sdcoc.k12.ca.us/online/Biomed/The%20case%20of%20Romeo%20and%20Juliet.pdf